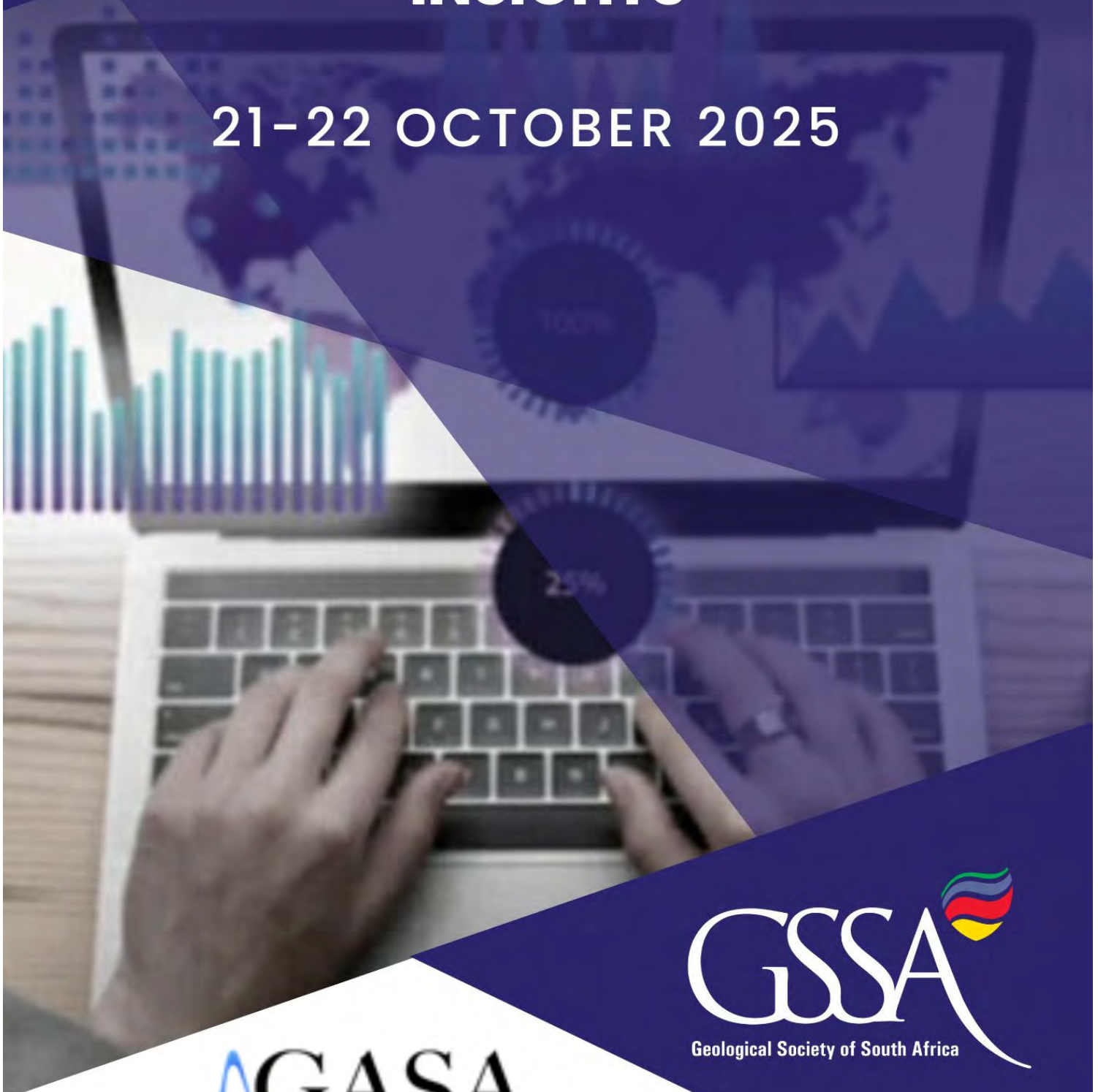
MINERAL RESOURCE MASTERY: TOOLS, TRENDS & INDUSTRY INSIGHTS

21-22 OCTOBER 2025



GSSA
Geological Society of South Africa

GASA
Geostatistical Association of Southern Africa
Furthering Geostatistics

PROGRAMME

Mineral Resource Mastery: Tools, Trends, and Industry Insights

This two-day online seminar (21–22 October 2025) features dynamic and engaging discussions, combining keynotes from industry leaders, technical papers showcasing leading industry practices, and thought-provoking panel discussions. Participants will gain practical knowledge on the latest trends, leading industry practices, and tools in mineral prospectivity mapping, geological modeling, mineral resource and reserves estimation, and risk management.

The event will be hosted by the Geological Society of South Africa (GSSA) and the Geostatistical Association of Southern Africa (GASA), in collaboration with South African universities, to advance education and research in mathematical geosciences and geostatistics.

Day 1 of the Geometallurgy and Exploration Seminar – 21 October 2025

The first day of the seminar opens with an atmosphere of anticipation and professional collegiality, as delegates gather for registration and introductory remarks from the organising leadership. This inaugural session sets the stage for a day devoted to the interrogation of mineral prospectivity, resource confidence, and the evolving toolkit of the exploration geoscientist. The morning begins with a keynote address that critically examines regional-scale mineral prospectivity mapping, considering the interplay between geological understanding, data synthesis, and spatial inference. Following this, the technical programme transitions into a focused discussion on the role of uncertainty in prospectivity modelling, an area of growing significance as the industry moves beyond deterministic targeting frameworks toward probabilistic, risk-aware methodologies. Advances in geophysical imaging techniques are then explored, with particular emphasis on their utility in subsurface delineation and structural interpretation within complex hard-rock environments. A mid-morning tea break provides a moment for informal exchange, after which the programme resumes with a reappraisal of sampling theory as applied to resource estimation, underscoring the statistical foundations upon which resource confidence is built. The essential, and often underappreciated, contributions of mining geology to resource modelling are then brought to the fore, reinforcing the continuity between data acquisition in the field and the robustness of downstream estimation outputs. After a luncheon interval conducive to networking and reflective dialogue, the afternoon session examines the state-of-the-art in geostatistical methods and their adaptation to the challenges of contemporary mineral development. The day concludes with a high-level panel discussion that seeks to interrogate whether integrated approaches, spanning geological models, spatial statistics, geophysical techniques, and sampling strategies constitute not merely a methodological trend, but a necessary evolution in the practice of mineral exploration and resource geology. The closing reflections affirm a commitment to rigorous science, practical relevance, and the value of collaboration in navigating the complexities of modern mineral systems.

Day 2 of the Geometallurgy and Exploration Seminar – 22 October 2025

The second day of the seminar builds upon the foundational themes introduced on Day 1, shifting focus toward the downstream applications of resource estimation and the integration of emerging considerations such as geometallurgy, sustainability, and risk modelling in modern mining. Proceedings commence with an examination of post-estimation processes, exploring how mineral resource outputs are refined, validated, and translated into operational frameworks. This is followed by a session on the role of geometallurgical variables in short-term mine planning, highlighting how orebody knowledge, metallurgical response, and spatial variability are integrated to enhance tactical decision-making. The discussion then broadens to encompass the inclusion of ESG factors in geometallurgical models, reflecting the industry's increasing accountability to environmental and social metrics alongside technical performance. A short tea break offers delegates the opportunity for informal dialogue before attention returns to matters of compliance and transparency through a detailed review of contemporary mineral reporting codes. The importance of rigorous disclosure practices and international harmonisation is underscored, emphasising the evolving expectations placed upon resource practitioners. Following lunch, the seminar returns with a presentation on probabilistic simulation as a means of quantifying geological uncertainty, a critical step in bridging the gap between resource estimation and risk-informed planning. This is seamlessly complemented by an exploration of simultaneous stochastic optimisation techniques, which address the dynamic, interconnected nature of modern mining complexes. The day culminates in a panel discussion that interrogates the role of stochastic models and ESG integration in shaping the future of technical reporting, inviting reflection on whether these approaches represent methodological evolution or foundational transformation. Concluding remarks tie together the diverse strands of the day, reinforcing the seminar's central theme: that the convergence of science, responsibility, and advanced modelling is not a theoretical ideal but an operational imperative in the twenty-first-century minerals sector.

PROGRAMME

Time	21 October 2025 Day 1 Session	Speaker / Moderator
08:00 – 08:30	Registration	ALL
08:30 – 08:45	Opening Remarks	**Geostatistics Education Chairperson:** Prof. Glen Nwaila **GASA Chairperson:** Jeremy Witley **GSSA Committee Member**: Dr. Tania Marshall
08:45 – 09:30	**Keynote Address 1:** Artificial Intelligence in Mineral Prospectivity Mapping	**Prof. John Carranza**, University of the Free State (UFS)
09:30 – 09:45	Q&A Session with Keynote Speaker	Moderated discussion
09:45 – 10:30	Mineral Prospectivity Mapping for Multi-Commodity Cu-Pb-Zn-Ag Deposits in the Aggeneys–Gamsberg District Using a Random Forest algorithm	**Musawenkosi Buthelezi**, University of the Witwatersrand
10:30 – 11:15	Integrated portable sensors for ore characterisation	**Viwe Notole**, University of the Witwatersrand
11:15 – 11:30	Tea Break	ALL
11:30 – 12:15	Sampling Theory in Mineral Resource Estimation: The Bedrock of Confidence	**Prof. Richard Minnitt**, University of the Witwatersrand
12:15 – 13:00	Nugget Effect – understanding causes and its application in Mineral Resource Estimation	**Jeremy Witley**, The MSA Group
13:00 – 14:00	Lunch Break	ALL
14:00 – 14:45	**Keynote Address 2:** Geostatistical Toolkit for Recoverable Resource Estimation in the Mining Industry	**Dr. Winfred Assibey-Bonsu**, Gold Fields
14:45 – 15:45	Panel Discussion: Are Integrated Approaches the Future of Mineral Exploration and Resource Geology?	Chair: **Prof. John Carranza**, University of the Free State (UFS) **Panellists: All Speakers of the Day**
15:45 – 16:00	Closing remarks and way forward	Chairperson of GASA: **Jeremy Witley**, The MSA Group

Time	22 October 2025 Day 2 Session	Speaker / Moderator
08:30 – 09:30	Post-Mineral Resources Estimation Processes	**Leon Tolmay**, Tolmay Enterprises
09:30 – 10:15	Quantifying Environmental, Social and Governance (ESG) parameters into geometallurgical workflows	**Dr. Evelyn R Manjengwa**, Stellenbosch University
10:15 – 11:00	21st Century Minerals Reporting Codes	**Dr. Jacqui Coombes**, SageAbility
11:00 – 11:15	Tea Break	ALL
11:15 – 12:15	Mineral Resource Classification – are we suffering from groupthink?	**Mark Burnett**, AMC Consultants
12:15 – 13:15	Lunch Break	ALL
13:15 – 14:15	**Keynote Address 3**: Simultaneous Stochastic Optimisation of Mining Complexes: From strategic planning to self-learning and remaining challenges	**Prof. Roussos Dimitrakopoulos**, McGill University
14:15 – 15:15	GeoML: Open-Source Python Library for Geological modelling and Mineral Resource Estimation	**Prof. Ítalo Gomes Gonçalves, Federal University of Pampa**
15:15 – 16:00	Panel Discussion: Are Stochastic Models and ESG the Future of Technical Reporting?	Chair: **Kathleen Body**; Red Bush Analytics Panellists: All Speakers of the Day
16:00 – 16:05	Closing remarks and vote of thanks	**Prof. Glen Nwaila**, University of the Witwatersrand

Day 1

21 October 2025

Time: 08:45 – 09:30 SAST (UTC+02:00)

Mineral Prospectivity Mapping for Regional Exploration

Emmanuel John M. Carranza

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Department of Geology, University of the Free State, Bloemfontein, South Africa

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Prof. Emmanuel John M. Carranza

John Carranza has worked, for 18 years (1983–2001), as exploration geologist/geochemist in the Mines and Geosciences Bureau of the Philippines. He earned his PhD on mineral potential mapping from Technische Universiteit Delft, Netherlands, in 2002. He has been working, for 23 years now (2001–present), in geoscience academia for education/research in mainly quantitative and/or GIS-based predictive modeling of mineral prospectivity and geochemistry for mineral exploration and ore genesis studies. He was Assistant Professor (for Predictive Modeling in Geological/Mineral Exploration) in the University of Twente, Netherlands, 2003–2012; was Associate Professor (for Computational Modeling in Exploration/Mining Geology) in the James Cook University, Australia, 2013–2016; was Professor of Geosciences in the University of KwaZulu–Natal, Sout Africa, 2017–2021; is currently Professor of Economic Geology in the University of the Free State, South Africa, since 2022.

He has expertise in (a) geochemistry for mineral exploration and ore genesis studies, (b) spatial mathematics/statistics for predictive modeling of mineral resources, (c) remote sensing for geological/mineral exploration. He has been working, for 27 years now (1997–present), at the forefront of research in quantitative and/or GIS-based predictive modeling of mineral prospectivity. He published in 2008 a book on "Geochemical Anomaly and Mineral Prospectivity Mapping in GIS". He has published 293 papers in peer-reviewed international geoscience journals. He has, per Google Scholar, an H-index of 79 and has been cited at least 20,424 times. He is Editor-in-Chief of Natural Resources Research journal, and Associate Editor of Ore Geology Reviews and Journal of Geochemical Exploration.

Time: 09:45 – 10:30 SAST (UTC+02:00)

Mineral Prospectivity Mapping for Multi-Commodity Cu-Pb-Zn-Ag Deposits in the Aggeneys–Gamsberg District Using a Random Forest algorithm

Musawenkosi Buthelezi

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Abstract

The polydeformed Aggeneys–Gamsberg district hosts world-class Broken Hill-type base metal deposits, which are strategically critical for energy transition technologies. This study developed a robust machine learning framework for mineral prospectivity mapping (MPM) to address exploration challenges in this complex, poorly outcropping terrane. We applied a Positive-Unlabelled Bagging Random Forest (PUB-RF) algorithm to integrate multi-source geoscientific data, creating a unified multi-commodity (Cu-Pb-Zn-Ag) targeting model. The models achieved perfect precision (1.000) and significant F1-score improvements, with high-probability zones capturing 96% of copper (Cu), 94% of silver (Ag), 83% of lead (Pb), and 71% of zinc (Zn) known occurrences, demonstrating 92% spatial concordance. Model robustness was rigorously validated. Exploration efficiency curves confirmed that the top 10% of the area captures over 80% of Zn and ~70% of Pb deposits, significantly outperforming random exploration. ROC analysis showed high global accuracy, with AUC values of 0.955 for Zn and 0.943 for Ag. An extensive stability analysis, involving hundreds of repeated runs, produced narrow uncertainty bands, confirming the results are stable and not artefacts of overfitting. SHapley Additive exPlanations (SHAP) analysis quantified key metallogenic controls, identifying commodity-specific associations: Zn prospectivity is associated with Mg-OH alteration, Cu anomalies with Total Magnetic Intensity (TMI) anomalies, Pb with potassium alteration, and Ag with structural features. Spatial analysis reveals distinct mineralisation patterns: Cu and Ag deposits show strong proximal clustering near faults, while Zn and Pb exhibit more complex, distal distributions. This is consistent with geological evidence; for instance, western Zn anomalies correlate with magnetite-rich lithologies in redox-controlled transition zones, while bimodal Ag anomalies reflect both shear zone-hosted and stratabound controls. A practical dual-threshold method (high probability >0.6, low uncertainty $\sigma<0.2$) refined targets, reducing the prospective area by 22–35% while retaining over 90% of known

occurrences, and identified four high-priority zones. This study provides a transferable, data-driven framework that integrates machine learning with geological principles for effective exploration in polydeformed metamorphic terranes globally, augmenting geological interpretation with quantifiable, probabilistic target rankings for strategic decision-making.

Musawenkosi Buthelezi

Musawenkosi is a PhD. candidate, the School of Geosciences at the University of the Witwatersrand. His work integrates economic geology, geostatistics, and machine learning to deliver regional scale prospectivity maps and decision tools for critical minerals in the Northern Cape. He is involved in several exploration projects in the Northern Cape." Musawenkosi holds an MSc in Geology (University of the Witwatersrand).

Time: 10:30 – 11:15 SAST (UTC+02:00)

Integrated portable sensors for ore characterisation

Viwe Notole

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Abstract

Rapid and accurate characterisation of ore bodies is important to modern mining, informing resource estimation, process optimisation and environmental management. Conventional laboratory-based analyses, although precise, are time-consuming, labour-intensive and limited by sample representativity, indicating the need for high-resolution, in-situ characterisation methods. Integrated portable sensor technologies have emerged as a transformative solution, allowing real-time, field-based ore characterisation with high spatial resolution and operational flexibility. We review the applications, advantages and limitations of integrated portable sensors, demonstrating their potential to improve decision-making in exploration, mining and beneficiation processes. Portable sensors, including handheld X-ray fluorescence (pXRF), laser-induced breakdown spectroscopy (LIBS) and hyperspectral imaging (HSI) devices, have demonstrated considerable potential for rapid elemental and mineralogical analysis. pXRF allows for non-destructive, on-site quantification of major, minor and trace elements in a wide range of lithologies, while LIBS provides complementary elemental profiling with micrometre-scale spatial resolution, including detection of light elements such as lithium and boron. HSI instruments enable direct mineral identification through spectral signatures, facilitating the delineation of ore minerals, gangue phases and alteration products. When integrated, these sensors generate multidimensional datasets that includes elemental, mineralogical and textural information, offering better understanding of ore characteristics. The integration of portable sensors is augmented by advanced data analytics, including chemometric modelling, multivariate statistics and machine learning algorithms. These approaches allow for the rapid interpretation of complex datasets, identification of mineral associations and prediction of ore properties such as grade, liberation and processability. Case studies on platinum group element (PGE) reefs, gold-bearing conglomerates and base metal sulphide ores demonstrate that integrated portable sensing can

accurately replicate laboratory results while providing the benefit of spatially resolved real-time data. These capabilities are particularly valuable in environments where rapid decision-making is required, such as drill-core logging, stockpile evaluation and heap leach monitoring. However, challenges remain in sensor calibration, matrix effects and the integration of heterogeneous datasets from multiple sensor modalities. Addressing these challenges requires site-specific calibration models, standardised measurement protocols and automated data fusion approach. Advances in sensor miniaturisation, wireless data transmission and cloud-based analytics are expanding the feasibility of large-scale deployment. Integrated portable sensors represent a paradigm shift in ore characterisation, bridging laboratory precision analysis and real-time field measurements. Integrating complementary analytical instruments with advanced data analytics, provides a rapid, cost-effective and spatially resolved approach for understanding ore composition, mineral and grade variability, supporting improved resource evaluation, process optimisation and risk reduction.

Viwe Notole

Viwe is a PhD candidate in the School of Chemical and Metallurgical Engineering at the University of the Witwatersrand. He holds an MSc in Economic Geology from the same institution. His work integrates metal accounting, mineral processing and hydrometallurgical techniques with machine learning-driven data analysis.

Time: 11:30 – 12:15 SAST (UTC+02:00)

Sampling Theory in Mineral Resource Estimation: The Bedrock of Confidence

Richard CA Minnitt

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School of Mining Engineering, University of the Witwatersrand, Johannesburg, South Africa

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Abstract

Mineral Resource estimation is the foundation for all mineral project evaluation, financing, and mine design and despite the huge advances in geostatistical estimation, the quality and integrity of any resource estimate is entirely dependent on the quality of the input data. Thus, representative sampling is the critical, non-negotiable foundation upon which all reliable resource estimation is built. Errors introduced during the sampling processes propagate through the entire modelling process, cannot be rectified after the event, and directly translate into significant technical and financial risk. The Fundamental Sampling Principals, the basic requirements of representative sampling and the Standard Unit Operations, the means by which sampling errors can be mitigated, are described. The total sampling error in a resource estimate is a cumulative function of errors from sampling, preparation, assaying, and data handling, with the magnitude of the primary sampling event being the largest potential source of bias and variability far outweighing the other components of sampling error. The sources and mitigation of sampling errors have been described in the so-called Theory of Sampling, the foundational work of Pierre Gy. The principal error, the Fundamental Sampling Error (FSE), is the minimum theoretically unavoidable error is captured in a formula for the variance of the sampling error that includes a number of constituent factors, with particular emphasis on the controlling relationship between particle size and sample mass. Calibration of the sampling parameters K (a constant for a particular material) and alpha (an exponent for the fragment size) dictates critical field decisions, such as the appropriate sample mass for a given drill core diameter or the necessary particle size before selection of the aliquot. The influence and mitigating methods of the Grouping and Segregation Error (GSE), arising from the physical distribution of particles and incorrect sampling methods. Real-world scenarios, such as biased sampling from a segregated stockpile or a poorly collected cyclone sample from RC drilling, will highlight how GSE introduces systematic bias that can severely misrepresent

the true grade of a lot. The theoretical principles linked to industry applications provide best practices for drill core splitting, reverse circulation sampling, and grade control protocols are contrasted with the common pitfalls associated with correct methods of particulate sampling, namely, sampling the entire stream. The effects of errors and biases arising from poor sampling, may result in the over-estimation or under-estimation of resources, misclassification of ore and waste, and the artificial inflation of the geostatistical "nugget effect," which degrades the accuracy of block models. It is emphasised that rigorous sampling is not a mere technicality but a primary risk management tool. The final message will be a call for the formal adoption of Site-Specific Sampling Protocols (SSSP), continuous QA/QC programs, and a cultural shift within project teams to view representative sampling as the essential first step in generating a resource estimate that is not just mathematically sound but truly fit for purpose. In an industry defined by uncertainty, mastering sampling theory is the bedrock of confidence.

Dick Minnitt

Dick Minnitt is retired from but retained by the School of Mining Engineering at the University of the Witwatersrand as a Visiting Emeritus Professor. He is a Fellow of the Geological Society of Southern Africa, the South African Institute of Mining and Metallurgy and the Geostatistical Association of Southern Africa. His principal area of postgraduate teaching, research and consulting practice is in the field of particulate sampling. He is married to one wife and recently returned from a three-month visit to friends and relatives in the UK.

12:15 – 13:00 SAST (UTC+02:00)

Mineral Prospectivity Mapping for Regional Exploration

Jeremy Witley

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Department of Geology, University of the Free State, Bloemfontein, South Africa

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Jeremy Witley

Jeremy Witley is Head of Mineral Resources with more than three decades' experience in mining. A specialist in Mineral Resource estimation and Mineral Resource Management, his background spans mineral exploration and mine geology. He has held technical and managerial roles at Lonmin, BCL, Anglo American and Snowden, combining operational depth with consultancy breadth.

Jeremy acts as a Competent/Qualified Person across a wide range of commodities and mineralisation styles. He holds an MSc (Eng.) and is a Professional Natural Scientist (Pr.Sci.Nat.), a Fellow of the Geological Society of South Africa (FGSSA) and a member of the Geostatistical Association of Southern Africa (MGASA).

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Time: 14:00 – 14:45 AM SAST (UTC+02:00)

Geostatistical Toolkit for Recoverable Resource Estimation in the Mining Industry

Winfred Assibey-Bonsu

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Winfred Assibey-Bonsu, Group Technical Services, Gold Fields, Perth, Australia

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Abstract

The mining industry is characterized by capital-intensive investments. Typical examples include Newmont's acquisition of Newcrest assets for US$16.8 billion (Businesswire, 2023), BHP's partnership with Lundin Mining to acquire Filo Corp. for approximately US$3.0 billion (BHP News, 2025), and Rio Tinto's 2007 acquisition of Alcan for US$38.1 billion (Financial Review, 2003). Gold Fields Limited's acquisition of the South Deep Gold Mine in South Africa cost US$2.5 billion (Reed, 2006). These transactions underscore the strategic importance of mineral resources and reserves and form the foundation of mining company valuations and investment decisions, highlight the scale of financial exposure and the strategic importance of getting resource evaluation right. Yet, one of the industry's most persistent risks is uncertainty in resource estimation. Overstated or poorly classified resources can derail mine projects, distort financial forecasts, and lead to costly misallocations of capital. To navigate this risk, mining companies must rely on three core pillars: high-quality data, robust geological models, and appropriate geostatistical methods. Geostatistics offers a powerful toolkit to reduce both technical and financial uncertainty. However, early-stage projects often rely on widely spaced drill holes, which may suffice for large block estimates but fall short when estimating recoverable resources. Smaller blocks, essential for selective mining, are prone to over-smoothing, leading to biased grade and tonnage estimates, particularly underestimating grades above cutoff. Recoverable resources are more than just a technical metric, they are the foundation of mine planning, feasibility studies, and investment decisions. Their accurate estimation directly influences project viability and profitability. As the industry evolves, so do the methodologies used to assess recoverable resources, shifting from global models to more localized, data-sensitive approaches. This paper presents a practical overview of

geostatistical techniques for estimating recoverable resources, including various kriging methods, uniform conditioning, and conditional simulation. Through a series of case studies, the paper illustrates the strengths and limitations of various approaches within real-world mining contexts. In addition, it presents a case study on a probabilistic model for mineral resource classification based on conditional simulation, designed to improve classification accuracy and reduce exploration costs. By combining appropriate geostatistical techniques for recoverable resource estimation with sound geological insight and optimal application, mining companies can significantly improve the reliability of resource models, reduce uncertainty, and make more confident investment and operational decisions.

Winfred Assibey-Bonsu

Dr Winfred Assibey-Bonsu is Principal Specialist for Geostatistics and Assurance in Corporate Technical Services at Gold Fields, based at the corporate office in Perth. With more than three decades in mining, he has led mineral resource assessment and new-business evaluations across Africa, Australia, the Americas, Europe and Asia, including projects in South Africa, Ghana, Côte d'Ivoire, Ethiopia, Tanzania, Australia, the Philippines, Cuba, the Dominican Republic, Russia, Finland, Romania, Papua New Guinea and the United States. He has produced or co-authored over 35 presentations and publications. Dr Assibey-Bonsu's recognition includes a SAIMM Medal, a UNESCO Research Fellowship, VALCO's Best Final BSc Mining Engineering Award, the Geostatistical Association of Southern Africa Best Paper Award, and the 2023 APCOM award. He has served on the SAIMM Technical Committee (Mining) and Council, been an external examiner (including PhD), a JSE reader for feasibility documents, and a member of the SAMREC re-write committee. He reviews for APCOM, SAIMM and AusIMM, delivered the inaugural Prof Danie Krige Memorial Lecture at Wits (2014), and gave the keynote at UMaT's ALUMaT lecture (2018). He is a former Council Chair of the International APCOM Council. Winfred holds a PhD, an Executive Development Programme qualification from Wits Business School, and is a Fellow of SAIMM (FSAIMM).

Time: 14:45 – 15:45 SAST (UTC+02:00)

Panel Discussion 1: Are Integrated Approaches the Future of Mineral Exploration and Resource Geology?

Day 2

22 October 2025

Time: 08:30 – 09:30 SAST (UTC+02:00)

Post-Mineral Resources Estimation Processes

Leon Tolmay

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Tolmay Enterprises

Abstract

Mineral resource estimates are a complex process requiring a knowledge not only of Geostatistics but also of mining, geology, economics, sampling, legal aspects, CRIRSCO code, minerals processing and rock engineering, but to name a few. All these need to be taken into consideration in order to ensure a rigorous account of the resource and reserve base of a particular ore body. All too often resource estimation is considered complete once a single grid of estimated values has been produced. (Normally a 30 by 30m grid). Nothing can be further from the truth, here one has a grid of values that most probably has multiple areas of concern:

1) Is the grid representative of the level of mining selection?
2) Has the estimates excessive amounts of smoothing?
3) Do the estimates suffer from conditional bias due to limited data?
4) Is there smearing of values on the outer extents of the data?
5) Have all structural losses been considered?
6) Have unavoidable sources of dilution been included in the model?

All of these will result in incorrect if not totally erroneous determination of the correct resource declared and will only at best result in reputational damage and at worst huge financial losses to the company involved. This paper will consider these aspects and provide solutions to these that will ensure (to the best of one's ability and levels of data) estimates that provide realistic final resource estimates and realistic and logical levels of confidence. Additionally, the paper will consider what to look out for and indicators of areas of potential

problems, what is required in every case and what is specifically required in some cases. The paper will attempt (insofar as possible) to explain the concepts in as simple a manner as possible, with due cognisance of the fact that some concepts are of a more complex nature.

Leon Tolmay

Leon Tolmay is the Founder and Managing Director of Tolmay Enterprises and an associate of SmartMin. He has more than 45 years of practical geostatistics in the mining and metals industry. Before founding Tolmay Enterprises, Leon served as Chief Evaluator in charge of Geostatistics and Evaluation for the Sibanye-Stillwater Gold Division responsible for all resource and reserve modelling and classification. Prior to joining Sibanye Stillwater, Leon was a lead geostatistics consultant for Goldfields. He also worked as a mining surveyor, chief mine planner and risk analyst. Throughout his career, Leon has created several geostatistics training guides and taught geostatistics as a guest lecturer in institutes of higher learning such as Witwatersrand university. Leon spent the early years of his career under the mentorship of Prof Danie Krige (School of Mining Engineering, University of the Witwatersrand).

Time: 09:30 – 10:15 SAST (UTC+02:00)

Quantifying Environmental, Social and Governance (ESG) parameters into geometallurgical workflows

Evelyn R Manjengwa

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African Rainbow Minerals (ARM) Geometallurgy research chair, Department of Chemical Engineering, Stellenbosch University, Stellenbosch, South Africa

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Abstract

Significant threats tied to prevalent narratives comprising Environmental, Social and Governance (ESG) pressures, and risk tied to the orebody, impact the viability and legitimacy of the mining industry. To address the existential threats confronting mining companies, geometallurgy allows practitioners to enhance exploitation of an ore body through improved knowledge sharing, enhanced predictability of process performance and mine waste management. In this regard the authors present a review that examines how the incorporation of ESG within geometallurgical approaches can reinforce mining company legitimacy. Through an assessment of the relationship between company performance, reputation and risk management, incorporating ESG metrics into geometallurgical programs holds immense potential for enhancing sustainability performance and driving responsible mining practices. A framework is proposed to support the inclusion of non - quantitative variables associated with each ESG metric in a geometallurgical block model. However, there are challenges including technical complexity, data quality, organizational silos, and resource constraints that may limit effective integration of ESG. By emphasising the need for a holistic approach to ESG integration, technical, organizational, and operational challenges will be resolved through investments in data infrastructure, talent development, and stakeholder engagement initiatives.

Dr Evelyn R Manjengwa

Evelyn R Manjengwa is a postdoctoral researcher with the African Rainbow Minerals Geometallurgy research chair at Stellenbosch University. She is a professional engineer and certified ISO series auditor (OHSAS, EMS and QMS) with membership in the Southern African Institute of Mining and Metallurgy (SAIMM). She has worked on projects related to analysis of competitive advantage factors affecting the phosphate industry and business diversification by exploiting e-waste as a secondary resource. She holds a PhD in Chemical Engineering and a Masters in Extractive Metallurgical Engineering from Stellenbosch University. For her PhD research, she looked at enhancing decision-making towards improving mine tailings management. Her research interests include organisational growth, the business of mining, e-waste recycling, waste management and valorisation, water treatment and minerals processing.

Time: 10:15 – 11:00 SAST (UTC+02:00)

21st Century Minerals Reporting Codes

Jacqui Coombes

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Abstract

The Minerals reporting codes have evolved into global frameworks designed to balance transparency, materiality, and accountability. While their foundations remain rooted in geology and estimation, 21st century practice demands far more of Competent and Qualified Persons. Competency today requires not only technical expertise but also a deep understanding of financial markets, regulatory expectations, and the principles of disclosure law. The effectiveness of a public report is ultimately judged by its clarity, reliability, and usefulness to investors, boards, and regulators. This paper examines how international reporting codes under the CRIRSCO umbrella are converging on common principles while responding to jurisdiction-specific regulatory environments such as the ASX Listing Rules, NI 43-101 in Canada, and SK 1300 in the United States. It highlights the critical role of the Competent Person in navigating these frameworks, ensuring compliance, and delivering disclosures that genuinely inform investment decisions. The discussion addresses challenges such as forward-looking statements, materiality thresholds, and the tension between regulatory minimums and best practice. By reframing competency as a blend of technical judgement, market awareness, and communication skill, the paper argues that reporting codes must be seen not merely as compliance tools but as vehicles for trust, confidence, and value creation in the minerals industry.

Dr Jacqui Coombes

Dr Jacqui Coombes is Executive Director of SageAbility, a talent strategy organisation, and serves as Chair of Mining3, Acting Chair of ICRAR, and an advisory board member for MADI, StartUpWA and State of Play. A former Managing Director and CEO of Amira Global, she brings extensive leadership and governance experience across the global minerals sector. Trained as a statistician and mathematician, Jacqui is a geostatistician of international standing with broad expertise across the mine value chain, commodities and jurisdictions. Her academic credentials include a PhD on competency frameworks for the minerals industry, a Master's in Commercial and Resources Law, and a Master's in Geostatistics. She is the author of "The Art and Science of Resource Estimation" and "I'd Like to be OK with MIK, UC?". Jacqui bridges science, governance and finance to deliver actionable strategies, combining quantitative and qualitative analysis to support robust, financially sound decisions. She is a strong advocate of multidisciplinary collaboration between industry, government and academia, and is committed to organisational resilience, talent development and embedding innovation to drive operational excellence.

Time: 11:15 – 12:15 SAST (UTC+02:00)

Mineral Resource Classification – Are we suffering from group think?

Mark Burnett

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Abstract

The mining industry has a history of examples of fraudulent behaviour, resulting in additional regulatory and legislative requirements. Some of the most significant misrepresentations include the American Comstock Lode exaggerations of the 1860's, the Great diamond hoax of 1872, the Australian Poseidon NL boom and bust (1969-70), and the Canadian Bre-X scandal of 1997. The latter episodes resulted in the development of the JORC (1972/1989) and NI 43-101 (2001) reporting requirements. Development of the CRIRSCO Reporting template (2006/2024), allowed for the international standardisation of terminologies. Sixteen standard definitions, applicable to all CRIRSCO members, are defined in the current CRIRSCO International Reporting Template. The basis of a mineral resource estimate classification into categories (Inferred, Indicated, Measured) is traditionally based on geometric criteria - drillhole spacing. The application of geostatistical approaches can offer greater rigour; however, they are data and model quality dependant, computationally complex and often misunderstood by investors (or even technical professionals!).

Although it may appear intuitive or even expected, that a consistent classification framework would be applied to a given deposit type, as exemplified by the GKZ approach, this is not the case for CRIRSCO "compliant" mineral resource estimates. In this context, groupthink is not considered to be a significant concern.

Comparative studies of the methodological approaches used to classify mineral resource estimates reveal significant variability in the confidence classes allocated. The variability seen is due to a number of reasons including methodology used, assumptions made, level of practitioner experience and skill, as well as external influences, such as Agency theory.

As the CRIRSCO family of reporting codes and standards only prescribes minimum thresholds for disclosure, reporting bias and incorrect application of classification methodologies may still occur. When the assumptions underpinning the mineral resource estimation and classification approach used, are not clearly explained, in non-technical jargon, it limits the ability of the potential investor (and their advisors), to make informed decisions and may potentially result in herding (groupthink), a classic example of this being the Poseidon NL boom and bust. Modern societal demands and expectations now require the Competent Person to include environmental, social, and economic aspects into their classification decision, in addition to geological risk and uncertainty. It is posited that while increased mentoring and training may assist in reducing reporting bias and misapplication of geostatistical methodologies, it cannot eliminate geological uncertainty or professional misconduct.

Mark Burnett

Mark is a Principal Geologist at AMC Consultants with over 30 years of experience across the mining value chain, including exploration, shaft sinking, mine operations, mergers and acquisitions, and asset disposals. He specializes in mineral resource estimation, technical reporting, and providing strategic exploration and production advice. Mark is an Executive Member of the Pan-European Reserves and Resources Reporting Committee (PERC), representing PERC on Committee for Mineral Reserves International Reporting Standards (CRIRSCO) and serving as its observer on International Raw Materials Observatory (INTRAW). He contributed to the development of the United Nations Resource Management System (UNRMS) and is a Fellow of both the Geological Society of London (Chartered Geologist) and the Society of Economic Geologists, where he is currently Vice President for Europe. He is a registered European Geologist (EuroGeol) with the European Federation of Geologists.

Time: 13:15 – 14:15 SAST (UTC+02:00)

Simultaneous Stochastic Optimisation of Mining Complexes: From strategic planning to self-learning and remaining challenges

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Abstract

The presentation outlines the simultaneous stochastic optimization of mining complexes, which are considered as integrated engineering systems, where raw materials extracted from mineral deposits are transformed into a set of sellable products while integrating waste management and progressive rehabilitation. This framework manages uncertainty in material types and grades from mines, as well as demand/market uncertainty, for the strategic planning of mining complexes. Geostatistical simulations are a major component of this framework and required input for the simultaneous stochastic optimization of a mining complex; related aspects are explored including conventional or high-order simulations and related effects, number of simulations needed and others. As new digital technologies enable mining complexes to acquire information on performance of different components and flow of materials from mines to products, the extension of the above framework leads to the self-learning mining complexes. These learn from their own experiences to adapt short-term production scheduling decisions and respond to incoming new information, including the updating of simulated mineral deposit properties. While the stochastic framework remains the core element, reinforcement learning approaches are developed to support the self-learning mining complex. Comparisons of production forecasts at gold and copper mining

complexes to conventional deterministic approaches, document the contribution of the technologies mentioned above.

Roussos Dimitrakopoulos

Roussos Dimitrakopoulos is a professor of the Department of Mining and Materials Engineering, McGill University. Holds a Canada Research Chair in Sustainable Mineral Resource Development and Optimization under Uncertainty and is director of COSMO Stochastic Mine Planning Laboratory. Roussos holds a PhD (École Polytechnique de Montréal) and a MSc (UofA). He works on geostatistical simulation, stochastic optimization and artificial intelligence in mine planning production scheduling and project valuation, along with the simultaneous optimization of mining complexes and mineral value chains under uncertainty. He maintains a partnership with AngloGold Ashanti, BHP, Anglo-American, AgnicoEagle, IAMGOLD, Kinross, Newmont, and Vale. He holds several fellowships (FRSC, FCIM, FAusIMM, FSAIMM, FAAIA) and has worked in Australia, North & South America, Europe, South Africa and Japan.

Time: 14:15 – 15:15 SAST (UTC+02:00)

GeoML: Open-Source Python Library for Geological modelling and Mineral Resource Estimation

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Abstract

Machine learning is rapidly becoming ubiquitous in everyday life, particularly with the recent popularization of large-scale natural language models. In geosciences, the adoption of newer methods is growing, albeit more slowly, possibly due to a traditionalist tendency among professionals in the field and the inherent complexity of spatial data. Geostatistics has a history of about 100 years and is now applied in many fields beyond geosciences. Machine learning-based improvements have been applied to geostatistics tentatively, generally in the form of data pre- or post-processing steps, parameter definition, etc., while the core paradigm of this discipline remains the same as it has been for the past few decades. One of the main limitations is the heavy reliance on variographic modeling, which, despite being well-established, requires considerable manual intervention and does not always adapt well to complex, multivariate, or noisy datasets. Recently, the machine learning community developed the Gaussian process, a method quite similar to kriging—commonly used in geosciences—but rooted in Bayesian statistics. This allows the model to effectively learn from available georeferenced data, extrapolating patterns and, more importantly, providing a calibrated measure of uncertainty for its predictions. Unlike classical kriging, the Gaussian process does not require explicit variogram modeling and automatically adjusts to the data, which represents significant advance, especially in high-dimensional contexts or with variables of different natures. The geoML library implements the Gaussian process and its generalization based on variational inference. This generalization enables the modeling of nonlinear relationships between variables, including categorical ones, automatic anamorphosis, and nonstationary correlograms. Recent advances have enabled the creation of a type of neural network based on the Gaussian process, capable of propagating the

uncertainty of random variables in each layer analytically. GeoML can also work with compositional data, robust statistics (without the need for manual grade truncation, for example), and implicit geological modeling. Its applicability extends beyond mineral deposit evaluation to include mineral prospecting over large areas, geophysical data integration, and time series prediction. The machine learning paradigm makes it possible to combine all previously separate stages of spatial modeling into a single, cohesive model capable of extracting maximum information from often scarce spatial data. GeoML is licensed under the GPL v3 license and is available at https://github.com/italo-goncalves/geoML.

Ítalo Gomes Gonçalves

Ítalo Gomes Gonçalves is an Associate Professor at Federal University of Pampa, Brazil. His current line of research is the development of machine learning methods specifically tailored to the mining industry and the geosciences in general. Ítalo holds a PhD and MSc in Mining Engineering (Federal University of Rio Grande do Sul).

Time: 15:15 – 16:00 SAST (UTC+02:00)

Panel Discussion: Are Stochastic Models and ESG the Future of Technical Reporting?