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Testing a rapid sampling and analysis workflow in the remote Nullarbor Plain, Australia

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INTRODUCTION

Winterburn *et al.* (2019) categorised the past decadal advances in exploration geochemistry in four areas; 1) understanding metal mobility and mechanisms, 2) rapid geochemical analyses, 3) improved data access, integration and interoperability, and 4) innovation in laboratory-based methods. Items 2 and 3 can be addressed with new technology and have the potential to improve efficiency and decision making in the field for large economic benefits and efficiencies. However, it can be hard to disrupt traditional work routines to realise these benefits. This paper specifically addresses items 2 and 3, with the objective to demonstrate some approaches used to rapidly sample, analyse and integrate data to geochemically map a region in remote South Australia. In a recent surface geochemical characterisation study, the Geological Survey of South Australia (GSSA) required a protocol for quick and efficient sampling, and with minimal environmental impact. The opportunity within this study was that there was no set protocol to adhere to, leaving the GSSA and CSIRO to test or adapt new rapid sampling technologies. The key criterion was based on the following question: can we geochemically characterise a region of 4000 km^2, by sampling and analysing 300 sites in 7 days using a single field team?

Physical sample collection time is difficult to reduce significantly, with motorised augers/drills/clippers and manual shovels used as needed in current practice. However, sample/data handling and field analysis techniques can be changed and improved. Recording data electronically in the field provides several advantages over pen and paper. Consistency between sampling teams is maintained, transcription errors are negated and the time taken at each individual sample location is significantly reduced. The less glorified technology changes such as data handling, sample tracking and similar management tasks are often overlooked.

Field digital notebooks are commonly known and used devices for field data capture and a number of platforms and examples exist with geological surveys using them for mapping. Adaption of the platforms for mineral exploration sampling is achieved through modified Electronic Laboratory Notebooks (ELNs – tablet-style computers). Scientists willingly make use of generic notebooking software to aid their work, yet most ELNs lack the required functionality to meet the needs of specific fields (Kanza et al. 2017). In mineral exploration, commercial offerings are usually linked to specific analytical inputs (e.g., IMDEXHUB-IQ™ or Vanta™ XRF software). Often, these field data are later transferred and adapted to a specified company database. Tracking of samples past this point is tied to the individual company. One option for future-proofing sample provenance is the use of International Geo Sample Numbers (IGSN) that has become standard use for CSIRO sampling. IGSN are persistent (digitally long-lived), globally unique identifiers of samples. Unique identification of samples also assists the tracking of samples through various institutions, repositories and laboratories (Devaraju et al. 2016). IGSN can link to other samples (e.g. sub-samples), sampling features which are identified by an IGSN (e.g. drill holes, outcrops), connect the sample to data identified by Digital Object Identifiers (DOI), and link to descriptions and interpretations of the sample and data in the literature. This way of identifying and connecting research resources will help to maintain traceability and reproducibility of research into the future (Stall *et al.* 2019).

While protocols for field sample identification and data tracking have not been as rapidly taken up by industry, industry has certainly adapted quickly to rapid geochemical analyses, principally through the application of field portable X-ray fluorescence instrumentation (fpXRF; Arne *et al.* 2014; Sterk *et al.* 2018). Workflows and QAQC protocols are available for fpXRF (Fisher *et al.* 2014; Hall *et al.* 2012; 2014; Lemière 2018) but not always applied. One critical issue is the quality of sample preparation, or the portability of sample preparation devices required to prepare samples of appropriate quality for fpXRF (and other instrument) analysis.

With a mandate to rapidly sample and characterise a remote region of Australia, we developed a sampling and analysis workflow to maximise efficiency, and appropriate field preparation and analytical processes to generate quality results as the campaign evolved. This paper demonstrates the components of both field sampling and analysis conducted on the Nullarbor Plain of South Australia in November 2017.

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EXPLORE

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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.
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- 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**:
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ADVERTISERS

Notes from the Editor

Welcome to the first **EXPLORE** issue of 2020 and welcome Steve Cook as our new **EXPLORE** Business Manager. This issue features one article that describes rapid sampling and analysis workflow in the remote Nullarbor Plain of Australia. It was written by Ryan Noble, Nathan Reid, Jens Klump, Jess Robertson, Dave Cole, David Fox, Tenten Pinchand, Ignacio González-Álvarez, Carmen Krapf, and Ian Lau.

EXPLORE thanks all those who contributed to the writing and/or editing of this first issue in 2020, listed in alphabetical order: Steve Amor, Dennis Arne, Al Arsenault, John Carranza, David Cohen, Dave Cole, Steve Cook, David Fox, Ignacio González-Álvarez, Jens Klump, Carmen Krapf, Ian Lau, David Leng, Ryan Noble, Tenten Pinchand, Nathan Reid, Jess Robertson, Dave Smith, and Brian Townley.

Beth McClenaghan
Editor

2020 AAG Dues Reminder

Reminder that AAG membership fees for 2020 are now due.

Membership fees can be paid on AAG's website at:
https://www.appliedgeochemists.org/membership/renew-membership

President's Message

I would like to begin by acknowledging the great honour bestowed upon me in being asked to serve as President of the AAG for 2020-2021. This year marks the 50th anniversary of the AAG and it brings to mind the many applied geochemists who started our Association in 1970 and the team of dedicated volunteers who have maintained the AAG since then and who continue to support it. I would also like to take this opportunity to thank Stephen Cook for shepherding the AAG through the last two years, beginning with our very successful contribution to the Resources for Future Generations (RFG2018) conference held in Vancouver in 2018, to planning for the 29th IAGS to be held in Viña del Mar, Chile, in November 2020, to be co-sponsored with the Geological Society of Chile (SGCH). Steve was ably supported by the AAG councillors and our business manager, Al Arseneault, and by the late Peter Winterburn, who led the local organizing committee for RFG2018.

As past president, Steve will now chair the Awards and Medals Committee. I would also like to thank Ryan Noble for heading this committee for the last two years. David Murphy continues to oversee the Education Committee, Paul Morris is responsible for New Membership, Nigel Radford manages the Admissions and David Cohen oversees Symposia. Gwendy Hall continues to serve us well as Treasurer and will face many new headwinds this year. David Smith is our unfailing guide to proper procedures as Secretary. Please feel free to contact any of these people if you'd like to help or have questions regarding their areas of responsibility.

Steve will also be stepping into the role of Business Manager for **EXPLORE** newsletter, replacing Pim van Geffen who has ably fulfilled the role for the past number of years. I would like to thank Pim for his good work and take the opportunity to thank Beth McClenaghan for her continuing efforts as Editor of **EXPLORE**. Our newsletter provides an excellent venue for short technical articles, reports from regional councillors, news regarding upcoming conferences and listings of recent publications relevant to our profession. Beth is supported behind the scenes by a team of peer reviewers and contributors. Please consider contacting Beth about making a short contribution or offering your assistance.

John Carranza has agreed to take over my role as AAG Vice President and will also be responsible for Regional Councillors. Our Regional Councillors play an important role is representing and advocating for the AAG in many parts of the globe. We are in the process of changing our council meeting times to accommodate councillors based in Europe and Africa and hope that this change will elevate their presence within the AAG. John will then assume the role of President for 2022-2023.

It is also a pleasure to welcome (and in several instances, welcome back) five new councillors for 2020-2021, Maurizio Barbieri, David Murphy, Yulia Uvarova, Thomas Bissig and Beth McClenaghan. Councillors provide the active support the AAG needs to carry out its activities and to promote the profession of applied geochemistry. Councillors must be Fellows of the AAG but this is not an onerous requirement. In addition to being sponsored by three existing Fellows (you need only approach one; they will help find the other two), candidates must:

(i) possess a Bachelor's or equivalent degree in pure or applied science from an educational institution recognized by the Council;
(ii) have completed a period of training and professional experience of at least six years in pure or applied science which shall include at least two years in applying, developing, researching, or teaching methods of applied geochemistry. Up to three years of post-Bachelor's training at a university can be applied toward the six-year requirement;
(iii) be actively practicing applied geochemistry at the time of their application;
(iv) satisfy the Council that they are a fit and proper person to become a Fellow.

encourage all members of the AAG to consider becoming Fellows if they meet the above requirements and to become more involved in the running of the AAG. I would further call upon existing Fellows to consider standing for council later this year. Like all organizations, new ideas are needed at council to ensure our continuing relevance.

As for the future, our membership numbers have stabilized but we need to do more to promote and engage with the next generation of geochemists. With that in mind council has endorsed several initiatives. One development underway is a new series of practical problems in applied geochemistry to be available to members on our web site. A prototype should be available for viewing shortly, and a call for contributors will be forthcoming. We are also looking into mechanisms by which completing the problems can be rolled into a micro-credential in applied geochemistry, perhaps with the support of university partners. Another proposed initiative would be through our journal, GEEA. This would involve a thematic issue to review the state of the science in applied geochemistry, including recent advances in instrumentation, digestions and data interpretation. We continue to either

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President's Message… *continued from page 4*

provide or contribute to short courses in applied geochemistry, not only at our own IAGS conferences, but in conjunction with partner organizations. Taken together, these initiatives will keep the AAG at the forefront of applied geochemistry and provide a professional development pathway for geoscientists seeking further qualifications.

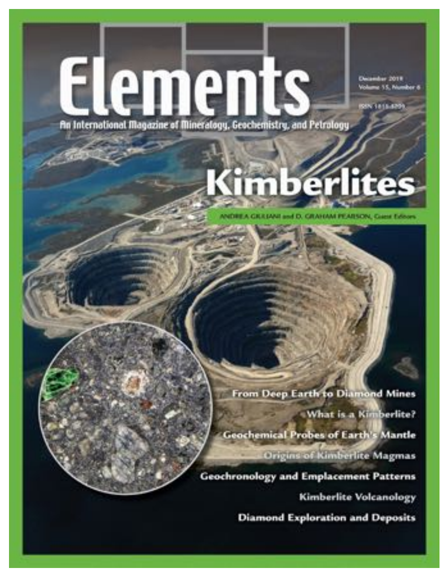
Other initiatives through GEEA include a recent call for papers to contribute towards a thematic volume entitled "Big Data Advances in Exploration and Environment Geochemistry". The deadline for contributions is April 30, 2020. A thematic set of papers based on the Exploration '17 conference edited by Hugh De Souza should be available as this letter is published. Another thematic volume, "Uranium Fluid Pathways (Advances in unconformity-related uranium exploration driven by discoveries in the Patterson Lake Corridor, Athabasca Basin, Canada)" is also currently underway. Guest editors include Eric Potter, Victoria Tschirhart and Jeremy Powell. Plans are also underway for a thematic volume in 2021 entitled "Carbon Sequestration in Mining", edited by Rob Bowell. I would like to thank Scott Wood for his work as Editor in Chief, as well as his editorial team.

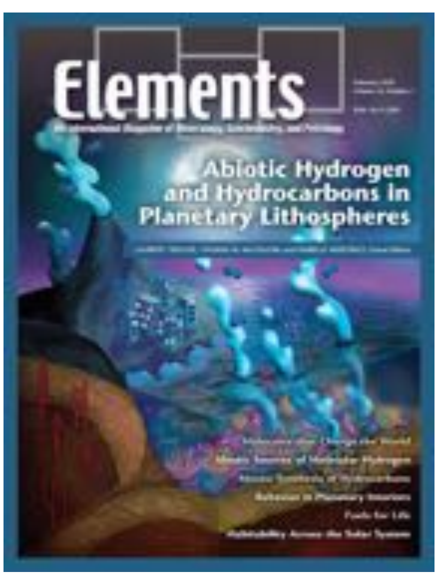
As mentioned previously, we will be celebrating the 50th anniversary of the AAG at the 29th IAGS in Viña del Mar, Chile. Brian Townley leads the local organizing committee which has been proactive in developing contingency plans should further civil disruptions happen after the constitutional referendum to be held on April 26th. This event is the start of a process that will hopefully result in a new constitution by March 2022. Council is keeping track of developments and updates will be provided should the situation change, but at the time of writing things appear to have stabilized in Chile and plans are well advanced for Viña del Mar. The conference web site is up and running at https://iags2020.cl/ and abstracts are due by March 31, 2020. I would encourage you to visit the web site to view the eclectic mix of technical sessions, workshops and short courses on offer and, of course, to register!

Dennis Arne
President

Recently Published in Elements

December 2019, Volume 15, no. 6, Kimberlites
This issue summarizes current knowledge and controversies on kimberlite formation, including key aspects of the petrology, geochemistry and volcanology of these unique rocks. It shows how kimberlites can be successfully dated, and explore links between the temporal and spatial distribution of kimberlites and known geological events. It reviews diamond exploration and resource evaluation methods, demonstrating the inextricable link between an accurate understanding of the characteristics of kimberlites, their entrained mantle cargo, and diamonds. AAG news in this issue include Message from the [Past] President, Stephen Cook, and Obituary for Dr. Victor M. Levinson (1956 – 2019).





February 2020, Volume 11, no. 1, Abiotic Hydrogen and Hydrocarbons in Planetary Lithospheres
This issue highlights recent developments in the understanding of geologic sources of hydrogen and methane, the biological utilization of these compounds, and the potential for human exploitation of these resources. AAG news in this issue includes an obituary for Peter Winterburn (1962-2019) and an abstract of article "Gold dispersion in transported cover sequences especially in chemical (palaeoredox front) and physical (unconformity) interfaces linked to the landscape history of Western Australia" by Ravi Anand and Walid Salama (which appeared in issue 183 (June 2019) of the Explore newsletter).

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

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SETTING

The study area is the Coompana region of the Nullarbor Plain, located in the southern central part of Australia, and has minimal topographic variation (Fig. 1). The Nullarbor Plain stretches over the states of South Australia and Western Australia and is the surface expression of the Miocene (~23-5 Ma) Nullarbor Limestone. It is one of the largest limestone outcrops on Earth (>300,000 km^2; O'Connell et al., 2012) and currently experiences semi-arid climatic conditions (annual precipitation ~150-400 mm and evaporation of ~2,000-3,000 mm; Bureau of Meteorology 2013). The study area shows a northwest-southeast elevation trend increasing to the north-west by ~100 m over the ~80 x ~50 km study area. The landscape surface above these sedimentary formations comprises a thin cover of shallow, red-brown, calcareous, loamy to sandy soil with occasionally outcropping limestone covered by a variably thick (a few metres), hard calcrete layer (Fig. 2). Vegetation here in the Coompana area is dominated by low shrubland of chenopods, mostly pearl bluebush (*Maireana sedifolia*) and bladder saltbush (*Atriplex vesicaria*) and minor samphire (*Sarcocornia sp.*; Dunn & Waldron 2014; Fig. 2).

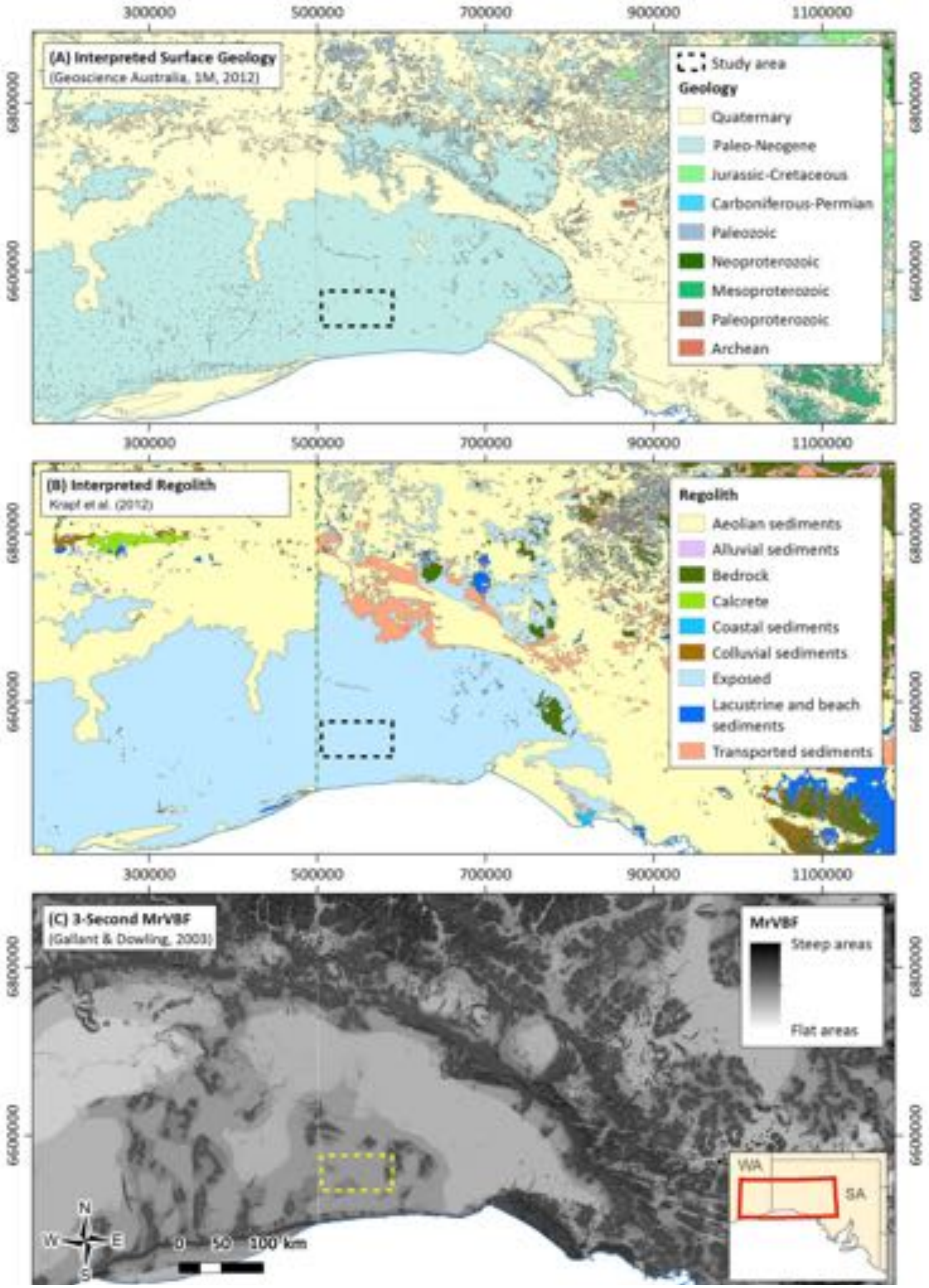

Figure 1. Reference regional maps for the Coompana region in Australia. (A) Interpreted age of surface geology units; (B) interpreted regolith map of the region; and (C) gradient slope map (Multiresolution Index of Valley Bottom Flatness, MrVBF) and inset showing the location of the region in Australia. Coordinates UTM GDA 94, Zone 52.

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The region was selected for the survey because it was a priority region of the South Australian Government as a new frontier for exploration, with little existing geological knowledge. Recognition of the area as a potential subduction driven, migrating magmatic arc with an age profile similar to some other well-endowed regions in South Australia and Western Australia (Dutch *et al.* 2018a,b) has generated interest for the exploration of magmatic nickel-copper sulphide deposits in particular (Lawley 2017).

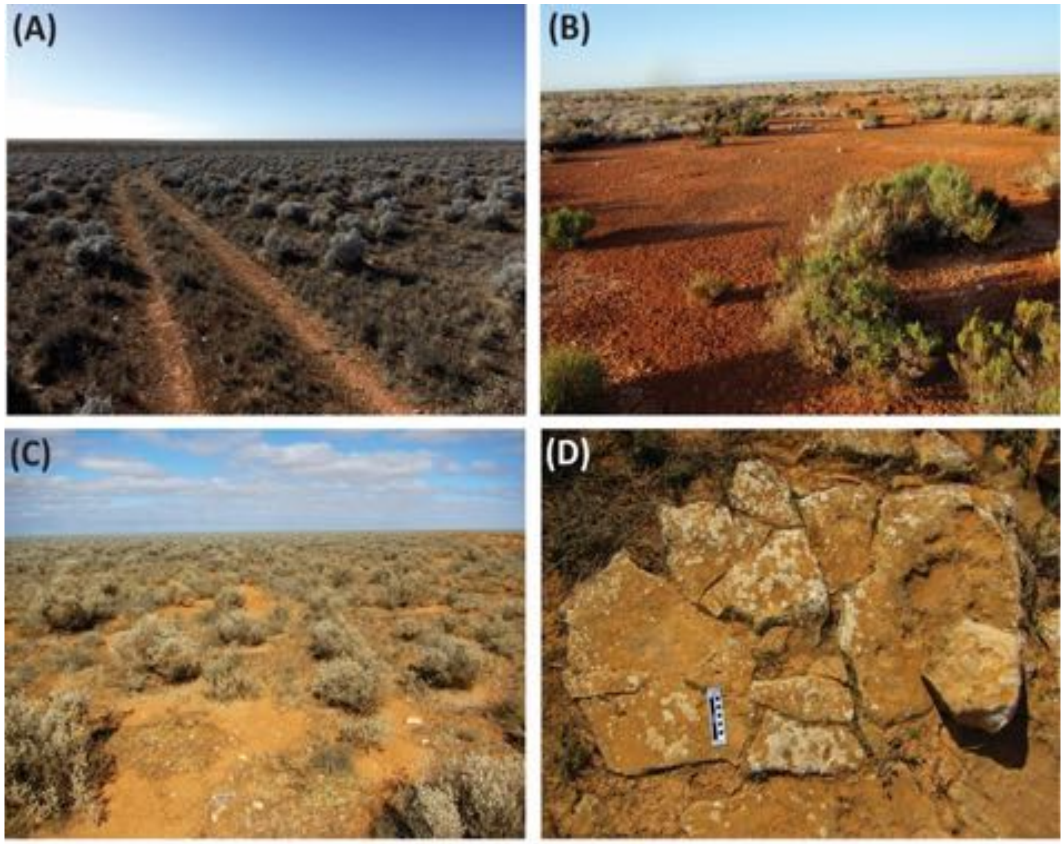

Figure 2. Examples of regolith landform types in the Coompana area: (A) Very gently undulating limestone plain on which a variably thick (less than a few meters) calcrete has developed, overlain by shallow calcareous loamy soil, sometimes with a sparse mantle of limestone and calcrete fragments. Dense vegetation of low shrubland of pearl bluebush and bladder saltbush cover most of the area. (B) Erosional residual plain with clay pans randomly distributed throughout. Vegetation is very scattered and dominated by samphire and minor grassland. (C) Erosional residual plain with NW-SE aligned vegetation. Very gently undulating limestone plain with abundant sub-/outcrop of Nullarbor Limestone and calcrete and/or mantle of mixed-sized rock fragments. NW-SE aligned vegetation of low shrubland and/or grassland. (D) Typical outcrop of Nullarbor Limestone within erosional residual plain.

METHODS

Rapid Field Sample Collection

Sample sites were selected based on being representative of the area (Fig. 2a, c) and commonly away from outcropping rocks or extensive clay pans (Fig. 2b) that represent shallow low-lying areas and possibly have a greater contribution of alluvial materials. Teams of three people collected samples on a grid at 4 km intervals (~280 sites) over a region of 4000 km^2 using a helicopter. This spacing was chosen to highlight regional geochemical variations and not specifically target mineral deposits or large systems. Field sampling times were 5-6 minutes per site to collect five sample media. With travel and refueling time factored in, this equated to 10 minutes per sample site over the 7 days of sampling. Five sample media were collected at each site:

- shallow soil sample (200-400g) from approximately 2-10 cm depth
- surface crust (<3 mm) approximately 20-30 g that is bound by cryptogams (moss/algae/lichens)
- carbonate/limestone lithic lag sample (100-300 g)
- bladder salt bush (*Atriplex vesicaria)* vegetation ~100 g of each (stems and leaves)
- pearl blue bush (*Maireana sedifolia)* vegetation ~100 g of each (stems and leaves)

Nearly all sites were able to be sampled for all five sample types, with the exception of approximately 10 sites that did not have blue bush present in the immediate area from the soils sample location (<50 m radius). Field duplicates were collected every 30 samples sites.

Rapid Field Data Collection

For each sample site, the Field Acquired Information Management System Project (FAIMS) application using the camera on a portable device such as a tablet or phone is used to rapidly scan the sample IDs, generate required information fields, take GPS locations, take photos and link the photos to the specific samples. One person is usually using the Android tablet (we used Samsung TAB A 10.5) and collecting site information including landscape setting and photographs and digging the hole for the dry soil sample (in this setting the hole was 25 cm in diameter and typically

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10-20 cm deep with no horizonation excluding the organic crust). The other person was responsible for collecting the mineral materials and bagging them. The third person conducted the vegetation sampling. The results presented in this article only relate to the soil and lag samples that were processed and analysed in the field. Full details of all sampling and analysis procedures and equipment are available in Noble et al. (2018).

Samples were documented and labeled in the field using the FAIMS application, an open source platform (Ballsun-Stanton et al. 2018). The application was developed with Macquarie University and is available through the Google Play Store and www.fedarch.org. The system was adapted to scan and print bar code labels, auto fill tables and display the appropriate drop-down menus (Fig. 3 and Fig. 4). The geochemical sampling customisation features an interactive GIS component overlying maps (as GeoTIFF) that can be pre-loaded to assist in sample location, although this was not needed as we preloaded sample points into the helicopter navigation system. QA-QC samples were incorporated into the existing automated data listing that is generated in the field as a separate sample ID with a very similar location (a few metres apart).

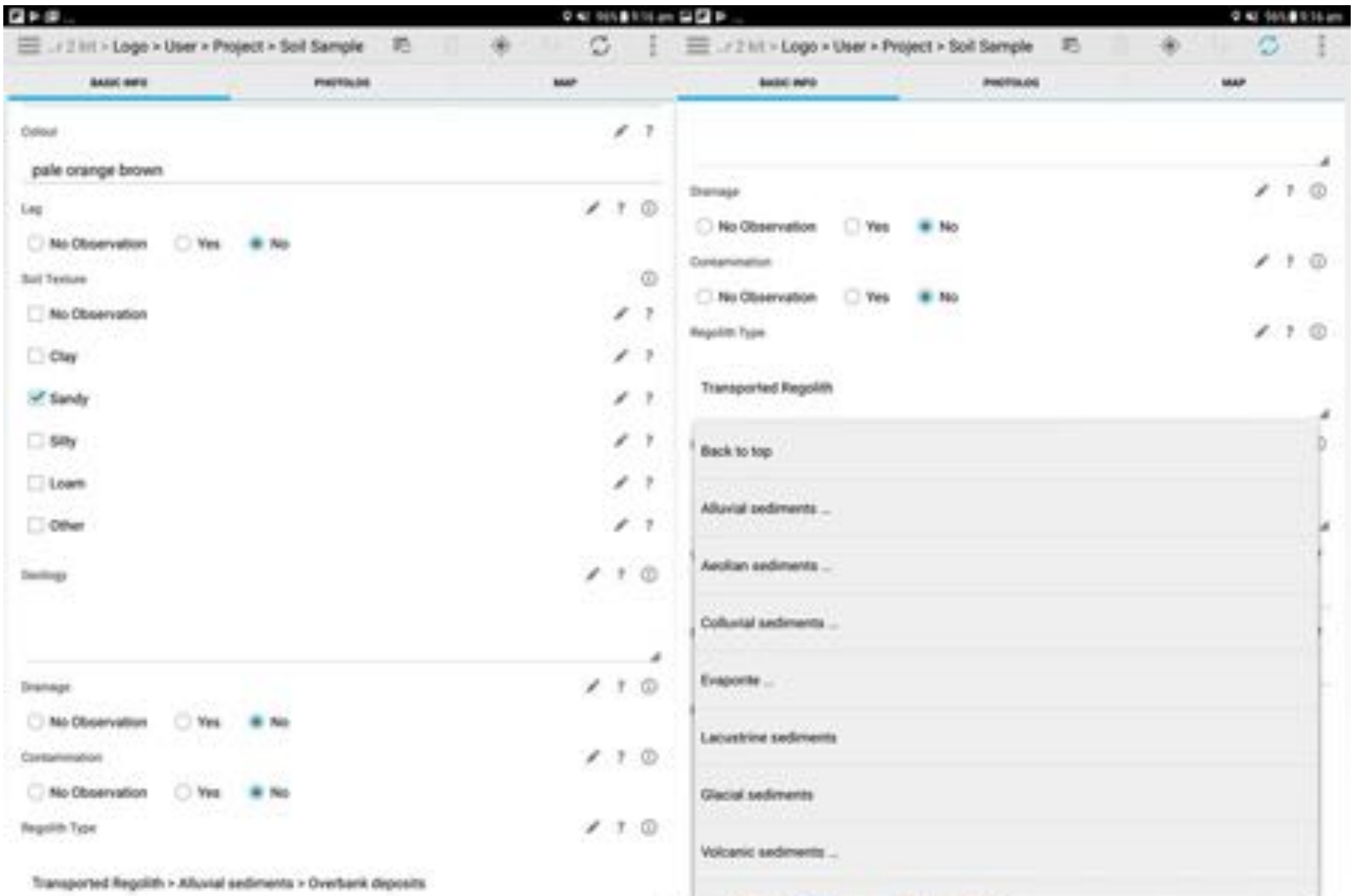

Figure 3. Soil sample site information with dropdown options and site specific parameters. Photos taken are also linked specifically to the site.

To assist the sample documentation and tracking, the FAIMS application was updated to include a barcode reader. Further modification included a field printer and using data matrix labels for scanning (Fig. 4). Sample labels were pre-printed with sample identifiers that were also encoded as a data matrix barcode (Fig. 4). By scanning the pre-printed label, the field team did not have manual data entry and saved a lot of time with in sample documentation. For increased efficiency, the sample labels were printed the evening before and placed on the sample bags. These were then put in numerical order so that a “site batch” of bags could be grabbed together easily. Field duplicate samples used two batches per site and required an additional 3 minutes in sample collection. The FAIMS application works with bags in different order (i.e., you can sample the deeper soil before the surface crust), but the information fields are locked by the sample type (e.g., you can’t enter a sample depth into the surface crust sample information). Scanning the first sample (crust and plant) bags prior to landing at the site decreased the time needed by 1 minute per site. For this task, two tablets were used at each site. By switching screens off between sites, the power would last all day, although a backup and emergency charger were also carried.

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All samples had field sample labels in the IGSN format; these were registered later once connected to the Internet from the office. A field portable server operating with Wi-Fi connectivity ensured all data were effectively captured, backed up and transferred in a useable format to the standard laptop PCs running the portable laboratory and generating data products like maps.

The equipment used in this study performed well in the dry, dusty, arid conditions. Extreme high and low temperatures may cause some problems. The GPS in the devices does not perform well in temperatures >50° C, such as the dashboard of a vehicle, so we keep devices shaded when not in use. The rugged cases are effective for high moisture conditions such as tropical environments. We are yet to test these in extreme cold conditions and expect they would be well suited to most geochemical sampling conditions.

Figure 4. Soil sampling showing the field printed labels and data matrix barcode for scanning the sample identifier into the mobile application.

Rapid Field-Portable Laboratory Preparation and Analysis

Analytical preparation and processing time of four minutes per sample was achieved with a three-person team (soil and lithic lag samples only). Sample preparation is identical for both the soil and the lithic lag samples. A field portable sample preparation laboratory (crush, mill and pellet press) was set up and coupled with fpXRF and Analytical Spectral Device (ASD) analysis (Fig. 5). All soil samples collected were prepared and analysed within 24 hours. Only a few samples required drying (for a few hours) which was managed using a commercial pie oven. Basic requirements for the laboratory were protection from weather, availability of power and working bench space/tables. Samples were not sieved as the soils were not gravelly and were similar in their particle size distribution. Samples were split equally using a riffle splitter with half retained as a bulk reference sample (~150 g) and archived. The split was crushed using a mobile crusher (Reflex™ Crusher model) and milled to <100 µm using a mobile disk mill (Reflex™ Mill model) with disk gap set to the approximate width using provided sample spacing tools (metal strips). Approximately 25 g of the milled soil was pressed into a pellet using a press (Reflex™ Press model) to provide a smooth, uniform surface for analysis with the fpXRF and ASD. Silica blanks were analysed approximately every 40 samples. Analytical duplicate sample analyses

Figure 5. The portable laboratory at Coompana. From left to right, riffle splitter, crusher and mill on one table, pellet press on the old desk, the fpXRF and ASD (inside cardboard box, far right) on the other table.

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were made approximately every 10 samples to assess instrument precision and detection limits. Data calibration of fpXRF measurements against known standard compositions was performed using custom CSIRO software that uses additive log-ratio transformation of data to account for compositional system closure, and a Bayesian linear regression algorithm to robustly estimate and propagate uncertainties (Fig. 6). A stand-mounted Olympus Vanta M-series fpXRF (50 kV X-ray tube and fitted with a large-area silicon drift detector) operated for a total of 60 seconds (30 seconds for each of two beams of different energy levels). All samples and standards were covered by a 4 μm polypropylene film. An ASD (Field Spec 3) with a high intensity contact probe was set up in the field laboratory for visible-near to shortwave infrared reflectance measurements of the pressed pellets. A piece of Spectralon was used as the white reference. Each measurement consisted of an average of 30 scans. Processing of the data consisted of correcting the spectra to absolute reflectance by applying the Spectralon calibration reflectance factor using The Spectral Geologist (TSG™ version 7). Automated feature extraction was performed to estimate the proportions of minerals using TSG® software. QA-QC duplicate samples were incorporated into the existing automated data listing by manually adding an “a” to the ID prior to analysis of that duplicate sample.

Additional analyses and data were also collected using more traditional laboratory decomposition and instrumental methods and are reported in Noble et al. (2018). Major element oxide analysis from LabWest Minerals Analysis, Malaga, Western Australia, was carried out for comparison with fpXRF data. A Li borate fusion (Code AF-02) was used to ensure total recovery of highly refractory mineral phases and silica. Major element oxide analysis was performed using ICP-OES (Perkin Elmer Optima 7300DV) and ICP-MS (Perkin Elmer Nexion 300Q) instrumentation.

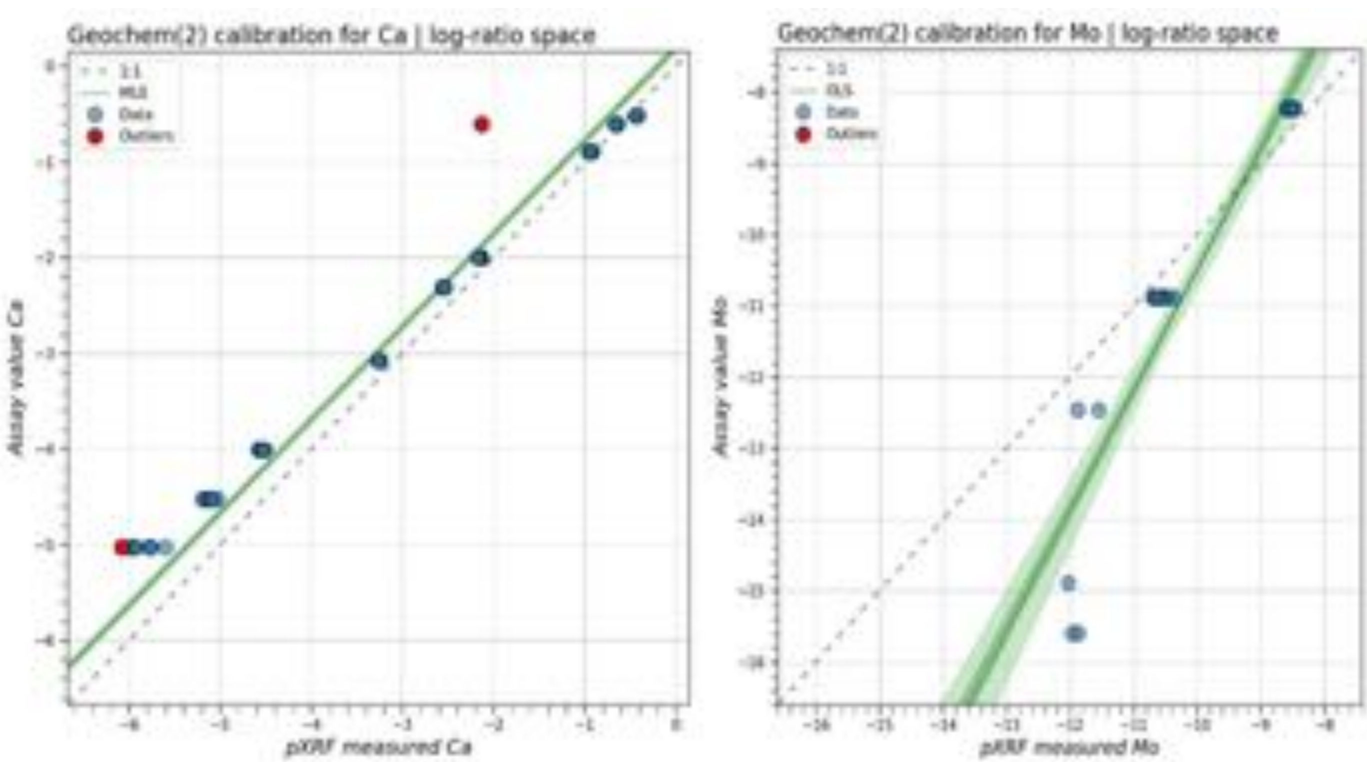

Figure 6. Examples of the CSIRO fpXRF calibrator output showing the data used for standards (blue dots) and rejected outlier data (red dots), 1:1 line and the derived calibration line (green). Laboratory analysis on the y-axis, fpXRF measurement on the x-axis for Ca (left) and Mo (right).

RESULTS

Workflow

The regional geochemistry sampling workflow established from this project is best represented by a flow chart (Fig. 7). Although a number of these points on the flow chart are flexible and will not fit all projects, the general steps are shown. The benefit of obtaining field geochemical data was greatly improved by using analytical standards based on the initial reconnaissance investigation. Machine learning models were tested in this project and the adaption of them to the workflow is shown in Fig. 7, but this aspect of the work is not covered in this paper.

Field Geochemistry and Mineralogy

Over 300 sites were sampled including a targeted infill sampling (36 additional sites at closer spacing) to generate regional geochemical and proxy-mineralogical maps of soil and rock over an area of nearly 4000 km^2 on the Nullarbor

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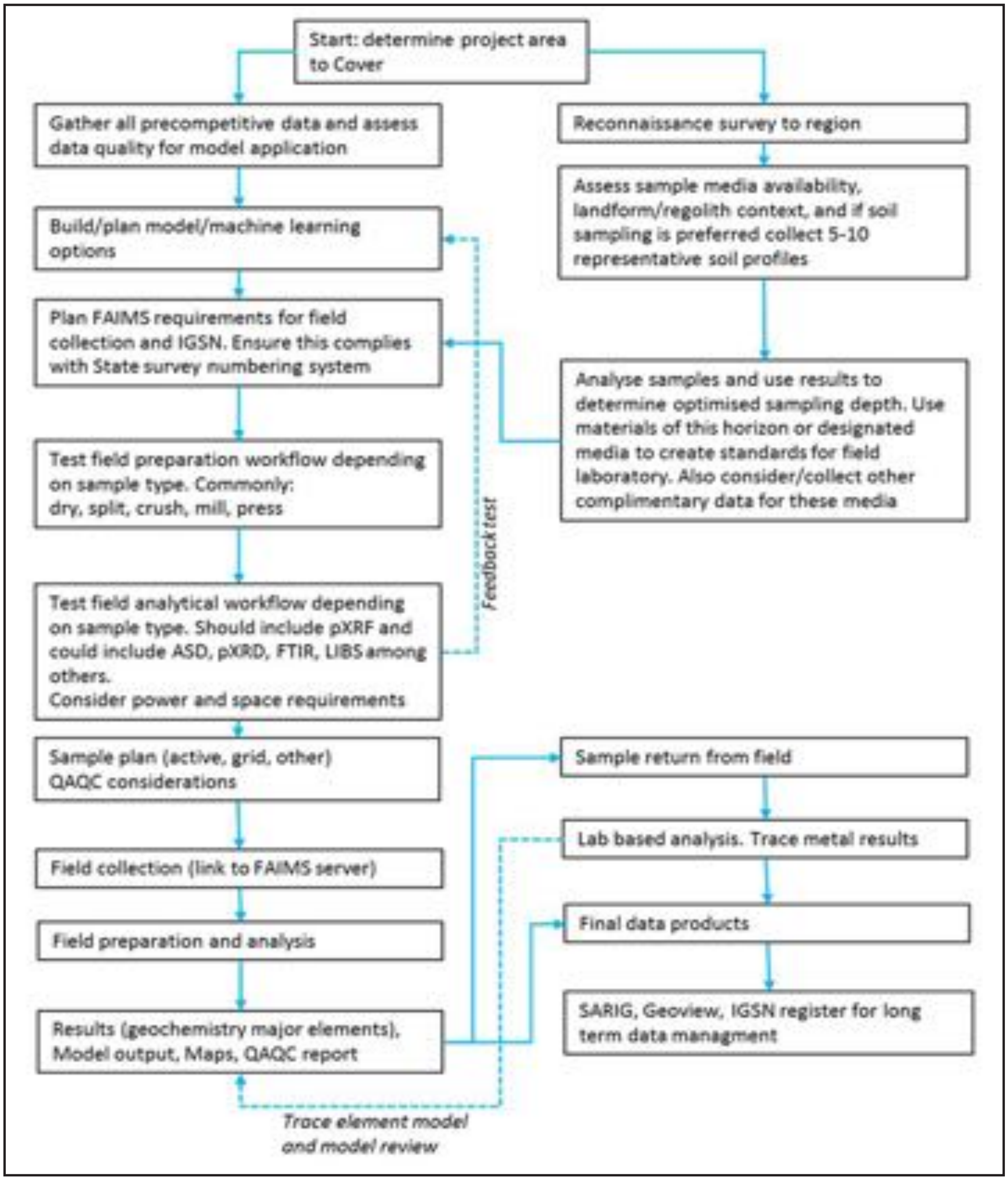

Figure 7. Regional geochemistry sampling workflow for optimised regional sampling and analysis as demonstrated on the Nullarbor Plain in South Australia. SARIG and Geoview are Australian State Geological Survey Data retrieval and visualisation platforms.

Plain. Elemental results from soil and lag were obtained using the fpXRF and mapped for approximately 20 elements and another 10 spectral mineralogical proxies were determined using the ASD.

A negative correlation between Al and Ca in the soils is interpreted as a result of increased clay minerals in ratio to carbonates. An increase of soil Ca in the SE of the region (Fig. 8) was identified as the results were being presented in element maps each evening. This pattern was assessed to relate to a change in the vegetation type and distribution (*Casuarina* sp. and *Eucalyptus* sp. trees were present in a nearly treeless plain) and an increase in some pedogenic carbonate. This observation would not have been recalled except for the near real-time results. Overall, soil Ca measured in the field by fpXRF was 8 to 14 wt.% (Fig. 8).

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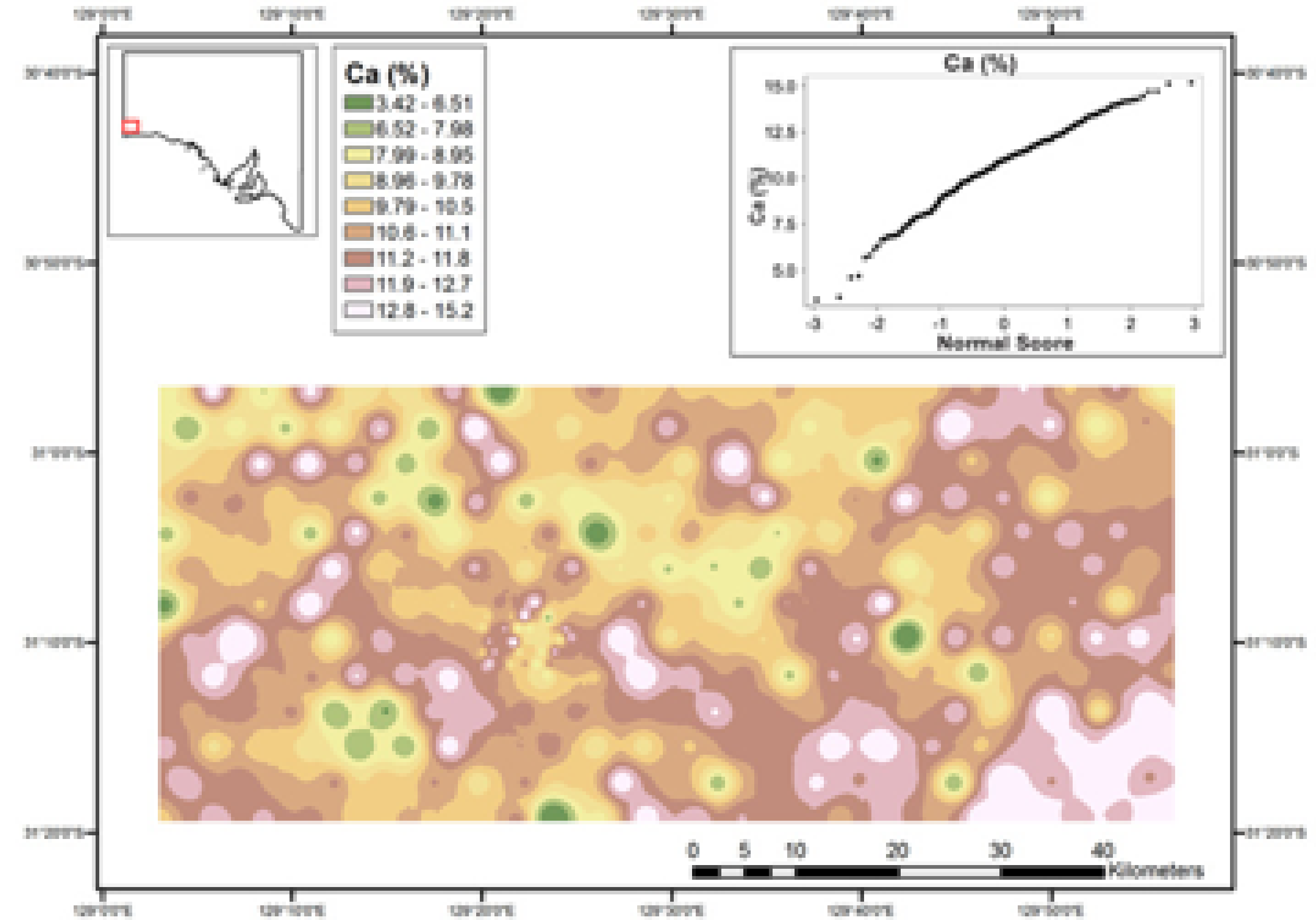

Figure 8. Calcium concentration in shallow soils measured using fpXRF. Data are contoured using inverse weighted distances. Insets show the distribution of the data and the site location with the state of South Australia as the reference.

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Testing a rapid sampling and analysis workflow… *continued from page 13*

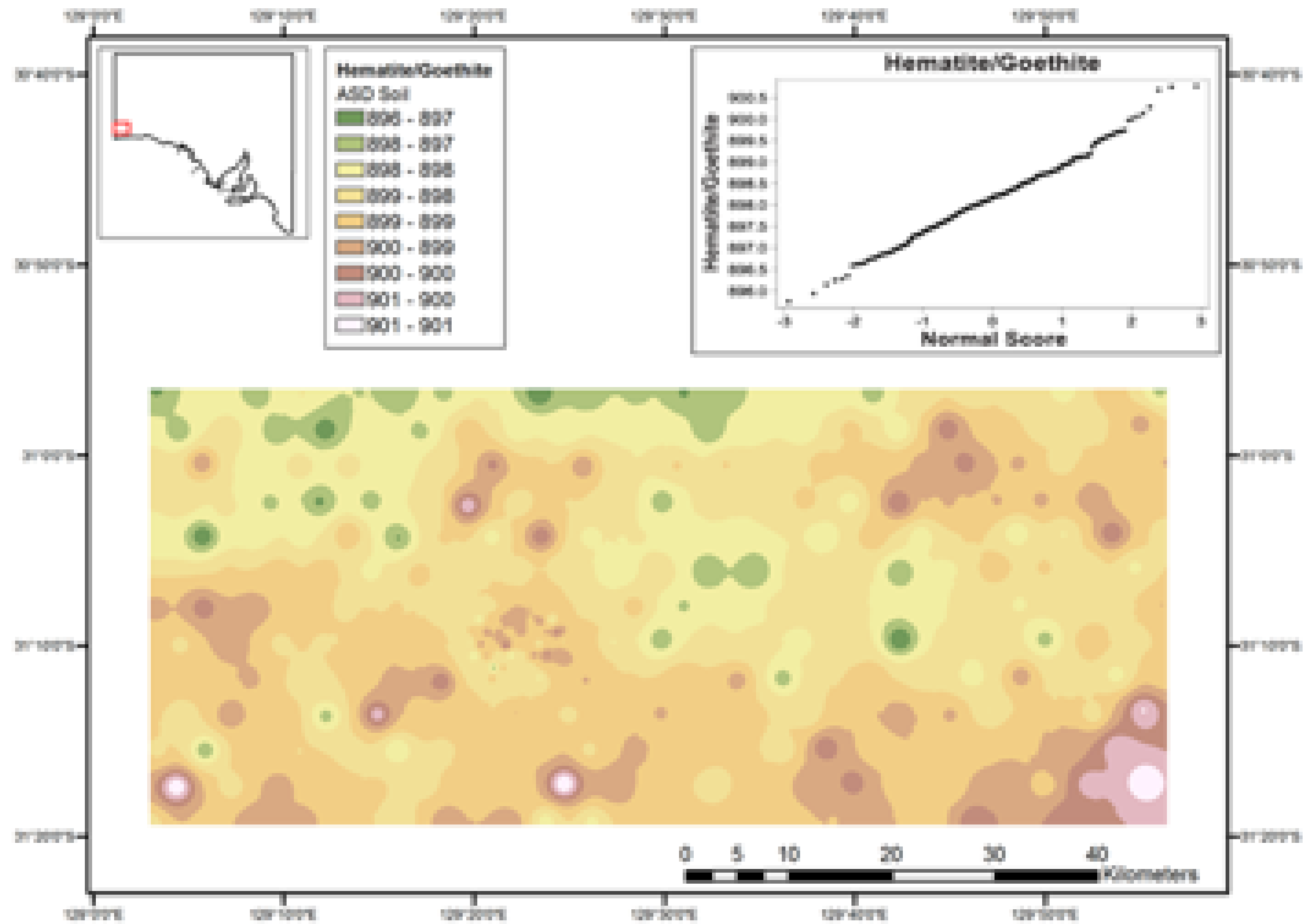

Figure 9. Hematite:goethite using the wavelength of the absorption feature around 900 nm in shallow soils measured using ASD for the Coompana region. Data are contoured using inverse weighted distances. Insets show the distribution of the data and the site location with the state of South Australia as the reference.

Field ASD soil results showed trends that correspond to kaolinite abundance being greater towards the northern extent of the surveyed area. This pattern is similar to the ferric oxide abundance and in contrast to the hematite:goethite ratio (Fig. 9) maps generated in the field. These results suggest subtle pedogenic changes (increased weathering) has occurred to the north of the survey area that are not evident in the surface landscape or vegetation. The Nullarbor Plain soils were all geochemically similar and there were no broad surface anomalies in the spectral reflective properties and element concentrations.

Lithic lag chemistry results showed little variation in major element composition across the area, which is expected given there is a large, relatively uniform, limestone sedimentary layer just beneath the surface. The fpXRF data for major elements (Ca, Al, Fe, K and Si) collected in the field are consistent with the commercial laboratory data (Table 1 and Fig. 10). This similarity was the case for both soil and lithic lag sample media with only few minor differences as noted in Table 1.

Other media collected and analysed at each site included a soil crust/cryptogam sample and the two dominant plant species pearl blue bush (*Maireana sedifolia)* and salt bush (*Atriplex vesicaria)*. These results are available in Noble *et al*. (2018).

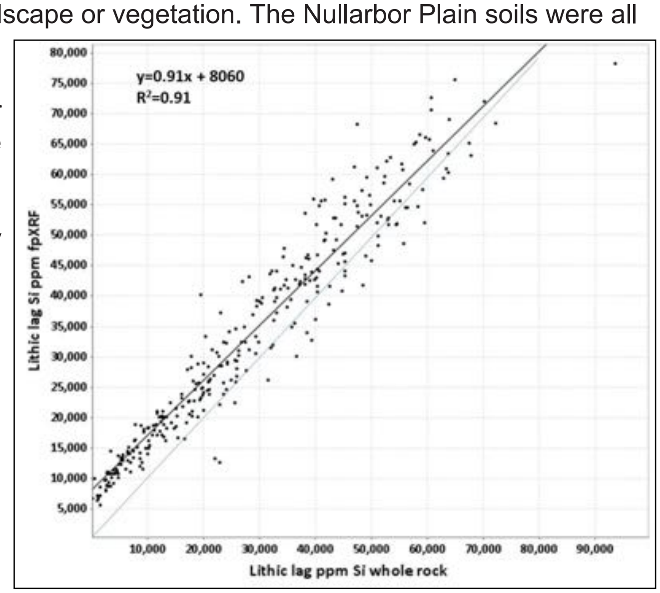

Figure 10. Scatter plot showing the results for Si determined by fpXRF and in the laboratory - major element oxides (whole rock). The blue line is the 1:1 line and the black line shows the linear regression line of best fit.

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Table 1. Geochemical comparison between major elements determined by fpXRF (acquired in the field) and Li borate fusion ICPMS/OES (laboratory). Regression results are for lithic lag analysis.

Element	Results
Al	Equivalent for spatial patterns and concentrations. R^2 = 0.88; fpXRF = 0.76 laboratory result + 1584
Ca	Equivalent for spatial patterns and concentrations. R^2 = 0.82; fpXRF = 1.03 laboratory result + 69325
Fe	Equivalent for spatial patterns and concentrations. R^2 = 0.91; fpXRF = 1.22 laboratory result + 1188
K	Equivalent results for spatial patterns. Concentrations near detection limit in fpXRF with less precision. R^2 = 0.91; fpXRF = 0.90 laboratory result + 296
Mg	pXRF not equivalent as Mg content was below detection limits for most samples using fpXRF. R^2 = 0.01
Mn*	Equivalent results for spatial patterns. Concentrations near detection limit in fpXRF with less precision. fpXRF did identify the anomalously high Mn value. R^2 = 0.00 * Mn assayed by 4-acid digest and ICP-MS outperformed both fpXRF and major element oxide analyses (not shown)
S	Equivalent results for spatial patterns. Concentrations with fpXRF had less precision. R^2 = 0.81; fpXRF = 0.81 laboratory result + 369
Si	Equivalent for spatial patterns and concentrations. R^2 = 0.91; fpXRF = 0.91 major oxide assay + 8060

DISCUSSION

Significant cost benefits were realised in this project via the use of portable laboratories. The reliability and reproducibility of fpXRF data were excellent and comparable to laboratory instruments for major elements (Ca, Al, Fe, K and Si; Table 1; Noble et al., 2018), meaning that the additional commercial analysis for major elements was not needed and would, in future work, significantly reduce the analytical budget. Analytical costs would have been reduced by > 60% (even with the consideration of mobilizing equipment and additional people on site) should we have had this comparative assessment knowledge prior to this project.

A few other more advanced rapid analytical platforms adjacent to drilling samples have been published such as Lab-At-Rig for drilling muds (Fabris 2017; Lemière & Uvarova 2017) or fluid analysis (Fabris 2017; Reid 2016), and this concept is broadly accepted as a positive transition for the industry. Greenfields rapid analysis has been primarily driven by individual handheld devices with "point and shoot" style analyses. Inconsistency in sampling with pXRF is a major problem that is often overlooked in the exploration industry. The very fact that we have used a portable field laboratory, rather than just "pointing and shooting" the instrument, is an example of how to address this problem.

The transition from more routine data capture and sample labelling processes is less well published. In our study, it was estimated that field time was reduced from approximately 15 minutes to 6 minutes per site. With limitations on helicopter flying time and related costs, the use of the faster workflow saved 10 days of field time and $150,000. In addition, the data transfer onto other devices saved at least a few hours per day of manual data entry. This saving is not a large economic one, but it enabled the team to quickly process data in the evening (and not miss out on sleep). The benefit of this savings became quickly apparent when the team was reviewing data in the evening, in some cases only a few hours after collection, and was able to make interpretations based on their recent memory (i.e. few larger trees in the area of increased pedogenic carbonate). This information would not have been captured if the review of these data occurred a month or so later from the

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city-based office. Although this survey was not a true mineral exploration targeting exercise, the comparison of the team's interpretations of changes in landscape setting with the geochemistry, and corollary to changing mineral exploration soil sampling patterns/locations in the field based on new information is clear. Infill sampling was conducted on 1 km spacing (36 sites) on the final day, to effectively demonstrate the agile sampling approach based on the results of the regional geochemistry maps being produced in nearly real-time. This study provided a demonstration of using a portable laboratory to focus exploration without the need for later remobilisation (second sampling trip). Remobilisation can be a major cost. In this project, it was a minimum of \$30,000, with much of that attributed to getting a helicopter to such a remote area (Perth is approximately 1600 km away and Adelaide 1400 km from the study site).

The region is an unknown for mineral potential, although a number of exploration licences have been granted with companies focused for Cu and Ni magmatic systems (Lawley 2017). The soils and the lithic lag do not highlight anomalous surface geochemical results for Cu or related pathfinders. The detection limits with fpXRF also limit the effectiveness of the field results for trace metal analysis, even though this is improving regularly. The most problematic elements based on this work were Mg and Mn for the major elements and Ag, As, Bi, Co, Mo, Sn and Zn being effectively below detection in this setting. Copper and Ni results were of marginal value and also approaching detection limits. This region is particularly difficult to characterize as the soils show low total base metal abundance (Noble et al. 2018). Due to the thickness the underlying sedimentary rocks any possible metal dispersion from the potential magmatic prospective sequences at depth are not reflected in the surface media as indicated by Gonzalez-Alvarez *et al*. (2018; 2019). In other regions where pathfinder or target elements were present and detected with fpXRF due to greater concentrations, (e.g., Sarala 2016; Sterk *et al*. 2018), this field-based approach could drive exploration targeting.

Using the ASD and spectral mineral proxies features such as soil colour, hematite, goethite and recognised accessory mineral phases were an effective way to detect atypical samples. Application of spectral mineralogy is expanding rapidly with major laboratories now offering this type of analysis. Presently, the geoscience community does not commonly merge the spectral mineralogy with the elemental chemistry for interpretation, but it is likely that this will become more widely used and manageable in the future. This study did not integrate the spectral data with the geochemistry in the tested machine learning model (see Noble et al. 2018). Other studies have used machine learning approaches to handle more geochemical data and gain different insight for mineral exploration or geological mapping (Zuo & Ziong 2018; Kirkwood *et al.* 2016), but the interoperability with other data types is not well developed. Easily adapted portable or field technologies include pXRF, pXRD, pNIR-SWIR, µRaman, and LIBS (Lemière & Uvarova 2017). It is expected future projects will adapt this workflow further to provide other portable instrument data, and combine this with precompetitive data and data analytics to better predict the geochemistry mineralisation targets in the field.

CONCLUSIONS

As a demonstration of rapid characterisation akin to greenfields regional exploration, the study showed that quick and efficient sampling and field analyses could be successfully achieved with minimal environmental impact. To generate new targets using standard regional surface geochemistry, three key activities commonly take place. Firstly, uniform sampling (using grids or cells) is conducted over a broad area, secondly, analyses of samples are conducted to establish geochemical backgrounds, and finally areas of interest are identified for further investigation. This process commonly takes months and is widely practiced. However, huge efficiencies can be delivered using straight-forward technologies such as tablets and Apps for rapid data gathering and transfer coupled with a portable preparation and analysis laboratory, using pXRF and ASD, to produce nearly real-time geochemical and mineralogical maps. We believe the next iteration of efficient regional sampling should arise through the development of "smart" or "active" sampling that will use other spatial data and models (machine learning) to inform sampling locations to maximise the information/minimize uncertainty. However, that requires further research and development.

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Acknowledgements

We would like to thank Chris Wilcox, Anna Petts, Rian Dutch, Amy Lockheed, Liz Broadridge, Ian and Hopton from GSSA for their support, as well as Felicity Brant, Jess Robertson, Alistair White, Monica LeGras and Tania Ibrahimi from CSIRO, Brian Ballsun-Stanton from Macquarie University for their help in the field and with the soil sampling labelling. James Cleverly and Des Pascoe from Imdex provided soil sample preparation gear. Aerotech Aviation assisted in soil sampling. Anais Pages, Renee Birchall, Steve Cook and Beth McClenaghan are thanked for reviewing and improving this manuscript.

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AAG Councillors for 2020-2021

Stephen Cook (ex officio)

Stephen served as President of the Association of Applied Geochemists for 2018-2019 and is currently the Past President. He has been active in exploration geochemistry for 35 years. He received his B.Sc. from Carleton University in 1984, and M.Sc. from The University of British Columbia in 1991. Stephen first worked with the Geological Survey of Canada (1985-1988), and the British Columbia Geological Survey (1991-2000). Subsequently he joined the mineral exploration industry, first with Anglo American as Senior Geochemist, North America & Europe (2000-2004), then with his own consultancy (2004-2006), and finally as Chief Geochemist, Exploration with Teck Cominco (now Teck Resources) for over 12 years (2006-2018). He was a member of the local organizing committees of both the 19th International Geochemical Exploration Symposium (IGES), and the 28th International Applied Geochemistry Symposium (IAGS), held in Vancouver in 1999 and 2018, respectively. He presently operates his own geochemical consultancy.

Maurizio Barbieri

Professor Barbieri holds a degree in Geological Sciences (1994) and a PhD degree in Earth Sciences (1998) from Sapienza University of Rome (Italy). He is currently Associate Professor of Environmental Geochemistry and Hydrogeochemistry at Sapienza University of Rome (Italy). His research includes interactions between water and the geological and chemical environment; freshwater-seawater interactions in coastal aquifers; basic and applied research on speciation and transformation of trace metals and metalloids during biogeochemical processes in both natural and anthropogenic environments; radiogenic and stable isotope geochemistry. He is an editorial board member for Springer, Elsevier and MPDI Journals on topics related to geochemistry, water and the environment.

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Thomas Bissig

Thomas graduated in 1997 from the Swiss Federal Institute of Technology (ETH) with a diploma in Earth Sciences. After working for Barrick Chile Ltda in the El Indio Belt in 1997-1998, he carried out his PhD research at Queen's University, Kingston, on the metallogeny of the El Indio belt. He graduated in 2001 after which he took a position as post-doctoral fellow at MDRU at the University of British Columbia where he worked on Central Peru and in the Guerrero Terrane of Mexico. Thomas was a Professor at the Universidad Católica del Norte in Antofagasta Chile from 2004 to the end of 2007, after which he returned to MDRU as a Research Associate. In March 2017 he joined Goldcorp Inc., now Newmont Goldcorp as Director Geochemistry, currently providing subject matter expertise to exploration teams across North America. Thomas has been involved in research topics ranging from regional metallogeny and magma fertility to landscape evolution and exploration geochemistry. He is author on more than 30 peer-reviewed publications and numerous published reports and conference abstracts. His main interest in being part of the AAG council is to support mentoring of young professionals and keep the communication between industry and academia open.

Beth McClenaghan

Beth McClenaghan is a graduate of the University of Waterloo and Queen's University in Canada. She is a research scientist at the Geological Survey of Canada where she has worked for the past 28 years and is Head of the Geochemistry Section. Her research focuses on methods development for the application of till geochemistry and indicator mineral to mineral exploration in glaciated terrain, with particular emphasis on diamonds, and precious, base, and strategic metals. She is an Adjunct Professor at Queen's University and supervises the indicator mineral research of several graduate students at Queen's and other Canadian universities. Beth has been a member of the Association of Applied Geochemists (AAG) since 1985, a Fellow of the AAG since 1993, and the Editor of the Association's quarterly newsletter EXPLORE since 2006.

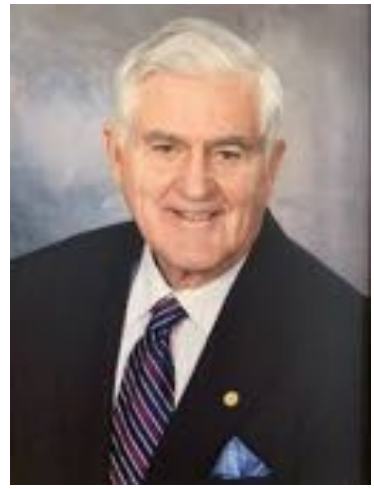
David Murphy

David holds a BSc (Hons) degree from the University of Edinburgh (1986), a MAppSc from Curtin University (1993), both in geology, and a PhD from the University of Western Australia (2009). After an early career as an exploration geologist (Geopeko – North Ltd, 1988 – 1994; Helix Resources NL, 1994 – 1996; Plutonic Resources Ltd, 1996-1997), David joined Normandy Mining Ltd (now Newmont; 1997 - 2009), where Nigel Radford instilled a love of geochemistry. This was cemented by Cliff Stanley, who supervised, along with Bob Gilkes, an eclectic thesis involving lithogeochemistry, clay mineralogy and linear algebra. In 2010 David joined Barrick as regional geochemist, then in 2012 his current employer, AngloGold Ashanti, where he assists with geochemical aspects of projects and operations in Australia, North and South America, and Africa. He is a member of the AAG council (2018-19) and chairs the Education Committee. David is interested in fine-fraction geochemistry, X-ray diffraction, mathematical applications, and data analysis. Outside work he enjoys learning ever more abstract programming languages and manages a few endurance runs between injuries.

Yulia Uvarova

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

John Alexander Hansuld



John A. Hansuld, a founding member of the Association of Applied Geochemists (originally named the Association of Exploration Geochemists, AEG), died recently at the age of 88 on November 26th, 2019. John played a key role in establishing the AEG/AAG. Stimulated by the well-attended International Geochemical Exploration Symposia (IGES) of the late 1960s, John and fellow geochemists such as Alan Coope, Herb Hawkes and Eion Cameron, recognised the need for a professional organization of exploration geochemists and thus the AEG was formed in 1970. John became President of the AEG in 1971. In a remarkably short time, the AEG had taken over responsibility for the IGES series (the 4th took place in London in 1972) and John had negotiated with Elsevier to launch the Association's flagship journal – the Journal of Geochemical Exploration – to be published from 1972 onwards. In the following years, John focused on the role of Business Editor. The early association newsletters (later to become 'EXPLORE') make for a very interesting a read and can be found at https://www.appliedgeochemists.org/explore-newsletter/explore-issues. Recognition of John's numerous important contributions to the AEG are shown by the Distinguished Service Award of the Association presented to him in 1982 and the Past-President's Silver Medal in 1999.

Ontario-born, John earned a BSc (Hons, Geology) from McMaster University in 1954, followed in 1956 by an MSc from the University of British Columbia where his work focused on the factors influencing the rate of leaching of Britannia ore (copper sulphide). While having a beer on a train to a Prospectors and Developers Association of Canada (PDAC) convention, John was recruited to do a PhD at McGill University in Montreal, Canada. That chance meeting led to a blossoming of his fascination for geochemistry, specifically into the mobility of metals (especially Mo) in the surficial environment using Eh-pH phase equilibrium diagrams, thus establishing this technique in predictive geochemical studies.

After obtaining his PhD in 1961, John joined Amax and in 1962 he was promoted to Chief Geochemist at their headquarters in Denver, followed by a further promotion to Manager of Exploration Research. In 1967, John returned to Toronto where he was responsible for managing exploration in Eastern Canada and the following year, supported by Amax, he obtained a PMD (akin to an MBA) from Harvard Business School. In 1973, John was further promoted to Canadian Exploration Manager and by the late 1970s Amax Exploration (Canada) was one of the largest groups in the country, with 91 active projects. In 1978, he became Vice-President of Amax with responsibility for the worldwide exploration budget. In 1983, John persuaded Amax to spin out its Canadian operations into a new company – Canamax Resources - of which he became President and CEO. The spin-out raised $30 million in its initial public offering, a major achievement as the financing introduced 'flow through' shares, already used by the Oil and Gas industry, to the Mining Sector. This tremendous boost to financing mineral exploration, especially for junior companies, led to the positioning of Canada as a global leader in the mining industry. John was dubbed 'the father of flow through' and was named "Mining Man of the Year" by the Northern Miner in 1988 and "Developer of the Year" by the PDAC in 1989.

John left Amax in 1989 to take on executive and directorship positions with various mining companies. He was President of the PDAC in the period 1993-1996 when, again, his leadership had a major impact through his strategic plan to revitalise and expand the organization beyond its North American focus to an international one with extensive influence. In 2012, John was inducted into the Canadian Mining Hall of Fame (https://www.mininghalloffame.ca/john-a-hansuld) and it was then that the presenters demonstrated the breadth of his accomplishments, as a geochemist, entrepreneur, mine-finder, financial investor, and leader. John remained active in the mining community up to the age of 85.

John and his wife of 64 years, Jane, travelled the world extensively. He was very much a family man. Jane, their three children, six grandchildren and two great grandchildren were his priority and his delight.

John Hansuld was a trailblazer and leader in the exploration and mining industry, and the AAG benefitted greatly from his many talents.

Gwendy E.M. Hall
Ottawa

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Geochemistry: Exploration, Environment, Analysis, v. 20:35-49, first published on May 15, 2019, doi:10.1144/geochem2019-019
http://geea.lyellcollection.org/content/20/1/35.abstract

Provenance, tectonic setting and mineralization significance in the Linxi Formation, eastern Inner Mongolia, NE China
Xi Wang, Yun-Sheng Ren, Jun-Wei Bo and Dong-Sheng Zhao
Geochemistry: Exploration, Environment, Analysis, v. 20:50-67, first published on June 20, 2019, doi:10.1144/geochem2019-018
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Listwaenitization and enrichment of precious metals in the hydrothermal mineralization zones of serpentinites in Sugeçer-Van (Eastern Anatolia, Turkey)
Tijen Üner
Geochemistry: Exploration, Environment, Analysis, v. 20:68-79, first published on March 25, 2019, doi:10.1144/geochem2018-087
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Assessing copper fertility of intrusive rocks using field portable X-ray fluorescence (pXRF) data
Ayesha Ahmed, Anthony J. Crawford, Christopher Leslie, Joshua Phillips, Tristan Wells, Amos Garay, Shawn B. Hood and David R. Cooke
Geochemistry: Exploration, Environment, Analysis, v. 20:81-97, first published on April 2, 2019, doi:10.1144/geochem2018-077
http://geea.lyellcollection.org/content/20/1/81.abstract

The application of pXRF for the chemical and mineralogical characterization of heavy mineral sands
D. Gallhofer and B. G. Lottermoser
Geochemistry: Exploration, Environment, Analysis, v. 20:99-111, first published on June 14, 2019, doi:10.1144/geochem2019-015
http://geea.lyellcollection.org/content/20/1/99.abstract

Refining fine fraction soil extraction methods and analysis for mineral exploration
R. R. P. Noble, I. C. Lau, R. R. Anand and G. T. Pinchand
Geochemistry: Exploration, Environment, Analysis, v. 20:113-128, first published on July 9, 2019, doi:10.1144/geochem2019-008 **OPEN ACCESS ARTICLE**
http://geea.lyellcollection.org/content/20/1/113.abstract

Application of ultrafine fraction soil extraction and analysis for mineral exploration
R. R. P. Noble, P. A. Morris, R. R. Anand, I. C. Lau and G. T. Pinchand
Geochemistry: Exploration, Environment, Analysis, v. 20:129-154, first published on July 1, 2019, doi:10.1144/geochem2019-009
OPEN ACCESS ARTICLE
http://geea.lyellcollection.org/content/20/1/129.abstract

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 29^{th} International Applied Geochemistry Symposium, IAGS 2020, which will be held in Viña del Mar, Chile from November 8^{th} to 13^{th}, 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!

Abstract Guidelines

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.

Abstract online submission deadline: March 31, 2020

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.

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

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, lithogeochemistry, 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.

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

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

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.

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:

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IAGS 2020: Experience Chile... *continued from page 24*

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.

The following Field Trips are proposed:

Responsible Person/People	Title
Reynaldo Charrier	***Tectono-magmatic evolution of Central Chile*** A transect of Central Chile, from coast (Vina del Mar) to the pre cordillera in Argentina (Mendoza).
Constantino Mpodozis	***Mineral deposits of Northern Chile*** Field visits to porphyry copper, precious metals epithermal and stratabound copper deposits of the Antofagasta region.
Sofía López and Ignacio Serra	***Geology and vineyards of Central Chile*** 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	***Polluted areas of Central Chile:*** 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.

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:

Steve Amor, Email: steve.amor2007@gmail.com
or
Tom Meuzelaar, AAG Webmaster, tom@lifecyclegeo.com

2020

8-10 APRIL	Mongolia Mining 2020. Ulaanbataar Mongolia. Website: mongolia-mining.com
15-17 APRIL	International Conference on Geoinformatics and Data Analysis. Marseille France. Website: www.icgda.org
18-22 APRIL	9th Geochemistry Symposium. Didim Turkey. Website: www.9thgeochemistry.com/en
28-30 APRIL	Discoveries 2020 (SEG Mining Conference). Guadalajara Mexico. . Website: tinyurl.com/v4oqbwe
29 APRIL – 1 MAY	SEG Workshop: Practical Exploration Methods. Littleton CO USA. Website: tinyurl.com/s5o3luv
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
11-12 MAY	World Congress on Earth Sciences. Paris France. Website: conferenceera.com/earth-sciences-conference
11-15 MAY	GeoConvention 2020 (includes GAC-MAC). Calgary AB Canada. Website: www.geoconvention.com
13-15 MAY	15th International Conference on Monitoring, Modelling and Management of Water Pollution. Valencia Spain. Website: tinyurl.com/r8cloa8
18-21 MAY	8th Symposium of Geological Society of Nevada. Sparks NV USA. Website: www.gsnv.org/2020-symposium
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
24-29 MAY	Geochemistry of Mineral Deposits (Gordon Research Conference). Castelldefels Spain. Website: tinyurl.com/ybkjgl37
8-10 JUNE	SIAM Conference on Mathematics of Planet Earth (MPE20). Garden Grove CA USA. Website: www.siam.org/Conferences/CM/Conference/mpe20
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
1-2 JULY	International Uranium Conference. Adelaide, SA, Australia. Website: uranium.ausimm.com
2-3 JULY	Sampling 2020. Lima, Peru. Website: tinyurl.com/v2xrc6w
4-10 JULY	Euroscience Open Forum 2020. Trieste, Italy. Website: tinyurl.com/y2qq3knh
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
18-20 JULY	Third International Workshop on Environment and Geoscience. Chengdu China. Website: www.iwegconf.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/yyzz4fdg
2-6 AUGUST	Microscopy & Microanalysis 2020. Milwaukee WI US. Website: www.microscopy.org/MandM/2020
2-9 AUGUST	5th International Symposium on Environment and Health. Galway Ireland. Website: www.nuigalway.ie/iseh2020

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CALENDAR OF EVENTS... continued from page 30

9-14 AUGUST	Biomineralization: Bridging Scientific Disciplines to Understand Biomineral Formation in Breadth and Depth (Gordon Research Conference). Castelldefels Spain. Website: www.grc.org/biomineralization-conference/2020
10-11 AUGUST	3rd International Conference on Earth Science & Geo Science. Atlanta GA USA. Website: tinyurl.com/vlc3ryf
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.confercare.manchester.ac.uk/events/icec2020
7-11 SEPTEMBER	Multidisciplinary Earth Science Symposium. Prague Czech Republic. Website: tinyurl.com/y5a8gvlm
13-16 SEPTEMBER	Fifth International Symposium on Ethics of Environmental Health. České Budějovice (Budweis) Czech Republic. Website: iseeh.org
15 SEPTEMBER	SEG 2020: Celebrating a Century of Discovery. Whistler BC Canada. Website: www.seg2020.org
21-25 SEPTEMBER	World Water Congress & Exhibition. Daegu South Korea. Website: www.worldwatercongress.com
10-18 OCTOBER	28th Colloquium of African Geology (18th Conference of the Geological Society of Africa). Fez Morocco. Website: www.fsdmfes.ac.ma/CAG28
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.
20-26 NOVEMBER	10th South American Symposium on Isotope Geology. Viña del Mar Chile. Website: ssagi.science
30 NOVEMBER – 4 DECEMBER	American Exploration and Mining Association Annual Meeting. Sparks NV USA. Website: www.miningamerica.org/2020-annual-meeting

2021

9-12 FEBRUARY	Australian Earth Sciences Convention. Hobart TAS Australia. Website: www.aesconvention.com.au
1-6 AUGUST	Geoanalysis 2021. Freiberg Germany. Website: geoanalysis2021.de
16-20 AUGUST	12th International Kimberlite Conference. Yellowknife NT Canada. Website: 12ikc.ca

Welcome New AAG Members

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.*

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.*

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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.

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