CSIRO

# DIME 2026

## Discovery *for* Innovation *in* Minerals Exploration Seminar

12 February 2025

Perth, Western Australia

## PROCEEDINGS

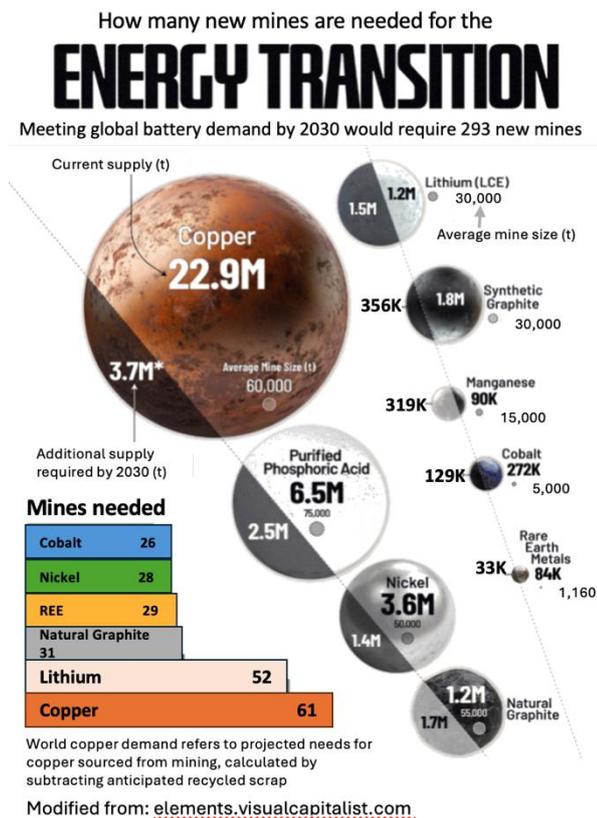| Start | Finish | Min | Title | Presenter |
|-------|--------|-----|-------|-----------|
| 8:45 | 8:55 | 10 | Welcome to Country | Freda Ogilie |
| 8:55 | 9:10 | 15 | CSIRO's new Portfolio of research: Sustaining Australia's Mineral Resources – What is our purpose and operating model | Sandra Occhipinti |
| **Session 1: Critical and strategic metals** | | | | **Chair: Shirly Hu** |
| 9:10 | 9:30 | 20 | Indicator minerals research for critical metals - update on project plans and tool | Margaux Le Vaillant |
| 9:30 | 9:50 | 20 | Utilising mineral alteration mapping at deposit scale: Insights from IOCG districts across | Tobias Schlegel |
| 9:50 | 10:10 | 20 | Application of isotope and fluid inclusion geochemistry to fingerprint ore-forming processes in mineral systems | Marta Sośnicka |
| 10:10 | 10:30 | 20 | Linking mineral signatures and numerical modelling to advance pegmatite exploration | Rosa Didonna |
| 10:30 | 11:00 | 30 | **Morning Tea,** incl. LogAR live demo | |
| **Session 2: Geophysics & remote sensing** | | | | **Chair: Marta Sośnicka** |
| 11:00 | 11:20 | 20 | Our geophysics capability and strategy, with some examples | Stephan Thiel |
| 11:20 | 11:40 | 20 | Petrophysics, geophysics and finding critical minerals – what's possible, and what's fantasy? | Sarath Samaya Manthri Patabendi Gedara |
| 11:40 | 12:00 | 20 | Good vibrations – riding the new wave of hyperspectral remote and proximal sensing technologies | Carsten Laukamp |
| 12:00 | 12:20 | 20 | Process modelling for mineral exploration: a quantitative approach to understanding mineral systems | Thomas Poulet |
| 12:20 | 13:20 | 60 | **Lunch,** incl. LogAR live demo | |
| **Session 3: Exploration in cover** | | | | **Chair: Alex Hunt** |
| 13:20 | 13:40 | 20 | Context is everything - How soil properties help us understand soil geochemistry and regolith processes | Anicia Henne |
| 13:40 | 13:50 | 10 | White fields = green fields for the gold fields | Ryan Noble |
| 13:50 | 14:00 | 10 | LEME AI: Developing an on-premise AI system to accelerate exploration in regolith | Jens Klump |
| 14:00 | 14:20 | 20 | Case Study: Putting it all together – Mineral systems and targeting in the Yeneena Basin using mineralogical mapping and thermodynamic modelling | Fariba Kohan Pour |
| 14:20 | 14:40 | 20 | Tackling today's challenges for tomorrow's opportunities: The future of iron ore | Yoram Teitler |
| 14:40 | 15:00 | 20 | **Afternoon Tea,** incl. LogAR live demo | |
| **Session 4: Tools, Technology & Collaboration** | | | | **Chair: Helen McFarlane** |
| 15:00 | 15:20 | 20 | Going beyond chemical buffers: lithological controls on fluid flow in the Kalkaroo sediment-hosted Cu-Au-(Co) deposit | Gabriel Valentim Berni |
| 15:20 | 15:35 | 15 | Developing a scalable LIBS–ML workflow for multi-commodity mineral systems: Progress, integration, and future direction | Ruixue Wang |
| 15:35 | 15:50 | 15 | Rapid mineral phase mapping via LIBS: Vision, insight, and geometallurgical application | Ryan Manton |
| 15:50 | 16:00 | 10 | A snapshot of our journey, trials and tribulations. | Carl Young, Northern Star Resources LTD |
| 16:00 | 16:10 | 10 | Transitioning innovation through SME engagement, with CSIRO in-house R&D and financial support | Liz Crompton |
| 16:10 | 16:25 | 15 | Growing Australia's PGE resource base: Opportunities across the mining value chain | Will Smith |
| 16:25 | 16:40 | 15 | Experiments & geochemical models: How mineral deposits form (Au, Base Metals, Critical Minerals) - An introduction to ECGL | Yanlu Xing |
| 16:40 | 16:50 | 10 | Closing remarks | Sandra Occhipinti |
| 16:50 | 18:30 | | **Sundowner, all welcome** | |

**CSIRO's new Portfolio of research: Sustaining Australia's Mineral Resources – What is our purpose and operating model**

Speaker:    **Sandra Occhipinti**

The minerals sector continues to navigate volatile markets, constrained access to land and infrastructure, increasing pressure on water resources, and persistent workforce challenges. Smaller companies, in particular, face difficulties securing investment. At the same time, global momentum toward climate adaptation, resilience, and clean energy technologies is driving demand for minerals essential to the energy transition, high technology manufacturing, and major infrastructure.



How many new mines are needed for the
**ENERGY TRANSITION**
Meeting global battery demand by 2030 would require 293 new mines

World copper demand refers to projected needs for copper sourced from mining, calculated by subtracting anticipated recycled scrap

Modified from: elements.visualcapitalist.com

In this context, CSIRO is focused on contributing to a Future Made in Australia—though for metals, we know that "Made in Australia" is a natural systems reality given the sector's central role in the national economy. Future growth of the minerals sector, however, depends on discovering high-grade and geometallurgically favourable deposits that support a sustainable and competitive industry creating wealth for Australia and beyond.

CSIRO's work to enable a clean, affordable energy transition—including engineering critical minerals into higher value products—directly aligns with the Government's expectations for applied research in a NetZero economy. This encompasses hydrogen, green metals, critical minerals processing and low-carbon fuels. Across the mining value chain, Mineral Resources is also advancing AI, quantum technologies, sensing, robotics and next generation manufacturing to help ensure Australia continues to generate prosperity from its mineral endowment. By accelerating innovation across core sectors and collaborating with partners nationally and internationally, we aim to position Australia as a leader in the responsible development of future technologies.

Historically, the Mineral Resources Discovery Program and precursor geoscience initiatives have not always communicated their contributions effectively. Yet CSIRO Mineral Resources has a long record of leadership: establishing Australia's first image processing laboratory in the early 1970s; producing the world's first magnetic susceptibility image in 1978; and creating the first continent scale multispectral mineral map in the 2000s using Japanese Space System's ASTER sensor onboard NASA's Terra satellite. In 2025, working with the European and US space agencies, we compiled new hyperspectral datasets from three international sensors, supported by IP arrangements that will enable us to deliver mineralogical information from space at multiple scales. In partnership with Geoscience Australia, we are also updating national scale mineralogy products beyond the original ASTER-based maps, leveraging hyperspectral satellite data to deliver the next iteration of mineral mapping.

This year we expanded our Indicator Minerals research for orthomagmatic nickel and associated metals, continued developing Indicator Mineral Assemblages for copper systems, and lithium pegmatites. Our teams build high-quality mineral libraries for hyperspectral, SEM and LIBS datasets, and progressing early geometallurgical tools, including site-based scanning, augmented reality logging (LogAR) and downhole automated logging (Data Mosaic). Translation and deployment projects are helping bring these technologies into industry use. Ultrafine+ and DetectORE continue to grow internationally through LabWest Mineral Analysis Pty Ltd and Portable PPB Pty Ltd. Our regolith specialists are advancing exploration under challenging cover—particularly in salt lake environments—by improving understanding of metal transport and enrichment processes.

Our geophysics laboratory and modelling capability spans shallow to deep imaging across electromagnetic, seismic and potential field methods, delivered by teams in Sydney, Perth and Adelaide. Working with geological surveys nationwide, we are developing new modelling algorithms with uncertainty estimates and new electromagnetic modelling tools. Beyond minerals, this expertise supports subsurface water assessments essential for mining, agriculture, the environment and communities. Over the past 12–18 months, we have collected hydrogeochemical data across multiple states, contributing to a growing seamless national dataset of our groundwater quality and in collaboration with state and federal agencies.

CSIRO remains committed to uncovering the unknown and extending Australia's tradition of research excellence. 90+ CSIRO Mineral Resources Discovery Program staff, additional affiliates and students working on geoscience problems focused on exploration in various environments and mining are focused on ensuring new knowledge and technologies continue to deliver long-term national benefit.
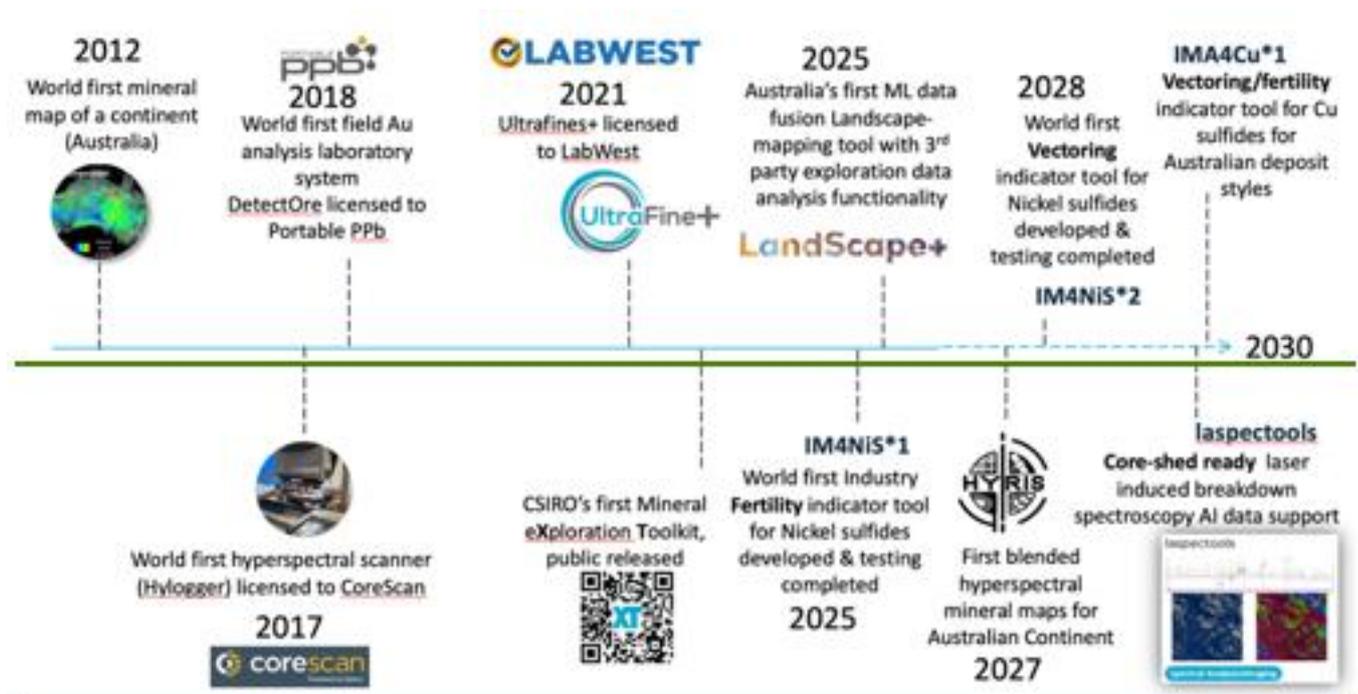


**Timeline of delivery of selected technologies for mineral geoscience solutions.**

**Indicator minerals research for critical metals - update on project plans and tool developments**

Speaker:     **Margaux Le Vaillant**

Mineral exploration in weathered and covered terrains has traditionally prioritised geophysical and geochemical approaches over mineralogical analyses, although these methods may not directly confirm mineralisation. While geochemical surveys such as the analysis of soils, vegetation, termites, or calcrete, are established for detecting various mineralisation types, their effectiveness diminishes in areas with deep or unrelated cover. In contrast, indicator minerals offer valuable insights for exploration in such challenging environments. The Discovery program encompasses multiple research initiatives aimed at advancing the use of indicator minerals, mineral chemistry, and mineral assemblages to explore a range of commodities, with emphasis on critical metals including Ni, Cu, Co, PGEs, REE, and Li.

Since 2021, research co-funded by industry and MRIWA has focused on mafic-ultramafic ortho-magmatic mineral systems, with current efforts directed towards: (1) refining prospectivity machine learning models utilising spinel and olivine chemistry to predict sulphide potential; (2) developing new evaluation models based on ilmenite, apatite, and pyroxene; (3) creating deposit-scale vectoring tools; and (4) making these resources accessible via the XT Minerals online platform.

In the domain of copper ore systems, CSIRO leads an AMIRA research initiative to develop mineral assemblage and chemistry-based exploration tools at multiple scales, with commencement anticipated in mid-2026.

Research on mineralised pegmatites within Discovery has examined the distribution of lithium and associated pathfinder elements in pegmatite minerals, enhancing understanding of the magmatic and hydrothermal processes underlying ore formation and subsequent alteration. This research employs advanced analytical techniques, including SEM-based automated mineralogy, micro-XRF, Electron Probe Micro-Analysis, and LA-ICP-MS, to investigate mineral assemblages, textures, and fine-scale chemical zoning in lithium-hosting and accessory minerals.

Finally, the use of mineral chemistry is also investigated as a potential prospectivity indicator and vectoring tool for intrusive REE systems, with complex zoning and trace element chemistry of apatite showing promising results.

**Mineral alteration mapping at deposit scale: Insights from IOCG districts across Australia**

Speaker:    **Tobias Schlegel**

Iron oxide–copper–gold (IOCG) and related deposits represent Australia's main copper resources. Exploration has long focused on the Olympic Cu–Au province and the Cloncurry district, yet the Curnamona province shows similar geological and magmatic characteristics, implying metallogenic potential. Using scanning electron microscopy–based mineral mapping and petrography of over 600 drill core samples from IOCG deposits (Carrapateena, Starra) and prospects (Crozier's Dam, Birksgate, Bassanio), we examine the links between hydrothermal alteration and Cu sulphide distribution.

Copper sulphides occur within alteration zones that evolve through iron oxide–alkali–calcic–hydrolytic assemblages. High-grade Cu mineralisation consistently coincides with late Fe-rich (F, $SO_4$) hydrolytic alteration that overprints earlier Fe–K–($CO_2$) assemblages, which replace early Na–Ca–Fe alteration distal from Cu peaks. Distinct mineral abundance trends including Cu sulphide enrichment zones radiate outward from centres of intense alteration, delineating fluid pathways and forming mappable halos.

In principle, anhydrous host rock and early alteration minerals such as magnetite, albite, and K-feldspar interact with acidic, Cu-bearing hydrothermal fluids. This leads to the development of hematite, quartz and hydrous alteration minerals including biotite, muscovite, and chlorite, in addition to carbonate and pyrite when approaching zones with Cu sulphides. Empirical observations suggest that relatively larger alteration halos correspond with broader Cu mineralisation. These observations suggest that targeting anomalous magnetic and gravity zones by drilling under significant cover may not reveal signs of Na–Ca–Fe, and Fe–K alteration.

At Carrapateena, bornite–covellite mineralisation occurs at interfaces between Fe-rich (F, $SO_4$) hydrolytic and Fe-rich hydrolytic–carbonate alteration-derived mineral assemblages, while rocks affected only by Fe-rich hydrolytic–carbonate alteration at depth host greater abundances of chalcopyrite. Early Na–Ca–Fe or Fe–K alteration that occur with hydrothermal albite, magnetite + K-feldspar assemblages are absent in our dataset from Carrapateena

This study confirms that mapping alteration mineral assemblages at deposit and prospect scales provides key insights into where IOCG mineralisation occurs and how high-grade ores form. These results refine exploration models and enhance predictive tools for targeting concealed IOCG systems across Australia.

## Application of isotope and fluid inclusion geochemistry to fingerprint ore-forming processes in mineral systems

Speaker: **Marta Sośnicka**

Application of multi-scale approaches to analysis of metal migration, coupled with isotope and fluid inclusion geochemistry remains a cornerstone in advancing our understanding of mineralizing processes. This also helps to refine genetic models of ore-forming systems enabling better targeting strategies to vector to high-value mineral deposits.

Fluid systems play a fundamental role in hydrothermally driven ore-forming processes across diverse geological environments. Their evolution from source to the sink including alteration through fluid-fluid and/or fluid-wall rock interactions during migration is critical for understanding the development of mineral systems. Integrated isotope and fluid inclusion geochemistry is a powerful tool to fingerprint fluid origin, composition, alteration, sources and physicochemical conditions controlling metal transport and deposition. The only unequivocal insights into these ore system components and metalliferous fluid characteristics are preserved in microscopic-scale fluid inclusions entrapped in various minerals.

The origin of the ore-forming fluids remains largely enigmatic in many case studies, whilst their metal budget is subject to modifications at any time on their migration pathway to the site of deposition. In this light, tracing sources and evolution of fluid systems through space and time is crucial and can be achieved by integration of multi-scale geological-mineralogical-geochemical investigations with C-N and H-O stable isotope analyses of fluid inclusions and minerals. Furthermore, geochemical fingerprints such as metal concentrations in fluid inclusions offer predictive value for mineral exploration, enabling discrimination between fertile and barren hydrothermal systems. In this presentation selected case studies will be used to demonstrate the use of isotope and fluid chemistry to constrain processes and controls of ore formation.

**Linking mineral signatures and numerical modelling to advance pegmatite exploration for lithium and rare earth elements**

Speaker:     **Rosa Didonna**

Lithium is a key resource for the global energy transition. While numerous studies have characterised lithium-rich pegmatite deposits, major knowledge gaps persist in understanding their formation, evolution, and the mechanisms controlling mineral enrichment within the broader geological framework. This limits the ability to explore for lithium-rich pegmatites, and understand the distribution of lithium and rare earth elements (REEs) within them. There have been significant advances in field-based and geochemical investigations; however, no robust numerical models have been developed to support our lithium-pegmatite formation knowledge, limiting our ability to predict both the volume and spatial distribution of critical minerals and REEs enrichments.

This study seeks to close this gap by investigating the geological, stratigraphic, and permeability controls on melt flow, transport, and commodity enrichment (e.g. Li, Cs, Ta, Rb) across selected Australian localities (e.g. Pilgangoora, Pilbara Region, WA). The modelling approach is supported by advanced analytical datasets obtained through microscopic-scale techniques (e.g., automated mineralogy, electron probe microanalysis and mass-spectrometry analyses) focusing on mineral assemblages, textures, and fine-scale chemical zonings in robust markers such as Ta-Nb oxides, garnet and apatite. Petrological data, including pressure-temperature conditions and melt compositions, provide critical constraints for the development of new flow-modelling approaches.

By integrating field observations, mineral-scale data, and numerical simulations, this research advances our understanding of pegmatitic melt pathways and thermodynamic controls on critical mineral distribution. Ultimately, outcomes aim to deliver a step-change in understanding Lithium-Caesium-Tantalum versus Niobium-Yttrium-Fluorine pegmatite systems (also magma crystallisation vs. anatectic processes) and directly enhance strategies for future exploration.

**Our Geophysics capability and strategy, with some examples**

Speaker:    **Stephan Thiel**

Geophysical surveys for mineral exploration span a vast range of scales including continental to regional scales, commonly deployed by geological surveys, to camp and deposit scale by mineral explorers. Each of these provide unique opportunities to develop multi-scale and multi-physics approaches to characterising the Earth's subsurface.

Here we present results that link state-of-the-art continent-wide and regional 3D inversion models derived from magnetotelluric data to surface geology and mantle information obtained from xenoliths/xenocrysts. Using a multi-physics approach and incorporating compositional and temperature models, we can quantitatively derive a measure of mantle metasomatism from geophysical models.

In following enhanced conductivity into the crust, we use in-fill MT surveys to jointly invert for crustal structure in prospective areas, showing recent gravity and MT joint inversion results in the prospective Olympic domain, demonstrating the value of this technique for targeting IOCG and other copper, precious or critical metal deposits.

**Integrating petrophysics and geophysics for critical minerals – What we can and cannot resolve**

Speaker:     **Sarath Patabendigedara**

Rising demand for critical minerals has increased interest in how petrophysics and geophysics can be integrated to characterise mineral systems concealed beneath cover sequences. However, the boundaries between what can be measured, inferred, or assumed remains uncertain. This presentation examines the relationship between measurable physical properties, geological complexity, and geophysical detectability. Using a conceptual Venn framework highlights three fundamental controls on geophysical expression: composition and proportions (mineralogical and textural make-up), geometry and scale (spatial distribution and detectability), and physicochemical conditions (alteration, oxidation, and environmental overprints).

Within this framework, petrophysics provides the quantitative bridge between geological observations and geophysical responses. It defines how mineral composition and texture influence intrinsic properties such as density, magnetic susceptibility, and electrical conductivity; constrains how these properties vary with geometry and scale; and captures how physicochemical processes alter primary signatures. The discussion draws on datasets and literature examples to illustrate how petrophysical measurements underpin realistic modelling of geophysical responses, and how integrating these datasets reduces ambiguity in interpretation.

By linking physical measurement with system-scale understanding, this approach helps define where petrophysics can meaningfully inform exploration models and where its limits lie. The goal is to provide a balanced perspective on how petrophysics-informed geophysics enhance the discovery of critical minerals beneath cover while acknowledging the complexities that govern their detectability.
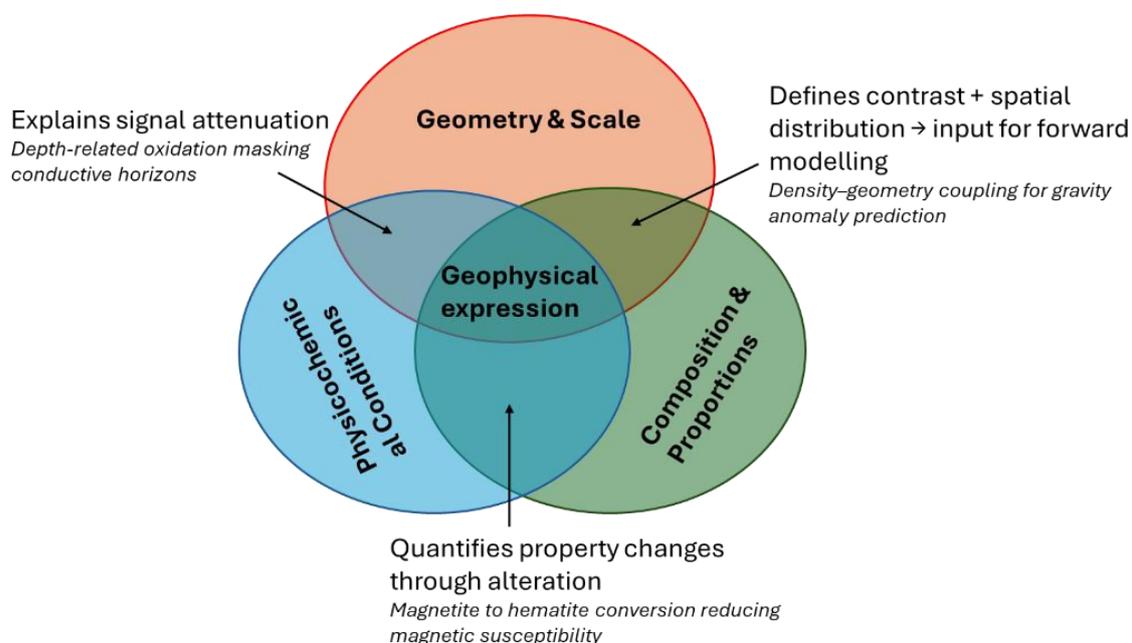


**Conceptual framework illustrating three key controls on geophysical expression, composition and proportions, geometry and scale, and physicochemical conditions. Petrophysics underpins each domain by quantifying intrinsic rock properties, constraining physical models, and characterising alteration or overprinting, thereby linking geological reality to geophysical observables.**

**Good vibrations – Riding the new wave of hyperspectral remote and proximal sensing technologies**

Speaker:     **Carsten Laukamp**

Hyperspectral reflectance spectroscopy has experienced a resurgence in the mineral resources sector, fuelled by recent technological developments. Examples include 1) the new generation of hyperspectral Earth observation instruments, providing unprecedent quality of spaceborne visible-near and shortwave infrared spectra, and 2) "full wavelength range" hyperspectral drill core sensors, which not only enable cost-effective logging of relative mineral abundance and mineral chemistry, but also can be used to infer grainsize and be integrated with geochemical and petrophysical data to derive higher level products.

This talk puts a spotlight on the latest hyperspectral sensing technologies – proximal and remote sensing - and how they can help to address challenges experienced by the mineral resources sector. Beyond the already established workflows and applications, such as in epithermal and porphyry Cu deposits and iron ore deposits, this presentation will demonstrate new applications including 1) spaceborne detection of Nd using German Aerospace Centre's hyperspectral satellite sensor EnMap (https://www.enmap.org/data_access/), 2) cm-scale mapping of Nd-host minerals in carbonatites and characterising Fe-alteration in spodumene-bearing Lithium-Caesium-Tantalum pegmatites by means of publicly available hyperspectral drill core data (https://www.auscope.org.au/nvcl), and 3) FTIR-based characterisation of W-Mo ratios in W host minerals.

## Process modelling for mineral exploration: a quantitative approach to understanding mineral systems

Speaker: **Thomas Poulet, Heather Sheldon, Juan Giraldo, Val Zuchuat**

Mineral exploration increasingly relies on robust conceptual frameworks to navigate geological complexity and reduce uncertainty. One effective strategy is to adopt a mineral systems approach, which dissects the exploration challenge into key components such as lithospheric architecture, favourable geodynamics, and geochemical signatures as expressions of fertility, ore deposition, and preservation. By applying a top-down, multi-scale methodology, we can systematically narrow the search space, either by identifying promising regions or ruling out less favourable ones. This presentation explores how process modelling can be used to test and refine mineral system hypotheses. Through physics-based simulations, we can evaluate the internal consistency of conceptual models, identify critical controlling parameters, and constrain their plausible ranges. Importantly, this approach is not limited by data availability or project maturity; it can be applied to both early-stage conceptual models and more advanced exploration settings where data gaps exist. We demonstrate how iterative cycles of observation, modelling, and interpretation can enhance geological understanding and guide exploration decisions. Case studies will include examples of multi-physics simulations as parts of an integrated workflow for sedimentary-hosted copper deposits. These examples highlight how process modelling can bridge the gap between theory and field data, offering a powerful tool to refine exploration targets and improve confidence in decision-making.
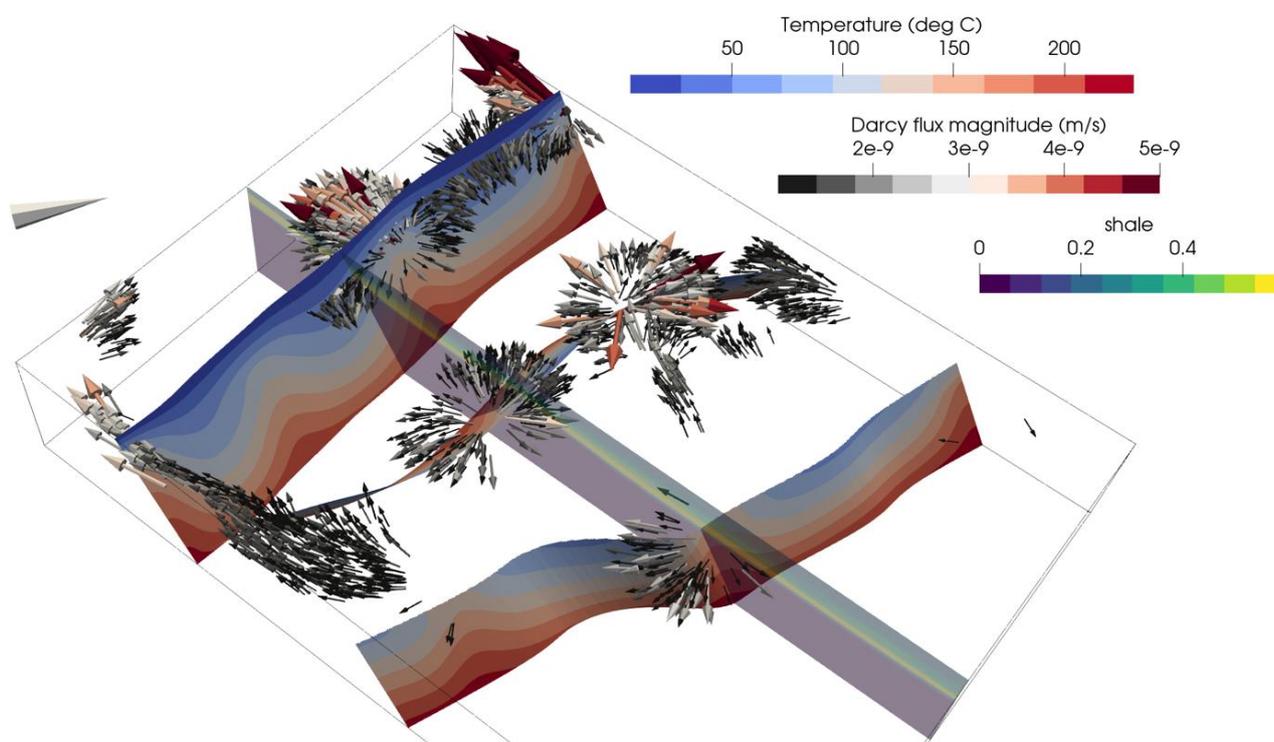


**Sedimentary basin example of thermal convection in faults and corresponding fluid flow in mud-rich layer where copper mineralisation is observed. Faults coloured by temperature. Fluid flow vectors coloured and scaled by fluid flow rate.**

**Context is everything - How soil properties help us understand soil geochemistry and regolith processes**

Speaker:    **Anicia Henne**

Soil surveys are often the first pass geochemical prospectivity method employed in greenfields exploration. However, complex regolith forming processes (erosion, transportation, and sedimentation) make the geochemistry extracted from soil samples notoriously difficult to interpret. Especially in transported cover, the concentration of metals of interest indicating anomalous values may be unknown and might change with the type and depth of cover. Other questions that hinder interpretation may be where does my signal come from and is it chemically mobile or detrital? To answer these questions context is essential and some of this context can be provided by additional soil properties such as mineralogy and pH. These can give crucial additional information to successfully characterise landform settings and be used to interpret soil geochemical data. Newly developed and commercially competitive methods do exist. These combine multi-element geochemistry, visible near-infrared reflectance spectroscopy and pH analyses on the ultrafine fraction of soil samples. This presentation will demonstrate how spectral mineralogy proxies and pH improves the ability to separate chemically mobile from detrital signals of target and pathfinder elements – a crucial advantage for exploration success. We will present data from over 20,000 soil samples across two sites in the Gascoyne Province and the Yilgarn Craton. While the lithology in both settings shows similarities (e.g., highly felsic, differentiated, low Ca, Mg and Fe granites), they have undergone vastly different weathering histories. By interpreting the geochemical analyses and mineralogy proxies in the context of additional soil properties, we can distinguish exploration-relevant signatures.

**Whitefields = greenfields for the goldfields**

Speaker:     **Ryan Noble**

In the eastern goldfields of Western Australia, the most recent large gold discoveries according to Paydirt's New Gen Gold volumes of past years include the Lake Rebecca (Ramelius Resources) and Invincible gold deposits (St Ives Goldfields). What unifies these two major discoveries is the proximity to salt lakes. Prospective geology is commonly well explored in the Kalgoorlie region, with the greenstone belts being considered brownfields exploration for many explorers. However, we observe discoveries or even subeconomic gold trends stopping along these lithologies as they disappear beneath the large salt lakes (or white fields) that cover a significant amount of the region. Why is this? Salt lakes are complex cover sequences and the last frontier for exploration in these well-endowed gold-rich terrains. How can we explore better in these settings, what are the known unknowns for understanding metal mobility and sediment transport as well as what geophysical techniques can be applied to improve our knowledge. This presentation will highlight the current project being developed with the aim of better exploring salt lakes, enabling new green fields terrains to become prospective in the future.
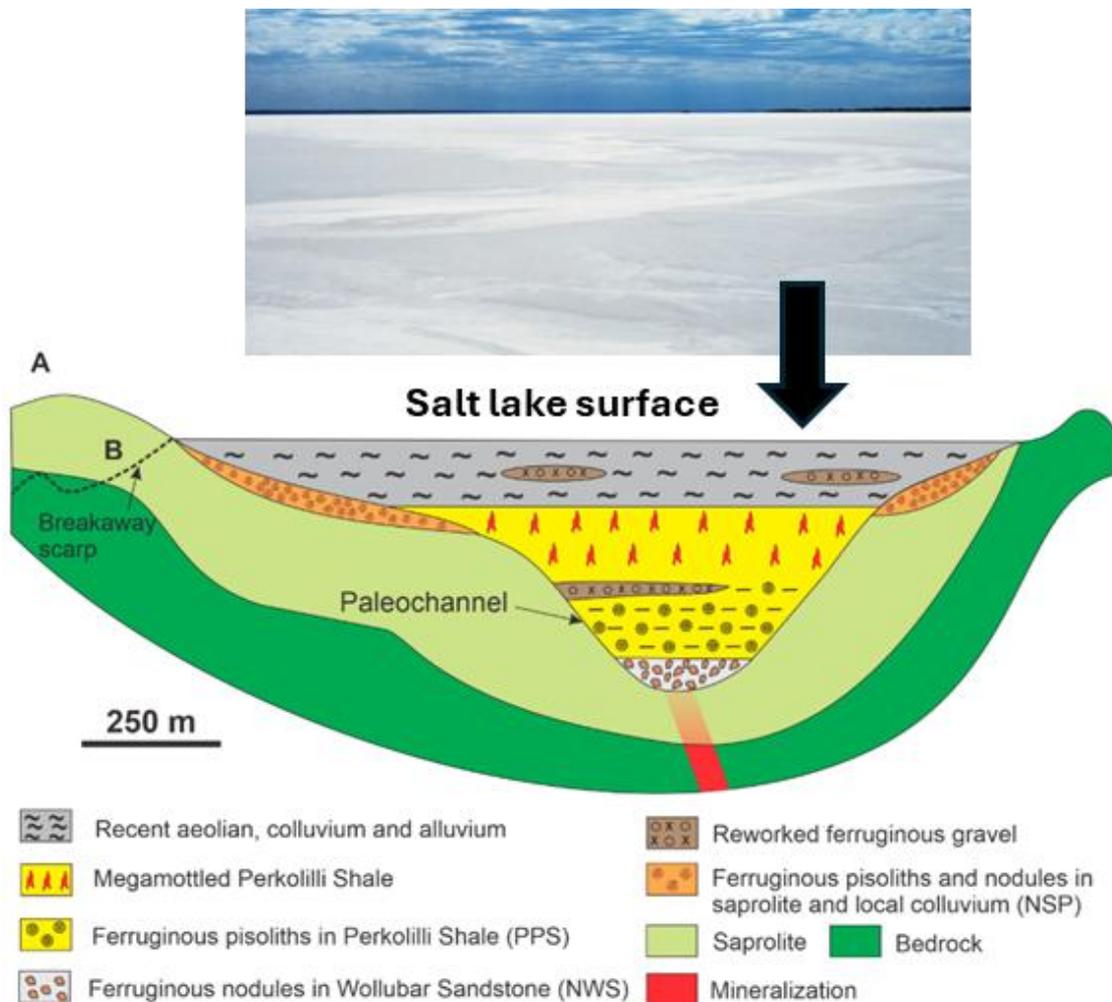


**Conceptual cross section of the complex regolith sediments in salt lake and paleochannel regions of the Yilgarn Craton. Modified from Ravi Anand (2011).**

**LEME AI: Developing an on-premise AI system to accelerate exploration in regolith terranes**

Speaker:     **Jens Klump and John Hille**

Insights from past projects, as documented in reports, become increasingly inaccessible over time, resulting in a loss of specialist knowledge as their authors move on or retire. The Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), which ended in 2008, aimed to provide the mineral industry with world-leading capabilities. The importance of the regolith research conducted in CRC LEME extends beyond achieving the project's initial objectives. New data on the regolith have raised questions about our geological thinking and the models underpinning the sampling strategies routinely employed by many mineral explorers. The results from the CRC LEME have led to breakthroughs in exploration within Australia's extensive areas covered by regolith.

Despite the years that have passed since the project concluded, the CRC LEME's findings remain highly relevant today. These project outputs are detailed in numerous project reports; however, their large number and dispersion across various platforms make the information difficult to access and extract.

In the meantime, technological advances have made it much easier to access and explore large volumes of text. LEME AI uses Retrieval-Augmented Generation (RAG), a powerful blend of data retrieval and generative AI models. Unlike Large Language Models (LLM), which rely solely on preexisting training data, RAG integrates newly available data at query time. This means that the RAG system can be updated with new source material, allowing the CRC LEME reports to be augmented with additional material. LEME AI includes source references in its responses, enabling users to verify information by reviewing the cited documents. Furthermore, LEME AI can be implemented on-premise, removing the risk of unintended leakage of proprietary data to external services.

**Putting it all together – Mineral systems and targeting in the Yeneena Basin using mineralogical mapping and thermodynamic modelling**

Speaker:     **Fariba Kohanpour**

Mineral exploration under cover relies on understanding ore-forming processes and their mappable proxies using a variety of geoscientific datasets. Mapping mineral system footprints, including alteration minerals and geochemical gradients and anomalies, is a standard method of vectoring towards an ore body. However, alteration in sediment-hosted deposits is subtle and challenging to identify during drill core logging or from whole-rock geochemical data. The Nifty deposit, which is the focus of this study, is an unexposed sediment-hosted copper deposit located within the Yeneena Basin, northwest of Paterson Orogen of Australia. This study mapped mineralogical assemblages within Nifty, including variations in mineralogical abundances and their compositions, to identify indicator minerals for sediment-hosted copper deposits, for subsequent application in geochemical modelling. A multi-scale approach (Fig.1) was taken where drill core samples were selected to identify alteration minerals associated with copper sulfide mineralisation across a traverse from unaltered country rock to distal to proximal alteration zones. Mineralogy inferred from hyperspectral drill core scanning (Hylogger 3™) and µXRF data was verified and analysed through Scanning Electron Microscopy and Electron Microprobe Analysis to explore the subtle variations in mineral assemblages and their chemical composition. Geochemist Workbench is used to model mineralisation stages constrained by studied mineralogical footprints and copper isotope studies. The findings of this study provide (1) identification of indicator minerals of sediment-hosted copper deposits and/or alteration zonation, (2) knowledge and quantitative data that can be applied for the understanding of mineralisation stages, (3) mineralogical-geochemical models to verify conceptual models of mineralisation styles. Integration of mineralogical studies and thermodynamic modelling constrains dominant mineralisation processes and their controlling parameters, thereby better informing prospectivity mapping.
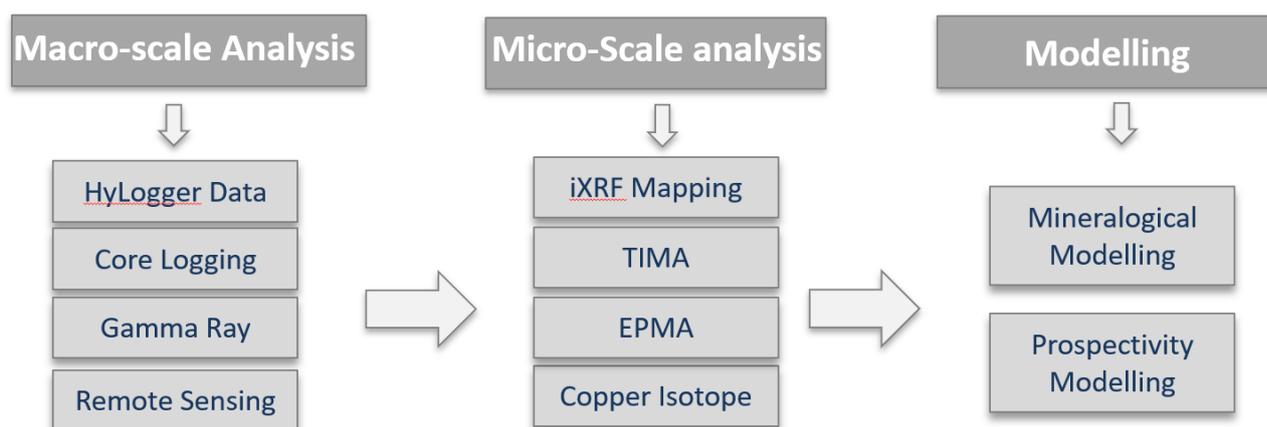


*Multiscale approach in understanding the mineral system*

**Tackling today's challenges for tomorrow's opportunities: The future of iron ore**

Speaker:     **Yoram Teitler**

The iron ore industry faces two converging challenges: the depletion of high-grade direct shipping ores (DSO) and the shift towards low-carbon steelmaking processes. In this evolving context, a comprehensive understanding of ore variability and its impact on processability has become essential to guide exploration, mining, pre-concentration, and processing strategies.

At CSIRO, we combine advanced mineral and petrophysical characterisation to generate process-focused insights that support industry through this transition. Our research delivers tools and integrated workflows to characterise ore types, quantify mineral abundances including goethite varieties, assess deleterious elements deportment, and link mineralogical variability to geometallurgical performance. These approaches allow a more predictive understanding of ore behaviour from deposit through to final product, helping optimise resource utilisation and product consistency.

As the steel sector transitions towards Direct Reduced Iron (DRI) and green steel technologies, our expertise encompasses both magnetite and high-quality hematite ores and concentrates. We identify and quantify the critical parameters influencing processing performances, such as mineral grain size, gangue composition, and comminution metrics to meet evolving industry requirements.

Working collaboratively across CSIRO's cross value-chain research, we provide integrated knowledge that supports the sustainable production of iron ore and underpins the industry's long-term competitiveness in a decarbonising world.
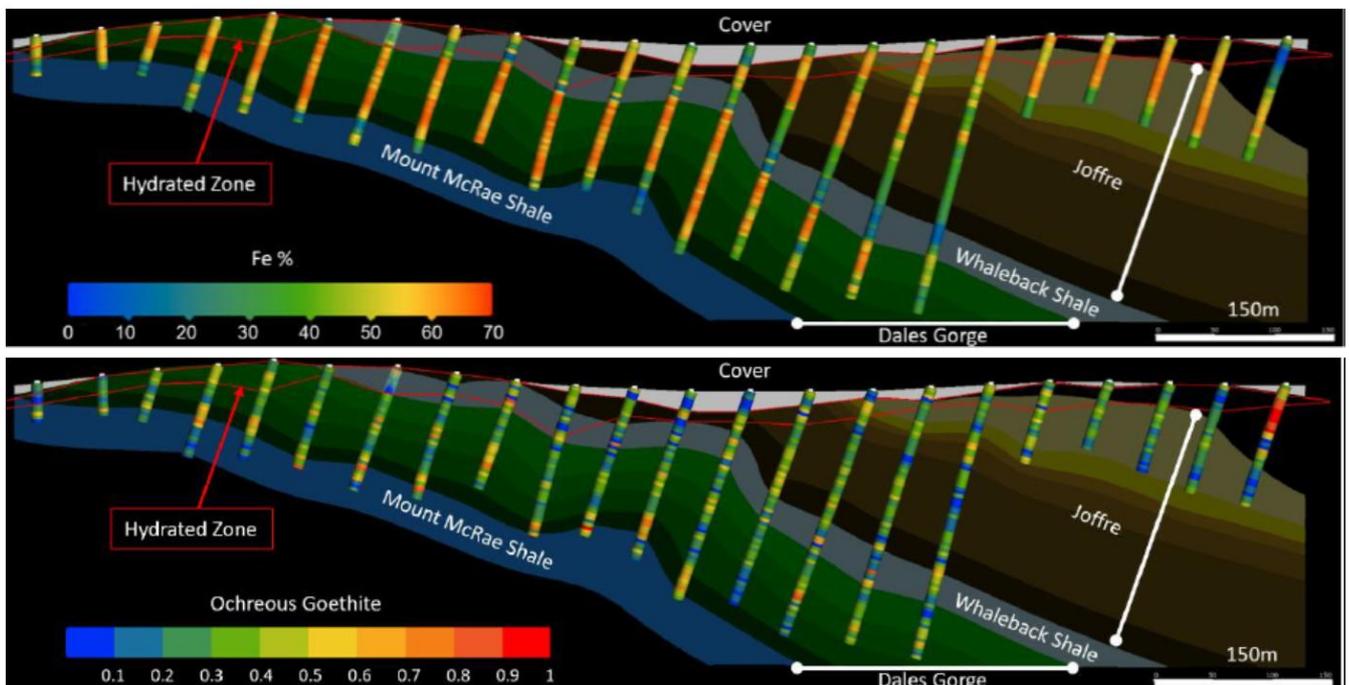


**Cross-section through the Brockman Iron Formation. Top: Fe grades derived from assay data. Bottom: ochreous goethite abundance index derived from hyperspectral (HyLogger-3) data.**

# Going beyond chemical buffers: lithological controls on fluid flow in the Kalkaroo Cu-Au-(Co) deposit

Speaker:     **Gabriel Valentim Berni**

The Kalkaroo Cu-Au-(Co) deposit is one of the largest undeveloped open-pit copper resources in South Australia. Mineralization is hosted within albitite-altered metasedimentary rocks of the Portia Formation, part of the Willyama Supergroup. A defining feature of the Portia Formation is the presence of abundant ovoids and rhomboids of variable composition within the albitite matrix. Three principal mineralization styles are recognized: breccia, vein, and stratabound, with the latter hosting most of the resources. Stratabound mineralization is associated with K-feldspar–biotite alteration and minor carbonate, whereas breccia and vein styles are characterized by carbonate-, quartz-, and chlorite-rich assemblages. Iron oxides are minor and largely confined to breccia-style mineralization. Accessory phases also vary systematically: stratabound mineralization is enriched in rutile, apatite, rare-earth element carbonates, monazite, and allanite, while breccia-style zones contain more abundant fluorite, barite, allanite, and anhydrite. Kalkaroo exhibits diagnostic features overlapping the Iron-oxide-copper-gold (IOCG), intrusion-related, and stratabound sediment-hosted Cu deposit classes, including extensive early albitization, high-temperature alteration mineralogy, brecciation, and stratabound geometry. Quantitative mineralogical and textural analyses using a Tescan Integrated Mineral Analyzer indicate that the ovoid and rhombohedral domains represent localized zones of enhanced porosity and permeability. These features acted as conduits for hydrothermal fluid migration, facilitating focused alteration, and metal endowment within the stratabound horizon. These observations, together with well constrained age which is contemporaneous with the copper mineralization of the major IOCG deposits in the Olympic Province, point to a major Cu-Au system across the Gawler and Curnamona cratons that express itself differently depending on a range of geological factors.
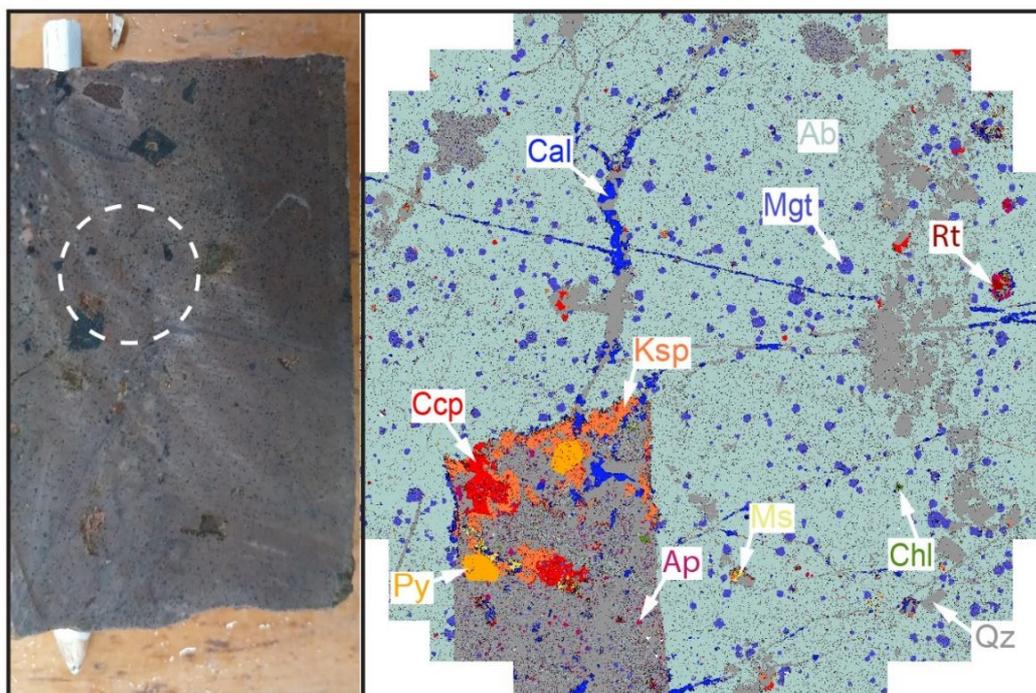


**Rock sample (left) and TIMA mineral map (right) of rhomboid filled with quartz ± K-feldspar, chalcopyrite, pyrite, calcite, apatite and muscovite within a red, magnetite altered albitite.**

**Developing a scalable LIBS–ML workflow for multi-commodity mineral systems: Progress, integration, and future directions**

Speaker:     **Ruixue Wang**

Laser-Induced Breakdown Spectroscopy (LIBS) enables rapid, in-situ geochemical characterisation of minerals, yet translating large volumes of spectral data into reliable mineralogical information remains a significant challenge. To address this, CSIRO has developed laspectools, an in-house Python package that integrates data preprocessing, visualisation, and machine-learning–based mineral classification. Initially applied to Au-bearing systems, laspectools is now being extended to support multi-commodity applications, including Cu, Li, and other ore types. Over the past year, the LIBS spectral library has expanded to more than 20 million spectra. LIBS has also been successfully applied to lithium-bearing clays and granites, resulting in a dedicated LIBS–Li spectral library and new machine-learning models adapted from the Au-system workflow. Operationally, laspectools is deployed on the Ecore Flex for routine acquisition and processing, and the next phase will extend these workflows to ECORE for continuous core scanning and higher throughput. In parallel, we are expanding the spectral library to include Cu, Ni, Co, REE, V, and Ti, and improving/validating mineral classification models to ensure consistent performance across deposits. This presentation highlights recent progress, key improvements, and upcoming directions, and invites collaboration with industry partners to accelerate LIBS–ML adoption in digital, data-driven mineral exploration.

# Rapid mineral phase mapping via LIBS: Vision, insight, and geometallurgical application

Speaker:    **Ryan Manton**

Laser-Induced Breakdown Spectroscopy (LIBS) has undergone rapid development as a technique to scan drill cores in recent years. Detailed mineral maps and modal mineralogy can be obtained from drill core, down to a 30 µm spot size, allowing the mineral chemistry to be assessed across entire deposits. Traditionally, geometallurgical properties, which are geological predictors of metallurgical performance, have been estimated using proxies derived from routine geological datasets (multi-element assay), often with large associated uncertainties. Core scanning LIBS datasets complement those produced by Scanning Electron Microscopy Energy-Dispersive X-ray Spectroscopy across whole ore bodies, but the former takes less time and is of lower resolution, though may be more applicable to a production workflow, minimising reliance on proxies and enabling direct mineralogically based interpretation. In coarse-grained rocks, these datasets may include (a) ore grain size, (b) ore grain morphology (aspect ratio, length, surface texture), (c) ore locking and middling relationships with gangue, and (d) the elemental quality of the ore. These textural parameters can be mapped along drill core in a quantifiable way, supporting the construction of predictive block models. LIBS core scanning datasets represent a step change in how we approach Ore-Body Knowledge (OBK). The combination of detailed, quantifiable textural information with semi-quantitative elemental measurements enables higher confidence geometallurgical models and more accurate flow sheet recovery predictions.
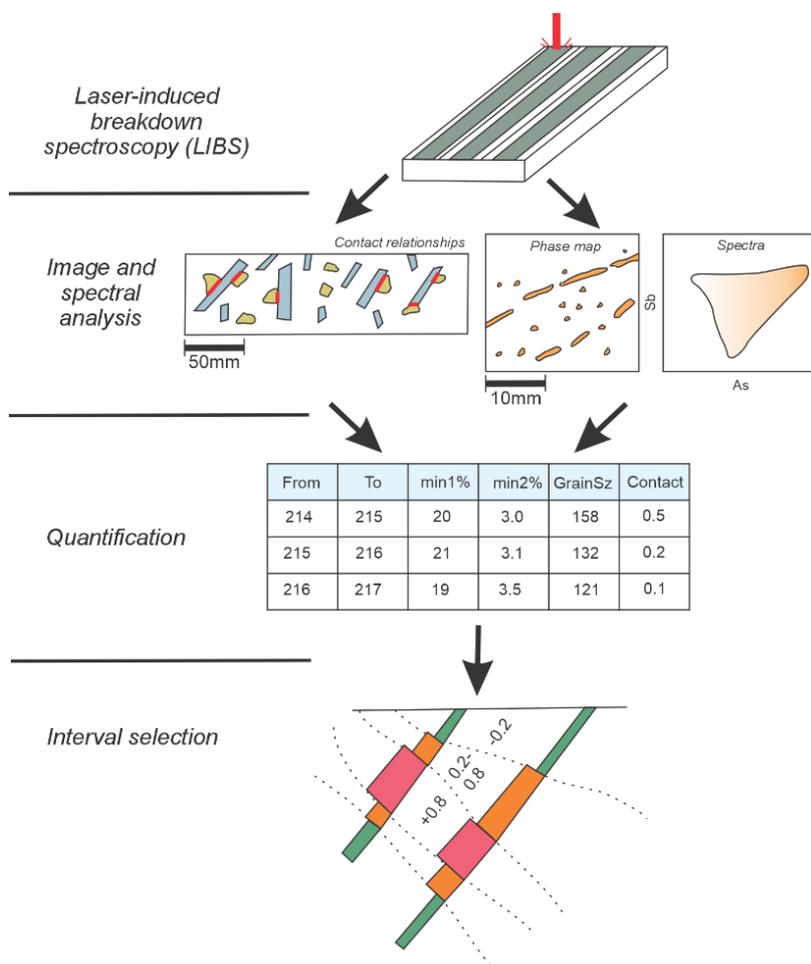


**Conceptual workflow showing how LIBS core scans are converted into decision-ready geomet inputs: LIBS spectra and imagery are processed to generate phase maps and contact relationships, quantified into interval-scale metrics (modal abundance, grain size, and association/contact indices), and used to select and prioritise intervals for follow-up testwork and processing prediction.**

**Kick-Start your R&D project with CSIROs Kick-Start program**

Speaker:     **Liz Crompton – SME Connect Program Advisor, CSIRO**

The CSIRO Kick-Start Program offers cost-matched funding up to $50,000 for start-ups and small businesses to undertake R&D projects with CSIRO. The program also offers end-to-end facilitation support with the CSIRO Kick-Start team helping businesses to develop their R&D ideas and connect with researchers at CSIRO. The CSIRO Kick-Start program is part of a broader suite of programs within SME Connect which help SMEs collaborate with the R&D sector.

**Growing Australia's PGE resource base: Opportunities across the mining value chain**

Speaker:   **William D Smith**

Platinum-group elements (PGEs) are six noble metals globally deemed critical for the green energy transition. Recurrent structural supply deficits, increased usage in fuel cells, and slow uptake for electric vehicle usage have sustained demand into 2026. While shortfalls are partly cushioned by improved recycling efficiency, more resources are needed to strengthen the presently narrow primary supply chains. Most of the world's PGEs are sourced from the Bushveld Complex in South Africa, the Noril'sk–Talnakh deposits in Russia, and the Stillwater and Lac des Iles complexes in North America, where production is increasingly constrained by ageing mines, rising operating costs, and deepening orebodies.

The PGEs are predominantly sourced as by-products from Tier 1 magmatic sulphide deposits and as primary commodities from stratiform horizons in layered mafic–ultramafic intrusions known as 'reefs'. These metals are concentrated within immiscible sulphide liquids that segregate from primitive mantle-derived magma in response to contamination or differentiation and are subsequently physically concentrated into an economically viable orebody. Reefs are typically thin (cm- to m-scale) and may occur at any stratigraphic level within an intrusion, sometimes associated with oxide-rich layers such as chromitites and magnetitites. Other non-conventional PGE occurrences include breccia-related intrusions, Uralian–Alaskan intrusions including associated placers, and PGE-enriched Cu-porphyries.

Chalice Mining's Gonneville PGE–Cu deposit is expected to be operational by 2027 and will be Australia's first primary PGE mine, representing a critical step toward diversifying global supply chains and reducing Australia's import reliance. Beyond Gonneville, Australia hosts a geologically diverse range of PGE projects, including chromitite- and magnetitite-hosted reefs, several of which carry valuable by-products (Ni, Co, Ti, V, Cr). Orebody knowledge is essential, and several challenges relate to PGE occurrences, including: (1) pronounced nugget effects due to micron-scale platinum-group minerals (PGMs); (2) variable metal deportment between mineralogically diverse PGMs and sulphides, complicating pre-metallurgical characterisation; (3) loss of PGMs in conventional sulphide-focused flowsheets, particularly for low-S–high-PGE ores; (4) complex processing requirements for oxide-rich systems, where Cr-spinel is especially deleterious; (5) hard and abrasive host rocks require high comminution energy; and (6) thin and medially dipping reefs are vulnerable to dilution, high stripping ratios, and extensive environmental footprints.

CSIRO's Magmatic Sulphides Team has deep expertise in magmatic mineral systems, demonstrated by a track record of globally renowned research underpinned by extensive datasets, sample collections, and pioneering analytical workflows. Currently, CSIRO is developing integrated research projects across the mining value chain, linking advanced petrological and lithogeochemical characterisation with flowsheet development, grindability testing, and equipment design to support Australia's emerging and established PGE projects in meet growing global demand.

## Experiments + Geochemical Models: How mineral deposits form (Au, base metals, critical minerals)- An introduction to ECGL

Speaker:    **Yanlu Xing**

The discovery of mineral ore deposits and recovery of metals from them present a series of intricate scientific and engineering challenges. While significant advances have been made in understanding ore-forming systems over the past two decades, the mining industry and geologists are still confronted with the difficulty of efficiently locating high-value resources hidden beneath cover and optimizing ore value through innovative recovery technologies. Addressing these challenges requires a deeper understanding of the fundamental physical and chemical processes that concentrate metals into high-grade deposits, as well as the development of cost-effective engineering solutions for their extraction. At CSIRO Mineral Resources, our Experimental and Computational Geochemistry Laboratory (ECGL) integrates cutting-edge geochemical experiments with advanced thermodynamic modelling to unravel the mechanisms driving ore formation in key deposit types, including gold, base metals, and critical minerals. By simulating fluid-rock interactions and ore-forming reactions under controlled laboratory conditions, and combining these insights with robust computational models, we provide new insights for exploration targeting and inform the development of next-generation metal recovery technologies. This presentation will highlight our laboratory's unique capabilities and demonstrate how our integrated approach improves ore genesis models, facilitate resource discovery success, and maximize ore value.
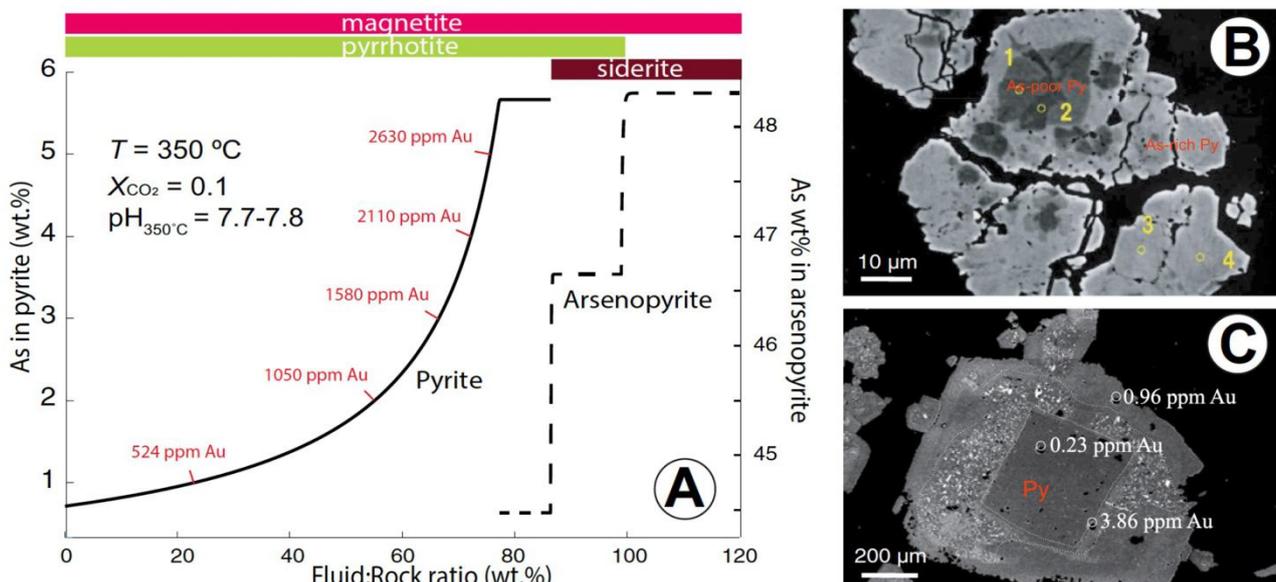


Geochemical modelling shows As levels in pyrite and arsenopyrite vary with fluid-rock interaction, affecting Au content (A). (B-C) highlights complex growth and recrystallization textures in arsenian pyrites from Au deposits due to hydrothermal processes.

**Sandra Occhipinti**



Dr Sandra Occhipinti is a geologist with 30 years' experience across government, industry and academia. She is currently a Research Director in CSIRO Mineral Resources, leading a team of 100+ people focused on delivering technological solutions that will increase resource discoveries and quantify geology, and mineralization footprints of ore bodies using novel techniques, including AI.

**Talk:** *CSIRO's new Portfolio of research: Sustaining Australia's Mineral Resources – What is our purpose and operating model*

**Margaux Le Vaillant**



Margaux Le Vaillant is a senior research scientist who has been working with CSIRO since 2014 and is currently leading the Orebody Geoscience Group. Her research is focused on improving our understanding of polymetallic ore systems (Ni, Cu, Co, PGEs, V, Ti) hosted in mafic-ultramafic rocks and the key genetic processes at play, using this knowledge to develop practical prospectivity and vectoring tools for the exploration industry. She has led multiple industry-funded research projects and is the recipient of the 2023 GSA Garry Davidson Award and the 2021 Young scientist Waldemart Lindgren Award (Society of Economic Geology).

**Talk:** *Indicator minerals research for critical metals – update on project plans and tool developments*

**Tobias Schlegel**



Tobias is a Senior Research Scientist at CSIRO Mineral Resources, specializing in iron oxide-copper-gold systems. He earned his BSc, MSc in geology and geochemistry, and PhD from ETH Zurich. His work focuses on exploration mineralogy and geochemistry to improve Cu-Au grades, from prospect to tenement scales. He integrates field studies, multidisciplinary datasets, and thermodynamic models to better understand ore deposit formation.

**Talk:** *Utilising mineral alteration mapping at deposit scale: Insights from IOCG districts across Australia*

**Marta Sośnicka**



Dr. Marta Sośnicka is an experienced geoscientist specializing in fluid systems and ore-forming processes in the Earth's crust. She graduated from AGH University of Science and Technology in Poland and held academic positions in South Africa and Germany. Her expertise in fluid inclusion science and integrated mineralogical, geochemical, and isotopic approaches has advanced understanding of mineral systems, including sediment-hosted Cu-Co deposits in the Katanga Copperbelt and Zn-Pb mineralization in German hydrocarbon reservoirs.

**Talk:** *Application of isotope and fluid inclusion geochemistry to fingerprint ore-forming processes in mineral systems*

**Rosa Didonna**



Rosa Didonna is a volcanologist, petrologist, and geochemist who joined CSIRO in 2023 as a Postdoctoral Research Fellow to study the textures and chemistry of minerals in plutonic rocks, specifically targeting lithium resources. Her current research investigates pegmatite deposits from Pilgangoora (Pilbara, Western Australia), the Omeo Zone (Victoria, SE Australia), Angola (Africa) and India, exploring the magmatic and hydrothermal processes that control the fractionation and crystallisation of selected mineral phases (e.g., spodumene, mica, Ta-Nb oxides, apatite). She applies a multidisciplinary approach, integrating techniques such as Hylogger analysis, automated mineralogy, electron probe microanalysis, and mass-spectrometry analysis. Through her work, she aims to refine lithium exploration workflows and improve the assessment of prospective and non-prospective pegmatite deposits.

**Talk:** *Linking mineral signatures and numerical modelling to advance pegmatite exploration*

## Session 2, Chair: Marta Sośnicka

### Stephan Thiel

Stephan Thiel is a Principal Research Scientist and team leader of Multi-scale Geophysics at CSIRO. He has 23 years of experience in applied geophysics working in academia, government and CSIRO across mineral system science, geothermal research and tectonic evolution.

**Talk:** *Our geophysics capability and strategy, with some examples*

### Sarath Samaya Manthri Patabendi Gedara

Sarath Patabendigedara studied geology and chemistry at the University of Peradeniya in Sri Lanka, where he also completed an MPhil in geoscience. He earned his PhD in Earth and Planetary Sciences from Macquarie University, Australia, in 2021.

At CSIRO, he works on characterising the physical properties of rocks and minerals to support mineral systems research. His expertise includes laboratory-based petrophysical measurements such as electrical conductivity and magnetism, with a focus on understanding their relationships to mineralogy, texture, and alteration, and how these properties influence geophysical expressions. His current work contributes to building integrated rock property datasets that support the interpretation of subsurface processes and mineral exploration.

**Talk:** *Petrophysics, geophysics and dinging critical minerals – What's possible, and what's possible, and what's fantasy?*

### Carsten Laukamp

Dr Carsten Laukamp is a Principal Research Scientist at CSIRO, with a strong background in mineralogy and economic geology. Carsten likes to unravel the electronic and vibrational modes of mineral assemblages across scales - from infrared microscopy to hyperspectral and multispectral Earth observation - for regolith landform classification and mapping alteration mineral footprints associated with a wide range of ore deposit styles. Evaluating the recently launched satellite hyperspectral systems (e.g. PRISMA, EnMap) for mineral characterisation and critical metals exploration is Carsten's latest passion.

**Talk:** *Good vibrations- riding the new wave of hyperspectral remote and proximal sensing technologies*

**Thomas Poulet**

Thomas Poulet studied applied mathematics at the École Polytechnique in France, graduated from the French National School of Telecommunications, and earned his PhD in geology from the University of Western Australia in 2012. At CSIRO, he is advancing numerical solutions for mineral exploration and energy systems. His expertise spans geomechanics, multi-physical numerical modelling, and physics-based machine learning, among others. His current research focuses on material instabilities in porous media and simulations of localised geological processes.

**Talk:** *Process modelling for mineral exploration – a quantitative approach to understanding mineral systems*

**Anicia Henne**

Anicia Henne is a former exploration and resource geologist with a PhD in bioprocessing of ore and mine wastes. Her research focusses on finding novel approaches for mineral exploration and related mining activities. By working together with multidisciplinary scientists and engineers, these approaches are made accessible to industry as new tools. Recent outputs include the LandScape+® modelling software and improvements to the UltraFine+® soil analytical method. Other research includes the investigation of (bio)geochemical weathering processes that lead to metal mobility and enrichment in laterites and supergene deposits and research on the draw-down of carbon dioxide from the atmosphere.

**Talk:** *Context is everything – How soil properties help us understand soil geochemistry and regolith processes*

**Ryan Noble**

Dr Ryan Noble is a Senior Principal Research Scientist and the Group Leader of Predictive Mineral Systems Science, hanging around CSIRO for the last 20 years. He likes dirt and water and applied research for industry application.

**Talk:** *White fields = green fields for the gold fields*

**Jens Klump**

Dr Jens Klump is a Senior Principal Research Scientist and the Group Leader of Exploration Through Cover. He has degrees in geology and oceanography from the University of Cape Town and a PhD in marine geology from the University of Bremen. Jens likes anything automated and algorithmic, bringing more than two decades of experience in data-driven science and building digital research infrastructures.

**Talk:** *LEME AI – Developing an on-premise AI system to accelerate exploration in regolith terranes*

**Fariba Kohan Pour**

Fariba is a geologist with expertise in applying multi-scale interdisciplinary geological datasets to understand mineral systems components. During her research career, she applied a multi-disciplinary, multi-scale approach, including geodynamic numerical modelling, geophysical interpretation, geochronology/isotope analysis, mineralogy and geochemical modelling to understand mineral and hydrogen systems components and basin development; she is interested in integrating the multi-scale obtained knowledge and geological datasets in understanding mineral system components and corresponding prospectivity modelling.

**Talk:** *Case Study – Putting it all together - Mineral systems and targeting in the Yeneena basin using mineralogical mapping and thermodynamic modelling*

**Yoram Teitler**

Dr Yoram Teitler is a Research Scientist at CSIRO Mineral Resources, specialising in iron ore and supergene mineral systems (Au, REE, Ni-Co). He investigates the geochemical and mineralogical signatures of regolith to assess the characteristics of near-surface enriched ores and to guide exploration in complex weathered settings.

**Talk:** *Tracking today's challenges for tomorrow's opportunities: The future of iron ore*

**Session 4, Chair: Helen McFarlane**

**Gabriel Valentim Berni**

Gabriel Berni is an economic geologist with over 16 years of experience in mineral exploration, mining, and research. He has worked across diverse mineral systems, including orogenic gold, IOCG, pegmatites, Cu-Au and PGE sediment-hosted deposits, magnesite, and fertilisers. He holds an MSc from UFMG (Brazil) and a PhD from ETH Zurich, with previous research and teaching roles at the University of Helsinki and the Federal University of Ceará. Formerly Exploration Manager at AngloGold Ashanti Brazil, he now leads the Structures and Basins team at CSIRO.

**Talk:** *Going beyond chemical buffers – lithological controls on fluid flow in the Kalkaroo sediment-hosted Cu-Au-(Co) deposit*

**Ruixue Wang**

Dr Ruixue Wang is a Research Scientist at CSIRO Mineral Resources specialising in mineralogy, geochronology, and integrating multi-disciplinary datasets to investigate ore-forming processes. Since 2022 she has focused on advancing LIBS for mineral system mapping, adapting workflows from gold to lithium, building spectral libraries, and applying machine-learning models to generate rapid elemental and mineralogical maps.

**Talk:** *Developing a scalable LIBS-ML workflow for multi-commodity mineral systems – Progress, integration, and future direction*

**Ryan Manton**

Dr Ryan Manton is a Research Scientist at CSIRO Mineral Resources with six years' experience in greenfields exploration and resource development. His work focuses on collecting and integrating data for geometallurgical modelling. Ryan is part of CSIRO's multidisciplinary LIBS team developing texture-based datasets to better predict metallurgical recoveries and identify problematic ore types. His research links mineralogical and geochemical variability to mineralisation processes and paragenesis to improve prediction and decision-making across the mining value chain.

**Talk:** *Rapid mineral phase mapping via LIBS: Vision, insight, and geometallurgical application*

**Liz Crompton**



Liz is a Program Advisor in CSIRO SME Connect where her role is to assist in the development of the ideas and innovations of Australian start-ups and small to medium-sized enterprises (SMEs) through research collaboration.

**Talk:** *Transitioning Innovation through SME engagement, with CSIRO in-house R&D and financial support*

**Will Smith**



Dr. William Smith is a researcher specialising in magmatic ore deposits, with experience characterising conduit-hosted Ni–Cu–PGE, reef-style PGE, and stratiform Fe–Ti–V occurrences. His research focuses on advancing the understanding of ore-forming processes operating in magmatic mineral systems and translating them into testable deposit-scale models and practical tools for mineral exploration.

**Talk:** *Growing Australia's PGE resource base – Opportunities across the mining value chain*

**Yanlu Xing**
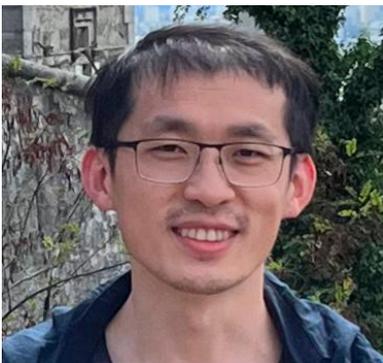


Yanlu Xing is a geologist and geochemist specialising in advanced exploration and recovery solutions. His research combines field studies, experiments, and modelling to help mining partners discover and extract valuable mineral deposits—such as gold, copper, and critical minerals—more efficiently. Awarded an ARC DECRA fellowship, Yanlu's work directly supports industry innovation in ore targeting and processing.

**Talk:** *Experiments & geochemical models – How mineral deposits from (Au, base metals, critical minerals) – An introduction to ECGL*