30th International Applied Geochemistry Symposium

14 — 18th October 2024

Adelaide, South Australia

‘Geochemistry For A Sustainable Future’

Abstracts

Theme : Technology

Compiled by P. A. Morris

Sponsors

Diamond

Platinum

Gold

Exhibitors


BRUKER


LITHODAT


oreas
certified reference materials


PAS
portable
analytical
solutions


PORTABLE
ppb


Actlabs


EVIDENT


LABWEST


MinEx CRC


NewSpec
HITACHI
Inspire the Next


nu
AMETEK


SciAps


Queensland
Government


VERACIO

Theme: Technology

Oral presentations **Page**

Sensitivity analysis of Data Driven Machine Learning algorithms for Laser Induced Breakdown Spectroscopy data.

Mr. Ivan Gutierrez Agramont[1,2], Dr. Ben van der Hoek[1,2], Assoc Prof. Caroline Tiddy[1,2],

Dr. Lequn Zhang[1,3], Mr. Neil Francis[1,3], Mr. Steven Tassios[1,3]

[1]Mineral Exploration Cooperative Research Centre (MinEx CRC), [2]Future Industries Institute, University of South Australia (UniSA), [3]Commonwealth Scientific and Industrial Research Organisation (CSIRO)

In the evolving landscape of geochemical analysis, the accuracy of Laser-Induced Breakdown Spectroscopy (LIBS) data interpretation through Data-Driven Machine Learning (DDML) models is paramount. This study presents a sensitivity analysis of DDML algorithms, evaluating their performance in predicting elemental compositions of powdered materials. Through this analysis, we explored the nuances vital for creating resilient DDML models and their implications for predicting geochemical compositions.

A prototype LIBS instrument for geochemical analysis in a drillhole in a mineral exploration scenario, being developed within MinEx CRC, was used to collect spectral data from MgO and NaCl powder mixtures. Training datasets comprising variable subsets of the complete analytical dataset were used to evaluate the influence of training data volume, variance, and representativity on DDML algorithm efficiency. Results were correlated with XRF analysis of the same samples to ensure accuracy.

The study showed that the accuracy of DDML models in predicting elemental compositions relies heavily on the representativity of the training data. Denser datasets resulted in improved model performance. However, the sensitivity of the model predictions varied for each element depending on how well the training data represented them, with Mg exhibiting higher sensitivity.

This sensitivity analysis contributes to understanding how machine learning algorithms can be optimised for complex geochemical data, providing a pathway towards developing in-situ, laser-based geochemical analysis tools for real- me applications in mineral exploration. The results indicate a direct correlation between the number of training data and the model's predictive accuracy, with denser sampling leading to lower prediction errors and higher accuracy. The study highlights the importance of careful dataset preparation and the potential for DDML to innovate LIBS-based geochemical analysis methods.

Development of a Primary Reference Material for Photon Assay.

B. Armstrong, J. Carter and L. Butler.

Independent Mineral Standards, Bayswater, WA

The photon assay technique is an emerging analytical technology for determining gold concentration in geological samples. A large mass analytical method, photon assay is a non-destructive x-ray technique analysing a crushed (-3mm) sample submitted to the machine in an enclosed jar. Similarly to other laboratory-based x-ray techniques, the spectral emissions, or the counts received for each element, need to be processed then converted into a concentration using a regression. Values for the regression are obtained from calibration samples with a known gold concentration determined by an alternate method such as fire assay. Whereas a gravimetric or a primary matrix matched calibration reference solution is routinely available for other spectroscopic gold techniques such as AAS and ICP, no such primary reference material is available for photon assay. Primary reference materials are those manufactured from first principles, usually gravimetrically, and are not characterised via secondary analytical methods and round robins to determine a consensus value. This paper describes the development and assessment of a primary reference standard for photon assay that exists in a similar form as routine samples – crushed rock chips. The characteristics important for a reliable, stable primary reference standard is discussed, along with an estimate of the uncertainty of the gravimetric determination. Reconciliation of the primary standard for gold concentration by fire assay and photon assay is provided. The resulting reference material can be used for independent calibration validation of photon assay, without reference to fire assay, or ongoing quality control to determine instrument precision and accuracy for a geological campaign.

Inclusion Hunter: A method for detecting and visualising m icro-inclusion populations in LA-ICP-MS mineral chemistry data

Matthew J. Cracknell, Javier Merrill-Cifuentes, Shaun L. L. Barker, Michael J. Baker, Ivan Belousov, Axel Cima, David R. Cooke

Micro-inclusions in magmatic-hydrothermal accessory minerals can serve as proxies for understanding magmatic-hydrothermal histories and processes. We present a new method, "Inclusion Hunter" for detecting signals in Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICP-MS) mineral chemistry data that suggest m icro-inclusion element associations. This method uses signal processing techniques to detect changes in LA-ICP-MS multi-element time varying counts per second (CPS) data that can be attributed to the ablation of inclusions. The results are visualised using graph networks to highlight, in any given dataset, inclusion populations and their chemical compositions. This information can be used to infer likely inclusion mineral associations. With automatisation tools such as "Inclusion Hunter", geoscientists can now summarise large LA-ICP-MS datasets automatically and focus on understanding geological process inferred by micro-inclusion populations rather than searching these data manually.

Predictive models of major oxides – building a high-resolution geochemical framework for the Australian continent

Adj Prof Patrice de Caritat, Curtin University, Geoscience Australia, Dr John Wilford, Geoscience Australia, Dr Sudipta Basak, Geoscience Australia, Philip Main, Geoscience Australia

The distribution and concentration of major oxides at the Earth's surface provide fundamental information on the surface geochemical composition, as well as on primary and secondary geochemical processes occurring in rocks and regolith. Most geochemical measurements are site assays of rock and regolith. In this study we have used a predictive mapping approach that generates continuous geochemical models over the surface of the Australian continent. The approach uses machine learning to establish relationships between site-measured oxide concentrations and a comprehensive library of covariates or features. These covariates include terrain derivatives; climate-related surfaces; geological maps; gamma-ray radiometric, magnetic and gravity grids; and satellite imagery. Modelling was based on the gradient boosted LightGBM machine learning algorithm, which combines multiple weak predictive models in the form of decision trees to create stronger and more accurate models. The training set included 15,750 surface rock and regolith sites and 1370 out-of-sample sites to assess model performance. All geochemical samples were filtered to remove non-surface samples, and inconsistencies in sample type and geochemical assay. The derived model grids (at 80 m resolution) consist of a prediction (median of multiple models) and uncertainty bounds (in the form of the 5th and 95th percentiles) for each of the oxides of aluminium (Al_2O_3), calcium (CaO), total iron (Fe_2O_3tot), potassium (K_2O), magnesium (MgO), manganese (MnO), sodium (Na_2O), phosphorus (P_2O_5), silicon (SiO_2), and titanium (TiO_2). Out-of-sample model performance assessment produced r-squared values ranging from 0.57 to 0.84 across the 10 oxides. We present these predictive oxide maps and explore their utility for understanding surface chemical properties and processes, presenting several examples of their potential for use in mineral exploration or environmental studies. We discuss the feature importance from the model predictions for valuable insights into the factors controlling geochemical composition and processes at a national scale, and opportunities to build on this work into the future. This work was funded through the Exploring for the Future program.

Detection of Significant Multielement Geochemical Anomalies by an Infomax – Deep Autoencoder Network

Saeid Esmaeiloghli [a], Seyed Hassan Tabatabaei [a], Emmanuel John M. Carranza [b]

[a] Department of Mining Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran

[b] Department of Geology, University of the Free State, Bloemfontein 9301, South Africa

Recently, deep autoencoder networks demonstrated huge capability to accomplish advanced operation for detection of significant multielement geochemical anomalies. By training a deep autoencoder network, multielement geochemical background is learnt by higher-level depictions of input signals, furnishing important indications for quantifying reconstruction errors associated with convoluted patterns of m ineralization-directing geochemical anomalies. Yet, the ability to learn geochemical background could be stifled by (a) superfluous joint information from inter-element relationships and (b) assorted information from elemental values due to various geological/geochemical processes. To address these concerns, we propose a novel deep learning architecture called Infomax – deep autoencoder network, which connects the Infomax (information maximization) processor to a network of piled autoencoders for geochemical data training. Being an adaptive learning system, the Infomax processor seeks to maximize the flow of information across a feed-forward neural network. Thus, it was used (a) to encode multielement concentration values into separate source signals from distinct populations of geochemical data and (b) to avoid the attenuation of background signals from superfluous inter-element relationships. Then, the encoded source signals were input into a deep autoencoder network to aid in improving the modelling of geochemical background and in boosting the signals of convoluted geochemical anomalies. The Infomax – deep autoencoder network was employed to analyse drainage geochemical data from the Moalleman district (Iran) and to assess its usefulness in detecting mineralization-directing geochemical anomalies. The assessment techniques used, namely, success-rate curves and prediction-area plots, showed that geochemical anomalies detected by the application of the Infomax – deep autoencoder network, in contrast to those detected by a deep autoencoder network only, exhibited more robust spatial associations with mineralization-controlling structures and locations of known mineralization. The results imply that, by using the proposed Infomax – deep autoencoder network, convoluted geochemical anomalies can be detected by its enhanced modelling accuracy for directing to mineralized exploration targets.

Geochemical data: Implications for multivariate data analysis

Marc L. Fassbender; Kat Lilly; Michael F. Gazley

RSC Mining and Mineral Exploration

Geochemical data are one of the most important tools in mineral exploration. Yet, the growing volume of data poses challenges to traditional data interpretation methods like scatterplots, discrimination diagrams, and multielement diagrams. Many of these methods overlook the compositional nature of geochemical data, leading to erroneous and misleading observations. Over the past decade, there has been a noticeable shift towards statistical techniques, driven by software advancements that make these techniques accessible to a wide community of geoscientists. This progress has fueled the widespread adoption of techniques such as Principal Components Analysis (PCA) across both industry and scientific communities. While unlocking the potential for quantitative insights, this surge has also seen its share of misapplications. In 2024, there are still significant implications of our findings for the industry, suggesting avenues for future research and overcoming limitations due to suboptimal usage of these techniques.

This study investigates various geochemical datasets collected for mineral exploration and mineral resource estimation, highlights the merits of multivariate techniques and underscores the imperative of accommodating the compositional nature of the data.

Multivariate techniques have a strong dependence on the selected variables. We demonstrate suboptimal usage of these techniques and how to avoid this, and outline a systematic approach to identify the ideal selection of elements, based on target commodity and underlying trends in the data. The study suggests that systematic selection of variables, and appropriate transformation and standardisation of the data significantly improves the performance. We demonstrate the significance of these steps in improving analytical performance and identifying geochemical trends and anomalies accurately. We also illustrate when standardisation techniques such as z-scores may be advantageous and when to use those.

By highlighting a systematic approach to compositional data analysis, including the selection of variables and the utilisation of standardisation techniques, our study contributes to enhance the effectiveness of mineral exploration practices and ore deposit knowledge.

Super-trace total gold detection limits to support successful geochemical exploration

Miguel Martinez

ALS Global

Recent research and development have considered the analysis of gold in geological materials at ultra-low detection limits, whilst maintaining a near-total recovery. The new approach incorporates hydrofluoric acid into the digestion process, along with a pre-concentration step and the use of sensitive ICP-MS instrumental analysis.

The technique can determine super-trace concentrations of gold (down to 0.02ppb) with high levels of accuracy and precision. Traditional fire assay determinations are often a very suitable option when gold concentrations are relatively high, and a total gold determination is required. Applications may include advanced or targeted exploration, project feasibility studies or mine site production. However, while fire assay can determine the total gold concentration in a sample, it cannot achieve ultra-trace detection limits. Alternative options, such as aqua regia and cyanide leaches can achieve ultra-trace detection limits and improved precision. However, these options may not fully recover and determine all of the gold in a sample, such as in cases where the gold is occluded by silicate minerals.

Ultra-trace detection limits can offer exploration advantages by identifying the subtle, dispersed geochemical expressions of mineralised systems and being able to determine the true background in an area. When paired with relevant pathfinder elements, the ability to consider data well below average crustal abundance becomes a powerful exploration tool.

This work will present examples that show how ultra-trace determinations of gold and pathfinder elements like selenium and tungsten can improve exploration outcomes.

Making hydrogeochemistry accessible using mobile applications, workflows and national datasets – a regional exploration tool.

Dr. Nathan Reid, Mr Alex Hunt, Dr. Robert Thorne, Dr David Gray (Deceased)

Hydrogeochemistry can assist mineral exploration. With a high signal-to-noise ratio groundwaters are a useful medium for geological sensing and mineral exploration. We are encouraging uptake of the technology, through development of a robust and cost-effective methodology. Field guides, a field sampling application (Fieldmark) and an automated processing tool (XTHydro) are now available as well as an Australian continental scale hydrochemical data compilation that can be used as a baseline. CSIRO has taken all publically available groundwater databases, combined them, QA/QC'd them to create as 'seamless' a whole dataset as possible across the Australian continent. This dataset has various numbers of elements for each sample from only Total Dissolved Solids (TDS) for the oldest samples up to 60+ elements and parameters for the CSIRO collected data.
CSIRO has also developed a number of indices and element ratios for mineral exploration using hydrogeochemical data which are able to highlight regions of known and potential mineralisation across Australia. We now have an online tool – XT HydroTM – to make the processing of these indices easier than ever before. A process which was previously time consuming for researchers is now producing faster, and more consistent results.

At the Terrain scale, specific indices can delineate large scale lithological groups, and major mineral camps. Such a broad-scale approach does obscure camp s cale-variation but does delineate major features. At the Prospect scale, indicator elements (e.g., Au, Ni, Cu, Zn, W, As) are commonly valuable, with Indices developed for specific commodities (e.g., AuMin or NiS). Combined with geophysics, this method assists in selecting drilling targets.

Integrating hyperspectral imaging datasets in 3D alteration and geometallurgical domaining models with case studies

Sam Scher, Adam Gorecki, Scott Burkett, Tom Carmichael

Porphyry copper deposits (PCD) represent the most important source of copper (Cu) on Earth. They are typically large tonnage and increasingly low grade, therefore, implementing technology to increase our understanding of these orebodies from early-stage exploration through life of mine is increasingly important. Underpinning our understanding of PCD is a clear understanding of their alteration and gangue mineralogy.

At first glance, hyperspectral imaging (HSI) is complemented for its colorful images while simultaneously questioned as it can be applied in solving exploration and mining issues. However, over the past decade, it has been successfully implemented into 3D alteration and geometallurgical domaining models.

Minerals such as, illite, chlorite, kaolinite, and smectites lend us important information as to “where” we are in the system, i.e., how close we are to ore, and furthermore can affect plant performance. On the other hand, mineral parameter data, such as white mica chemistry, can provide invaluable vectoring tools to mineralization. Significantly, these minerals are easily identified by hyperspectral technology. If we can understand the relationships between these minerals and space, then we can code these into our 3D models, rapidly updating them as we receive new data.

The case studies showcase the application of HSI systems at two porphyry Cu deposits; one in the United States and one in Chile. The goal of these case studies is to demonstrate that there are relatively straightforward workflows that integrate data-driven tools in the mineralogical characterization of alteration and geometallurgical modeling of PCD.

In the first case study, a 3D alteration model of a PCD from the United States integrates mineralogical information from HSI and core logging data; the latter supplements the HSI with mineralogical phases not active in the VNIR-SWIR.

In the second case study, a more data-driven approach is utilized whereby factors important in an alteration model, such as paragenesis, are essentially ignored in favor of capturing mineralogic domains (e.g., domains that simultaneously contain biotite, amphibole, and smectites). In this workflow, unsupervised learning techniques are utilized to find natural groupings in the data that reflect discrete mineral domains that are subsequently modeled in 3D.

Log-Ratio Analysis and Geochemical Processes: A Square Nail in a Round Hole

Professor Cliff Stanley, Ph.D., P.Geo., Dept. of Earth & Environmental Science, Acadia University Wolfville, Nova Scotia, Canada, B4P 2R6 cliff.stanley@acadiau.ca; 902-670-0817

Closure in geochemistry is the effect that compositions summing to 100 % produce during material transfer (the addition/loss of a component to/from a system). Popular opinion has for some time now decided that geochemical data should be evaluated and interpreted using log-ratios because they avoid closure. In this presentation, I will examine the nature of geological material transfers and discuss what impact log-ratios have on these processes, illustrating how log-ratios can actually complicate geochemical interpretation.

For example, consider a lithogeochemical dataset from the Wildcat Brook Mo-W deposit in Charlotte County, New Brunswick. This deposit is hosted by a leucocratic, peraluminous dyke containing high grades of molybdenite (0.27 wt. %) and intruding turbiditic wackes and argillites of the Fredericton Trough. Fresh rocks exhibit variable proportions of quartz, albite, K-feldspar and igneous muscovite. Albite and muscovite alteration that accompanied mineralization have modified these igneous minerals. Molar element ratio analysis of drill core samples from the dyke reveals that Na was added and K and Ca were lost during albite alteration: $\boldsymbol{Microcline + Na^{+} => Albite + K^{+}}$, and $\boldsymbol{Anorthite + 4Quartz + 2Na^{+} => 2\,Albite + 3Ca^{+2}}$, and that K was added and Na was lost during muscovite alteration: $\boldsymbol{3Albite + K^{+} + 2H^{+} => Muscovite + 6Quartz + 3Na^{+}}$.

The crystal sorting and hydrothermal alteration in this dyke can be described by balanced chemical reactions, illustrating that these material transfer processes are linear. When plotted on scatterplots, the data form linear trends, but the slopes are modified by closure. Plotting concentration ratios on scatterplots also produce linear trends, but without the closure effects. Unfortunately, log-ratios of concentrations make these trends decidedly n on-linear, significantly complicating data interpretation. Moreover, the use of linear statistical procedures (principal components or regression analysis) on concentration log-ratios is thus clearly numerically invalid (straight lines modelling curves), and is not an appropriate way to understand the causes of compositional variations in rocks.

Clearly, the use of ratios, and not log-ratios, to interpret geochemical processes is the preferred way to interpret geochemical data, as most geochemical processes are linear. Log-ratio analysis has validity in the statistical realm, and should e applied to the parameter analysis for which it was originally developed.

Mineralogical and alteration signatures of Ravenswood gold deposit, NE Queensland

Al-Tamini Tapu[1], Elena Belousova[1], Courteney Dhnaram[1], Friedrich von Gnielinski[1], Alkis Kontonikas-Charos[1], Lisa Kearney[2], Rhiannon Jones[1], Vladimir Lisitsin[1]

1 Geological Survey of Queensland, Brisbane, Australia

2 School of Earth & Atmospheric Sciences, Queensland University of Technology

Charters Towers Province in Townsville-Cairns hinterland of NE Queensland hosts a number of Intrusion Related Gold Systems (IRGS). Notably, the Ravenswood gold deposit, one of the largest in the Charters Towers goldfield, exemplifies this association. Here, gold mineralisation is spatially associated with complex quartz-sulfide vein networks hosted by intermediate plutonic rocks. Recent advances in microanalytical techniques allow us to capture the full spectrum of petrographic, mineralogical, and geochemical signatures, moving beyond the limitations of singular analytical techniques. Recognising this, Geological Survey of Queensland (GSQ) has taken a leading role by deploying a suite of advanced in-house microanalytical tools, including micro-XRF (M4 TORNADO PLUS) and TESCAN TIMA. Recently collected microanalytical data on the Ravenswood vein system reveals native gold particles up to 0.2 mm in size, primarily associated with the quartz + pyrite + galena ± chalcopyrite ± sphalerite assemblage. Elemental imaging from TORNADO and TIMA instruments (up to 60 μm resolution) indicates a positive correlation between gold, lead, and bismuth, suggesting a complex interplay between these elements within the quartz-sulfide vein system. Gold-bearing veins exhibit distinct zonation patterns in their associated alteration mineralogy. *In-situ* micro-XRF elemental maps also reveal a progressive transformation of the tonalitic host rock into a fine-grained assemblage (50–100 μm) dominated by muscovite and chlorite, with occasional biotite. Our multi-analytical approach reveals some important, previously implicit elemental and textural relationships within the Ravenswood IRGS, that would remain unresolved by traditional geochemical techniques. Furthermore, these high-resolution elemental analyses facilitate a more robust interpretation of geochronology data (Ar-Ar) and contribute to a comprehensive metallurgical characterisation. This innovative approach is proving valuable for unlocking geochemical-mineralogical-metallurgical complexities of deposits like Ravenswood, a common challenge across Queensland where microanalytical characterisation remains underutilised.

In-situ LIBS analysis within a drillhole

Dr Ben van der Hoek[1,2], Mr Steven Tassios[1,3], A/Prof. Caroline Tiddy[1,2], Dr Jessica Stromberg[1,4], Mr Neil Francis[1,4], Dr Lequn Zhang[1,4]

1. Mineral Exploration Cooperative Research Centre (MinEx CRC) 2. University of South Australia, Mawson Lakes, SA 5051, 3. CSIRO, Research Way, Clayton, VIC 3168 4. CSIRO, Kensington, WA, 6151

Obtaining in-situ chemical data directly from drillholes presents a significant advantage for drilling techniques such as auger, rotary air blast, air-core, or reverse circulation. These methods are prone to sample mixing or compositing, making in-situ analysis particularly valuable, especially in cases of poor sample recovery. The capability for in-situ analysis offers the potential to provide precise, high-fidelity data directly at the point of origin, facilitating an adaptive workflow across various fields including mineral exploration, mining, agriculture, and environmental monitoring. Furthermore, in-situ analysis enables informed decision-making on infill drilling or sampling protocols including guiding sample selection for off-site analysis. However, in-situ geochemical analysis in a drillhole environment is challenged by the highly diverse conditions within the drillhole itself, including geological heterogeneities and rock composition variations, drillhole geometry, surface roughness, moisture content and potential contamination.

Within MinEx CRC we have developed a prototype LIBS instrument tailored for in-situ geochemical analysis within drillholes. Leveraging the LIBS technique, our instrument demands minimal sample preparation, is well-suited to harsh environments, and can operate without direct contact with the sample to be analysed. This self-contained instrument is deployable into drillholes exceeding 75 mm diameter, requiring only electrical power and surface communication for operation. In this presentation, we provide preliminary results from a wireline-deployed LIBS analyser with a range of data processing methods that can be tailored to suit the application.

The work has been supported by the Mineral Exploration Cooperative Research Centre whose activities are funded by the Australian Government's Cooperative Research Centre Program. This is MinEx CRC Document 2024/12.

Supporting quality control in pXRF data collection

Vladimir Vermus[1], Walid Laouar[1], Todd Houlahan[1], Qu Long[1], Michael Gazley[2], Kat Lilly[2]

[1]Evident Scientific, [2]RSC Consulting

Portable X-Ray Fluorescence (pXRF) analyzers have become a standard tool for exploration and mining companies worldwide and are now ubiquitous within our industry. Data from pXRF are used at every stage of the resource cycle, from early-stage exploration through to grade control and all stages in between. These data can at times be considered indicative, qualitative, semi-quantitative and quantitative. They are also used in exploration and mining of commodities that are not directly quantifiable by pXRF, for example by the use of pathfinder elements for Au and Li projects. Portable XRF use became so prevalent in the mid-2000s that they were specifically referred to in Table 1 of the Joint Ore Reserves Committee Guidance document (2012 Edition). This represented an effort to encourage users of the technology to provide details of their methodology - the nature of sample being tested and information around the instrument used and the calibration and operating conditions. Despite this effort to encourage improved quality control and transparency around portable XRF use, many users would benefit from further training and better understanding of best practice workflows on how to monitor pXRF data quality and implement matrix/deposit specific calibrations to generate more robust data that would (1) withstand greater interrogation and scrutiny; (2) provide improved transparency to industry stakeholders; and (3) add value to XRF users by allowing the data to be used quantitatively in a greater number of instances.

This contribution will address this subject and detail a collaboration between industry consultants and an XRF instrument manufacturer to directly address this issue. The outcome is a workflow that streamlines and automates the pXRF quality control process and provides robust daily calibration procedures and guidance. The platform also provides enhanced analytical features such as unsupervised clustering and predictions for elements (e.g. Li, Na), minerals, or physical properties not measured by portable XRF, when used in conjunction with a training dataset of mineralogical or laboratory chemistry data.

Lithological mapping based on convolutional recurrent neural networks and geochemical survey data

Ziye Wang, Renguang Zuo

State Key Laboratory of Geological Processes and Mineral Resources, China University of, Geosciences, Wuhan 430074, China

Geochemical survey data analysis is recognized as an implemented and feasible way for lithological mapping to assist mineral exploration by analyzing the chemical composition and concentration, especially useful for detecting underlying rocks in vegetated terrain that are inaccessible. With respect to available approaches, recent methodological advances have focused on deep learning algorithms which provide access to learn and extract information directly from geochemical survey data through multi-level networks and outputting end-to-end classification. Accordingly, this study developed a lithological mapping framework with the joint application of a convolutional neural network (CNN) and a long short-term memory (LSTM). Convolutional layers in a CNN were adopted to extract the basic correlation of geochemical samples, and the following recurrent layers in a LSTM network were designed to further learn complex coupling interactions among geochemical elements as sequences of inputs. This hybrid approach was demonstrated by mapping leucogranites in the Himalayan orogen based on stream sediment geochemical survey data, where the targeted leucogranite was expected to be potential resources of rare metals such as Li, Be, and W mineralization. Three comparative case studies were carried out from both visual and quantitative perspectives to illustrate the superiority of the proposed model. A guided spatial distribution map of leucogranites in the Himalayan orogen, divided into high-, moderate-, and low-potential areas, was delineated by the success rate curve, which further improves the efficiency for identifying unmapped leucogranites through geological mapping. In light of these results, this study provides an alternative solution for lithologic mapping using geochemical survey data at regional scale and reduces the risk for decision making associated with mineral exploration.

The Application Of The Triple Quad ICPMS To Geochemical Analysis - The Next Level

M Witham[1], R Holdsworth[2]

1.Chief Chemist, Intertek, Maddington WA 6109. Email: matthew.witham@intertek.com 2.Technical Manager, Intertek, Maddington WA 6109. Email: richard.holdsworth@intertek.com

Single quadrupole ICPMS instrument with collision cell technology such as the Agilent 7900 have revolutionized geochemical analysis by offering ultra-low detection limits, with analytical data below average crustal abundances in most cases and producing extended multi element suites at highly competitive prices.

Despite these advances, there remain unresolved issues concerning interferences and detection limits that can compromise data utility for certain elements. The use of triple quad "QQQ" ICPMS instruments such as the Agilent 8800 and Agilent 8900 has been investigated with particular reference to solving analytical difficulties associated with the single quadrupole ICPMS analysis. Discussed is the application of the QQQ instrument to analysis of low-level sulphur, gallium in the presence of elevated light rare earth elements, selenium in the presence of elevated heavy rare earth elements, impurity analysis for HPA and other high purity products, and ultra low-level tellurium in porphyry deposits to discriminate between the magmatic and epithermal phases of the intrusion. In each of these cases, the QQQ has proven its capability as a valuable addition to the modern geochemical laboratory delivering quality assays with rapid throughput.

Graph attention networks based on causal inference for geochemical mapping

Yihui Xiong, Renguang Zuo

State Key Laboratory of Geological Processes and Mineral Resources, China.

University of Geosciences, Wuhan 430074, China

The deep learning method with correlation as the core is the main tool for processing geochemical data at present. However, correlation does not equal causation. In particular, the assumption that deep learning relies on the independent and same distribution of data makes it difficult for deep learning to explain the causal relationship between geochemical variables and mineral deposits, which results in poor interpretability and robustness of geochemical data processing methods represented by deep learning. In response, a graph attention network based on causal inference named causal graph attention network (C-GAT) is proposed to improve the robustness of the network. The model first calculates the causal weights between the neighborhood of the target node and its label and uses them to sample the neighborhood. Then the attention coefficient between the sampled neighborhood and the target node is calculated. Finally, the embedding features of the target nodes are obtained by weighted aggregation of the neighborhood information based on the attention coefficients. Experimental results on a case study of geochemical mapping for lithium deposits in Southern Jiangxi Province of China show that the extraction performance of C-GAT is higher compared to the classical GAT model, with a better balance of robustness and interpretability.

Can field-based geochemical data assist in rapid cover characterisation?

Hamid Zekri[1, 2], David Cohen[1, 2], Neil Rutherford[1, 2]

[1]School of Biological, Earth and Environmental Sciences, University of New South Wales, NSW 2052, Australia, [2]Mineral Exploration Cooperative Research Centre (MinEx CRC), Bentley, WA 6102, Australia

Surficial geochemical processes can mask the dispersion of trace elements from mineralisation in bedrock through in-situ regolith to transported cover. Although low-concentration haloes may form at critical zones of the weathered profile, discovering these intervals usually requires precise and detailed laboratory analyses. While field-portable instruments offer rapid and cost-effective geochemical insights into drillhole material, the precision and effectiveness of these devices are limited by their detection limits for certain analytes. Multivariate analysis of the data, combined with appropriate methods for characterising cover, can mitigate the masking issue and limitations of definitive co-anomalous geochemical data available from portable instruments. Real-time interpretations facilitate geologists' decision-making during drilling campaigns and establish a foundation for subsequent exploration.

This study introduces an automated workflow to identify significant boundaries within the weathered profile, utilising portable X-Ray Fluorescence data from various drillholes. Employing a multivariate boundary detection method, enhanced by machine learning algorithms, the research assesses the effectiveness of different geochemical variables in distinguishing various geological units in New South Wales, Australia, including the Cobar Basin, Delamerian Orogen and Thomson Orogen. It proposes a tailored suite of elements for characterising the drillhole material in each regolith setting. Findings indicate that the significance of variables varies depending on regolith settings and mineralisation type. The framework also evaluates the reliability of each geochemical variable in a data-driven manner, ranking their contributions to the boundary detection process. Results demonstrate that discarding irrelevant and redundant elements for each regolith landscape enables an optimum subset of geochemical data available from pXRF to effectively identify critical intervals overlooked in initial visual loggings for further sampling and laboratory analysis.

KEYNOTE: Big data analytics and AI-driven geochemical mapping

Renguang Zuo

State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China

Geochemical mapping plays a critical role in geological studies, mineral exploration, and environmental applications by providing information on geological events and processes such as mineralization and environmental pollution. Various mathematical and statistical models have been developed and continue to be developed for successful modeling and mapping of geogenic and anthropogenic geochemical patterns to facilitate identification of anomalies from such patterns to support mineral exploration and environmental monitoring. As a result, for example, various mineral deposits have been discovered with the support of geochemical mapping. We have recently entered the era of big data, and how to apply big data analytics and artificial intelligence (AI) to mine geochemical exploration or environmental data from a variety of geological and environmental settings in order to extract subtle and complex geochemical anomalies associated with mineralization or pollution has become even more challenging. This presentation will focus on state of the-art big data analytics and AI in geochemical mapping and document successful case studies.

Theme: Technology

Poster presentations Page

Contrasting Terminology and Estimation of Uncertainty in Certified Reference Materials for Minerals

B J Armstrong[1] and J Carter[2]

1. Operations Manager, Independent Mineral Standards, Bayswater, WA, 6053. Email: bruce@imstandards.com.au

2. General Manager, Independent Mineral Standards, Bayswater, WA, 6053. Email: john@imstandards.com.au

Certified Reference Materials (CRMs) play a pivotal role in assuring the quality and traceability of analytical measurements in various industries, including the exploration and mining sectors. Most mineral Reference Material Producers (RMPs) use a well-established procedure for certifying CRMs typically involving the characterisation of an operationally defined measurand via a network of competent laboratories. However, there are significant discrepancies in the methods employed by different RMPs in the estimation of uncertainty of these CRMs.

This study investigates the current state of uncertainty estimation in mineral CRMs and addresses the critical issue of inconsistency in terminology and methodology. Reference Material Producers issue values and uncertainties using proprietary methods and certificate formats. While ISO17034:2016 and ISO Guide 35:2017 provide a valid methodology for processing analytical results and estimating uncertainty, our survey of several mineral RMPs has revealed substantial variations in the estimation of commonly used uncertainty terms. These differences in approach result in incompatible values for identical terms across CRMs from different RMPs.

The lack of standardisation in uncertainty estimation across ISO17034 accredited mineral RMPs should raise concerns among users of CRMs. These users, who rely on CRMs to ensure the accuracy and reliability of their analytical measurements, expect commonly used uncertainty terms to be consistent and comparable between different MPs. The absence of such uniformity may hinder the effective utilisation of CRMs in quality control and analytical validation processes.

This paper addresses inconsistencies within the minerals RMP industry in order to assist CRM users to understand the statistical methods used to estimate certified uncertainties and how they should be applied. Understanding of the uncertainty measurements is vital to their appropriate application in quality assurance methods, enabling users to make informed decisions and optimize the value of CRMs in their quality control processes.

Mineral Network Analysis for the Heavy Mineral Map of Australia: Implications for lithium exploration.

Dr Evgeniy Bastrakov, Geoscience Australia, Adj Prof Patrice de Caritat, Curtin University, Geoscience Australia, Dr Alexander T. Walker, Curtin University, Mr Phil Main, Geoscience Australia, Dr David Huston, Geoscience Australia, Dr David Champion, Geoscience Australia, Prof Brent I. A. McInnes, Curtin University.

The Heavy Mineral Map of Australia (HMMA), a component of Geoscience Australia's Exploring for the Future program, assessed the presence and patterns of heavy minerals (HMs; specific gravity >2.9 g/cm^3) in 1315 floodplain sediment samples from the National Geochemical Survey of Australia (NGSA). The 75-430 μm fraction of the NGSA samples underwent dense media separation and was analysed using a TESCAN Integrated Mineral Analysis (TIMA) system at Curtin University. This analysis produced approximately 150 million mineral observations across 163 unique mineral species, necessitating a novel workflow to enable users to explore, visualize, and understand mineral co-occurrence and spatial relationships effectively.

Here, we show how Mineral Network Analysis (MNA), through a custom web application, serves as an efficient interactive tool for uncovering and visualizing complex patterns in large mineral datasets. We examine rare metal minerals (Mo, Nb, Sn, Ta, and W) – key indicators of magmatic-related lithium mineralization – to demonstrate how their presence and relationships are shaped by primary geological and geomorphological processes, and how they relate to geological provinces, exposed lithologies, mineral deposits, topography, and major river basins.

We compare this analysis to a continental-scale ‘total’ lithium map based on the NGSA's top sediment coarse fraction. The underlying analytical dataset was derived from near-complete sample digestion (low-level mixed acid method) followed by ICP-MS analysis. This comparison reveals the complex redistribution of lithium in transported regolith, identifying several Li-enriched regions displaced from primary lithium sources, indicative of lithium's high migration capacity in the critical zone. Heavy minerals demonstrate a stronger association with known lithium mineralization (LCT pegmatite deposits) and occurrences – thereby highlighting other areas of potential lithium mineralization (e.g., Aileron Province). These findings underscore the potential of heavy-mineral automated mineralogy as a valuable tool in exploring for lithium pegmatites, particularly at densities exceeding those employed by the NGSA.

Mineral Network Analysis for Heavy Minerals (MNA4HM) web application, MNA4HM,is freely accessible at https://geoscienceaustralia.shinyapps.io/mna4hm.

A comprehensive workflow for digitisation and validation of data from historical mineral exploration reports

Sheng Fan[1, 2], Kat Lilly[1], Michael Gazley[3,4] [1]RSC, Dunedin, New Zealand

[2]Department of Geology, University of Otago, New Zealand [3]RSC, Wellinton, New Zealand, [4]School of Geography, Environment and Earth Science, Victoria University of Wellington, New Zealand

Historical mineral exploration and mining data contain significant potential for supporting exploration. However, unlocking this potential is challenging. The primary obstacle involves digitisation of data that is in portable document format (PDF) files. The diversity of text embedding techniques, inconsistent quality of optically scanned documents, and a substantial amount of unstructured information are barriers to high fidelity digitisation. This hinders the effective use of historical data and limits our ability to leverage historical data. Our workflow digitises various types of PDF data and extracts tabulated data from these reports. Our methodology is designed to address the challenges of format diversity and data quality inconsistency, to facilitate the effective use of structured and validated historical data.

Our workflow first identifies how text is embedded in PDF files, and segregates them into text-based PDFs, where text is selectable and can be directly extracted, and photo-based PDFs, where text is represented as images. For text-based PDFs, our strategy involves the direct extraction of textual content, coupled with an automated mechanism to identify and extract tables. This mechanism leverages geometric models and contextual analysis to adeptly identify tabular data. The digitisation of photo-based PDFs integrates machine learning (ML) to address the challenges posed by the graphical data. Employing image processing and optical character recognition (OCR) techniques, this ML-driven approach identifies and extracts text and tabular data from images. By training these models with existing datasets with manual labelling, we can enhance the accuracy of digitisation and recognition, ensuring a precise conversion of images into a manipulable and analysable digital format. For images of poor quality, we apply image enhancement techniques that typically improve the success rate of digitisation.

We will showcase the application of this workflow to process PDF reports acquired from the Geological Survey of Western Australia (GSWA), the New Zealand Petroleum and Minerals (NZPAM) Geodata Catalogue, and other publicly available exploration data repositories. The tabulated data digitised from individual PDFs were combined into a validated master database. This consolidated resource greatly facilitates the availability and searchability of historical data to drive mineral exploration targeting programmes.

LithoSurfer: A Novel Geochemical Data Integration and Analysis Platform

Dr. Fabian Kohlmann, Dr. Wayne Noble, Moritz Theile, Alejandra Bedoya-Mejia and Dr. Romain Beucher

The integration and analysis of geochemical data are crucial for advancing geosciences and enhancing mineral exploration. LithoSurfer, a novel spatial data platform, addresses these challenges by enabling the synthesis and interrogation of geochemical datasets in an innovative environment. It offers advanced visualisation, data harmonisation, and analysis tools, tailored for geochemical data, enhancing geoscientists' interpretative capabilities. LithoSurfer uses state-of-the-art data integration techniques to merge and standardise heterogeneous geochemical datasets, providing a comprehensive view of geochemical signatures. Its robust data management system and advanced visualisation capabilities, including multi-variable plots and geochemical maps, support nuanced exploration of geochemical processes and relationships. Additionally, interactive, geospatially referenced mapping tools allow spatial contextualization of data, aiding in the identification of exploration targets.

The platform's scalable architecture ensures it remains relevant and adaptable, supporting emerging geochemical analysis techniques and data formats. LithoSurfer's development highlights the importance of integrated geochemical data analysis in decoding complex geological phenomena and formulating exploration strategies. By streamlining the research workflow and promoting interdisciplinary collaboration, it significantly reduces computational overhead.

LithoSurfer represents a transformative approach to geochemical data analysis, providing a suite of tools that boost the precision, efficiency, and impact of geochemical research and exploration. Its contributions offer insights into Earth's geochemical dynamics and support the strategic development of mineral resources, marking a significant leap in geochemistry.

Headless GAS: A real time solution for characterizing and fingerprinting analytical data

Dr David Lawie[1], Jack van der Pal[2,*], Putra Sadikin[1], James Waldron[2], Dr Nigel W. Brand[2]

[1] IMDEX International Pty Ltd., [2] Portable Spectral Services, West Perth, Australia

Traditional methods used to analyse geoscience data can take many hours and are often prone to human error. This was common practice prior to the introduction of ioGAS™ in 2008. ioGAS is a exploratory data analysis software application, developed specifically for the resources industry, allowing for rapid analysis without a loss of accuracy. Since then, ioGAS™ has become an industry standard and integral to the workflow for evaluation and interpretation in the resources industry.

Headless GAS introduces a new frontier of real time ioGAS™ analysis. While preserving all the functionality and flexibility of the ioGAS software, Headless GAS allows for the processing of workflows within a cloud-based system, analysing data taken directly from associated scanning platforms. With an unlimited data package size, Headless GAS is ideal for processing large volumes of data "big data" and providing user-defined solutions, without requiring a user interface.

One of the Headless GAS-compatible scanning platforms is the General Element & Material Analysis (GEMA), an integrated, automative micro-XRF system developed by Portable Spectral Services. This innovative end-to-end system is ideal for integration with APIs and other applications. The joint use of GEMA with Headless GAS can provide rapid, non-destructive materials analysis. This end-to-end system is enabled by various APIs and applications to access a high level of detail under the broad scope of elemental and mineralogical big data. An ideal system for integration with Headless GAS.

In this study, we'll showcase how GEMA in tandem with headless GAS can be utilized for real time analysis of drill chips. This is achieved through various APIs and data processing techniques to deliver meaningful graphical representations and easy to digest data reports. Use cases include; lithological classification, fertility indexes for sample types such as LCT pegmatites and quantifiable interpretation of mineralogy and geochemistry.

UltraFine+ and LandScape+: the evolution of refining soil analyses and providing data driven geochemical context for exploration

Ryan Noble, Anicia Henne, Dave Cole, Morgan Williams

CSIRO Mineral Resources, Kensington, Western Australia

Mineral exploration soil sampling and analysis has not changed significantly over the past few decades: that is, digest a dry-sieved, perhaps milled, soil sample and, subsequently, analyse the solution for its elemental concentrations, examine key pathfinder elements, then rinse and repeat at the next tenement package. Industry needs to explore differently to improve success in covered terrains. The CSIRO research team has fundamentally changed the soil analysis and interpretation approach in Australia with developments of UltraFine+® and LandScape+® as outcomes of two major R&D projects with ~40 industry and government collaborators.

In this presentation we highlight the evolution of both the soil analytical method and the machine learning analytics, and the key findings from this research. The soil analytical method captures the mobile element signature by separating the <2 μm soil fraction for multielement analysis along with spectral mineralogy, pH, electrical conductivity and particle size distribution. This effectively increases concentrations of Au, and many pathfinder elements by 100-250%. We demonstrate how the integration of elemental geochemistry of the clay sized soil fraction with spectral mineralogy and other soil parameters can improve understanding of landscape processes and the formation of geochemical anomalies. In addition to improving the "standard method" soil geochemistry, we have also incorporated machine learning approaches with spatial data to generate landscape types using dimensionality reduction and clustering methods. These data driven landscapes (LandScape+) will soon be available for small to moderate exploration sites in Australia through an online portal. There are limitations to the unsupervised machine learning landscape models and these will be discussed along with the value of identifying coherent soil anomalies in semi-arid landscape settings such as sand dunes and sheetwash that are notoriously difficult to explore.

How solid-3D digital core is future-proofing the way we explore, mine and process deposits – Case Studies from Copper and Critical Mineral Deposits

Dr. Heidi E. Pass (heidi.pass@orexplore.com)* Dr. Stephen Coward, Dr. Thomas Drage

Orexplore Technologies, 75 McDonald Cresent, Bassendean, WA, 6054 Australia

With the ever-present thirst for reduced risk, speed and orebody knowledge, the past two decades have seen the use of hyperspectral, pXRF and other mineral and elemental drill-core sensors gain industry acceptance. These tools are often limited to 2D surface scans or require destruction of part or all of the core. Multiple analyses are needed to provide both mineral and elemental information which are rarely co-located at scale. This severely limits interpretation and reduces archive to photographs, subjective logs and possibly sample pulps.

Drill-core logging and analysis remain essential tools in any exploration and mining project. Many logging and sample selection output variables are limited to database codes and subject to the discretion of the human eye and (in)expertise, with samples recording discrete point data or bulk averages in heterogeneous systems. Inconsistencies are common, compound over time and lead to uncertainty and even additional drilling to satisfy the specific needs of different workflows. Blind, continuous and destructive sampling is a partial solution, but removes the possibility for additional investigations and iterative concept testing now and in the future. The result is added cost, time and risk to critical decisions across the value chain.

The novel Orexplore Technology Platform is an industry-first, non-destructive, drill core sensing and analysis system. High-resolution X-ray tomography (as used in hospital CT scanners) capture the complete surface and internal core volume at a default 200 micrometer. Additionally, powerful X-ray fluorescence scanners sense the entire 360° core surface. These data streams are integrated using advanced physics and mathematical modelling to produce a detailed, solid, 3D digital twin of the core in 15min/meter on-site or in a warehouse.

Presented here are three new case studies, highlighting the significance of continuous, objective downhole identification and preservation in solid-3D of co-located minerals, textures, elements, structures, density and rock breaks from one instrument. These case studies illustrate how the combination of these foundational data sets (as well as their derived products) reveal and bring forward key net-present-value decision-making information, enabling pro-active decisions on large capital investment plus repeated interrogation and testing of new concepts of operation and practical scenarios at any scale required, now and into the future.

Sustainability benefits of MinEx CRC's downhole geochemical assay tool

A/Prof Caroline Tiddy[1,2], Dr Ben van der Hoek[1,2], Dr Jessica Stromberg[1,3], Dr Lequn Zhang[1,3], Mr Steve Tassios[1,4], Mr Neil Francis[1,3], Dr Yulia Uvarova[1,3]

[1]Mineral Exploration Cooperative Research Centre (MinEx CRC), [2]University of South Australia, Mawson Lakes, SA 5051, [3]CSIRO Mineral Resources, ARRC (Australia Resources Research Centre), P.O. Box 1130, Bentley, WA 6102, [4]CSIRO Mineral Resources, Gate 1, Normanby Road, Clayton, VIC 3169

Advancements in technology are considered essential to meeting Net Zero 2050 targets as they will facilitate the transition from fossil fuels to clean energy sources. Technologies such as photovoltaic cells, wind turbines and electric vehicles are key components in this transition. However, the widespread adoption of these technologies is reshaping global mineral demands, leading to the identification of a suite of 'critical minerals' worldwide. For instance, based on current mining and recycling rates the world-wide supply-demand gap for copper is expected to reach a significant deficit of approximately 10 million metric tonnes by 2035, which is a 20% shortfall in the volume of copper required to build technologies needed to meet Net Zero 2050 targets (S&P Global, 2022). This demand surpasses the capacity of existing reserves, recycling efforts, remining of mine waste, and substitution, necessitating the discovery of new deposits.

Despite the promise of new technologies, they also pose potential challenges in the future. Therefore, it is imperative to assess the sustainability of emerging and developing technologies through the lenses of environment, social and governance (ESG) considerations. This holistic evaluation is essential to ensure that these technologies yield desired long-term benefits while minimising adverse impacts.

MinEx CRC is dedicated to advancing mineral exploration technologies and techniques to achieve greater efficiency, environmental sustainability, and lower costs in the discovery of critical metal deposits. As part of MinEx CRC Project 3: Real-time Downhole Assay, we are developing a tool capable of rapid, in-situ geochemical analysis within drillhole environments. This innovative tool has the potential to revolutionise drilling practices in mineral exploration and mining sectors by providing comprehensive data across the periodic table within hours of completing a drill hole, which is a stark improvement over the typical 3-month waiting period in current workflows.

In this presentation, we conduct a sustainability analysis of MinEx CRC's downhole LIBS tool, examining its environmental impact and climate economics. Additionally, we explore how this tool may influence drilling workflows, offering insights into its potential implications for industry practices.

Boosting the integration of hyperspectral data sets to enhance orebody knowledge.

Rocio Vargas Soto, Teck Resources

Accurately delineating the geological features of orebodies is crucial for optimizing the overall value of a deposit, supporting operational efficiency, and enhancing sustainability. This involves understanding not only the mineral system but also ensuring smooth downstream processing without geologically induced disruptions. Core scanning systems play a vital role in the mining industry, providing continuous measurements of geological materials in a rapid and cost-effective way. One common application involves the use of hyperspectral cameras, offering semiquantitative measurements of mineral characteristics in drill core or chip samples.

Despite technological advancements, the integration of diverse datasets collected at different stages of a deposit's life cycle presents challenges. The vast amount of data and proprietary processing workflows make dataset management and integration complex, requiring innovative solutions for efficiently handling these large datasets. Establishing a workflow for integrating data captured with different scanning sources is crucial for enhancing the usability of these datasets and providing objective and reproducible products for orebody characterization.

This study outlines two initiatives for in-house processing of large hyperspectral datasets from a porphyry copper deposit. The first case demonstrates the creation of an objective quantitative mineralogical model, through the reprocessing of existing drill hole hyperspectral data, which addresses challenges related to the scalability of spectral measurements and mineral interpretation. The second case involves integrating two dense hyperspectral datasets collected with different sensors into a unified spectral model, effectively tripling the spatial coverage of the mineralogical model. These models have proven to be successful inputs for alteration modelling and geometallurgical characterization, significantly expanding the utility of these datasets beyond previously explored limits.

Machine-learning applied to near-shore lake sediments from the Bear-Slave corridor (NWT/NU, Canada).

Alexandre Voinot[1], Mohammad Parsasadr[1], Beth McClenaghan[1]

[1]Geological Survey of Canada, Ottawa, Ontario, CANADA. E-mail: alexandre.voinot@canada.ca, Tel: +1 (343)-598-5887

The Geological Survey of Canada (GSC) has conducted regional-scale lake bottom sediment surveys in the glaciated Precambrian Shield terrain of Canada for more than 50 years. However, few of these datasets for northern Canada have been interpreted using modern state-of-the-art machine learning techniques to assess mineral potential. In addition, some factors involved in Arctic Lake sediment geochemistry are not fully understood, and these unknowns can affect interpretations of these large lake sediment datasets. Here, we present a project aiming at using machine-learning and artificial intelligence techniques on 4000 near-shore lake sediment samples from the northern Bear-Slave corridor region (about 93,000 km2) collected in the summer of 1972. The approach is looking at legacy data obtained in the early 1970s by analytical methods such as direction emission spectroscopy, fluorometry and colorimetry, to data from recent reanalysis (2022-2023), using modern analytical techniques such as Aqua Regia/ICPMS and Instrumental Neutron Activation Analyses (INAA), as well as isotopes of Li and Sr in select samples. Mineralogical data (XRD and SEM) were also collected.

We are presenting here the framework of the machine-learning algorithm, as well as consideration for the integration of the various geochemical datasets in the data analysis, in tandem with non-numerical data such as bedrock geology. As some samples had insufficient amounts of solid residues for reanalysis (about 25% of the initial set of samples), we are also discussing ways to optimize the approach on prediction of missing data based on the existing dataset.

This innovative approach compares results from the various analytical methods to extract additional information on sample mineralogy to infer the bonding environment of metals and the implications of their mobility in the surficial environment. Guidelines as well as maps can in turn be generated and employed for mineral prospectivity or environmental monitoring purposes.

Heavy mineral concentrates, indicator minerals & mineral sands: Automated holistic sample analysis offering non-destructive, rapid, real-time results

James R. Waldron [1*], Jack van der Pal [1], Melvin W. Hartley [1], Kyle Halse [1], Dr Nigel W. Brand [1,2]

[1] Portable Spectral Services, West Perth, Australia. [2] Centre for Exploration and Targeting, University of Western Australia

Heavy mineral concentrates, indicator minerals, and mineral sands play crucial roles in mineral exploration, geological assessment, resource evaluation and definition. Traditional methods often involve multiple analytical techniques which are costly, time-consuming, and destructive, hindering rapid assessment and decision-making processes.

These traditional methods include manual processing and visual identification by skilled mineralogists. Grains of interest are meticulously selected and mounted in an epoxy support and polished to establish a flat surface for analysis. These workflows typically entail the utilization of scanning electron microscopy (SEM) for major elements or more precise techniques such as electron microprobe analysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for comprehensive determination of both major elements and trace constituents.

This presentation demonstrates an end-to-end innovative approach developed by Portable Spectral Services, integrating advanced non-destructive analytical methods, imaging, and machine learning algorithms for the rapid, real-time, and holistic analysis of various sample types. The General Element & Material Analysis (GEMA) system efficiently characterises loose mineral grain concentrates using micro-XRF and robot automation. It enables precise analysis, facilitating mineral grain and phase identification, with accurate assessment of modal abundance down to 10ppm, as well as grain morphology (size, shape, roundness, and colour). Additionally, it provides comprehensive chemical characterization ($Z > 11$) supported by quality control for accuracy and reproducibility. Attributes can be identified at both grain-by-grain and sample-by-sample scales. This approach enables efficient mineral exploration, enhances geological understanding, and supports sustainable resource management practices. Through case studies and practical applications, this presentation demonstrates the effectiveness and versatility of the GEMA system and how it can offer significant advancements in the field of heavy mineral concentrates, indicator minerals, and mineral sands analysis.