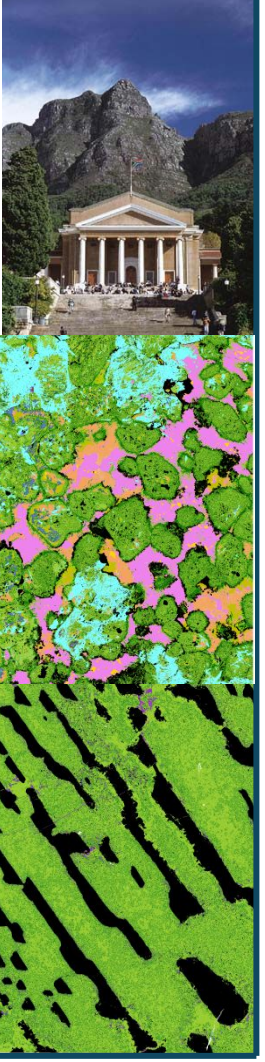


The role of mineralogy in geometallurgical programmes

Megan Becker

Centre for Minerals Research, Department of Chemical Engineering,
University of Cape Town

SAIMM Geometallurgy Conference

14-15 October 2025

CENTRE FOR MINERALS RESEARCH

The pioneers …


FLOT-ATION

BY
A. M. GAUDIN
Research Professor of Ore Dressing, Montana School of Mines

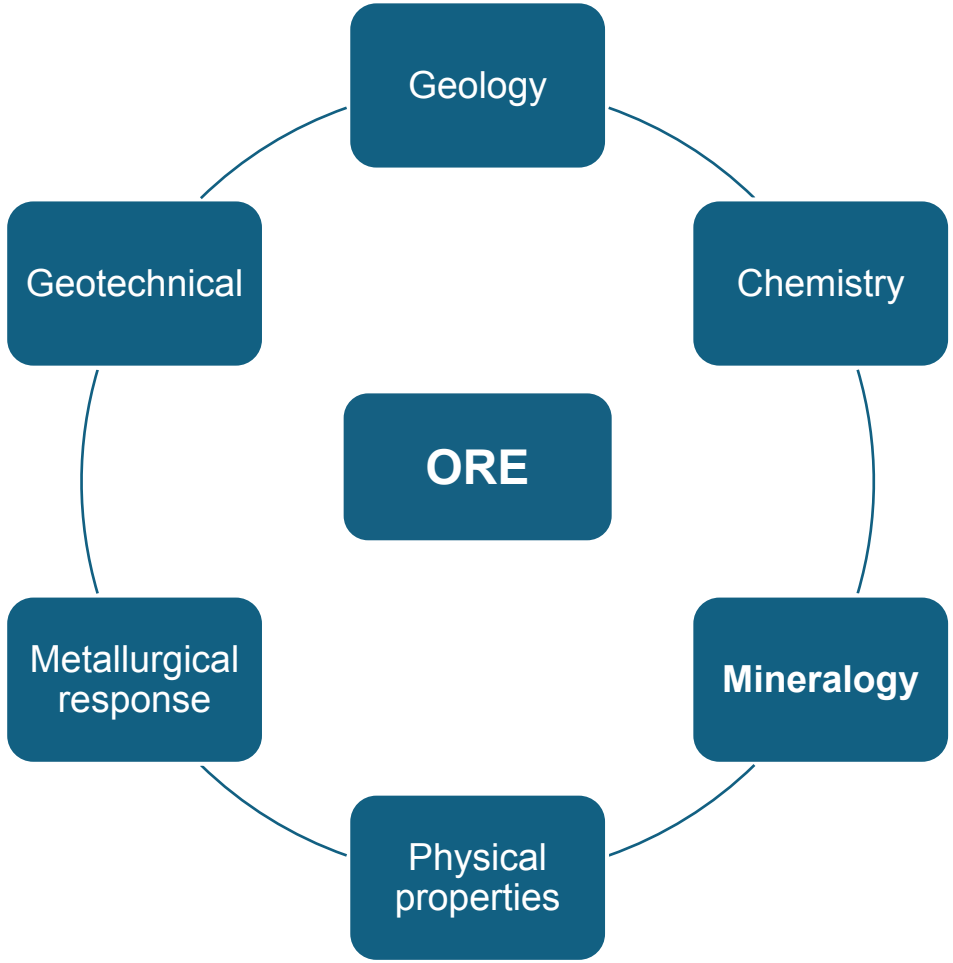
McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1922

'Although inspection of only the coarsest part of an ore pulp is critically severe in respect to the liberation that has been accomplished, it supplies a crude picture of grinding requirements. It is more desirable, however, to quantify the degree of liberation for any one set of grinding conditions by means of quantitative determinations of the percentage liberation' (A.M. Gaudin, 1932)

Recognition of the importance of mineralogy in flotation 93 years ago!

The rise of Geometallurgy

- Integration of the activities as a discipline to manage risk – 1990/2000
- Key components of Geomet mapping (Williams & Richardson, 2004)
  - Define Geomet matrix
  - Use Geomet matrix to guide sampling
  - Ore characterization (includes **mineralogy**)
  - Incorporate data into 3D block model

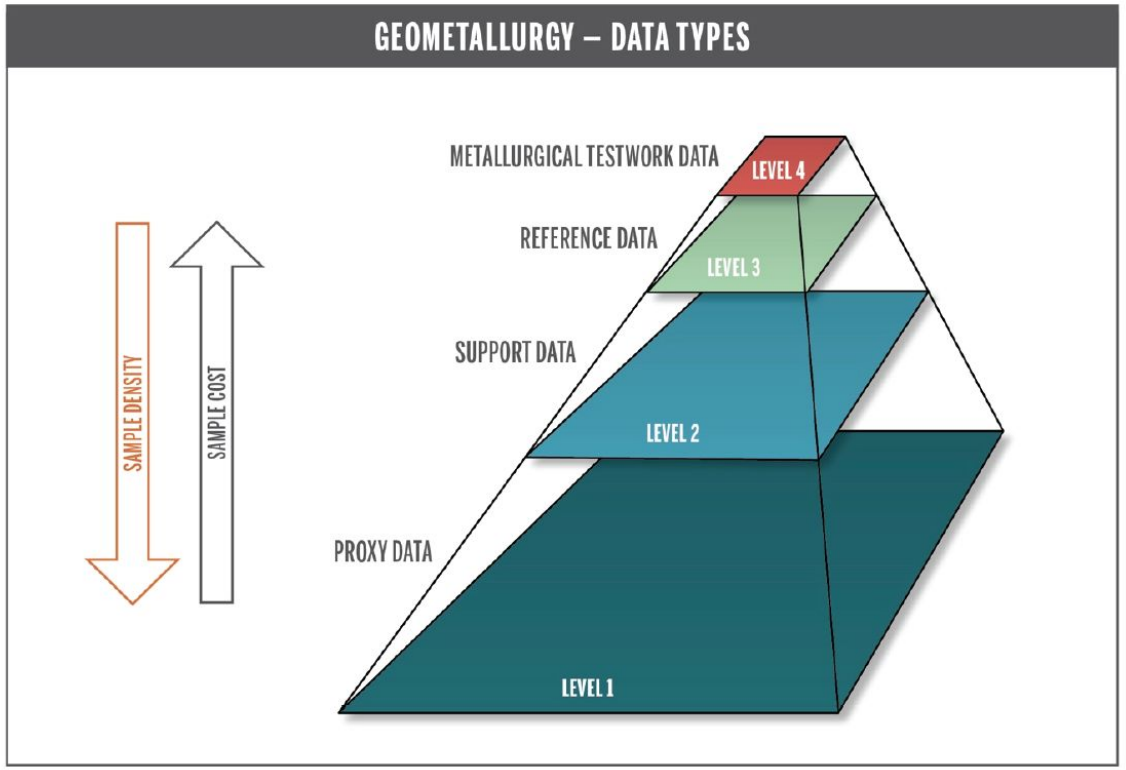


Disciplines contributing to ore characterisation (Williams & Richardson, 2004).

The rise of Geometallurgy

Contribution of AMIRA GEM project (e.g. Walters, 2008)

- The geometallurgy framework construct
- A focus on predictive geometallurgical indices for greenfield applications
- Importance of **mineralogy** also recognized

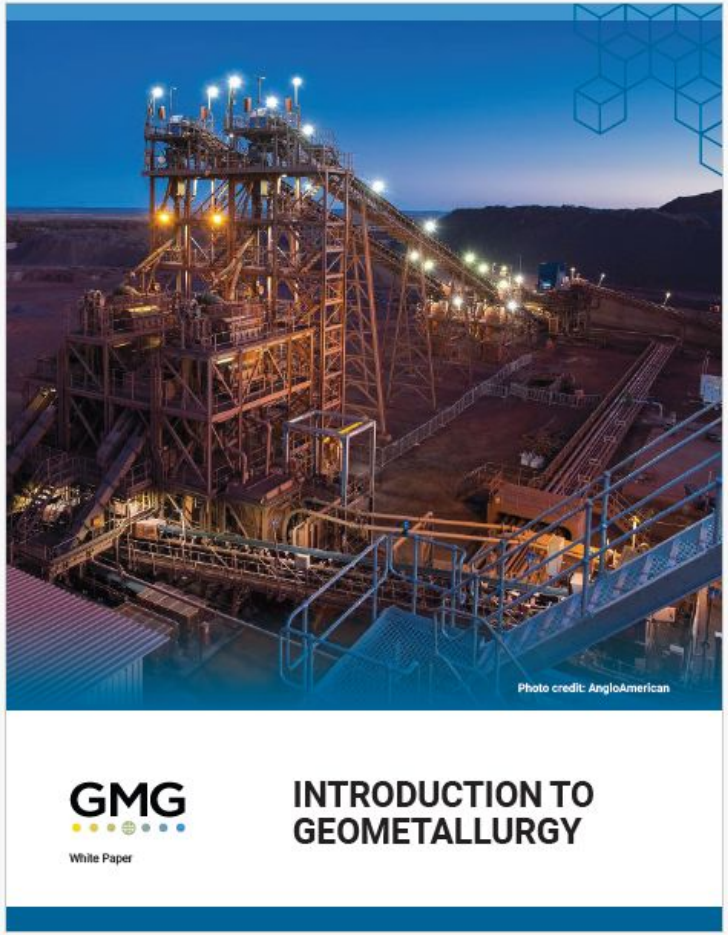


Geometallurgical framework (Cloete et al 2018 and references therein).

Geometallurgy in 2025

GMG ‘Introduction to Geometallurgy’ White paper (Jan 2025)

- Current drivers / focus
  - Data-driven technologies
  - Ore characterization and future resources
  - Waste management and closure planning
- No accepted standards on practice and reporting
- Importance of **mineralogy** also recognized



Where does mineralogy fit in Geomet programmes?

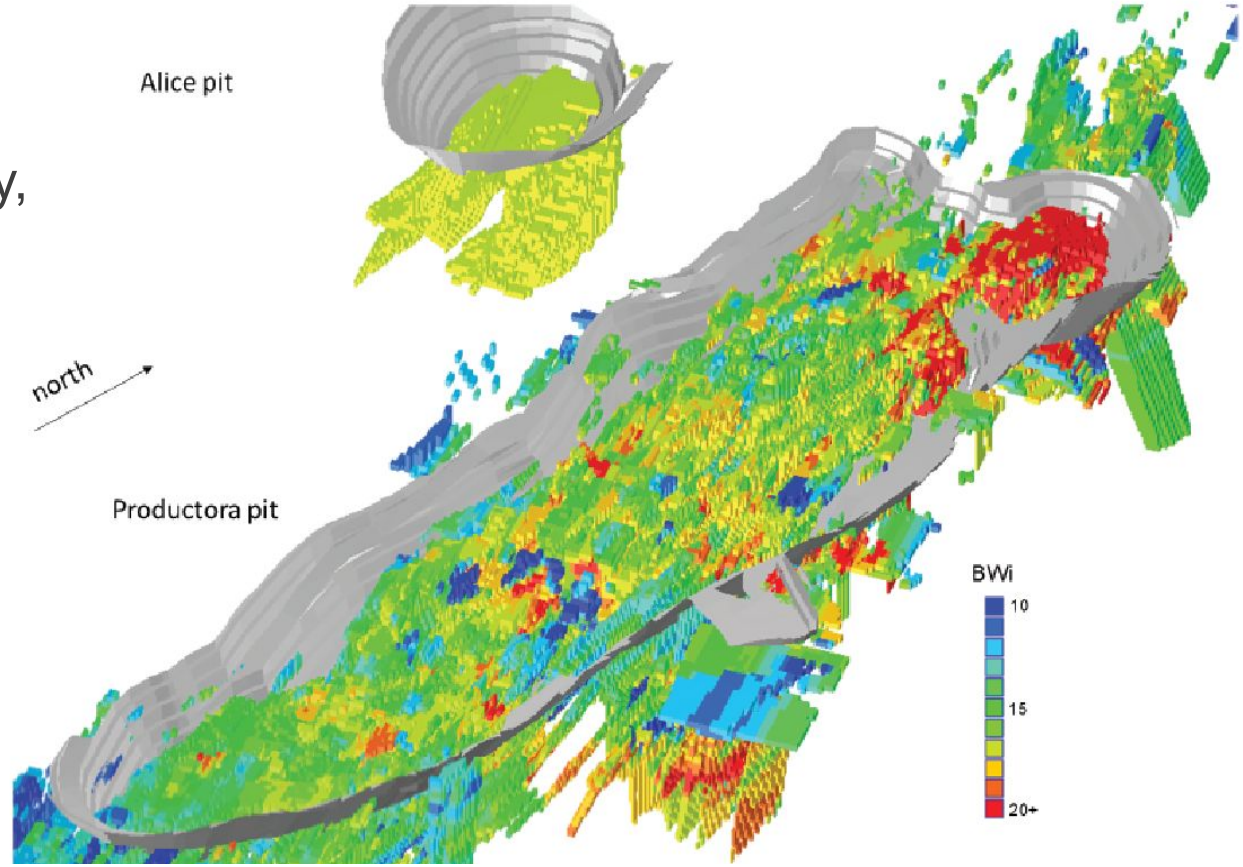
- Traditional approach*
- Proxies approach*
- Mineralogical approach*
- Direct approach?
- Hybrid approach (e.g. fundamental + data driven models, von Stosch et al. 2014)

Supergene copper ore textures

**After Lischuk et al (2015)*

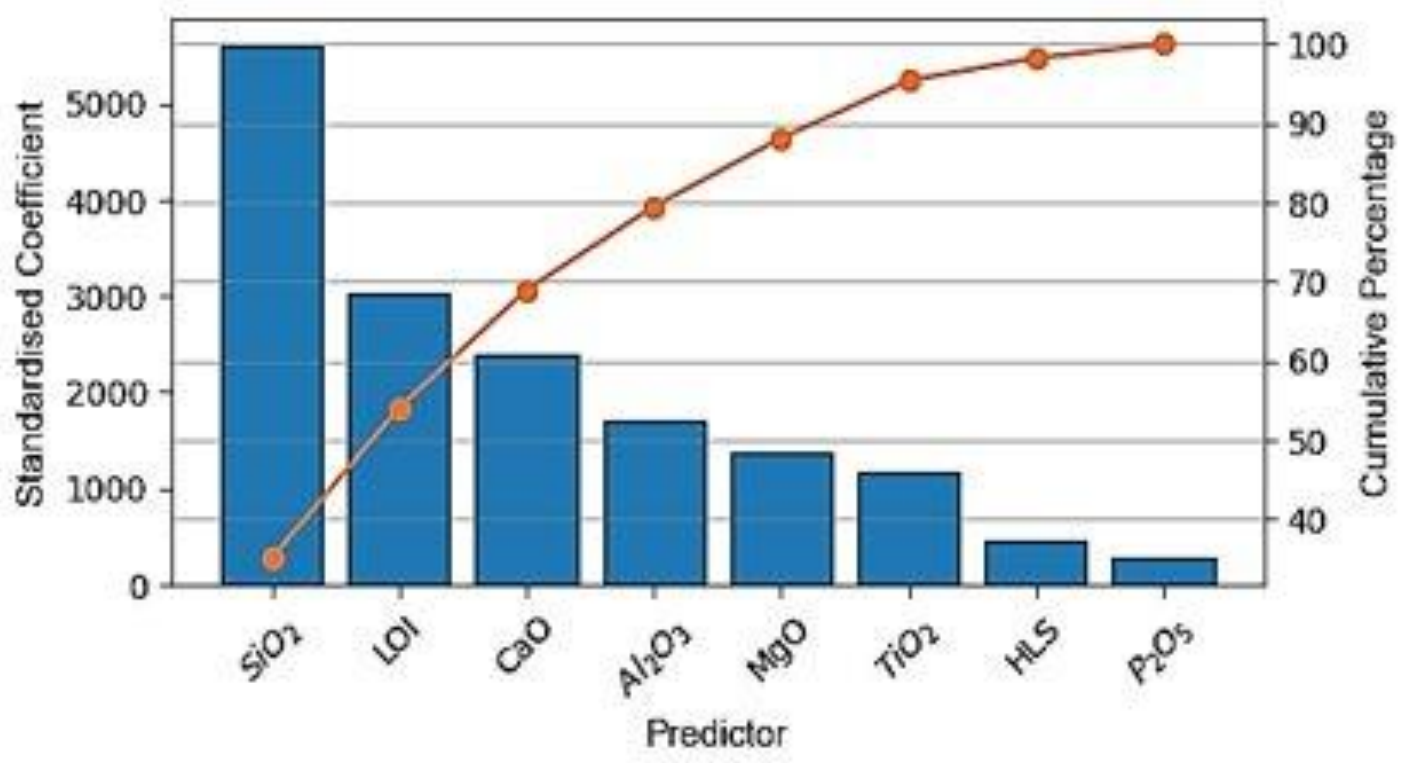
Where does mineralogy fit in Geomet programmes?

Traditional approach - predicting BWI from chemical assays, Productora Cu-Mo porphyry, Chile. King & McDonald (2016). BWi = 0.9796Al + 1.5071K +3.3686



Where does mineralogy fit in Geomet programmes?

Proxies approach – predicting A*b using chemical assays and HLS (Leeb) for cemented hard layers in a mineral sands deposit

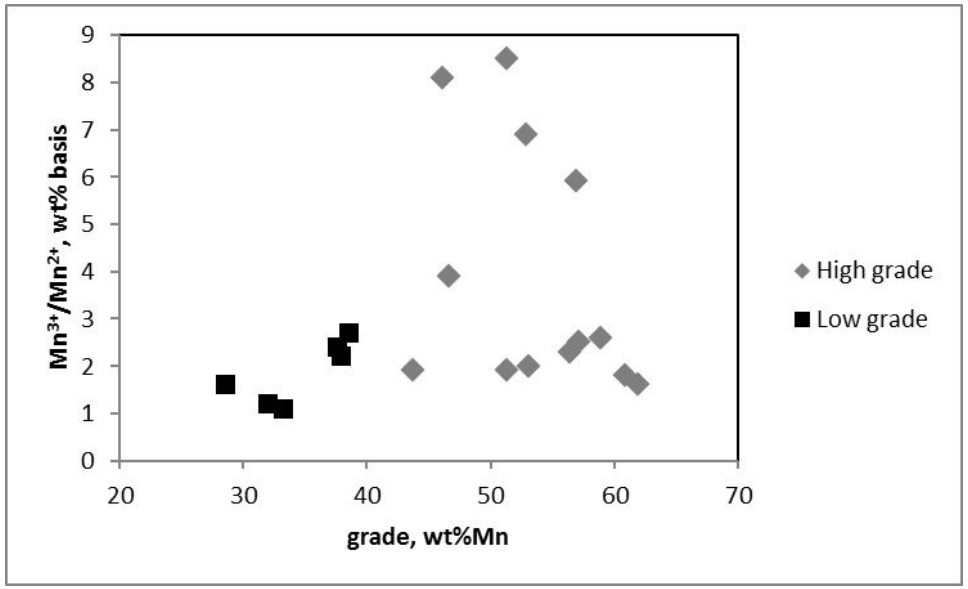


*Sikushumane, M., van der Westhuizen, A., Philander, C. & Becker, M., submitted. Development of preliminary geometallurgical proxies to predict the hardness of the cemented hard layers in a mineral sands deposit. Natural Resources Research.

Where does mineralogy fit in Geomet programmes?

Mineralogical approach - predicting Mn^{3+}/Mn^{4+} ratios from mineralogy as a means to optimise energy consumption in Kalahari Mn smelting (Chetty & Gutzmer, 2016)

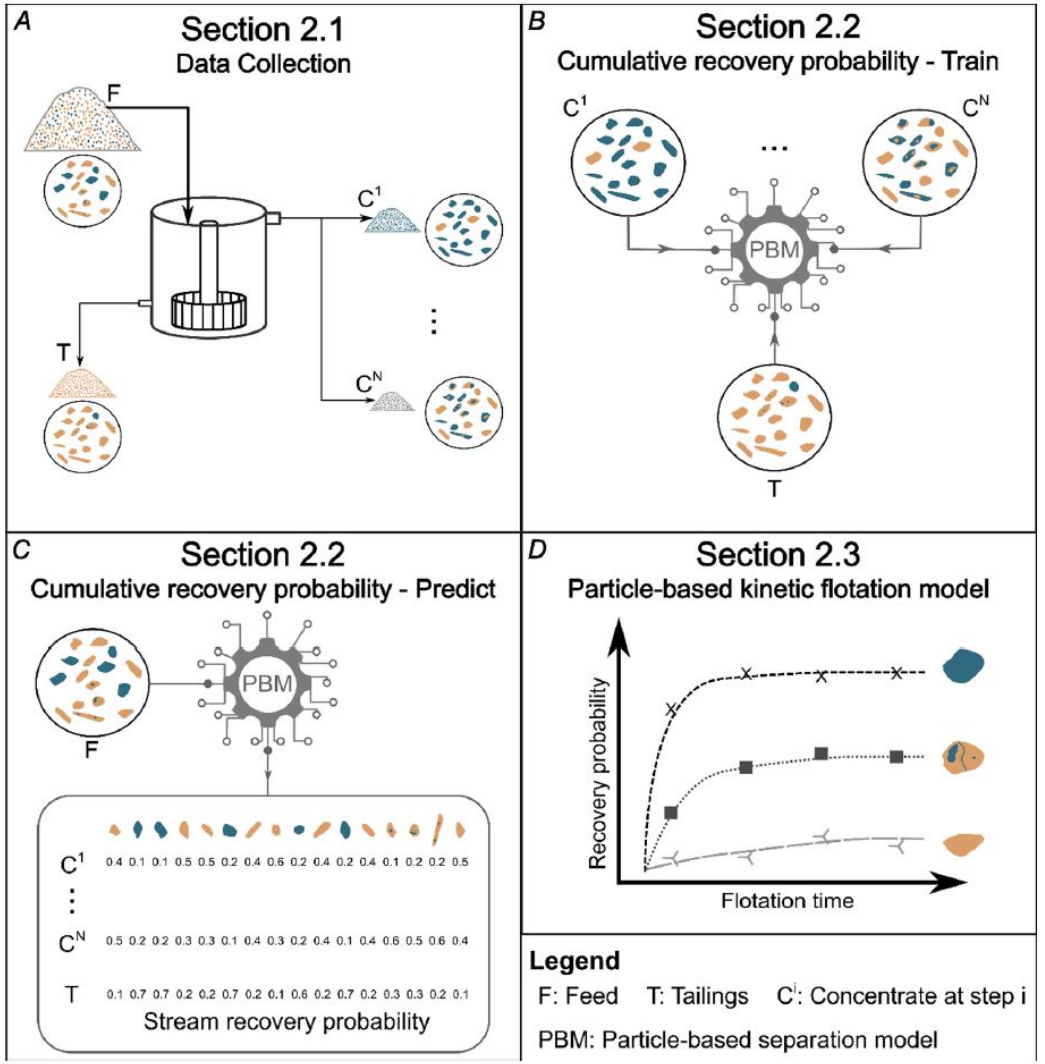
Oxide (nearest mineral)	Grade (wt. % Mn)	O:Mn (molar)	ΔH (kJ/mol)
MnO_2 (pyrolusite)	63.2	2	+213
Mn_2O_3 (bixbyite)	69.6	1.5	+270
Mn_3O_4 (hausmannite)	72.3	1.3	+286
MnO (manganosite)	77.4	1	+274



Ore grade vs calculated bulk oxidation state (Chetty & Gutzmer, 2016)

Where does mineralogy fit in Geomet programmes?

Hybrid approach – predicting flotation recovery using a combination of a data driven particle based separation model combined with a fundamental (1st order kinetic) flotation models … Pereira et al (2021)



The theory statement

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The **mineralogy** is a matrix (blueprint) that encapsulates all the properties of a rock (primary variables) carrying signatures of the ore-forming and subsequent alteration processes. These ultimately define the response to an applied process (response variables).

Mineralogy can be described by:

MINERAL COMPOSITION TRIAD

MINERAL TEXTURE

Mineralogy descriptors: Mineral composition triad

Mineral composition triad is described by

$$b_i = \sum(A_{ij} \times x_j)$$

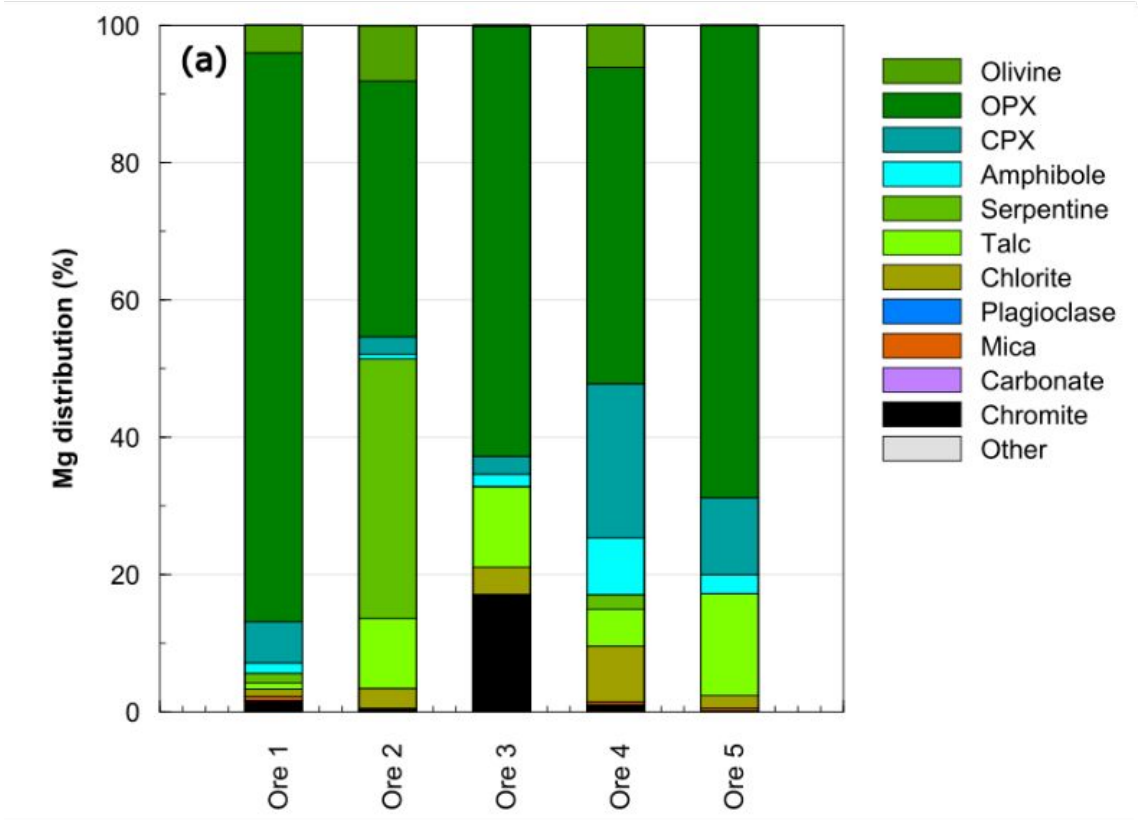
Where:

b_i: bulk chemistry of element *i*

A_{ij}: mineral chemistry (conc of element *i* in mineral *j*)

x_j: grade of mineral *j* in the bulk

- Mineral composition triad can be used:
  - To calculate the element distribution
  - To validate measured mineral grades
  - To calculate mineral grades (EMC)



Using the mineral composition triad to understand element distribution

Mineralogy descriptors: Mineral composition triad

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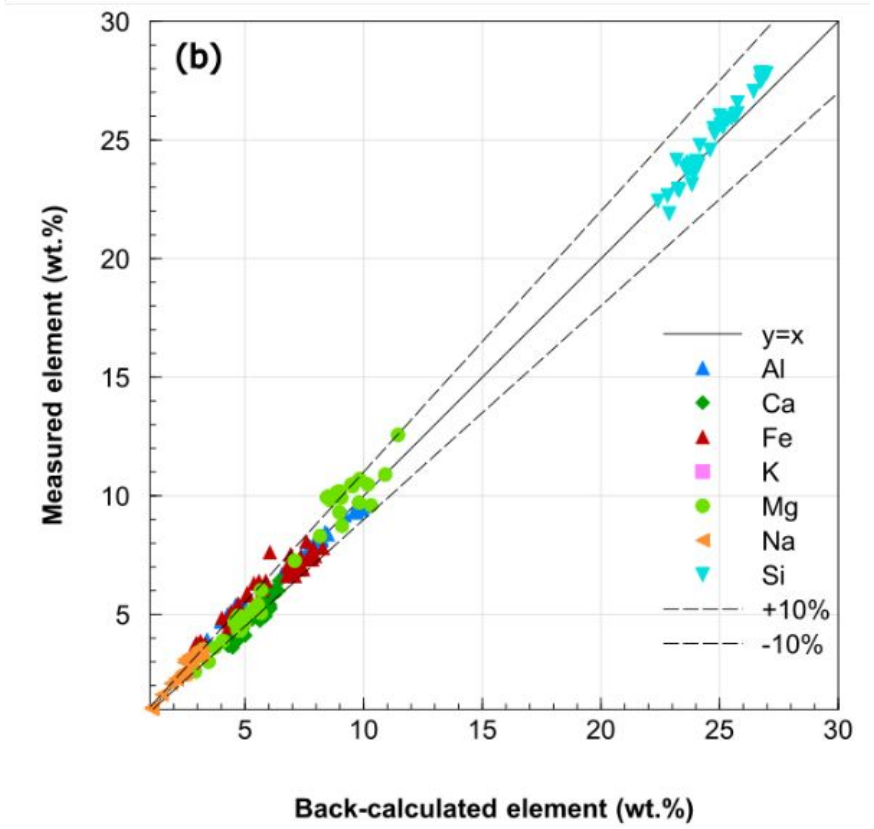
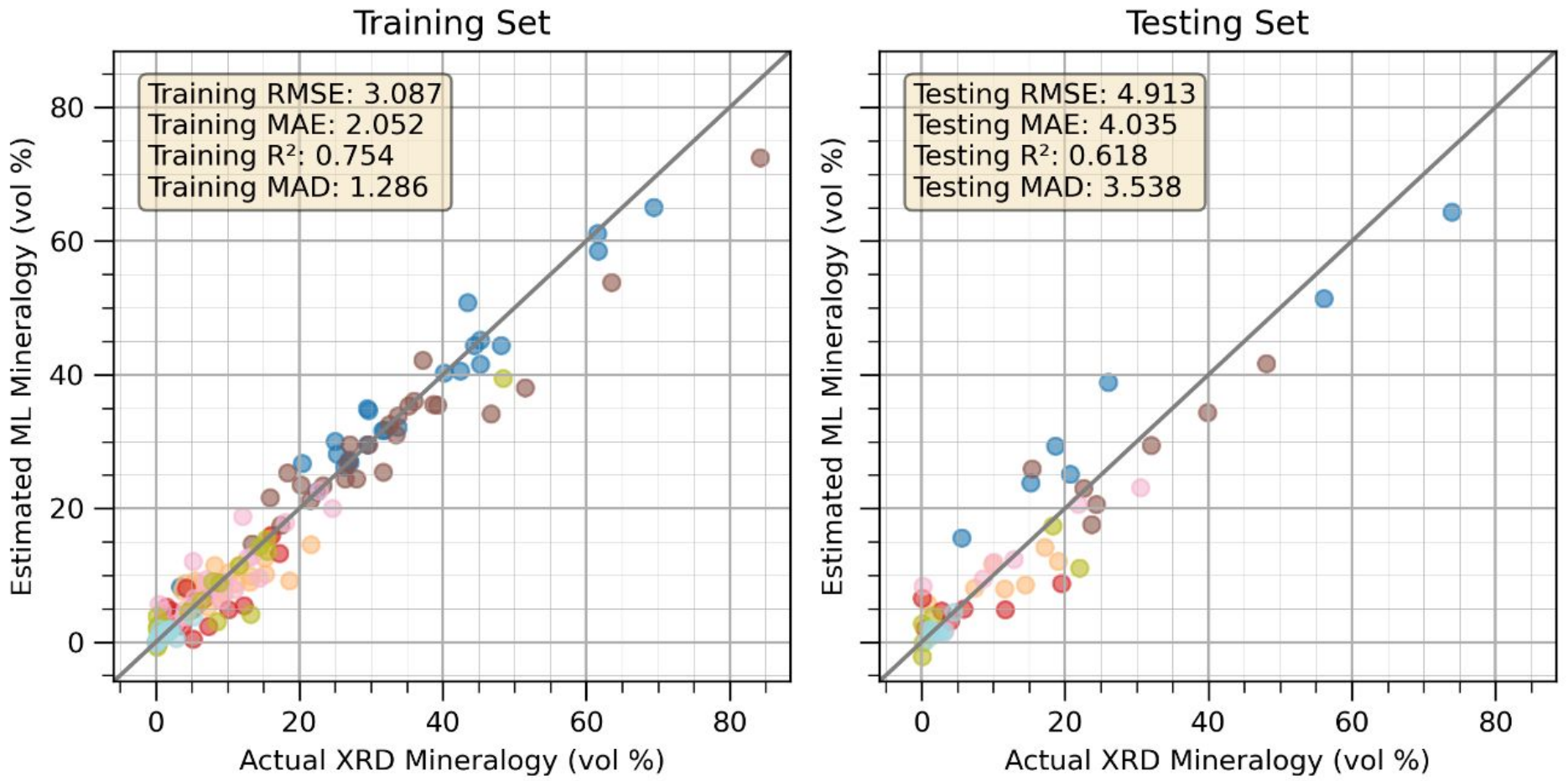


Using the mineral composition triad to validate measured mineral grades

Mineralogy descriptors: Mineral composition triad

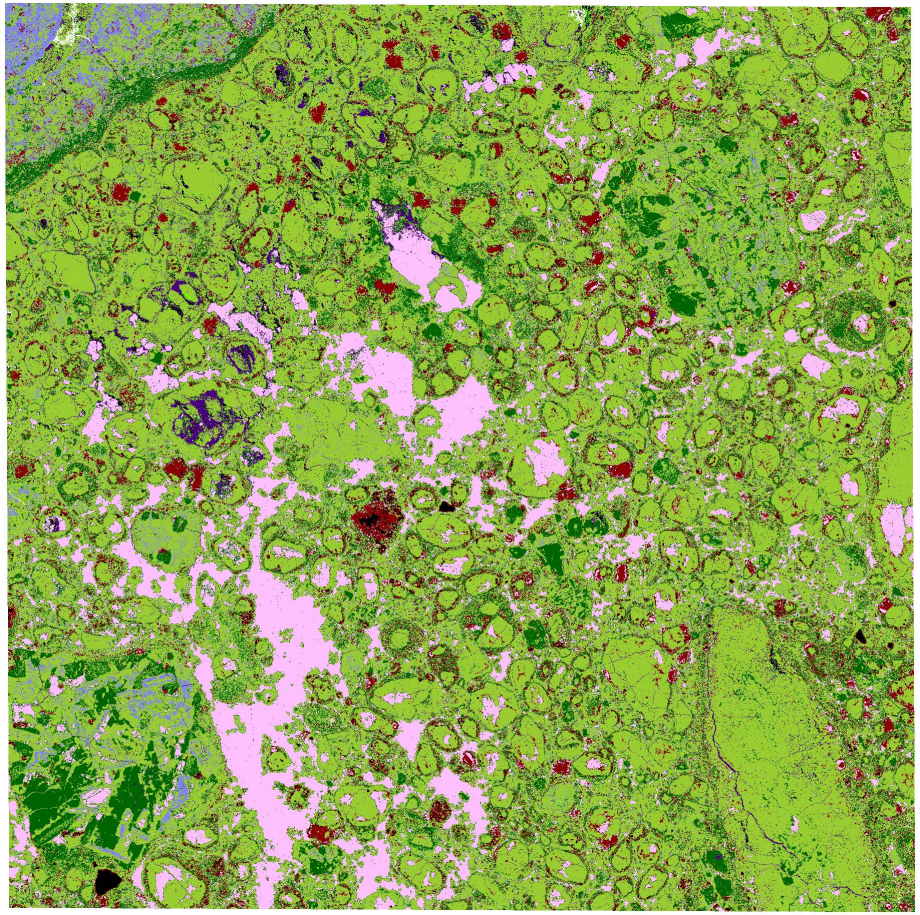


Estimating mineralogy using ML based on the mineral composition triad (Cupido, Burness, Becker & Nwaila, 2024)

Mineralogy descriptors: Mineral texture

The interrelationship between different minerals grains. Some common descriptors:

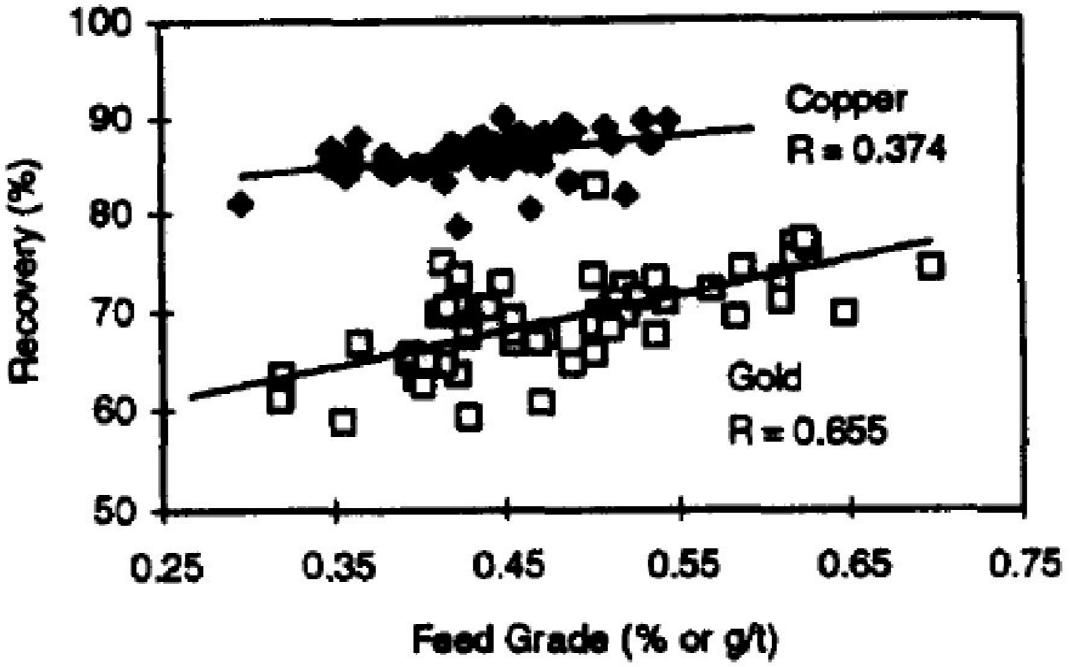
- Grain size distribution
- Grain shape distribution
- Crystallite size
- Associations
- Liberation



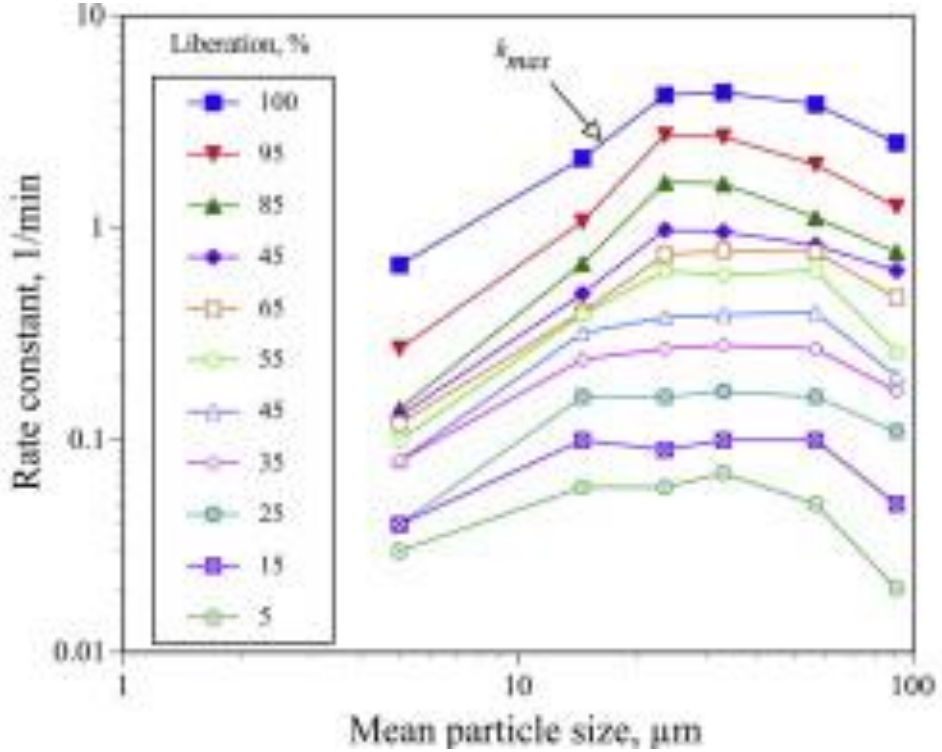
QEMSCAN false colour image of a kimberlite

Linkages between the mineral descriptors

Rule of thumb relationship: Higher feed grades deliver better recovery …



Napier-Munn (1998)

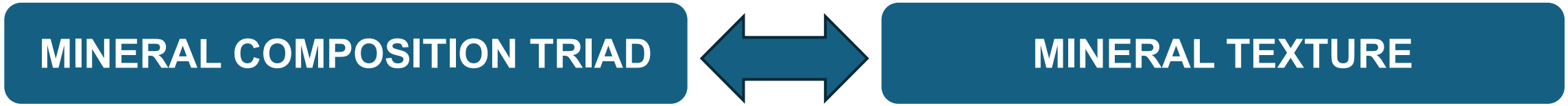


Jameson (2012)

Higher grade ores are expected to have coarser grain size distributions (texture), yielding more liberated particles with faster flotation rate constants

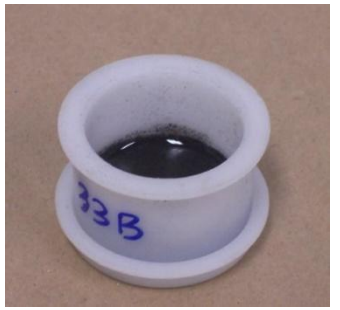
Linkages between the mineral descriptors

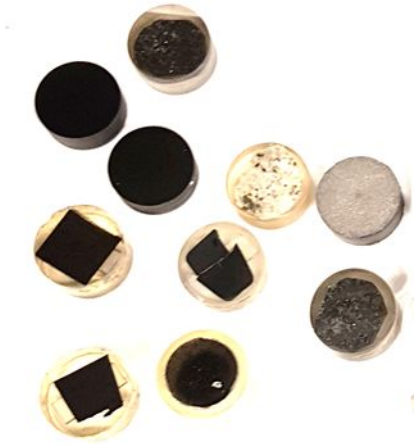
- Valuable element grade (mineral composition triad) – grain size (texture)
- More applicable for high-grade/massive ores (e.g. Von der Heyden et al. 2024)



Key steps in acquiring mineralogy data

- Define the problem to be solved and develop a practical strategy
- Representative subsampling
- Careful sample preparation
- Measurement
- Data validation (incl. parity charts, complementary techniques)
- Processing and reporting (incl. confidence)





Key steps of sample preparation for Auto-SEM-EDS

Applying the theory statement

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The **mineralogy** is a matrix (blueprint) that encapsulates all the properties of a rock (primary variables) carrying signatures of the ore-forming and subsequent alteration processes. These ultimately define the response to an applied process (response variables).

What should we measure for Geometallurgy?

What happens if we cannot prove our theory statement?

What should we measure – ideal vs practical?

- Variability samples
- Composite samples
- Research samples
- Build models that link responses to mineral composition triad or to mineral texture
- Build models that link responses to all available information

Cu-Pb-Zn ore (Photo courtesy: H Gordon)

What happens if we cannot prove our theory statement?

- Was our sampling representative?
- Were our samples presented for mineralogical analysis representative?
- Are our mineralogical measurements accurate?
- Did we measure the correct mineralogical attributes, at the correct scale and use the correct descriptors?
- Did we measure response variables correctly? Are we sure that the effects of different operators, devices and laboratories (i.e. noise) are not ‘louder’ than the true responses?

GMG

Workshop > Type > Events | Virtual > Location | Mineral Processing Working Group > Working Groups

Workshop | Common Data Reporting in Geometallurgy

Published: January 21,2025

What happens if we cannot prove our theory statement?

- Do we fully understand the mechanism of our response variables?

Final thoughts …

- Is the model developed on ‘trusted data’?
- Can the traditional approach deliver the required confidence? Can a combined approach (traditional + proxies) deliver the required confidence? Mineralogical approach needed when mineral texture effects predominate. What is the role of hybrid modelling?
- Does the model deliver the required accuracy for ‘Future-ready’ Geometallurgy?
- Increasing application of data driven models using traditional, proxies & mineralogical approaches

Project stage	Scoping	Prefeasibility	Feasibility	Mining
~ # samples	1 000	1 000-10 000	10 000-100 000	100 000 – 1 000 000
Accuracy	±50%	±25%	±15%	±10%

After Dominy et al. (2018)

Acknowledgements