30th International Applied Geochemistry Symposium
14 — 18th October 2024

Adelaide, South Australia

‘Geochemistry For A Sustainable Future’

Abstracts

Themes : Define/Extract, Environment, Society

Compiled by P. A. Morris

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Theme: Define/Extract

Oral abstracts

Electrochemical Reactivity of Chalcopyrite Ore: Implications of Comminution Environments on Flotation Performance

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The electrochemical reactions and interactions resulting from galvanic coupling within grinding environments, particularly between sulphide minerals like chalcopyrite and grinding medium (such as steel balls and water), continue to present significant challenges in downstream processing, notably in flotation. Understanding the influence of the grinding environment—whether wet or dry—on modulating the electrochemical reactivity of sulphide minerals, such as chalcopyrite, is essential for optimizing downstream process recovery. This study investigates the electrochemical reactivity of sulphide minerals subjected to dry and wet comminution processes using methods such as the oxygen demand test, EDTA extraction technique, and froth flotation together with electrochemical techniques. Emphasis is placed on examining how different comminution environments affect the reactivity of sulphide minerals and subsequently impact downstream processes like flotation. Advanced analytical techniques, including inductively coupled plasma optical emission spectroscopy and x-ray photoelectron spectroscopy, were employed in the investigation to explicate the observations. The findings are valuable to processing of complex low-grade ores in addressing the growing demand for copper.

KEYNOTE: Vertical exposure of >1800m of IOCG mineralization at Olympic Dam

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The Olympic Dam breccia hosted Fe-oxide Cu-U-Au-Ag (IOCG) deposit is without doubt one of the world's largest metalliferous deposits. Most of the publically declared Resource lies at depths of ~300-1200 m below the surface, with the deepest known areas in the SE part of the deposit. Recent mine-based diamond drilling has outlined mineralization extending for more than 2 km along strike and 1 km in depth below previously delineated mineralization (referred to as the Deeps). To date, drilling has yet to close off mineralization at depth and its lateral extents.

Mono- and polymictic-breccia textures are complicated to interpret, yet the ore and alteration mineralogy are systematically zoned across the deposit. Large syn-post mineralization faulting is followed by partial erosion during post-mineralization events with regional expression. Even though bornite-chalcocite-chalcopyrite-pyrite are present across the shallower parts of the deposit, chalcopyrite and pyrite are the dominant sulfides in the Deeps which also contains uraninite-coffinite-brannerite and Au-Ag minerals. The ratios of hematite to magnetite and siderite to Ca-Mg-Fe-carbonates decreases, while chlorite and carbonates increase with increasing depth. Likewise, the REE mineralogy changes from bastnäsite-synchysite-florencite to monazite-apatite-xenotime-allanite. Muscovite/illite, quartz, barite, fluorite and intensely altered K-feldspar are also present. Hydrothermal biotite has not been observed. The best indicator of approaching the edges of mineralization, even though the rock is significantly altered, is a rapid decrease in the concentrations of sulfides, in particular pyrite.

The distinct mineralogy and associated geochemical signatures across the deposit are used for vectoring to mineralization and recognizing when the limits of Fe-oxide alteration are nearby. The geochemical signature (Mo-As-Sb-Sn-W) of the Deeps is similar to the mineralized areas which overlie the Deeps. Hematite is the dominant mineralogical host of Mo-As-Sb-Sn-W. In fact, granitophile element (U-W-Mo-Sn) enriched hematite is ubiquitous to other IOCG deposits in the region surrounding Olympic Dam.

Optimal geometallurgical design for new or extension on existing deposits depends on early quantitative characterisation of the deposit mineralogy/geochemistry. This is a critical part of the deposit journey from discovery through to production and eventual closure.

Funding: BHP Olympic Dam and ARC LP200100156

Predicted Mineralogy from Field-Portable Laser-induced Breakdown Spectroscopy (pLIBS) Spectral Analysis for Real-time Orebody Knowledge

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Successful mineral processing relies on robust orebody knowledge. How a rock responds to mining and processing (including rock breakage, fragmentation, liberation, concentration, and disposal) is a direct reflection of the mineralogy and texture of the rock mass itself. The minerals industry routinely collects bulk geochemical information across an orebody to better understand rock behaviour, but geochemistry alone often fails to adequately capture the variability in mineralogy. Additionally, routine bulk geochemistry is commonly obtained from pulverized rock material with can lead to significant lag times for sample preparation and analysis and does not preserve the mineral associations.

Advancements in field-portable laser-induced breakdown spectroscopy (pLIBS) systems allow for low-cost, rapid, in-situ elemental rastering of geological materials, requiring almost no sample preparation. Most elements can be detected by pLIBS, even elements with low atomic numbers which can be difficult to accurately detect using commonly-employed geochemical methods (e.g., B, C, and O for wet chemical assay and Li, Na, and Mg for x-ray fluorescence).

Atomic emission spectra obtained from pLIBS can be used to rapidly assess mineralogy while the rastering capabilities of these systems capture mineral distributions. Commonly, the pLIBS emission intensity of characteristic elemental lines are quantified by comparing them to standards. Here, we present a mathematical approach using unquantified pLIBS spectra to predict the mineralogy in each pLIBS analysis and the raster outputs to assess mineral associations. After performing background corrections and noise filtering, the emission line intensities for a range of elements are extracted from each pLIBS spectrum. Constrained by the expected elemental proportions for a user-defined library of minerals, the incoming pLIBS line intensities are used to predict the proportion of each library mineral in the individual pLIBS spectra for each shot in the raster. The spatial relationships of these mineral predictions can be used to assess mineral distributions and associations at the mm- and sub-mm scale.

From exploration to mine closure, access to rapid mineralogical tools will improve orebody interpretations and enable key mineralogical characteristics to be assessed at any stage. Predicted mineralogy and mineral distribution derived from pLIBS enables real-time orebody knowledge across the mineral processing value chain.

Successful Application of Hydrogeochemistry in Undercover Mineral Exploration in the Pilbara Region, Western Australia

Marina Joury, IGO

IGO in collaboration with CSIRO are conducting a hydrogeochemistry sampling program in the Pilbara region of Western Australia with the purpose of exploring for stratiform-hosted copper and intrusion-related copper gold deposits hidden beneath complex transported cover. The application involves an adaptive method of hydrogeochemical sampling of established water bores and PVC cased regional air core holes using a pneumatic double-valve interval pump.

Each air core hole had slotted PVC inserted twelve meters from the bottom of hole, within the lower saprolite of the Precambrian target stratigraphy. The holes were capped and left to equilibrate for six to twelve months before an interval sample was collected. This innovative approach allows for groundwater to be collected from a specific depth that is isolated from the atmosphere throughout the entire collection process, thereby allowing for the collection of the physical and chemical parameters in equilibrium of the deep groundwater aquifer.

An orientation survey was conducted in proximity to two known resources, Minyari Au-Cu and Nifty Cu mine to characterise deposit signatures of two different mineralisation styles. The results were compared with 178 regional hydrogeochemical samples collected over two years. The samples are analysed for a full multielement suite along with oxygen and hydrogen isotopes.

The results indicate that both gold-copper intrusion related systems and stratiform-hosted copper mineral systems have distinct hydrogeochemical signatures. Hydrogeochemistry is also capable of mapping key lithologies under cover, identify the signature of weathered sulphides, and determine the presence of a reductant within 1-1.2km radius of the sample sites. In addition, analyses suggest areas where meteoric water is contaminated with other water sources, for example, deep seated brines moving along fault zones. The hydrogeochemistry results are interpreted with geologic understanding of the region and integrated with CSIRO’s spinifex biochemical dataset. The success of the technique identified several regional anomalies potentially vectoring to the two mineral systems undercover, which generated targets for the IGO’s Copper Exploration group to follow up on.

Routinised Geochemistry Classification Workflow to Improve Orebody Knowledge at the Onto Cu-Au Deposit

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This case study presents an application of routinised geochemistry classification workflow on multi-element geochemical data collected from drill core at the Onto lithocap-hosted high sulphidation epithermal Cu-Au – porphyry deposit in the Huu district, Nusa Tenggara Barat province, Indonesia. 6813 multielement geochemical samples from ten diamond drillholes were selected to represent the range in the geology from the distal to proximal parts of the deposit. Classical exploratory data analysis (EDA) approaches utilising univariate and multivariate graphs can provide a rapid visual representation of geochemical signatures. Molar ratio discrimination diagrams were used to identify the geochemical signatures of the dominant alteration in the drill core samples. The spatial distribution of the interpreted hydrothermal alteration mineralogy from the geochemistry data enabled the characterisation and detailed logging of the extensive vertical and lateral argillic and advanced argillic alteration zones, which overprints older potassic porphyry alteration signatures. High-field strength element (HFSE) ratios were successfully used to discriminate between the andesite flow cap and three types of porphyry intrusions.

Classical EDA approaches were augmented with several data dimension reduction and multivariate machine learning (ML) techniques, including Self-Organising Map (SOM), Uniform Manifold Approximation and Projection (UMAP), and Density-Based Scanning (DBSCAN) clustering technique. A combination of classical EDA and ML techniques applied at the deposit were found to be robust in repeatability across the selected drillholes. These were used to create training models for refining of existing lithological and alteration domains in the deposit. Supervised machine learning methods such as decision trees and random forest were utilised to identify parameters that can distinguish between geochemical classes, and to be used for classifying data from other drillholes outside of the training model.

Routinising the data analysis and interpretation process allows resource companies to productionise the creation of orebody knowledge. This approach allows geologists to 1) inform, augment and validate lithological and alteration core logging on-site, 2) Improve the reliability of the 3D geological model with follow-on benefits to the resource and geometallurgical models and 3) Incorporate the improved orebody knowledge as the basis for a conceptual system to identify other deposits in the vicinity of the Onto deposit.

Cobalt occurrence and potential recovery from copper mining tailing deposits in Chile

Brian Townley, Sebastian Garcia, Erica Gonzalez, Manuel Caraballo, Patricio Martínez-Bellange, Natalia Zúñiga-Prohaska, Roberto Collao and Pilar Parada.

Cobalt, an essential element for modern technologies such as non-conventional renewable energy and electro mobility, is primarily sourced from the Democratic Republic of Congo (130,000 MT/year), followed next by Indonesia (10,000 MT/year) and other countries with lower productions (Russia, Australia, Canada), with Chile holding only a historical production between 1865 and 1944. Despite no reported production since 1944, Chile's copper mining tailings present an untapped resource. Studies conducted in the El Teniente and Punta del Cobre districts reveal initially low cobalt concentrations, but significant increases during processing, attributed to cobalt's presence in pyrite.

In the El Teniente porphyry copper district, examination of old tailings shows modest cobalt levels (15-20 ppm), with copper and molybdenum being the primary elements of interest for reprocessing. However, further sampling within the reprocessing plant demonstrates a tenfold increase in cobalt concentrations during the copper concentrate cleaning stage, mainly found within pyrite. Similarly, studies in the Punta del Cobre IOCG district reveal cobalt concentrations ranging from 50 to 300 ppm in tailing deposits, with an average of 83 ppm. Cobalt concentrations also increase significantly during processing, with cobalt in pyrite reaching levels of 1,000 to 4,000 ppm. Utilizing bioleaching, a process that also yields sulfuric acid, offers a promising alternative for cobalt recovery from pyrite.

Beyond the economic benefits, reducing or eliminating pyrite from final tailings could mitigate environmental impacts. Given the potential for cobalt recovery from IOCG deposits alone, Chile's production could potentially reach 10 to 15 KT/year, providing a significant contribution to global cobalt supply.

In conclusion, Chile possesses untapped cobalt resources within its copper mining tailings, with studies indicating the feasibility of cobalt recovery through innovative processing methods. Harnessing these resources not only offers potential economic opportunities but also aligns with environmental sustainability goals by reducing waste and environmental impact.

Theme: Define/Extract

Poster abstracts

Pressure Leaching of Refractory Laterite Ores for Nickel and Cobalt Recovery

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The complex mineral composition of nickel laterite ores poses challenges for existing atmospheric extraction methods, leading to a preference for high-pressure acid leaching. This method is industrially desired owing to its high metal extractions. In this study, a microwave reactor was employed to simulate the conditions of a high-pressure autoclave system. The research aims to elucidate the influence of elevated temperatures and pressures on the extraction efficiency of nickel and cobalt from lateritic nickel ores. Advanced analytical techniques, such as X-ray diffraction (XRD) and inductively coupled plasma optical emission spectrometry (ICP-OES), were employed to investigate the mineralogical characteristics and chemistry of the ores.

Understanding Ore Mineralogical and chemical Limitations in Wet and Dry Grinding: Implications of Ore Texture on Comminution Processes

T. Amos - Judge*, Dr. G. Abaka-Wood, Assoc. Prof. M. Zainin, Prof. W. Skinner, Dr. R. Asamoah

The comminution of ores, whether through wet or dry grinding methods, is a fundamental aspect of mineral processing operations. However, the effectiveness of grinding processes is intricately linked to the mineralogical and chemical composition of the ore such as its texture. Comprehension of the fundamental interplay between ore mineralogy, composition, and their impact on grinding performance in both wet and dry environments is key to enhancing ore beneficiation technologies and efficiency. This paper examines the limitations imposed by ore mineralogical and chemical characteristics particularly ore texture and their implications on different comminution processes using model and real sulphide minerals such as pyrite and chalcopyrite. Advanced analytical techniques including x-ray diffraction spectroscopy (XRD), quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN), scanning electron microscopy (SEM) will be employed. Through a deeper understanding of the complex interactions between ore properties and comminution environments, this work contributes to the development of strategies for enhancing ore processing technologies and advancing sustainable mineral resource utilization.

Behaviour and deportment of rare earths elements in copper smelter slags

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Air-cooled slags from the Olympic Dam (South Australia) flash (FF~1350 °C) and electric (EF~1300 °C) furnaces contain magnetite, two types of glasses (early glass1 and late glass2), and minor copper metal. Glass1 in both slags in richer in Si and rare earth elements (REE): 6.9 and 5 wt.% La2O3+Ce2O3 in FF and EF, respectively. Glass2 contains lower concentrations of the same elements. Monazite is a minor phase throughout glass1 in both slags, occurring as nanoparticles (NPs) up to a few microns in size. Fayalite, absent in FF slags, forms a eutectic with glass1 in EF slags, whereas delafossite (absent in EF slags) forms peritectic rims on magnetite in FF slags.

Micron- to nanoscale investigation focuses on understanding the distribution and deportment of REE + yttrium (REY) in all main phases except delafossite and copper. REY concentrations measured by laser ablation inductively coupled-plasma mass spectrometry (LA-ICP-MS) shows all phases are consistently enriched in light REE (LREE) over heavy REE (including Y), an observation partially attributable to fine particles or NPs of monazite within any of the phases. Delafossite, too small to be analysed by LA-ICP-MS, occurs as filaments throughout glass1. In addition, glass1 also shows nanometre-scale droplets of amorphous La-Ce-oxide. Mean ΣREY concentrations are 31,043 (n=32) and 13,717 ppm (n=108) in EF/FF glass1, and 2,821 (n=34) and 3,236 (n=140) ppm in EF/FF glass2. Nonetheless, many time-resolved downhole LA-ICP-MS profiles show smooth REE signals in glasses, implying these elements occur within the glass and not as monazite inclusions. Both glasses in the two slag types show reproducible chondrite-normalised REY fractionation patterns, with well-defined positive Eu-anomalies in glass2. In contrast, REY concentrations in magnetite are low and heterogeneous (mean ΣREY 7.9-30.5 ppm, n=230; and 15-29.8 ppm, n=177, in EF and FF, respectively). Chondrite-normalised REY fractionation patterns for magnetite display a marked upwards concavity indicating mild HREE enrichment relative to glasses. Fayalite (ΣREY 52 ppm n=23) shows an even more pronounced upwards HREE trend and conspicuous Y enrichment relative to magnetite and glasses.

The REY concentrations in slag glasses reported here are compatible with grades of secondary-REE-enriched ores. New kinetic models for monazite growth could provide a mechanism to coarsen monazite grain-size, potentially enabling recovery of REE from slags. Funding: ARC LP200100156.

Sampling and Analysis of Ferruginous Gravels and Duricrust gold deposits: A challenge for representativeness

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Gold concentrations in lateritic horizons have often been interpreted closer to the concept of geochemical anomalies rather than economic deposits, contributing to uncertainty in grade estimation and resource assessment. Lateritic gold deposits face substantial challenges due to Fundamental Sampling (FSE) and Grouping and Segregation (GSE) errors, complicating the critical process of mining evaluation. These deposits, characterized by high heterogeneity and intricate gold distribution, present spatial and textural complexities, amplifying result variability, especially in low-grade ranges. The relatively small sample obtained from drilling material, generally of a few kilograms, is insufficient to represent the true gold particle distribution, so it is widely accepted that to assess the grade of gold ores, samples will have to be large enough to detect coarse gold grains. Additionally, due to their friable nature, lateritic materials exhibit low overall sample/core recovery values, ranging from 55 to 70%. In contrast, saprolite, transition zone, and fresh rock horizons typically show mean values of 80%, 85%, and 94%, respectively. Fire assay remains the most common analytical method for gold. However, where coarse gold is present, the use of the Fire Assay is unrepresentative due to the small quantities used for the tests. Despite the variability reflecting the natural heterogeneity of gold mineralization, leaching methods generally seem to increase grades and consistency, especially in the lower ranges, typical of lateritic mineralization (0.5 to 1.5 g/t Au). Intense artisanal mining activity has been observed in areas defined as barren by geochemical campaigns, revealing the disparity in results due to sampling and analytical methods, i.e., pan “analysis” for coarse gold and geochemical analysis of fine fractions. A comparison of the two procedures examined a total of 314 samples from different horizons of a lateritic profile in northern Gabon. Statistical analysis of those duplicate samples showed an extraordinary discrepancy, with minor correlation between the results obtained by both methods. This case illustrates the importance of quality in the sampling procedures and the assessment of new domains with the lateritic gold deposits.

A preliminary study to investigate the recovery of copper from complex low-grade ore: modelling and optimization through Box-Behnken design and response surface methodology

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This preliminary study explored an efficacious approach to recover copper from a complex low-grade ore using a combination of milling and direct froth flotation process. By employing a Box-Behnken experimental design (BBD) and response surface methodology (RSM), the study determined the flotation parameters including pulp pH, collector dosage and frother dosage, to achieve significantly higher copper grade and recovery. In this study, Potassium amyl xanthate (PAX) and Methyl isobutyl carbinol (MIBC) were employed as collector and frother, respectively. Through the use of BBD and RSM analysis, it was established that pulp pH, PAX dosage and MIBC dosage have significant impacts on copper recovery and upgrade, where high recoveries were obtained at pulp pH 11 at increased PAX dosage. Furthermore, insights into the behaviour of reagents in flotation processes are garnered, providing valuable information for optimizing copper recovery and upgrade in the ore. By elucidating the interplay between pulp pH levels, collector dosage, and frother dosage, this study contributes crucial insights to the field of mineral processing. The practical implications of these findings extend to the mining industry, facilitating more efficient extraction and recovery processes for sustainable resource utilization.

Liberation limits for chalcopyrite flotation in conventional and novel flotation cells

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The major shortcoming for coarse particle flotation in conventional flotation cells is detachment of particles for bubbles. Coarse composites are usually not fully liberated to expose more hydrophobic surfaces but rather expose more hydrophilic phases causing the particles to behave at reduced contact angle. This feature also reduces the stability of bubble-particle attachment reducing flotation efficiency. The floatability of composite particles is contingent upon the relative proportions of various types of valuable and gangue minerals present within them. Hence, always exists a crucial proportion of valuable mineral essential to flotation of composite particles. This work aims to expound the liberation limits of a chalcopyrite ore in a mechanically agitated cell, identifying the minimum liberation required to float coarse composites.

Theme: Environment

Oral Abstracts

Critical metal signatures of mine wastes produced from Australian volcanogenic massive sulphide deposits

Rosie Blannin, Allan Silva Gomes, Kam Bhowany, Lexi K Ng, Laura Jackson, Olivia Mejias, Anita Parbhakar-Fox

Volcanogenic massive sulphide (VMS) deposits are renowned for hosting base metals (Cu, Pb, Zn) and precious metals (Au, Ag). Critical metals such as Co, Mn, In, Se, Bi, Te, Ga, Ge and Sb also occur in VMS mineralisation, and may be recovered as by-products. In the past, critical metals may have instead reported to the residues from mining and processing (e.g. tailings, waste rock). The high contents of sulphide minerals, particularly pyrite, in VMS deposits renders the associated mine wastes prone to the production of acid mine drainage. Mitigation of these risks may be accomplished by re-processing the wastes to recover critical metals hosted by sulphide minerals and producing an inert residue. To achieve this requires a strong understanding of the geochemistry, mineralogy, and deportment of critical metals in the mine wastes.

Mine wastes produced from eight VMS deposits in Australia were sampled: Mount Morgan and Thalanga in Queensland, Woodlawn and Tritton in New South Wales, Zeehan and Bobadil in Tasmania, and Iron Blow and Mount Bonnie in the Northern Territory. Various types of mine waste were sampled, depending on those present at each site, including tailings, waste rock, metallurgical waste (slag, heap leach residues), run-of-mine piles, salt and sediments from mine waters. The geochemistry of all samples was measured with inductively coupled plasma-optical emission spectrometry or -mass spectroscopy. The critical metal endowment was assessed and around 10 samples selected per site for mineralogical and mineral chemistry analyses, using X-ray diffraction, automated mineralogy, and laser ablation inductively coupled plasma mass spectrometry. Results from all sites were compared to investigate the occurrence and mineralogical hosts of critical metals in different VMS deposits across Australia, enabling a better understanding of the partitioning of critical metals into mine waste streams. This research will allow further targeting of historic mine sites, or even current operations, for the recovery of critical metals from mine waste materials derived from VMS deposits.

Geochemical characterisations of east Indonesian karstic sediments. Sediment sources and processes, and the implications for palaeoenvironmental records

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This study investigates the geochemical signature of karstic sedimentary deposits located on several islands across the eastern Indonesia archipelago (Nusa Tengarra), including Rote, Timor, Misool and Seram. The aim of the study is to reconstruct an environmental record from these sediments to contribute knowledge to regional archaeological research, regarding human migration pathways to Australasia. Chronological investigations indicate a predominately Late Pleistocene - Holocene (<15 ka BP) signature for the sedimentary deposits. A suite of geochemical techniques, including grain size, mineralogical, geochemical, and stable isotopic ($\delta^{13}C$ and $\delta^{15}N$) analysis were applied to characterise the sediments. Results indicate variable mixes of combined allogenic and autogenic inputs, including clay-silts and limestone, as well as organic materials such as guano and surface vegetation. These mixes appear to be driven primarily by site location, geomorphology, and local climate. Kaolinite, calcite, muscovite, and quartz predominate the clastic fraction; however, secondary mineralisation, in the form of the phosphate mineral variscite and to a lesser extent taranakite, is evident. These minerals are the result of autogenic reactions between guano and the authigenic clay, kaolinite and muscovite under low pH conditions in the cave systems. Enriched $\delta^{15}N$ signals (>10‰) are common, and correlate with secondary phosphate mineral formations, derived from guano deposits. Organic matter $\delta^{13}C$ values indicate a dominant C3 vegetation signature, which is consistent across the eastern island sites. This signature contrasts with the more $\delta^{13}C$-depleted signatures that have been observed for cave sediments in the western part of Indonesia, suggesting wetter climates in that region. Trace element analysis identifies local Tertiary siltstones and marls as the likely origin of the fine clastic component, whereas the sand and carbonate components are related to localised bedrock collapses. There is little evidence for volcanically derived materials or regional aeolian dust sources. Thus, the palaeo-environmental history of these deposits is affected predominantly by local processes, combined with some regional environmental signatures that are quite homogeneous when compared to records from other, wetter, parts of the Indonesian archipelago.

Identification of non-carbonate sources of acid neutralisation capacity

Hon. Prof. Andrea Gerson[1], Dr Paul Weber[2], Emeritus Prof. Roger Smart[1], Dr Rosalind Green[3]

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Correct evaluation of acid neutralisation capacity (ANC) in mine tailings is essential for development of appropriate closure strategies for tailings storage facilities (TSFs) that may be affected by acid and metalliferous drainage (AMD). It has been observed, for a specific site, that ANC values measured by the standard titration approach are significantly greater than those calculated using total carbon assays. Historically, ANC has been calculated, for tailing classification at this site, using total C. On examination of four composite tailings samples, it was found that all the composite samples were determined to be potentially acid forming using the current AMD classification system. Calculated ANC (using Mg, Ca, Na, K and Mn concentrations before or after ANC back-titrations) are in good agreement with the measured ANC and are approximately double those calculated using C assays. Quantitative XRD analysis indicates that calcite is completely dissolved from the mineral assemblage and approximately half of the chlorite is dissolved upon ANC testing, which reasonably accounts for the non-carbonate ANC. It is concluded that it would be appropriate to change the evaluation of ANC for these tailings to incorporate the non-carbonate neutralisation. The chlorite-based component of the ANC will provide long-term acid neutralisation and therefore fast-reacting calcite is still required to be present until the pyrite content has decreased sufficiently to enable matching of the rates of neutralisation to acid production. A new classification system is proposed, albeit requiring verification by application to a greater number of tails samples.

The Levelled Geochemical Baseline of Australia

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National- and regional-scale surface geochemistry data can provide valuable information about mineral prospectivity and geology of a country or region, and allow for informed decision-making around environmental management. Whilst a number of regional geochemistry surveys of varying heritage exist across Australia, they currently stand as individual surveys with limited ability to utilise with other surveys. To increase our understanding of the surface of Australia and aid in determining areas of mineral prospectivity, a decision was made to level each of these individual surveys and thus create a unified levelled geochemical baseline of Australia.

Levelling of regional surveys can remove the analytically-introduced variation; however, the majority of the survey areas are spatially isolated from one another. Fortunately, Australia has a national-scale survey, the *National Geochemical Survey of Australia* (NGSA), which acts as a backbone interlinking each of the higher density regional surveys. A pilot project released in 2020, utilised this approach to create a levelled geochemical baseline for the northern Australia. The pilot project highlighted several limitations, particularly the small number of chemical elements analysed for in historical regional surveys. Another limitation was the common absence of analytical data for reference materials meaning the accuracy and/or precision of these surveys is unknown.

To address these shortcomings ~9,000 samples from historical regional surveys from around Australia were reanalysed by one laboratory using modern analytical techniques to produce a comprehensive suite of analytes. The results for these surveys were then levelled with recent regional geochemistry surveys (e.g., southern Thomson regional geochemistry survey, Northern Australia Geochemical Survey) and the NGSA, to produce a national geochemical baseline to which future geochemical surveys can be added.

Initial examination of this new levelled Australia-wide dataset has identified new areas of interest for rare earth element enrichment. These areas of interest were not present in the original dataset due to the limitations of the original analytical techniques. The new data allows for examination of the mechanisms and source of these areas of enrichment. These initial findings demonstrate the power of bringing Australia's historic archive of samples up to modern standards, and the utility of levelling them to create a seamless product.

Isotopic fingerprinting in groundwater and rocks of the Great Artesian Basin: characterisation of source aquifers and hydrogeological connectivity

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The Jurassic to Cretaceous Great Artesian Basin (GAB) covers approximately 1.7 million km^2, corresponding to nearly 25% of the Australian continent, and is one of the largest and most iconic aquifer systems in the world. The GAB is a complex groundwater system composed of multiple sub-basins (Carpentaria, Clarence-Moreton, Surat and Eromanga basins) and aquifer-aquitard sequences with valuable groundwater resources in arid to semi-arid regions of central Australia. Beneath the GAB lie Permian-Triassic sedimentary basins (e.g. Gallilee, Cooper and Gunnedah basins), hosting economically significant coal and gas resources. Understanding the locations and mechanisms of hydrogeological connections between different aquifers, sedimentary basins or between groundwater and surface water is crucial for water planning and management in complex hydrogeological systems with many competing water resource users.

Over the last decade, as part of multiple research projects aiming to understand recharge and connectivity processes, we have collected strontium isotopes (^{87}Sr/^{86}Sr) from over 300 groundwater bores, collated existing groundwater ^{87}Sr/^{86}Sr data and analysed ^{87}Sr/^{86}Sr in whole-rock and partially digested rock samples across different sub-basins of the GAB.

Our study demonstrated that there are distinct patterns of groundwater and whole-rock ^{87}Sr/^{86}Sr in different hydrostratigraphic units within the GAB. For example, Early Jurassic GAB formations generally exhibit higher (more radiogenic) ^{87}Sr/^{86}Sr in groundwater and whole-rock than Late Jurassic to Cretaceous formations. These systematic differences between different formations indicate the utility of ^{87}Sr/^{86}Sr as a useful hydrostratigraphic and chemostratigraphic tool in the GAB. Furthermore, ^{87}Sr/^{86}Sr shows limited changes compared to other parameters (e.g., salinity, groundwater type or age tracers such as ^{14}C and ^{36}Cl) along inferred flow paths from recharge areas to deeper aquifers for most formations in most regions of the GAB, enhancing its value as a fingerprinting tool to complement hydrochemistry.

Integration with complementary lines of geoscientific evidence, such as 3D geological models and geophysics, allows for a systematic assessment of $^{87}Sr/^{86}Sr$ in groundwater and rocks, enhancing our understanding of the potential hydrogeological connectivity processes. This approach underpins informed decision-making for groundwater management and resource development in the GAB and adjacent basins.

Hydrogeochemistry to define aquifer baselines for mineral exploration

I. Schroder, N. Reid, R. Thorne, T. Evans

Hydrogeochemistry has grown in popularity as a non-invasive technique to quickly assess a region and narrow the focus for more targeted mineral exploration. As part of Geoscience Australia’s Exploring for the Future program, we present a new approach for applying hydrogeochemistry for more sensitive anomaly detection, using hydrogeochemistry collected in the wider Broken Hill region.

The Broken Hill region is extremely well-endowed with mineral systems, including the world-class Broken Hill Line of Lode (Pb-Zn-Ag). Previous work from Geoscience Australia and CRC LEME has already demonstrated the capability of hydrogeochemistry to vector towards Pb-Zn mineralisation, which we re-investigate here using new geochemical baselines to define more sensitive, aquifer specific anomalies.

This approach characterises hydrogeochemical baselines for the major aquifer systems of the Broken Hill region (including the Proterozoic fractured rock aquifers and the Eromanga, Darling, Murray, and Lake Eyre basins), using major, minor and trace element hydrogeochemistry. Several approaches have been used to define hydrogeochemical baselines to date. Pre-selection methods filter a dataset to remove contaminated samples, while statistical approaches separate background and non-background populations via statistical tests. However, these approaches are often limited by subjective thresholds and apply to single parameters. The application of multivariate statistics (and in particular cluster analysis) presented here addresses these issues by considering the variance in all parameters and samples together, to build an understanding of the underlying hydrogeological processes and cluster geochemically related samples. These clusters are then interpreted with respect to independently assessed hydrostratigraphy to identify subgroups, which we interpret with high confidence as being diagnostic of specific aquifer systems. Using physicochemical parameters (i.e. T, EC, Eh) and stable isotopes, we demonstrate the robustness and geochemical sensitivity of the defined aquifer subgroups. These subgroups are then investigated for detecting geochemical anomalies relating to base metal mineralisation, by looking for the confluence of geochemical outliers of potential indicator species (such as Zn, Cu and δ^{34}SSO4) within these sub-populations.

The opportunity to apply this multivariate baseline approach to target critical-mineral related systems, where groundwater is uniquely placed for distal detection (i.e. clay-hosted REEs, evaporative brines, sediment-hosted deposits) will be explored.

Assessing groundwater time scales at and beyond ^{36}Cl/Cl using ^{81}Kr and radiogenic noble gas isotopes in Australia

Axel O. Suckow, Alec Deslandes, Christoph Gerber, Punjehl Crane, Cornelia Wilske, Matthias Raiber, Guo-Min Yang, Wei Jiang, Karina Meredith.

The arid and flat inland of Australia relies heavily on groundwater supplies with old groundwater beyond the ^{14}C timescale. Appropriate for determining these timescales in groundwater is ^{36}Cl– a dating technique applied and developed in Australia. Difficulties with interpretation of ^{36}Cl/Cl relate to spatially variable initial values and unknown possible temporal variations of ^{36}Cl/Cl. For example, variations in Earth's magnetic field and paleoclimatic influences such as proximity to the coast affect initial values.

Since 2016CSIRO Australia operates a facility to routinely measure noble gases, adding two further elements with radiogenic isotopes in this time range(^{4}Heand ^{40}Ar).Furthermore, applications of^{81}Kr become more and more routine at CSIROsince2016,withsamples taken and purified at CSIRO and measured in Hefei. The Australian ATTA facility at The University of Adelaide will soon also routinely measure^{81}Kr. But for the near future, ^{36}Cl will be easier to sample and cheaper to analyse than ^{81}Kr.. The present study evaluates whether the difficulties of ^{36}Cl can be mitigated by calibrating it with other tracers, especially the more reliable^{81}Kr and whether the timescales of ^{81}Kr and ^{36}Cl can be extended using the radiogenic noble gas concentrations and isotopes. Studies from CSIRO in the eastern Great Artesian Basin(GAB)and published studies in the western GAB resulted in a total of 49existing samples combining^{81}Kr and^{36}Cl. Most of these samples also include noble gas results. Therefore, this study addresses the question: Is it possible to calibrate the time dependent ^{36}Cl input with ^{81}Kr, use both to get a better understanding of the sources of radiogenic isotopes and finally, possibly extend the groundwater timescales with helium and argon?

Regional differences in initial^{36}Cl/Cl over Australia were compiled to create a map of initial values of ^{36}Cl/Clin groundwater using ^{14}Cand ^{3}H. The comparison between ^{81}Kr and ^{36}Cl suggests time variation in the ^{36}Cl/Cl input, with a peak in^{36}Cl/Cl at ^{81}Kr activities of70-90pmKr. Our first analyses of radiogenic ^{40}Ar in groundwaters, for which ^{36}Cl is at natural equilibrium, point towards a mechanism of sediment-stored radiogenic argon released into these groundwaters.

Investigating the metal leaching and bioavailability of copper-rich tailings treated with a deep eutectic solvent

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Tailings consist of finely-ground rock waste remaining after separation of the valuable commodities from ore in mining operation. These wastes are often difficult to remediate. A novel class of solvents known as deep eutectic solvents (DES) have been proposed as an alternative to traditional hydrometallurgical solvents in the processing of metal ore due to their unique solvometallurgical properties and tunability. These solvents are typically classed as environmentally benign due to high biodegradation rates and low toxicity. DES have also been identified for use in the re-processing of mine waste to facilitate remediation and to potentially extract additional metals from the waste. However, the environmental consequences of such activities remain uncertain.

An experiment was conducted to investigate the effects of DES in on the liberation and availability of metals in copper rich tailings from the Philippines. Tailings were leached with a oxidative-DES solvent consisting of chlorine chloride:ethylene glycol in a 1:2 molar ratio. The DES was removed and the tailings washed with deionised water at two contact times (1 and 24 hrs) and in fixed Solid:Liquid ratios corresponding to 1, 2.5 & 5 years of average annual *in-situ* rainfall equivalent. An unleached tailings control underwent the same sequential extraction process. Both leached and unleached material underwent sequential extractions (washings). A final aqueous and bioavailable extraction was performed on the material at the end of the experiment to assess for long-term leachability.

An increase in the amount of copper liberated in leached compared to unleached tailings was observed across sequential washings. Copper concentrations were also proportional to DES concentrations at initial washings. A significant fraction of residual post-leach DES remaining in the tailings was removed in subsequent extractions, suggesting reduced potential for solvent retention. The recalcitrant copper fraction in DES-treated tailings was lower than in the control suggesting that DES may be useful as a long-term remediation tool. However, there was no significant difference between the plant bioavailable copper in DES-treated and control tailings. Initial leaching of copper is elevated in DES leached tailings but no enhanced bioavailability and long-term elevated metal leaching under the rainfall scenarios used in this study was observed.

Theme: Environment

Poster abstracts

Hydro-geochemical perspectives on hydrogeological processes in the arid to semi-arid Barwon– Darling-Baaka River region, New South Wales, Australia

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As part of Geoscience Australia's Exploring for the Future Program, the Upper Darling River Floodplain groundwater project has contributed to an improved understanding of hydrogeological systems of the Barwon–Darling-Baaka River system in northwest New South Wales, a region where a lack of water security impacts communities and the environment, and limits future economic opportunities.

Key goals of the project were to assess the quality and extent of groundwater resources within the alluvium of the Barwon–Darling-Baaka River system to provide a greater knowledge base for supporting water management and enhanced drought resilience in the region. Groundwater and surface water hydrochemical and isotopic data were used to inform on aquifer characteristics, inter-aquifer and groundwater-surface water connectivity, and groundwater recharge and discharge in this complex arid to semi-arid alluvial system.

Sixty-eight groundwater and twenty-one surface or rainwater samples were collected, and selected sample suites were analysed for field parameters, major and trace ions, stable water isotopes ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C_{DIC}$), strontium isotopes ($^{87}Sr/^{86}Sr$), radiocarbon (^{14}C), sulphur hexafluoride (SF6), chlorofluorocarbons (CFCs), tritium (^{3}H), chlorine isotopes ($^{36}Cl/Cl$), noble gases (He, $^{3}He/^{4}He$, Ne, Ar, Kr, Xe), and radon (^{222}Rn).

Statistical clustering analysis of this new data in combination with historical datasets identified three distinct hydrochemical facies: surface water and recently recharged low salinity groundwater, saline alluvial groundwater, and groundwater associated with aquifers of the Mesozoic Great Artesian Basin. Isotope and residence time tracer signatures revealed spatial differences in recharge, groundwater-surface water connectivity, and inter-aquifer connectivity between low salinity groundwater in hydraulic connection with the Darling-Baaka River, and the saline groundwater systems that characterise most of the alluvium throughout the study area.

Integrating this hydrochemical data with other geoscientific data and information provides new insights into hydrogeological processes relevant to key water management issues including controls on the distribution of low salinity groundwater, and identification of areas at potential risk from impacts of saline groundwater.

Cobalt environmental geochemistry across Australian surface environments

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Cobalt (Co) is a key critical metal both in Australia and globally. Australia is in the top three countries for global cobalt reserves (over 1.5 million tonnes), but currently only produces ~5000 tonnes per year. As for many critical metals, the environmental cycling of cobalt in weathering environments is poorly constrained. A better understanding of cobalt cycling allows us to understand which processes enrich cobalt in natural and anthropogenic sites and may lead to improved processing pathways to extract cobalt from waste mine processing streams. To help address this we are examining cobalt mineralogy and transformation reactions in the oxidation zones of several Australian deposits. Regolith and rock samples were collected from the pyrite-hosted Broken Hill cobalt project, NSW; cobalt sulf-arsenide deposits at Mt Cobalt and Queen Sally, Queensland; lateritic iron-manganese oxide-hosted cobalt from two localities in the Redbank Copper Project, NT and the siderite-hosted Young's cobalt prospect in South Australia. Fresh rock and crushed and weathered samples derived from the pyrite-rich Mt Lyell mine in western Tasmania, including samples from the modern tailings dam and the historic sediment banks and delta of the King River were also examined. Single particle inductively coupled plasma mass spectrometry (SP-ICPMS) was employed to determine the number and mass of cobalt-based nanoparticles in the regolith and laser ablation ICPMS (LA-ICPMS) was used to determine the concentration and elemental distribution of cobalt in sulfides from Mt Lyell. X-ray fluorescence mapping and X-ray Absorption Near Edge Spectroscopy (XANES) were conducted at the ID21 beamline of the European Synchrotron Radiation Facility (ESRF) to analyse cobalt elemental distribution and oxidation state in the regolith. Together, these techniques show that cobalt is cycled dynamically from soluble through to oxide nanoparticle forms. A strong nanoscale association between cobalt and manganese was observed for many of the deposit types.

A geochemical baseline survey of urban soils in Wellington, New Zealand

Ms. R. Morgenstern, Dr. A.P. Martin, Dr. R.E. Turnbull, Ms. C. Doogue, Assoc. Prof. K. Norton, Dr. M.S. Rattenbury, Dr. K.M. Rogers

The first geochemical baseline survey of urban soils in Wellington – New Zealand's third largest city and capital – reveals chemical variation of the soil the city is built upon and how urbanisation has impacted the natural geochemical baseline. Urbanised land (residential and commercial properties) and a variety of less disturbed land use types (parks, forests, agricultural pasture) were sampled at 151 sites. At each site a hand auger was used to sample the surficial O-depth (0-2 cm) and a shallow A-depth (2-20 cm). Several deeper B-depth (50-70 cm) samples were also collected. Samples were dried, sieved to <2 mm and split, before being analysed for a suite of 65 elements using aqua regia digestion and inductively coupled plasma mass spectrometry. The relatively monolithologic geology of the area, Mesozoic quartzofeldspathic greywacke and Quaternary sediments largely derived from them, has limited influence on the variability of element concentration and no obvious correlations exist between analyte enrichment and soil order. However, distinct geochemical differences are observed in soils from less disturbed environments compared with soils where anthropogenic land uses prevail. Soils in urban areas and proximal to some major highways, especially in the shallower soil profile, show elevated levels of Ag, Au, Ba, P, Sb and Sn, as well as the heavy metals As, Cd, Cr, Cu, Hg, Pb and Zn which are potentially harmful to human health. Higher concentrations are particularly pronounced in locations that have the longest history of European settlement, commencing in the mid-1800s, and industrialisation. At 23 sites Pb, As and/or Cd exceeded the most restrictive category in the Ministry for the Environment soil contamination standards. Median Pb, As and Zn values are above baseline values established for New Zealand and global soils but are below those observed in Dunedin City. Elevated heavy metals in the urban soils of Wellington are attributed to contamination as a direct result of anthropogenic activities. This survey provides a baseline for assessing and monitoring the level of environmental contamination and potential related human health impacts in this major urban centre.

Upper King River Managed Aquifer Recharge Hydrogeochemistry Investigation

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Groundwater in the Northern Territory of Australia plays a key role in the economic development of a uniquely remote and environmentally dynamic landscape. However, water resources are already fully allocated in many regions, limiting agricultural economic development. Recent studies have highlighted that the Katherine region is an area that would benefit from additional water supply to increase water availability and security for local irrigators and the environment. Managed aquifer recharge (MAR) allows water to be stored long-term underground for supply during dry and drought years, or to smooth the seasonal availability of water.

The upper King River MAR investigation aims to progress the assessment of an Aquifer Storage Transfer and Recovery scheme in the Katherine region of the Northern Territory. Projects such as this are essential to building drought resilience and underpinning growth in regional economies in a sustainable manner.

MAR scheme assessment is undertaken in accordance with the risk-based framework of the Australian Water Recycling Guidelines: Managed Aquifer Recharge (‘MAR Guidelines’). Several investigations and field studies are being undertaken to ensure risks to human health and the environment are reduced to an acceptable level prior to progressing to a trial. These investigations include chemical and physical characterisation of the source water (King River) and target storage aquifer (Tindall Limestone Aquifer).

To do this, a nested piezometer monitoring network perpendicular to the King River has been installed to improve understanding of the Tindall Limestone Aquifer at the location of the potential MAR scheme. Characteristics of the Tindall Limestone Aquifer, such as mineralogy, geochemistry, yield, transmissivity and storativity etc., are being determined through a drilling program and subsequent aquifer testing program.

A groundwater monitoring program has also commenced following drilling to establish baseline groundwater quality parameters. Additional environmental tracer sampling is being used to characterise Tindall Limestone Aquifer, including understanding recharge, geochemical reactions, heterogeneity within and river-aquifer connectivity.

Finally, these investigations will inform a pre-commissioning residual risk assessment to identify risks and appropriate preventative measures to reduce risks to an acceptable level. Where the potential scheme was of low residual risk, it may then proceed to a trial MAR scheme.

Theme: Society

Oral Abstracts

The forensic comparison of trace amounts of earth materials using geochemical and synchrotron X-ray diffraction techniques in homicide investigations

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Earth materials such as soils, rocks, minerals and human-made mineral particles like bricks provide excellent evidence to link criminals to crime scenes. Through two investigations involving a cold murder in 1988 and homicide in 2007 this paper will demonstrate how combined pedological, traditional laboratory X-ray diffraction (XRD), synchrotron XRD and Scanning Electron Microscopy (SEM) have been critical in developing reliable forensic information, from landscape to microscopic scales, to help in forensic investigations, which were used as evidence in two Australian Supreme Courts.

In the 1988 cold murder case, trace amounts of soil were identified on a 10 year old victim's pyjama-top. Synchrotron μ-XRD provided greater sensitivity and resolution than the laboratory XRD source to better identify small amounts of pyrite and clay minerals on the pyjama-top. The soil samples in the pyjama-top had a strong degree of comparability with subaqueous soils containing pyrite in the Onkaparinga River estuary – providing evidence that the soils have similar origins. SEM confirmed that the mineral particles are deeply impregnated in gaps between fibres of the fabric, which likely originated under water with force being applied on the pyjama-top – implying the victim was pushed into the mud. This was substantiated from transference shaking experiments where mineral particles are dominantly located on the surface of the fabric. The accused was found guilty by a Supreme Court judge of murder.

The 2007 murder investigation involved comparing small (<0.5 mm diameter) red brick fragments and soil on the victim's clothing (mainly bra) and body (mainly hair) to a collection of old brick pavers in the front yard of the victim's home – even to one specific type of brick. While traditional XRD techniques were adequate for determining the mineralogy of the small red brick fragments, synchrotron XRD with high X-ray intensity was found to provide greater sensitivity and resolution to quantify the mineralogy of polycrystalline minerals (cristobalite and mullite). The judge concluded that the mineralogy of the brick fragments on the victim's clothing and bricks from her front driveway indicated that she was initially attacked in her front yard and not at Kings Park where her body was buried.

Evidence-based solutions for improving equity, diversity and accessibility in geochemistry

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[1]Women in Earth and Environmental Sciences Australasia Network

Diversity and inclusion in the workplace optimise performance through the input of a range of perspectives and approaches that drive innovation. However, gender inequity is prevalent in STEM, and women remain underrepresented in geosciences including geochemistry.

In tertiary geoscience education globally, there is an approximately even gender split that persists into research degrees. However, the number of women begins to decrease from workforce entry, becoming progressively worse at higher levels. In academia, this presents as the “leaky pipeline” where the gender split at postdoctoral levels (often short-term fixed contract) is relatively even and there is a sharp decline in women entering continuing (tenured) positions and going on to senior (Professor) levels. In the minerals industry, the most male-dominated industry in Australia comprising only 21% women, most women are in non-geoscience roles. In mining, there is a strong divergence in the proportion of men and women at increasingly senior levels, with 92% of CEO positions held by men.

Research into the causes of the “leaky pipeline” reveals that there are numerous contributing factors including unconscious bias against women, lack of role models, workplace arrangements that don’t suit mothers, barriers to awards and jobs, unequal access to parental leave, bad experiences during fieldwork and sexual assault and harassment.

The elimination of sexual assault and harassment through the pervasive implementation of recommendations handed down from Parliamentary inquiries and institutional and corporate investigations is essential for creating a safe space for women in geochemistry. Communication and implementation of best-practice, evidence-based approaches, and solutions to the many other factors contributing to the loss of women from geoscience will be valuable in creating positive change. Improved efforts to understand and address the reasons why women leave geoscience careers will help to repair the “leaky pipeline”.

Integrating Geoethics into Applied Geochemistry: Strategies for Sustainable and Responsible Practices in Australia

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Australia boasts a robust mineral and energy resources sector where geochemistry plays a vital role in various stages of mineral deposit exploration, characterisation, processing and environmental rehabilitation. The continual evolution of geochemical analytical tools and methodologies has significantly influenced industry growth, employment opportunities and research advancements. However, Australia’s heavy reliance on exploration and mining for economic prosperity raises concerns regarding social acceptance, particularly with respect to potential conflicts with land use such as agricultural areas or regions dependent on natural resources.

This presentation explores the interdependence between geoethics and applied geochemistry, emphasizing the ethical dilemmas and best practices associated with environmental stewardship and resource extraction. Our focus lies on the pivotal roles of education, policy formulation, and the national perspective in driving sustainable geochemical practices forward. By drawing on the IAPG White Paper on Responsible Mining, we propose establishing a framework for fostering ethical consciousness and informed decision-making within the Australian geochemistry community. Responsible mining, as outlined in the IAPG White Paper, entails commitments to environmental preservation, community engagement, and ethical conduct.

In this context, geochemical methodologies play a crucial role in mitigating environmental impacts and facilitating responsible resource management. Key practices include conducting comprehensive geochemical assessments to identify potential environmental risks, engaging local communities to address their concerns and needs, and leveraging geochemical data to devise sustainable extraction strategies. Transparency, support for local economies and contributions to conservation efforts are integral components of this approach.

Ultimately, aligning applied geochemistry with responsible activities across the minerals value chain endeavours to strike a balance between mineral resource exploitation, environmental preservation and societal wellbeing, thereby ensuring that the mining industry contributes positively to global sustainable development goals.

Theme: Society

Poster abstracts

Geochemical field training as a part of international research cooperation to promote the green transition in Estonia

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The EGT-TWINN project aims to enhance research and technical capacity at the Geological Survey of Estonia (EGT) to accelerate Estonia transition from fossil fuel energy to green energy. The project will contribute to the development of multidisciplinary research and innovation in geological studies in Estonia and enables EGT to enhance the scientific excellence of its personnel and to collaborate with experts from leading international research institutions. One of the project priorities is to support early-career researchers at EGT in the geology fields crucial to Estonia.

The capacity building will mainly be focused on developing state-of-the-art geological, geochemical, and geophysical survey skills, data management workflows, and subsurface modelling capability for the exploration. An aim is to promote the geological resource assessment of European critical raw materials but also geothermal energy as a future potential green energy source for Estonia. The EGT geological capacity enhancement will be implemented via range of joint activities such as knowledge exchange and scientific conferences as well as through the delivery of targeted training programmes provided by three leading geological surveys in Europe – the Geological Surveys of Finland (GTK) and Denmark (GEUS), and the British Geological Survey (UKRI/BGS). A further partner is the Oulu Mining School (OMS) from the University of Oulu, which provides field technique training for surficial geochemical exploration as well as a unique state-of-the-art platform for mining-related research and education.

One of the field training courses, organized by OMS, focuses on a multidisciplinary approach to mineral exploration in the glaciated terrain. It highlights in practical ways how (i) sampling and different field survey techniques commonly can be used in generative greenfield exploration campaigns in the glaciated, transported cover and (ii) understanding of geochemistry, indicator minerals and the use of surficial deposits in ore exploration. The importance of understanding the regional geological framework is a major theme during the course. Furthermore, the dispersion mechanisms of elements in different glacigenic environments are described. The use of on-site geochemical and mineralogical analysers, mobile metal ion -based techniques and geophysical survey methods are included in the course contents. This project is funded by the Horizon Europe, Grant Agreement no. 101079459.