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Portable X-ray Fluorescence (pXRF) detectORE™ Analysis for Au in Soils from the Archean Pilbara Craton, Western Australia

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INTRODUCTION

In this paper, we provide one of the first discussions of a new technology (detectORE™) for preconcentrating Au in the field and measuring its concentration to low ppb levels using field-portable XRF (pXRF). This approach can provide geochemical data immediately during and/or following sample collection, meaning that exploration programs can be modified in close to real time, as opposed to the delays of weeks or even months when samples must be shipped to laboratories for analysis. Field-portable XRF is already a widely used approach to achieving real time geochemical data. A range of elements from Mg (z = 12) to U (z = 92) can be measured in seconds to minutes, to varying degrees of precision and accuracy, and varying lower levels of detection (LLD; Hall *et al*. 2014). Although continuing hardware and software development has increased both the number of elements that can be measured and the quality of data (e.g. Piercey and Devine 2014; Simandl *et al*. 2014), some target elements such as Li remain beyond the capabilities of pXRF. Other elements such as Au, can be measured but reported concentrations are in the ppm range, usually orders of magnitude greater than the ppb levels encountered in most crustal rocks and surficial materials. This issue is related to low count rates but can be exacerbated by spectral interference (Hall *et al*. 2014). In the absence of precise and accurate low-level Au data needed for effective mineral exploration, pXRF has relied on the analysis of pathfinder (e.g. chalcophile elements) and alteration-related elements such as Ca, K, Al, Rb, Fe, and Sr.

The vexing issue of obtaining pXRF Au analysis at suitably low levels has been recently addressed by detectORE™ technology, a field-based preconcentration technique. Using this technology, Au in unconsolidated samples is released during partial leaching and concentrated on a collector device which is then analysed by pXRF (Lintern 2018; Lintern and Bolster 2018). The patented detectORE™ technology was invented at Australia's National Science Agency, CSIRO, between 2015 and 2018. It has been exclusively licensed for commercialization to Portable PPB Pty Ltd.

The detectORE™ - pXRF Au analytical methods discussed here were generated from a soil sampling program on exploration tenement E46/1026 in the eastern part of the Pilbara Craton of Western Australia (Fig. 1, 2). These data identified a broad zone of anomalism coincident with a regional structure (Blue Spec Fault; Fig. 3) hosting mineralization to the east of the tenement at Blue Spec and Gold Spec (Fig. 2). Based on the pXRF Au results from the soil samples, a drilling program in late 2022 confirmed the presence of Au mineralization, with intercepts including 6 m @ 40.15 g/t Au from 38 m depth, 7 m @ 5.42 g/t Au from 46 m depth, and 41 m @ 2.37 g/t Au from 32 m depth (Calidus Resources Ltd. 2023).

REGIONAL GEOLOGY

Calidus Resources Ltd ('Calidus') is exploring for Au on tenement E46/1026 with Gondwana Resources Ltd., who is the tenement holder. The tenement lies within siliciclastic metasedimentary rocks of the Mesoarchean Mosquito Creek Basin on the exposed eastern edge of the Pilbara Craton. The basin is about 60 km long from east to west and 30 km wide from north to south and overlies Paleoarchean granite–greenstone belts of the East Pilbara Terrane along a sheared unconformity (Fig. 1, 2; Hickman 1990; Van Kranendonk *et al*. 2004).

The lower part of the basin fill comprises medium- to coarse-grained, poorly sorted and chemically immature sandstone and conglomerate and komatiitic and tholeiitic basalt of the Coondamar Formation, which is overlain by thin-bedded sandstone, siltstone, and shale of the Mosquito Creek Formation (Hickman 2021; Fig. 2). Units of the Mosquito Creek Formation display graded bedding (as part of well-developed Bouma sequences), local cross-bedding, and sole marks (Hickman 2021). The Mosquito Creek Basin has been interpreted as an intramontane basin with coarse-clastic fan-delta marginal facies rimming an east-west basin centre with predominantly finer grained mass flow-dominated sediments (Nijman *et al*. 2010).

The age of the Coondamar Formation is poorly constrained, but that of the Mosquito Creek Formation is constrained by a maximum depositional age of 2926 ± 29 Ma (U-Pb detrital zircon date; Bagas *et al*. 2004) and a minimum deposi-

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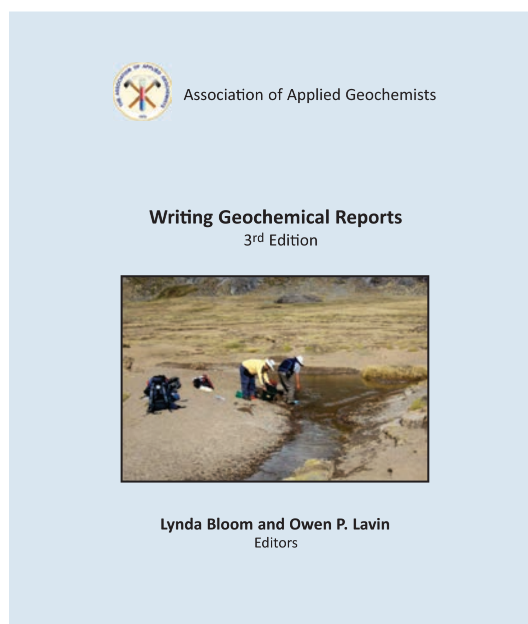
Guidelines for surficial geochemical surveys
Edited by Lynda Bloom and Owen Lavin



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

The guide may be downloaded free of charge from the AAG website:
https://www.appliedgeochemists.org/publications/writing-geochemical-reports-3rd-edition

President's Message

Greetings! I hope all of you in the northern hemisphere had a good summer while we here in the southern are looking forward to springtime.

As you all may have noted, our newsletter has a new page layout and design starting from the EXPLORE 199, June 2023 issue. The page layout services for EXPLORE have been switched from Vivian Heggie (Denver, USA-based), who has retired after overseeing the page layout and mailing of hard copies of EXPLORE for many years. The EXPLORE 199 issue is the last that Vivian helped us with, and we thank her for her dedication to this service. Elizabeth Ambrose (Ottawa, Canada-based) has taken over the responsibilities for page layout and design for the future issues of EXPLORE.

Nominations for the 2023 AAG awards have been opened since the start of the year, but so far none has been received in the preceding months. So, this message serves as a reminder to AAG members to send your nominations to Dennis Arne (arne.dennis@gmail.com; Past President, Awards & Medals Committee Chair). Significant contributions to applied geochemistry and service to AAG are recognized by the AAG Gold Medal award and the AAG Silver Medal award, respectively. The history of how these medals came about and the formulation of guidelines for awarding them are discussed in the April 1992 issue of EXPLORE. Guidelines for nominating individuals for either medal are posted in 'The Association' section of the AAG website (www.appliedgeochemists.org) under the 'Awards' area. Nominations for either medal will be considered in the following year provided they are received prior to December 1.

Last year, we had 350 members, comprising 119 Fellows (including 32 senior Fellows), 200 Regular members (including 12 seniors), 25 Students and 6 subsidized members. As of June this year, we have 314 members, comprising 115 Fellows (including 32 senior Fellows), 182 Regular members (including 15 seniors), 14 Students and 3 subsidized members. The present 314 members include 14 new members, and 5 of these new memberships were generated from following up with downloads of the *Writing Geochemical Reports* from our website. Therefore, we thank Paul Morris's efforts to find ways to recruit/attract new members. Although our present numbers have not decreased significantly compared to last year's, each of us should encourage our colleagues and students, who are non-members, to join our Association. Hopefully, the next International Applied Geochemistry Symposium (IAGS), to be held in Adelaide, Australia, will attract new members.

The local organizing committee of the next IAGS, led by Dr Anna Petts, has held a number of meetings in the preceding months to select the preferred professional conference organizer, the main themes of the symposium, the design of the sponsorship prospectus and the initial consideration of workshops and field excursions. We look forward to getting the first circular out in the coming weeks and the final program (including workshops and field excursions) by the second circular so that interested participants can book early for convenient flights and accommodation.

As the end of 2023 is not far away, we need candidates to stand for election to the AAG Council for the 2-year term 2024–2025. Our Council needs young blood, and so I encourage our younger Fellows to stand for election. For our Regular members who are interested in serving in our Council, you first have to request conversion of your membership status to Fellow (*see* the Membership Registration page of our AAG website).

I look forward to meeting you all at our forthcoming Annual General Meeting.

John Carranza
President

Note from the Editor

Welcome to the third EXPLORE issue of 2023. This issue features an article describing portable X-ray fluorescence detectORE™ analysis for Au in soils from the Archean Pilbara Craton, Western Australia and was written by Paul Morris, Stephen Sheppard, Rory Eakin, and Nicolas Meriaud. EXPLORE thanks all those who contributed to the writing and/or editing of this issue including: Elizabeth Ambrose, Steve Amor, Dennis Arne, Al Arsenault, Chris Beckett-Brown, John Carranza, Steve Cook, Theo Davies, Grant Hagedorn and Jessey Rice.

Beth McClenaghan
Editor

Steve Cook,
Business Manager

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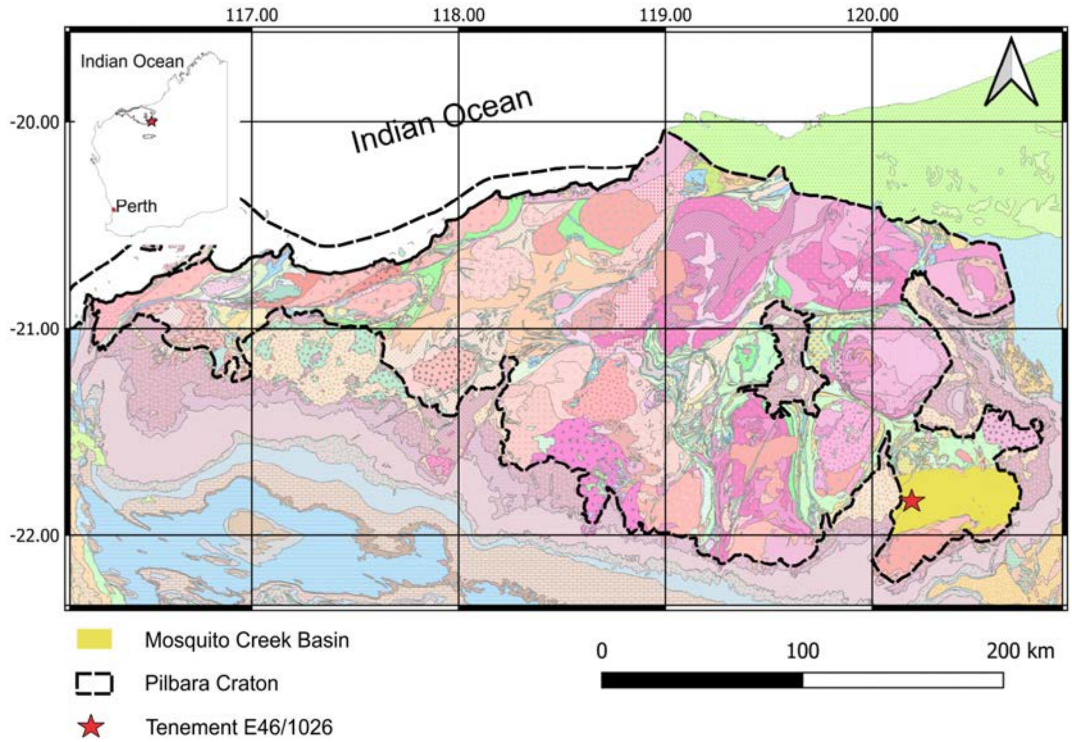

Fig 1. Regional 1:500 000-scale map of the geology and the outline of northwestern Australia, showing the extent of the exposed Pilbara Craton (black dash line), and the location of the Mosquito Creek Basin (yellow shading) in the eastern part of the Pilbara Craton (data source: Department of Mines, Industry Regulation and Safety (www.dmirs.wa.gov.au)). Inset, top left: Map showing the location of the Pilbara Craton in Western Australia. Geocentric Datum of Australia 2020 (GDA2020)).

tional age provided by a Pb-Pb model age of 2905 ± 9 Ma from galena associated with Au mineralization (Thorpe *et al*. 1992).

All units of the Mosquito Creek Basin were overprinted by regional metamorphism of zeolite to lower greenschist facies and up to six deformation events (Farrell 2006) during the Mosquito Creek Orogeny (Hickman 2021). The most important events consist of major east–northeast-trending folds, thrusts/reverse faults, and a penetrative slaty cleavage, and later dextral movement along east- to northeast-trending fault zones. Thrust and reverse faults are north-verging in the north of the basin and south-verging in the south of the basin (Farrell 2005; Nijman *et al*. 2010) leading Nijman *et al*. (2010, p. 269) to suggest that the architecture of the folds and thrusts could be the result of "…transpressive push-up or positive flower structure."

Over almost 150 years, 42 t of Au or 50% of the total production from the Pilbara Craton has come from the Mosquito Creek Formation (Bagas *et al*. 2008). Mineralization is controlled by east–west fault zones roughly parallel to major fold axes. Two principal zones of mineralization, the Blue Spec and Middle Creek zones, are recognized (Fig. 2). The style of

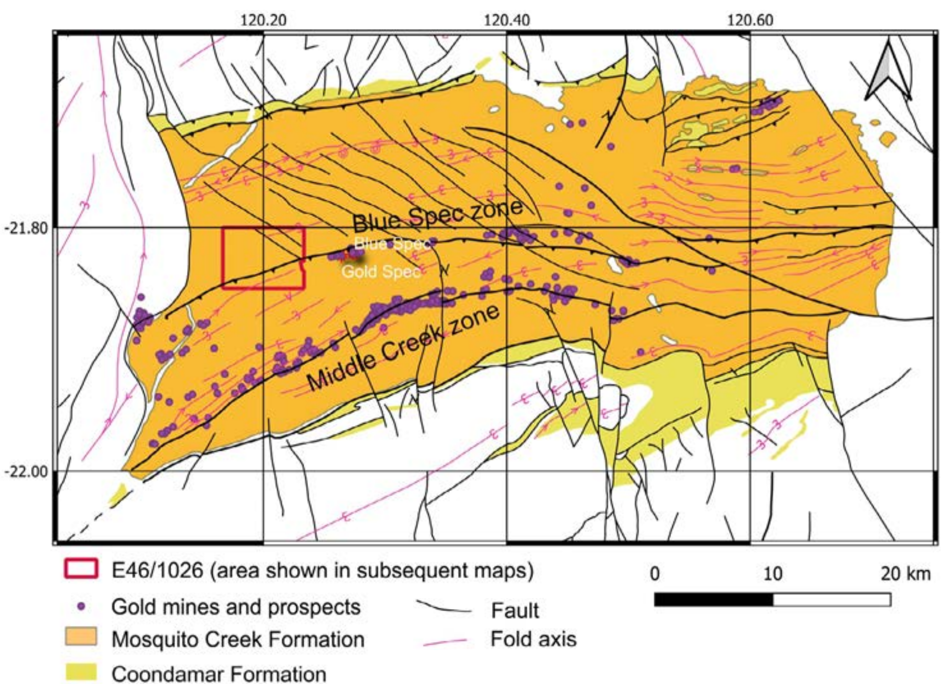

Fig 2. The 1:500 000-scale map outlining the components of the Mosquito Creek Basin with interpreted structure. The purple dots show the locations of gold deposits and prospects, most of which lie on major faults of the Middle Creek Fault zone or Blue Spec zone. The Blue Spec and Gold Spec mines are shown, as well as the outline of tenement E46/1026 (data source: Department of Mines, Industry Regulation and Safety (www.dmirs.wa.gov.au)).

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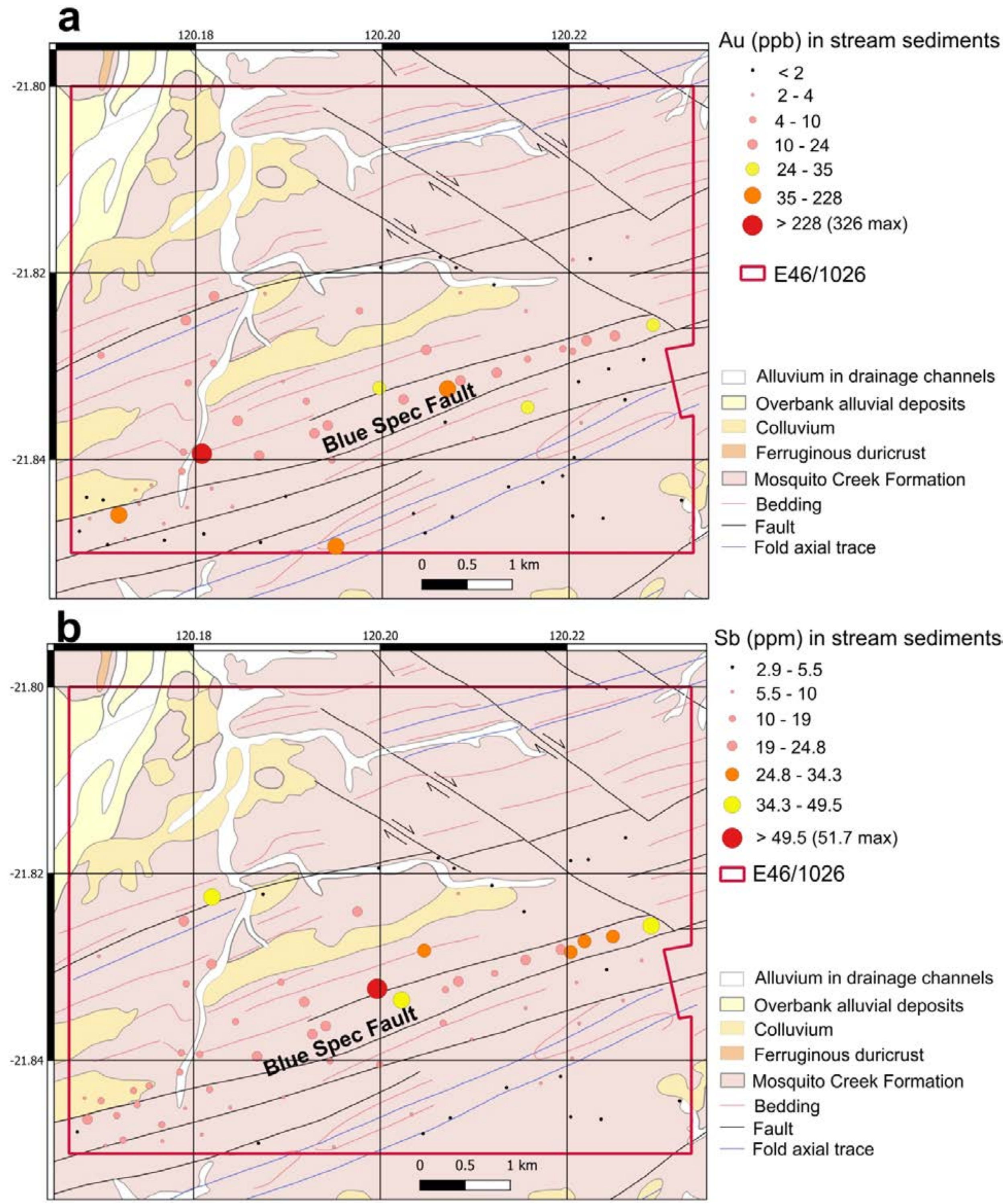

Fig. 3. A 1:100 000-scale surface geology and structures for tenement E46/1026 (data source: Department of Mines, Industry Regulation and Safety (www.dmirs.wa.gov.au)): a) Au (ppb) and b) Sb (ppm) in the <425 μm fraction of stream sediment samples. Symbols shown in orange and red have statistically anomalous element concentrations.

mineralization in both zones is similar, but the strong association of Sb with Au in the Blue Spec zone is not seen in the Middle Creek zone.

The historic Blue Spec mine (Fig. 2) has accounted for 2 t of Au, at an average grade of >18 g/t Au as well as concentrates containing 1500 t of Sb from >110 000 t of ore (Hickman 1983; Ferguson and Ruddock 2001). Mineralization at Blue Spec is hosted in a vertical to steeply south-dipping 15–20 m wide fault zone, characterized by quartz veining, and sporadically associated with carbonate alteration (Morrison 1978). Panning of some drill spoil on E46/1026 revealed free gold or gold liberated from weathered sulphides. DetectORE™ and pXRF analysis of drill spoil produced Au (ppb) concen-

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trations that were approximately 50% of fire assay determinations, suggesting that some gold is hosted in silicates or quartz veins. In addition to gold, the quartz veins contain stibnite (Sb_2S_3), aurostibite ($AuSb_2$), pyrite, pyrrhotite, with minor scheelite, arsenopyrite, marcasite, sphalerite, chalcopyrite, magnetite, calaverite ($AuTe_2$), rickardite (Cu_7Te_5), and gudmundite (FeSbS). Bagas *et al*. (2008) argued that the mineral assemblage is indicative of relatively shallow-level, epizonal orogenic Au mineralization.

EXPLORATION ON TENEMENT E46/1026

In late 2020, Calidus commenced exploration on E46/1026 (Fig. 2) to search for Au on structures extending west from Blue Spec and Gold Spec as well as subparallel structures to the north of the fault zone, and folded rocks to the south.

A stream sediment sampling program (76 sample sites) in the second half of 2021 (Calidus Resources Ltd. 2022), confirmed the potential of the Blue Spec Fault area, with maximum Au fire assay/AAS (30 g sample; SGS code FAM303) concentrations of 326 ppb (Fig. 3a). Although anomalous Au values associated with structures to the north of the Blue Spec Fault are less common, the potential for mineralization was indicated by anomalous Sb values of up to 51.7 ppm (Fig. 3b, four-acid digest and ICP-MS finish, SGS code ICM40Q). Samples from a small area of folded rocks to the south of the Blue Spec Fault returned few anomalous Sb or Au values. Multi-element analysis of stream sediment samples confirmed field observations that elevated Au concentrations are commonly associated with chalcophile enrichment, potassic alteration, carbonation or ferruginization (Calidus Resources Ltd. 2022).

Based on the results of the stream sediment chemistry, a follow up soil sampling program was carried out in mid-2022 (Fig. 4), focusing on the Blue Spec Fault area and the structures to the north, but including the less prospective area to the south. Samples were collected from sites on north-south transects spaced at either 100 m or 200 m, with samples spaced along lines at either 20 m or 50 m intervals. The transect and sample spacing reflects perceived prospectivity indicated by stream sediment chemistry. The soil sampling covers an area of approximately 6 km^2.

Twelve hundred and thirty-two samples were analysed by pXRF using the detectORE™ method (www.portableppb.com). Three hundred and sixty-eight samples were analysed for Au by 30 g fire assay/ICP-AES (method Au-ICP21) to a lower limit of detection (LLD) of 1 ppb, as well as for 48 additional elements by four-acid digest/ICP-MS (method ME-MS61) at ALS Laboratories (Perth, Western Australia). Of these 368 samples, 26 do not have corresponding pXRF data (Fig. 4, yellow symbols).

GOLD ANALYSIS OF SOIL SAMPLES

Sampling

Tenement E46/1026 is characterized by low, east-trending ridges separated by broad floodplains. Soils consist of disconnected patches of thin lithic-rich, sandy material in areas of outcrop, or sandy colluvium and less common sheetwash approaching drainage channels. Sample sites are largely confined to upland areas, where soil consists of moderately weathered coarse to fine sand with lithic fragments, and minor silt or clay. Due to the dominantly erosional landscape and immaturity of soils, organic matter is usually absent.

Soil sampling was carried out over about four weeks in June and July 2022. At each sample site, the top 5 cm of soil was removed to avoid any anthropomorphic contamination or windblown material. Where possible, each sample was collected at a uniform depth of 25 cm using a small metal entrenching shovel. For most sample sites, the selected <180 µm grain size fraction was screened at the time of sampling. In some cases, the rough terrain slowed the sampling rate, and in these cases, approximately 3–4 kg of <2 mm material was collected, with further screening carried out at the field

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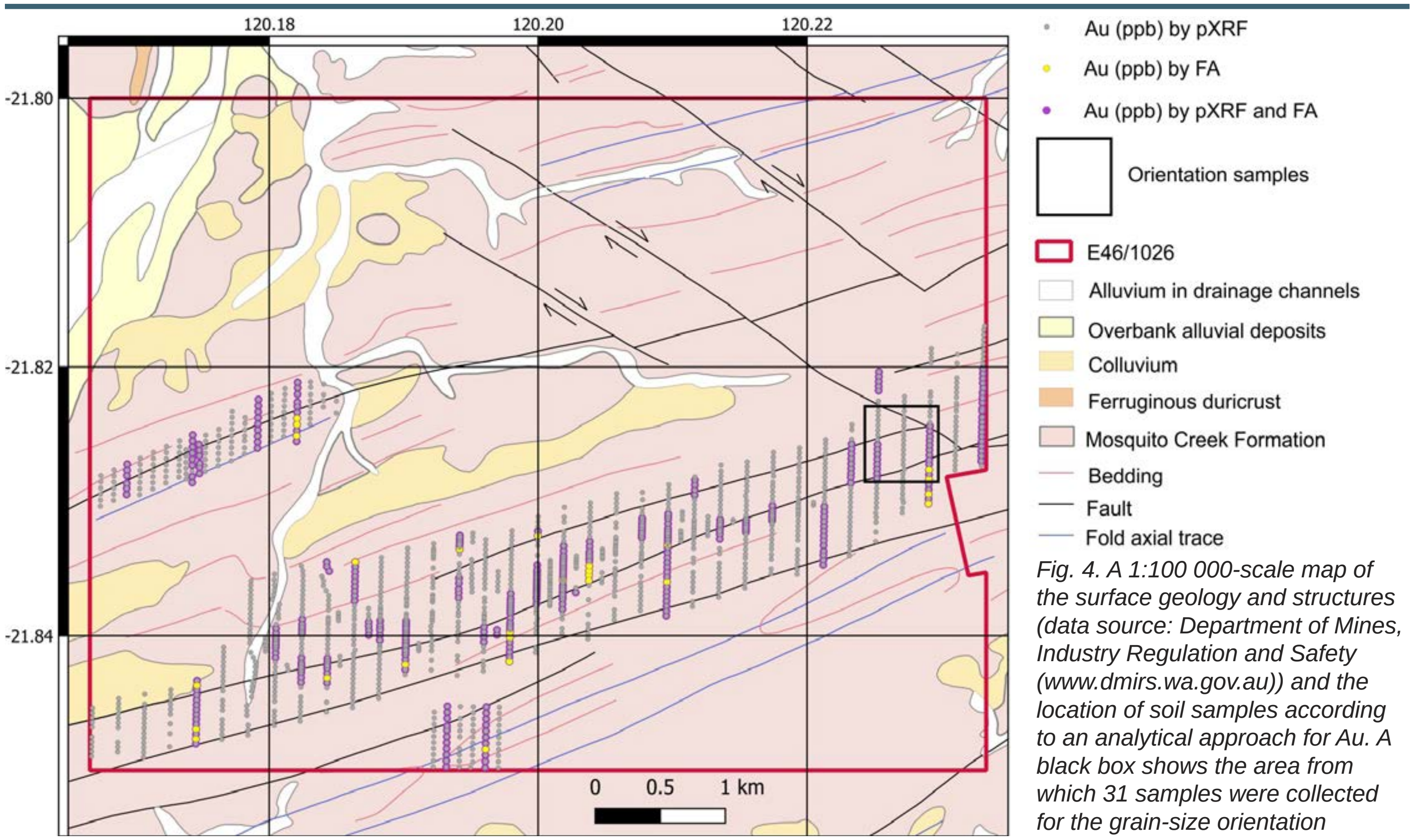

Fig. 4. A 1:100 000-scale map of the surface geology and structures (data source: Department of Mines, Industry Regulation and Safety (www.dmirs.wa.gov.au)) and the location of soil samples according to an analytical approach for Au. A black box shows the area from which 31 samples were collected for the grain-size orientation exercise.

camp. For each sample, approximately 400 g of the <180 µm (-80 mesh) fraction of soil was collected using a plastic sieve and collection pan. This amount is sufficient for detectORE™ digestion (250 g), with the remainder (i.e. 150 g) for fire assay and multi-element geochemistry at a laboratory, if needed.

The screened material was placed in a 25 x 38 cm 125 µm thick plastic bag sealed with a plastic cable tie. A unique site identification number was written on the bag with an indelible marker. In order to ensure that the site information was not rubbed off the bag during transit, the sample bag was placed in a 45 x 30 cm drawstring calico bag, also annotated with the unique site number. After completion of sampling, any residual material was removed from the sieve, collection pan and shovel using a stiff nylon brush. At designated sites, a second sample (site duplicate) was collected from within a 50 cm radius of the original sample using the same sampling protocol. At these sites, the letter “D” was appended to the site number written on the bag.

pXRF Analysis

The patented detectORE™ technology involves a leach and collect process using a proprietary non-toxic, non-hazardous reagent called GLIX-20™ and a collector device (CD). Sample preparation, carried out at the field camp at Marble Bar (Western Australia), involved partial digestion of approximately 250 g of unconsolidated sample material for 6 hours in a vessel containing 500 ml of GLIX-20™, and a collector device (CD) on which the released Au is collected. Following digestion, the CD was removed, rinsed and dried, then analysed by a pXRF device in detectORE™ mode loaded with Portable PPB’s pLIMS™ software. Results are reported in detectORE™ Units

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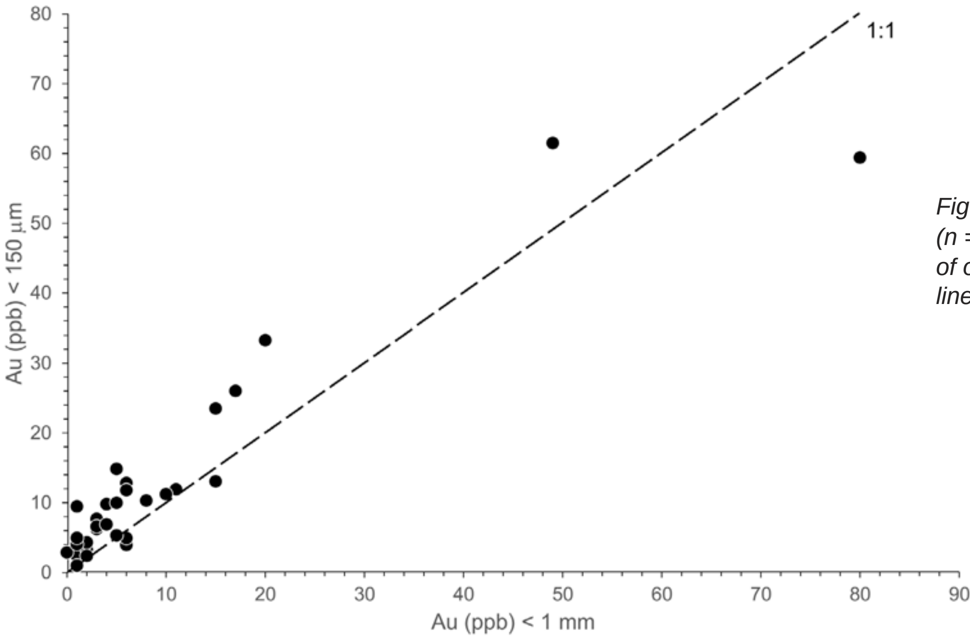

Fig. 5. Bivariate plot of Au (ppb) by pXRF (n = 31) for the <1 mm and <150 µm fractions of orientation samples. r^2 is 0.87. The dashed line has a slope of 1 and a y intercept of 0.

(dU). A detectORE™ unit represents the µg of Au per kg of sample that is extracted from a sample; henceforth, the concentration of Au measured by pXRF in this study is discussed in terms of parts per billion (ppb).

<u>Grain size selection orientation study</u>
As the detectORE™ technology involves a partial digest of the sample, it is likely that a better signal-to-noise ratio is achieved with finer grain sizes, as a greater surface area of the sample is exposed to the lixiviant (e.g. Leybourne and Rice 2013). Accordingly, 250 g of the <1 mm fraction (-18 mesh, i.e. coarse sand and finer) and a similar amount of the <150 m (-100 mesh; fine sand and finer) fractions were screened from each of 31 samples in the northeast of the sampling area for an orientation survey (Fig. 4, black square). As each of the 31 sample sites are only 50 m apart, and because the area is underlain by only turbiditic sediments, the effects of bedrock variations are reduced.

A bivariate plot of Au (ppb) according to grain size shows a high level of correlation (r^2 = 0.87), but the Au concentration is the same or higher in the <150 µm fraction of all but four of the 31 samples (Fig. 5). Accordingly, the <150 µm fraction was selected for pXRF Au analysis in the remaining soil samples. Because a 150 µm screening cloth was not available for the main sampling program, each of the 1,232 soil samples was screened to -80 mesh (<180 µm), with sufficient screened material retained for laboratory analysis, if required.

Sample Digestion and Analysis
Soil samples were leached mostly in batches of 90 samples and the CDs analysed by pXRF at the field camp, using an Olympus Vanta M-series pXRF (serial number 801756). Leaching took place typically within 48 hours of sample collection. The CDs were analysed the day after digestion, which allowed sufficient time for them to dry; advice from PortablePPB is that any moisture retained by the CD can affect the Au analysis. In each batch, two reference materials were analysed. These reference materials, supplied by Portable PPB, contain a precise mass of a Certified Reference Material diluted with barren regolith material.

<u>Site duplicates</u>
A second soil sample—a site duplicate—was collected at 59 sites to test within-site homogeneity. A bivariate plot of Au (ppb) in the primary and site duplicate (Fig. 6a) plot around a 1:1 line, with r^2 = 0.886. There is more scatter at concentrations <20 ppb.

<u>Collector device duplicate analysis</u>
Fifty-two CDs were analysed twice, with a different part of the

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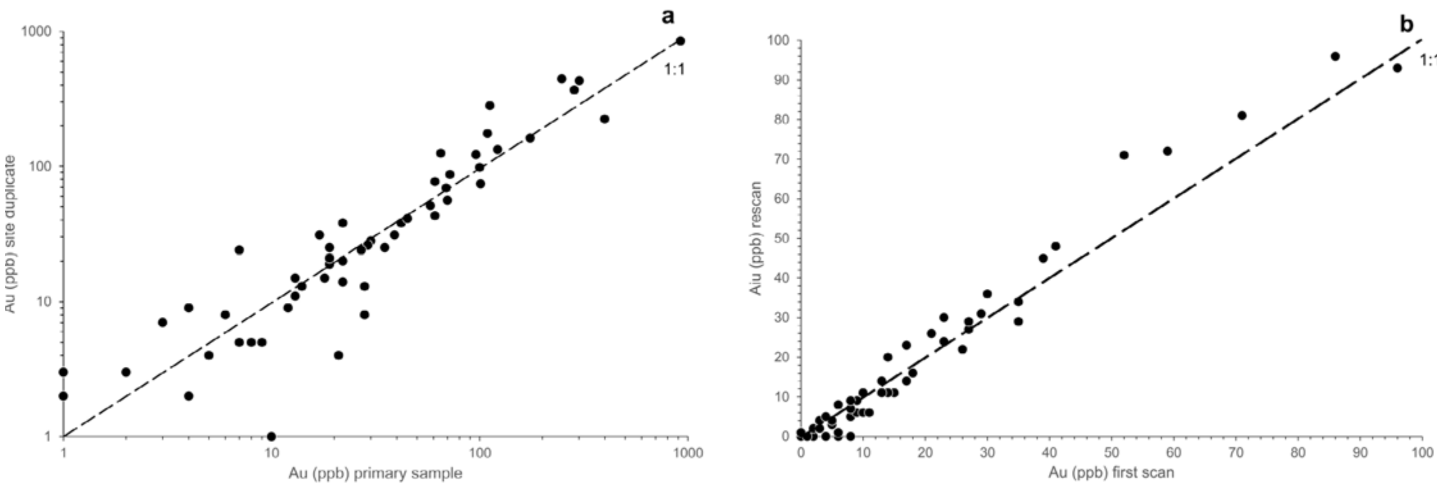

Fig. 6. Plots showing a) pXRF Au (ppb) for parent and site duplicate samples (n = 59). r^2 is 0.886 and b) duplicate analysis of pXRF Au (ppb) of CDs (n = 52) shown as first scan versus rescan. r^2 is 0.99. The dashed line has a slope of 1 and a y intercept of 0.

CD exposed to the pXRF. The second CD measurement (i.e. rescan) was carried out immediately following the first scan. A bivariate plot (Fig. 6b) shows excellent agreement, with r^2 close to 1 and analyses plotting close to a 1:1 line. These results indicate Au is homogeneously distributed in the CD.

<u>Fire assay analysis</u>

The -80 mesh (<180 µm) fraction of 368 samples was analysed for Au by fire assay/ICP-AES (method Au-ICP21; LLD = 1 ppb;) and for multielements by four-acid digest/ICP-MS (method ME-MS61) by ALS (Perth, WA). Prior to analysis, each sample was milled to nominal <75 µm in a low-Cr steel ring mill (method PUL-31L). Soil samples were analysed along with reference materials (most of which have certified values for Au), sample duplicates (i.e. an analysis of a second aliquot of the sample pulp), and a silica pulp blank with a target range documented by ALS of <0.001–0.002 ppm (i.e. <1–2 ppb) for Au.

<u>Reference materials</u>

Four of the five reference materials have certified values for Au (GPP-14 (Geostats), KIP-19 (OREAS), TAZ-20 (OREAS), and OREAS 254b) ranging between 0.909 and 2.52 ppm. The fifth (AMIS0448; African Mineral Standards) has a provisional Au value of 1.31 ppm. Where reference materials have been analysed at least three times, the percent relative standard deviation (%RSD) has been calculated. It is <5 % in all cases, indicating acceptable precision. The certified or provisional Au value has been compared with the average Au concentration from at least three analyses using 100HARD (i.e. 100 x [(x1 - x2)/(x1 + x2)]; Stanley and Lawie 2007). The 100HARD values lie between +5 and -5, indicating acceptable accuracy. Despite the acceptable precision and accuracy results, the data are disappointing in that they have limited application in terms of understanding the accuracy and precision of soil analysis, as only three soil samples have Au concentrations within the range of reference materials (i.e. 0.909–2.52 ppm, or 909–2520 ppb).

<u>Duplicate and blank analyses</u>

A second pulp aliquot for nine soil samples, with Au concentrations between 4 and 421 ppb, were randomly chosen by ALS for Au duplicate analysis. The Au concentration of the parent and duplicate samples were compared using 100HARD. Six of the parent samples have Au concentrations of more than 10x the LLD, so the effects of poorer precision close to the LLD are minimized. A 100HARD comparison for these pairs produced values between -10 and +10, which is taken as acceptably precise. Two other parent-duplicate pairs with <10 ppb Au also produced 100HARD values in this range, showing that good precision persists to low concentration levels. Eleven analyses of a silica blank were carried out, with values of <1 ppb for all but one determination (1 ppb), indicating compliance with the target range.

COMPARISON OF detectORE™ pXRF AND FIRE ASSAY Au DATA

A bivariate plot of Au according to method (Fig. 7, n = 342) shows a strong correlation (r^2 = 0.902). The slope of a best fit line is 1.63, and assuming that FA/ICP-AES is a 'total' approach, these data show that detectORE™ - pXRF has

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determined approximately 60% of the available Au. Log-scale box and whisker plots for samples analysed by both pXRF and FA/ICP-AES (n = 342; Fig. 8a, b) show that both techniques have the same number of samples (35) with statistically anomalous Au concentrations (>144 ppb for pXRF and >258 ppb for FA/ICP-AES), and of these, 21 samples have extreme values (>228 ppb for pXRF and 408 ppb for FA/ICP-AES). For all pXRF data (n = 1232, Fig. 8c), 172 samples (14%) have anomalous Au concentrations >49 ppb, and of these 118 samples (10%) have extreme concentrations (i.e. >76 ppb). For FA/ICP-AES data (n = 368, Fig. 8d), a similar proportion of samples (10%) have anomalous Au concentrations (>245 ppb, n = 37), and of these, 23 have extreme concentrations (>386 ppb).

The spatial distribution of all samples symbolized according to Au concentration is shown in Figure 9. Samples with anomalous Au concentrations, as identified by the box and whisker plots (Fig. 8c,d), are shown as orange and red dots. The distribution of Au is similar for pXRF and FA/ICPMS, with a high proportion of anomalous samples on or near to the Blue Spec Fault. A few anomalous samples plot approximately 200 m north of, and subparallel to, the Blue Spec Fault, and other samples with anomalous Au concentrations coincide with sub-parallel faults in the central west of the tenement.

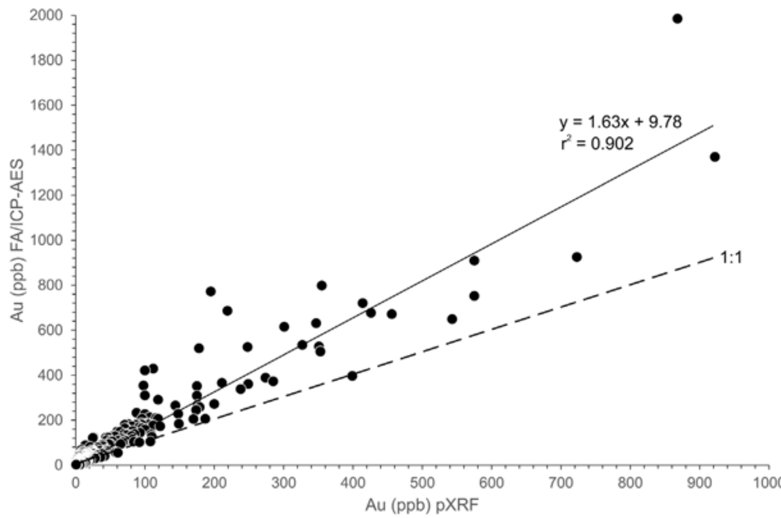

Fig. 7. Plot of Au concentrations determined by FA/ICP-AES (ppb) versus Au by pXRF (ppb). The solid line is a calculated best fit, and the dashed line has a slope of 1 and a y intercept of 0.

DISCUSSION

Both detectORE™ - pXRF and FA/ICP-AES Au analysis of soil samples on tenement E46/1026 have confirmed the potential for Au mineralization on the Blue Spec Fault, and sub-parallel structures to the north. A considerable time saving was achieved using the detectORE™ - pXRF approach compared to laboratory-based FA/ICP-AES analysis: sample collection and detectORE™ pXRF analysis of the soil samples was completed on-site in 36 days, compared to about 90 days from the submission of samples for FA/ICP-AES analysis to receipt of results. Of note is that the initial drilling program, involving 31 shallow reverse circulation holes with hole collars based on the detectORE™ - pXRF results, was completed by the time the FA/ICP-AES analyses were obtained from the laboratory. This drilling program returned significant intercepts in 25 holes, including 6 m @ 40.15 g/t Au (with 1 m @ 220.17 g/t) in one hole, and several holes containing multiple intercepts (Calidus Resources Ltd. 2023).

The receipt of detectORE™ results within 48 hours of sample collection allowed for samples on infill lines and extensions to existing lines to be collected while the sampling crew was still in the field. Therefore, the cost of mobilizing and demobilizing the sampling crew months later for a second round of sampling was avoided.

Once an area of interest is identified for drilling, a Program of Work must be submitted to and approved by the Department of Mines, Regulation and Safety (DMIRS) and a heritage survey carried out to ensure that no Aboriginal cultural heritage is damaged. Given the demands on Aboriginal organizations for heritage surveys, it is quite likely that without the detectORE™ results, a survey would have had to wait until after the hiatus of the summer wet season. The timeframe for conducting the earthworks and securing a drill rig would have meant that, if soil samples had been sent only to a laboratory, drilling probably would not have commenced until April or May 2023, a delay of five to six months.

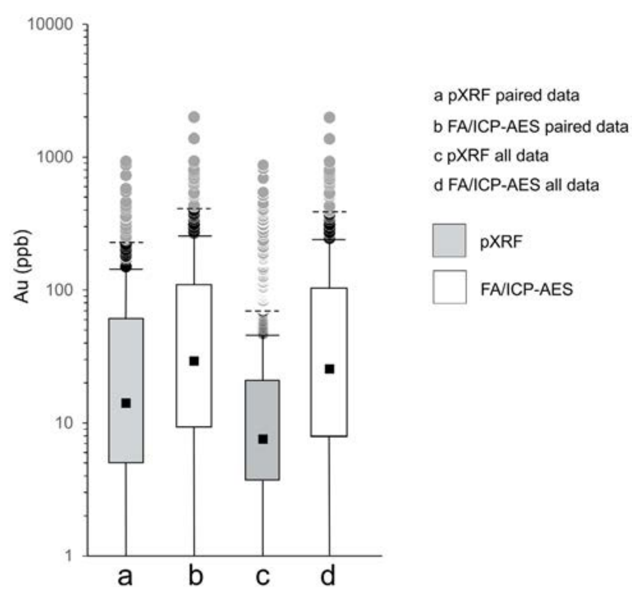

*Fig. 8. Log-scale box and whisker plots for paired data (n = 342) and all data (pXRF n = 1232), FA/ICP-AES n = 368). The black and grey dots are, respectively, outlier and extreme values. Anomalous samples have Au (ppb) concentrations >[(1.5 * IQR) + 75th percentile]. The division between outlier and extreme is at [(3*(IQR) + 75th percentile], as shown by a dotted line in each plot. The black square shows the median value. IQR is the interquartile range, calculated as the 75th – 25th percentile values (Reimann et al. 2008).*

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pXRF detectORE™ Analysis for Au in Soils... *continued from page 13*

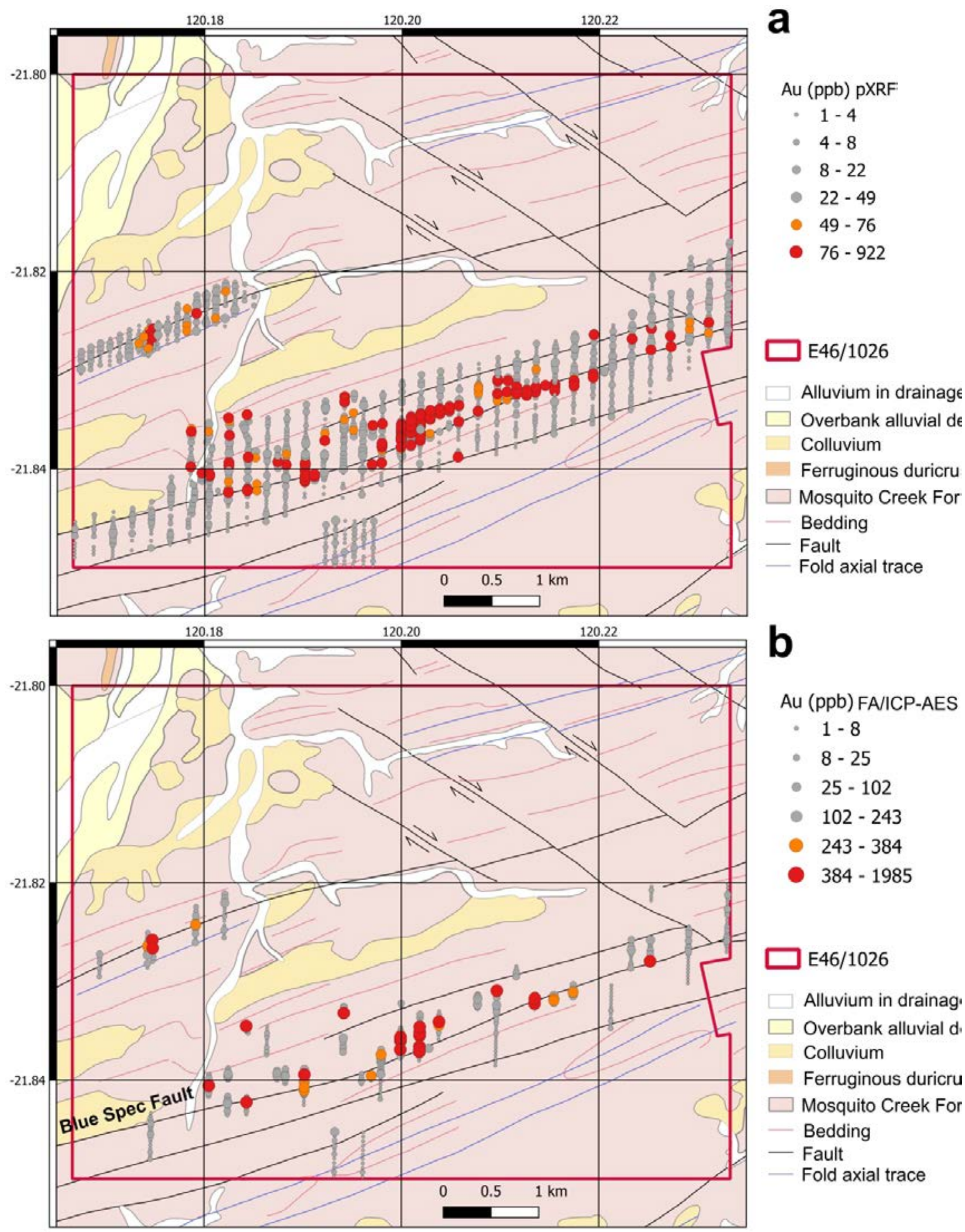

Fig. 9. Dot maps showing Au (ppb) according to method for all samples: a) pXRF b) FA/ICP-AES. Classes are minimum to 25th percentile, 25 to 50th percentile (median), 50 to75th percentile, 75th percentile to outlier, outlier to extreme (orange dots), and greater than extreme to the maximum value (red dots).

Aside from the direct application to the Au exploration on tenement E46/1026, the pXRF data discussed here have highlighted some issues with the broader applicability of the detectORE™ pXRF approach in Au exploration, particularly the vectoring towards mineralization from areas of background. Of the 1,232 samples analysed by pXRF, 57% (i.e. 698 samples) returned <10 ppb Au. For these 698 samples, Au by FA/ICP-AES ranged from 2 to 67 ppb, with 59 samples having values of >10 ppb. At the reconnaissance stage of exploration, samples above 10 ppb by a method with an LLD of 1 ppb (i.e. at or above 10x the LLD) would attract interest (e.g. Noble *et al*. 2018), yet if only pXRF data for these samples are considered the data are unremarkable. To expand the application of the detectORE™ approach to the early stages of exploration, the significance of sub-40 ppb pXRF data requires clarification. For the data discussed here, this is difficult to assess, as QC data do not include analyses of certified reference materials and blanks, crucial for estimating precision

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and accuracy and providing an estimate of a LLD. An impediment to routine generation of CRM data is the 250 g sample size required by detectORE™, making robust QA/QC programs a costly exercise.

A comparison of pXRF and FA/ICP-AES Au data must take into account the fundamental differences in the analytical approach. The detectORE™ methodology is a partial digest, and although the composition of the GLIX lixiviant is not documented, it is fair to assume that it would be ineffective in liberating refractory Au — that is, Au encapsulated in silicates. In contrast, fire assay collection is an aggressive digestion approach, which is relatively unaffected by matrix issues (Hall and Pelchat 1994). The geology of the E46/1026 tenement consists of siliciclastic sedimentary rocks, with soils having undergone limited chemical weathering. As matrix effects can result in variable Au recovery (Chao 1984; Chao and Sanzalone 1992; Hall 1998), caution should be exercised in translating the level of Au recovery by detectORE™ within and between different projects.

A further consideration in comparing pXRF and FA/ICP-AES data in this study is that the coarse grain size of samples digested in the detectORE™ process (<180 µm) relative to the nominal <75 µm grain size for fire assay Au collection. The grain size orientation data discussed here indicate that the detectORE™ approach benefits from finer grain size samples, where presumably more Au is exposed to the lixiviant. However, the 250 g sample size currently required by detectORE™ also has implications for using a fine grain size fraction, such as silt and clay, to optimes the signal-to-noise ratio. Soils on tenement E46/1026 are lithic-rich and typically sand dominated, with only a few percent silt and clay. To extract sufficient mass of silt and clay for analysis would require collection of an estimated 4–5 kg sample of <180 µm material at each site, followed by screening to <63 µm, introducing a significant time and cost factor.

CONCLUSIONS

The detectORE™ - pXRF approach to the determination of ppb-level Au concentrations in soils from the Calidus tenement in the eastern part of the Pilbara Craton of Western Australia has been evaluated using comparative FA/ICP-AES data. In terms of validating the results of stream sediment chemistry and identifying areas of anomalous Au concentrations, both detectORE™ - pXRF and FA/ICP-AES data are valid approaches, although Au determined by detectORE™ in siliciclastic rocks on E46/1026 is approximately 60% of that determined by fire assay/ICP. However, detectORE™ - pXRF has the major advantage of substantial time savings, providing the opportunity to react to results as they are generated in the field. The work on tenement E46/1026 puts pXRF in a strong position to directly evaluate not only Au, but Au pathfinder elements (e.g. Sb, As) and elements related to alteration (Ca, K, Al, Rb, Fe).

The detectORE™ approach could have a wider applicability in the earlier stages of mineral exploration if the significance of Au reported at levels <40 ppb can be better quantified. A current drawback of the detectORE™ approach to tackling this issue is the large sample size required for leaching (250 g), which makes routine analysis of low-Au CRMs costly. This sample size also has cost and time implications for exploration where large volumes of material must be screened in order to produce sufficient fine-grained material appropriate to a partial digestion approach.

ACKNOWLEDGMENTS

Simon Bolster, Melvyn Lintern and Wade Lonsdale of PortablePPB are thanked for commenting on a draft of the paper. An incisive and thoughtful review by Stephen Cook resulted in significant improvements to the manuscript. Beth McClenaghan is also thanked for a careful review and editorial handling. Ryan Noble provided important discussions on data presentation.

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*Available to download free of charge from the eBookshop at www.dmirs.wa.gov.au.

Highlights of Some of the Applied Geochemistry Applications in Southern Africa during 2022–2023

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Faculty of Natural Sciences, Mangosuthu University of Technology, 511 Mangosuthu Highway, Umlazi 4031, KZN, South Africa (theo.clavellpr3@gmail.com)

There is an apparent increase in the application of applied geochemistry in southern African laboratories and field campaigns in the past few years, coinciding with the acquisition of smaller, more compact and accurate, easy-to-use analytical instrumentation such as the portable X-ray spectrometer.

Applied geochemistry teaching and research at Southern African universities

Teaching and research at African geochemistry departments continue to gather strength since the early 2000s, partly as a result of the acquisition by a number of laboratories of portable, analytical instrumentation that require little technical expertise for their operation.

More compact and significantly faster than its older, larger predecessors, the R 7.9 million (just over USD 400,000) mass spectrometer, recently (2022) installed in the Geological Sciences Laboratory of the University of Cape Town, serves as a national facility for researchers in South Africa and Africa as a whole. Fittingly named *Attom*, this equipment can determine the concentrations of elements with remarkable speed and precision, and will focus on uranium lead dating (https://www.news.uct.ac.za/article/-2022-06-13-attom-set-to-revolutionise-geochemistry-research (accessed 04.06.2023)).

The School of Geosciences at the University of the Witwatersrand (WITS) in Johannesburg is one of the largest and most diverse departments in Africa, with strengths in geology, geochemistry, geophysics and palaeontology.

The B.Sc. Honours course in Geochemistry at WITS draws on results from cosmochemistry (including analyses of meteorite samples), along with geochemical and geophysical information of the Earth. Theoretical material is integrated with practical

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components that provides students with a comprehensive understanding of the various analytical methods and instruments available to geochemists for the analysis of various samples (rocks, minerals, soils, etc.) using a range of analytical instrumentation - X-ray Fluorescence Spectroscopy (XRF), Inductively-Coupled Plasma Mass Spectrometry (ICP-MS), Thermal Ionization Mass Spectrometry (TIMS), Secondary Ionization Mass Spectrometry (SIMS) and Electron Microprobe Analysis (EPMA) (https://www.wits.ac.za/course-finder/postgraduate/science/geochemistry/ (accessed 04.05.2023)).

The acquisition of a portable XRF (Olympus VANTA C Series Handheld XRF Analyser) by the Mangosuthu University of Technology (MUT) of South Africa in October, 2022, has enabled the determination, through sampling and analyses, of the concentration of potentially harmful elements (PHEs) and assessment of their levels of contamination in the soils, natural waters and food crops at several abandoned mine sites in South Africa. A key aim of the original 'UNESCO/SIDA/MUT Abandoned Mines Project' was: " … to identify, through experimentation, the most appropriate technology and remedial actions for the sequestration of metals in mine dumps and tailings at abandoned mine sites in South Africa, and so obviate their environmental and health impact on the surrounding ecosystem".

The Olympus Vanta Handheld XRF Series held at the Technology Station of the Mangosuthu University of Technology, South Africa. Credit: Evident. Printed for non-commercial use (https://www.olympus-ims.com/en/terms-of-use/ (accessed 05.06.2023)).

Mineral Exploration

The Damara Orogenic Belt in Namibia is a highly prospective terrane hosting four currently known gold deposits. However, a large part of the belt is covered by calcrete and/or wind-blown sand and remains completely unexplored. Osino Resources, a gold mining company of Namibia announced in the December edition of the bulletin 'Mining Review', the completion by Newmont Corporation of a geochemical orientation programme during October 2022 aimed at testing their (Newmont's) proprietary Deep Sensing Geochemistry (DSG) technique over known covered mineralization at Osino's Twin Hills gold project.

Newmont Corporation is an American gold mining company based in Greenwood Village, Colorado, and is thought to be one of the world's largest gold mining corporations. Surface sand and sheet wash samples covering the calcrete in soil sampling traverses across the Twin Hills are currently being analysed in Newmont's in-house laboratory to measure ultra-low concentrations of gold and associated metals, with a view to determining its effectiveness in the Namibian covered terranes. Results are expected sometime this year (2023) (https://www.miningreview.com/gold/newmont-tests-deep-sensing-geochemistry-in-namibia/ (accessed 31.05.2023)).

Commercial Laboratories

(1) Earlier this year (2023), Sci Apps of Woburn, MA, USA announced the inauguration of the smallest, fastest, and most precise handheld XRF available, with the most powerful X-ray tube. Perfect for gold pathfinders, transition, and heavy metals this equipment is known to be the World's only pXRF optimized for rare earth elements. Several varieties have already appeared in the African market; the X-555, for instance, is known to be the most advanced X-ray tube technology available, led by a 55 kV X-ray tube - the world's only handheld XRF with this capability.

The 55 kV operation, rather than the industry typical 50 kV, delivers higher performance for critical "light" and some "heavy" REEs, making it a superior option for REE analysis. Contact: sales@sciaps.com; 339-927-9455; Office; 7 Constitution Way, Woburn, MA 01801, United States (https://www.sciaps.com/industries/geochemistry?gclid= EAIaIQobChMI4YLNotCp_wIVg-PtCh341QgNEAAYASAAEgJWwfD_BwE (accessed 04.05.2023)).

(2). SGS announced the opening of its new laboratory in Yamoussoukro in the Ivory Coast on March 22, 2022 to support the growing Ivory Coast mining industry that handles the Country's huge untapped resources which cover two-thirds of the country. Gold remains the most valuable of these mineral resources. This commercial laboratory is equipped with atomic absorption spectrometry (AAS) and fire assay equipment, providing an extensive range of services related to sample preparation and fire assay analytical testing (https://www.sgs.com/en/news/2022/03/sgs-opens-new-geochemistry-laboratory-in-yamoussoukro-ivory-coast (accessed 04.05.2023)). To find out more about the capabilities of the Yamoussoukro commercial laboratory, please get in touch with: Nat Neequaye, Business Manager, Côte d'Ivoire and Senegal: Tel.: +225 27 21 75 22 32; or Tia Innocent Gonti, Laboratory Supervisor; Tel.: +225 07 07 04 26 91.

The Geocongress of 2023

A number of geochemistry conferences were held, or will be held during the period under review, e.g., "African Exploration and Technology Showcase 2022" held between 17–18 November 2022 in Johannesburg, South Africa, and hosted by

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Highlights from Southern Africa during 2022–2023

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the Geological Society of South Africa (GSSA) (https://www.csaglobal.com/geological-society-of-south-africa-african-exploration-showcase-2022/ (accessed 04.06.2023)); and the International Conference on Applied Mineralogy and Geochemistry (ICAMG) that will be held on November 04–05, 2023 in Cape Town, South Africa (https://waset.org/applied-mineralogy-and-geochemistry-conference-in-november-2023-in-cape-town (accessed 04.06.2023)).

However, the Geocongress held in January, 2023 was by far the most prominent meeting in terms of the pertinence of Geochemistry papers presented. Convened by the Department of Earth Sciences at Stellenbosch University, the GSSA and the Igneous and Metamorphic Studies Group (IMSG), a significant part of the 'Proceedings' is comprised of Applied Geochemistry papers, ranging from articles such as: "Hydrogeological characterization of the coastal aquifer in Gqeberha, Eastern Cape, South Africa", by Tamakloe (Abstract Vol., p. 140) to "Trace metal detection along an AMD-contaminated stream using VNIR-SWIR spectroscopy" by Jamie-Leigh Abrahams *et al*. (Abstract Vol., p. 296).

The abstracts of the oral and poster presentations at this conference are available at https://www.gssa.org.za/wp-content/uploads/Geocongress-2023-ABSTRASTS-for-WEB.pdf (accessed 04.06.2023).

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This 2023 paper illustrates South Africa's potential as a global leader in implementing strategies targeting geochemical carbon dioxide removal (CDR) using mine tailings, utilizing methods for alkalinity production and mineral carbonation.

* Regenspurg, S., Virchow, L., Wilke, F., Zimmer, M., Jolie, E. *et al*. 2022. Origin and migration of fluoride in the area of the Aluto Volcanic Complex (Main Ethiopian Rift).Applied Geochemistry 146 (2),105403. https://doi.org/10.1016/j.apgeochem.2022.105403.

This study investigates the origin of fluoride and the reason for its accumulation in the rift waters,

* Vane, C.H., Kim, A.W., Lopes dos Santos, R.A.,, Gill, J.C. Moss-Hayes, V.M. *et al*., 2022. Impact of organic pollutants from urban slum informal settlements on sustainable development goals and river sediment quality, Nairobi, Kenya, Africa. Applied Geochemistry 146, 105468. https://doi.org/10.1016/j.apgeochem.2022.105468.

"Urban sediments from informal settlements (slums) on the Nairobi, Ngong and Mathare rivers (*n* = 25), were evaluated for sediment quality. Microtox bioassay identified 8 sites as toxic, 9 as moderately toxic and 8 as non-toxic".

30th International Applied Geochemistry Symposium (IAGS)

The IAGS is a prestigious scientific event, commonly run on a biennial basis, and is held under the auspices of the Association of Applied Geochemists (AAG), representing a significant gathering of geochemists from all over the world.

Our theme for the 2024 conference is "Applied Geochemistry for a Sustainable Future" and our goal is to attract over 300 representatives from industry, universities, research organizations, government departments and consultancies, along with a strong contingent of recent and current students.

This chance to host the IAGS once again in Australia (last held here in 2005) will present many opportunities to advance geochemistry and its application to exploration and the environment, promote the exchange of scientific knowledge and encourage research and development, and foster geochemistry as a profession of choice. With a strong focus also on diversity and inclusion, plus the financial and governance support of the AAG, we believe that the IAGS presents an exciting opportunity to showcase your organisation to an international audience.

The scientific program is currently being developed and will be announced as soon as practical, but it is envisioned that the topics will cover all domains of applied geochemistry, and will attract strong abstract submission and attendance. The programming will involve 4 days of scientific sessions, with a day of field trips on the Wednesday.

Sponsorship opportunities are available.

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

or email iags2024@bie.com.au

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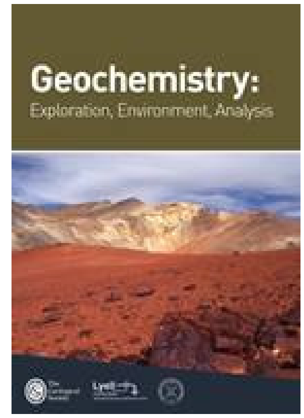
Geochemistry: Exploration, Environment, Analysis

Volume 23, Issue 2, May 2023

Research Articles



Comparison of lithium borate fusion and four-acid digestions for the determination of whole-rock chemistry – implications for lithogeochemistry and mineral exploration
Z. Zivkovic, L. Danyushevsky, S. Halley, S. Barker, and M. Baker
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2).
https://doi.org/10.1144/geochem2022-054

Comparison of main and accompanying metals distribution patterns in newly documented deposits of the Northern Copper Belt in Poland
A. Pietrzela and T. Bienko
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2).
https://doi.org/10.1144/geochem2022-046

Quantitative analysis of Li, Na and K in single-element standard solutions using portable laser-induced breakdown spectroscopy
N. Schlatter and B. Lottermoser
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2). https://doi.org/10.1144/geochem2023-019

Biogeochemical fractal characteristics of trace elements in the Shizhuyuan polymetallic mining area and their significance for prospecting
H. Zhou, K.,Tan, Y. Li, Y. Xie, S. Han and W. Xiao
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2). https://doi.org/10.1144/geochem2022-062

Combined use of multiple external and internal standards in LA-ICP-MS analysis of bulk geological samples using lithium borate fused glass
R.M. Conrey, D.G. Bailey, et al.
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2). https://doi.org/10.1144/geochem2023-001

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N. Reid, C. Plet, R.L. Thorne, A. Hunt, J. Hille, R.R.P. Noble and D.J. Gray
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Geochemistry: Exploration, Environment, Analysis (2023), 23 (2) https://doi.org/10.1144/geochem2022-034

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Geochemistry: Exploration, Environment, Analysis (2023), 23 (2) https://doi.org/10.1144/geochem2023-006

Thematic collection: Reviews in exploration geochemistry

Soil gases in mineral exploration: a review and the potential for future developments
C. Plet and R.R.P. Noble
Geochemistry: Exploration, Environment, Analysis (2023), 23 (2) https://doi.org/10.1144/geochem2023-008

New Surficial Geochemistry Team at the Ontario Geological Survey

Dr. Chris Beckett-Brown recently joined the OGS as a surficial geochemist, replacing long time AAG member Stew Hamilton who retired in 2022. Chris completed his PhD in 2021 in Mineral Deposits and Precambrian Geology at the Harquail School of Earth Sciences, Laurentian University. His PhD research focused on assessing the indicator mineral potential of tourmaline supergroup minerals for porphyry Cu exploration. Following his PhD, he spent a year as a Postdoctoral Fellow in the Applied Geochemistry Section of the Geological Survey of Canada where he focused on developing and defining surficial geochemical methods and footprints for porphyry Cu exploration at the Casino deposit, Yukon. He was also involved in developing and refining drift exploration methods for critical mineral pegmatites, specifically Li-pegmatites, through the study of the Brazil Lake pegmatites in Nova Scotia. Chris' research at the OGS focuses on the development of surficial geochemistry techniques (indicator minerals, till, stream and lake sediment geochemistry) for a broad range of deposit types.

Grant Hagedorn joined the OGS in 2022 as a surficial geologist, replacing Andy Bajc who retired in 2019. Grant obtained a BSc from the University of Guelph in Environmental Geoscience and Geomatics in 2017 and a MSc in Earth Science from the University of Waterloo in 2022. His MSc research used till major oxide geochemistry and ice flow indicators to determine till provenance in southern Northwest Territories. Grant's research at the OGS focuses on drift prospecting and surficial mapping. His current project is in the Georgia Lake area, sampling till for regional prospectivity (specifically Li-pegmatites), deciphering the ice flow history of the area, and surficial mapping.

Heavy Mineral Map of Australia Release Workshop 12 October 2023

The Heavy Mineral Map of Australia (HMMA) is the world's first public domain, continental-scale heavy mineral dataset and atlas. Through a collaboration between Geoscience Australia and Curtin University, over 1,000 archived samples from across Australia have been analysed for automated identification and quantification of heavy minerals. The HMMA and accompanying cloud-based mineral network analysis (MNA) tool are likely to positively impact mineral exploration and prospectivity modelling around Australia, as well as have other applications in earth and environmental sciences. The HMMA and MNA tool will be publicly released at a workshop in Perth, Western Australia, on 12 October 2023. Registration is fere and available for in-person or online attendance.

AAG Council Elections 2023

This is the annual reminder to AAG Fellows (and Members that could become Fellows) that we need your participation on Council for the coming term. Each year the Association of Applied Geochemists (AAG) seeks motivated and energetic AAG Fellows to stand for election to the position of "Ordinary Councilor." Similarly, each year some of our most outstanding Fellows are ready, willing, and able to meet this challenge. I encourage those Members that have the experience and enthusiasm to be involved, to convert your membership status to Fellow, and work to make a bigger contribution to the AAG (see the website for details).

It is our sincere hope that this notice might entice more people to step forward for election to this important position. If you are not yet a Fellow but want to be more involved, please send me an email as we are looking to get more of our junior members active in the AAG and other opportunities will be coming available.

Councilor Job Description

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

Qualifications and Length of Term

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

Each Councilor serves a term of two years and may then stand for election to a second two-year term. The By Laws forbid serving more than two consecutive terms, although someone who has served two consecutive terms can stand for election again after sitting out for at least one year. Elections are usually held in October-November of the year for a term covering the following two years. Our next election will be held in October-November 2023 for the term of 2024–2025.

How to Get Your Name on the ballot

If you are interested in placing your name into consideration for election to AAG Council, simply express your interest to the AAG Secretary (Dave Smith, dbsmith13@gmail.com) by October 15, 2023 and include a short (no more than 250 words) summary of your career experience. This summary should include the following:

- Your name
- Year that you became a Fellow of AAG
- Earth science degree(s) obtained, graduation year(s) and institution(s)
- Employment—list major employers and state years worked for each, e.g. 1980–1990, and type of work
- Position held as part of AAG or other past contributions to AAG
- 1–2 sentences about your professional experiences in applied geochemistry

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

John Carranza
President

Consider Becoming a Fellow of the AAG

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

Download the form here:
https://www.appliedgeochemists.org/

The AGG-SGS Student Presentation Prize

The Association of Applied Geochemists,
through the support of the 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 presentation of high-quality research by students at an International Applied Geochemistry Symposium (IAGS) and provide furhter 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 presentation 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.

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 the Department my 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 IASG 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 the 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 subscriptions to the GEEA and EXPLORE.
3. A certificate of recognition.

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

Welcome New AAG Members

Regular Members

Regular 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.

Mr. Christopher Oorschot
Exploration Manager, Yandal Resources Ltd.
33 Shaftesbury Avenue, Bayswater, WA
AUSTRALIA 6053
Membership # 4512

Kimberley Beisner
Hydrologist, U.S. Geological Survey
6700 Edith Blvd NE, Albuquerque, NM
UNITED STATES 87113
Membership # 4513

Mr. Nicolas Maminiaina
Lecturer, University of Antananarivo, Geology Engineering
Lot AV 679 TER Faliarivo, Antananarivo
MADAGASCAR
Membership # 4514

Mr. Christopher Smith
Senior Geologist, Stratex Geoscience
2548 22nd Ave. E.. Vancouver, BC
CANADA V5M 2X5
Membership # 4515

Dr. Christopher Beckett-Brown
Surficial Geochemist, Ontario Geological Survey
933 Ramsey Lake Road, Sudbury, ON
CANADA P3E 2C6
Membership # 4516

Dr. Fabrizio Colombo
Principal Consultant, Ultra Petrography and Geoscience
202-2171 West 2nd Avenue, Vancouver, BC
CANADA V6K 1H7
Membership # 4517

Mr. Carlos Jimenez
Project Geochemist, Barrick Gold Corp.
CR 35 # 72 sur-251
1502, Torre de la Provincia I, La Doctora, Sabaneta, ANT
COLOMBIA
Membership # 4518

Dr. Carl Spence-Jones
Senior Geologist, Allied Gold Corp.
5 Delph Court, Leeds, England
UNITED KINGDOM LS62HL
Membership # 4519

Dr. Marie-Claude Williamson
Research Scientist, Geological Survey of Canada
601 Booth Street, Ottawa, ON,
CANADA K1A 0E8
Membership # 4520

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.

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

Please let us know of your events by sending details to:
Steve Amor, Email: steve.amor2007@gmail.com
or
Elizabeth Ambrose, Email: eambrose0048@rogers.com

2023

2–5 October	5th Euro-Mediterranean Conference for Environmental Integration. Rende Italy. Website: tinyurl.com/4776md4f
4–6 October	Mongolia Mining 2023. Ulaanbaatar Mongolia. Website: mongolia-mining.com
15–18 October	GSA Connects 2023. Pittsburgh PA USA. Website: community.geosociety.org/gsa2023
22–27 October	2nd Joint Symposium of the International Societies for Environmental Biogeochemistry & Subsurface Microbiology. Banff AB Canada. Website: iseb-issm2023.org
31 October – 2 November	14th Fennoscandian Exploration and Mining conference. Levi Finland. Website: femconference.fi
7 November	Drill, Deal, or Drop: Exploration Decision-Making through Commodity and Project Cycles. Online using Zoom. Website: tinyurl.com/2858wjvw
26 November – 1 December	XVI Congreso Geológico Chileno (Chilean Geological Congress). Santiago Chile. Website: congresogeologicochileno.cl/en
27–30 November	Mediterranean Geosciences Union Annual Meeting. Istanbul Turkey. Website: medgu.org
28 November – 1 December	28th International Mining Congress and Exhibition of Turkey (IMCET 2023). Belek Turkey. Website: tinyurl.com/4z2cvzy8
4-8 December	American Exploration and Mining Association Annual Meeting. Sparks NV USA. Website: www.miningamerica.org/annualmeeting

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2024

14–19 January	Gordon Research Conference: Geobiology: Past, Present and Future. Galveston TX USA. Website: www.grc.org/geobiology-conference/2024
15–20 January	Winter Conference on Plasma Chemistry. Tucson AZ USA. Website: icpinformation.org/winter-conference
22–25 January	Mineral Exploration Roundup 2024. Vancouver BC Canada. Website: roundup.amebc.ca
2–3 February	Atlantic Geoscience Society Annual Colloquium. Moncton NB Canada. Website: atlanticgeosciencesociety.ca/colloquium-2024
18–23 February	2024Ocean Sciences Meeting. New Orleans LA USA. Website: www.agu.org/ocean-sciences-meeting
3–6 March	Prospectors & Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/convention
3–7 March	Minerals, Metals & Materials Society 2024 Annual Meeting & Exhibition. Orlando FL USA. Website: www.tms.org/AnnualMeeting/TMS2024
18–21 March	XV Latin American Symposium on Environmental Analytical Chemistry. Ouro Preto Brazil. Website: tinyurl.com/3v76363s
14–19 April	EGU General Assembly. Vienna Austria. Website: www.egu24.eu
2–4 May 2024	10th International Conference on Geographical Information Systems Theory, Applications and Management. Angers France. Website: gistam.scitevents.org
8~9 May	International Mining Geology Conference 2024. Perth WA Australia. Website: tinyurl.com/4dp4mffx
19–22 May	GAC-MAC Annual Meeting. Brandon MB Canada. Website: gac.ca/events/gac-mac-annual-meeting
21–23 May	11th World Conference on Sampling and Blending. Muldersdrift South Africa. Website: tinyurl.com/ycx9psc8
17–19 June	GeoConvention 2024. Calgary AB Canada. Website: geoconvention.com
23–28 June	Geochemistry of Mineral Deposits (Gordon Research Conference). Newry ME USA. Website: tinyurl.com/bddja374
23–28 June	Geochemistry of Mineral Deposits for a Low Carbon society (Gordon Research Conference). Newry ME USA. Website: tinyurl.com/bddja374

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Articles in Past Issues of EXPLORE

5 years ago EXPLORE 180 (September 2018)
Lithogeochemical classification of hydrothermally altered Paleoproterozoic plutonic rocks associated with gold mineralization: examples from the Nanortalik Gold Belt of South Greenland and the “Gold Line” of northern Sweden

10 years ago EXPLORE 170 (September 2013)
Application of heavy stable isotopes to explain (bio)geochemical processes occurring during the formation, transport and remediation of metalliferous mine waters

20 years ago EXPLORE 121 (November 2003)
Biogeochemistry: Discovery using metal concentrations in plants — Bisbee (Cochise County, AZ)

30 years ago EXPLORE 81 (October 1993)
Another cry from the heart- advice about multivariate statistical procedures

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

CALENDAR OF EVENTS

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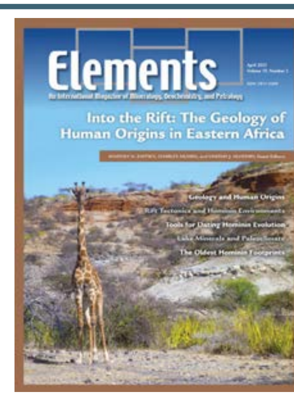
2024 continued

8–12 July	12th International Kimberlite Conference. Yellowknife NT Canada. Website: 12ikc.ca
15–18 July	11th Annual International Conference on Geology & Earth Science. Athens Greece. Website: www.atiner.gr/geology
21–26 July	International Conference on Mercury as a Global Pollutant. Cape Town South Africa. Website: tinyurl.com/mw37tdh4
11–15 August	IWA World Water Congress & Exhibition. Toronto ON Canada. Website: worldwatercongress.org
18–23 August	4th European Mineralogical Conference. Dublin Ireland. Website: emc-2024.org
18–25 August	Goldschmidt 2024. Chicago IL USA. Website: tinyurl.com/5cr87s7e
24–30 August	35th International Geographical Congress. Dublin Ireland. Website: igc2024dublin.org
25–31 August	37th International Geological Congress. Busan, Republic of Korea. Website: www.igc2024korea.org
15–19 September	Geoanalysis 2024. Wuhan China. Website: tinyurl.com/yeyj8nuh
6–9 October	MS&T24: Materials Science &Technology. Pittsburgh PA USA. Website: www.matscitech.org/MST/MST24

Recently Published in Elements



April 2023, v. 19, no. 2 Into the Rift: The Geology of Human Origins in Eastern Africa

The articles in this issue are about the East Africa Rift, which extends from the Horn of Africa in the north down to Lake Malawi in the south, wherein a plethora of paleoanthropological sites (e.g., Olduvai Gorge, Turkana, Awash) is preserved, documenting our evolutionary journey spanning the last seven million years of Earth's history.

The AAG news item in this issue of Elements is about our new Councillors for 2023–2024.

June 2023, v. 19, no. 3 Olivine

The articles in this issue review olivine research from the atomic scale to the Solar System and beyond, highlighting olivine research that crosses many disciplines, from seismology and geodynamics, petrology and volcanology to low-temperature geochemistry and remote sensing.

There are no AAG news items in this issue of Elements.

Reminder

AAG members can access past issues of Elements at

http://elementsmagazine.org/member-login/

using their e-mail address and AAG member ID.

John Carranza
President

EXPLORE Publication Schedule

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

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

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

- **Manuscripts** should be double-spaced and submitted in digital format using Microsoft WORD®. Articles should be between 2000 and 3000 words. Do **not** embed figures or tables in the text file.
- **Figures and/or photos** (colour or black and white) should be submitted as separate high-resolution (2000 dpi or higher) tiff, jpeg or PDF files.
- **Tables** should be submitted as separate digital files in Microsoft® EXCEL format.
- All scientific/technical articles will be reviewed. Contributions may be edited for clarity or brevity.
- Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for *Geochemistry: Exploration, Environment, Analysis* (GEEA) that are posted on the GEEA website at: https://www.geolsoc.org.uk/geea-authorinfo
- An **abstract** of about 250 words must also be submitted that summarizes the content of their article. This abstract will be published in the journal ELEMENTS on the 'AAG News' page.

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