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Mineralogy as a Predictor of Comminution Behaviour for Merensky Reef Low-Grade Ores

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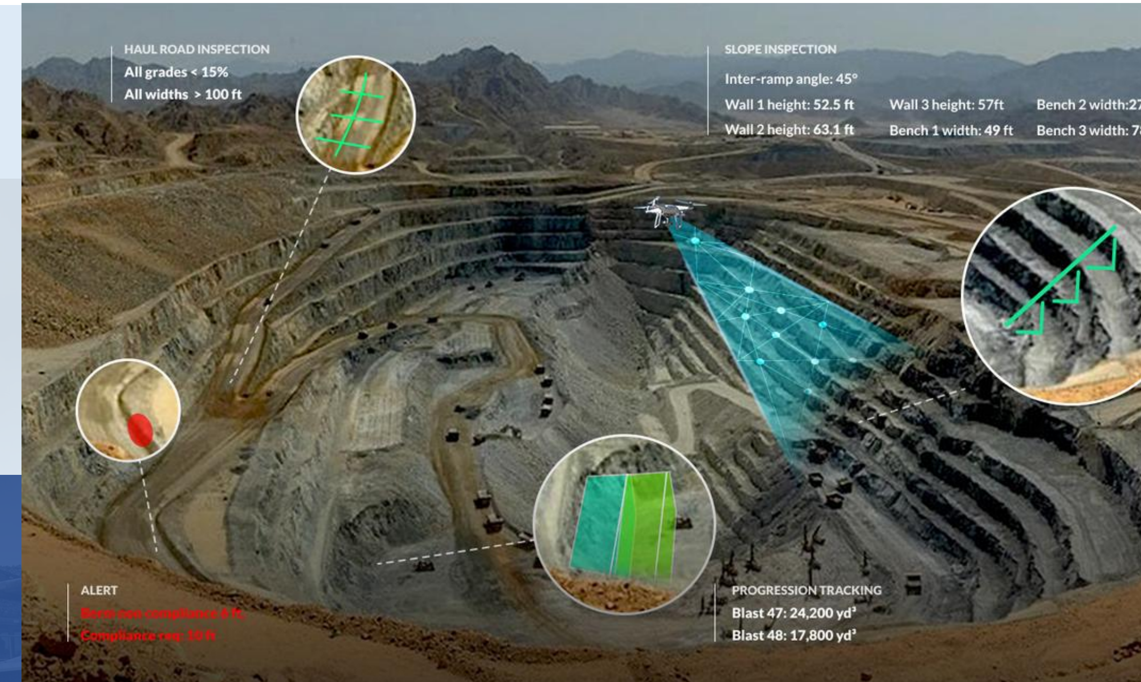

ECSA and SACNASP Validated CPD Activity Credits = 0.1 per hour attended

Geometallurgy Conference 2025

Future-Ready Geometallurgy: Trusted Data, Advanced Tools, Smarter Decisions

13 October 2025 Technical Workshops
14–15 October 2025 Conference
16 October 2025 Technical Visits
Venue: Glenburn Lodge and Spa, Muldersdrift
(1-hour drive from O.R. Tambo International Airport, Johannesburg, South Africa)

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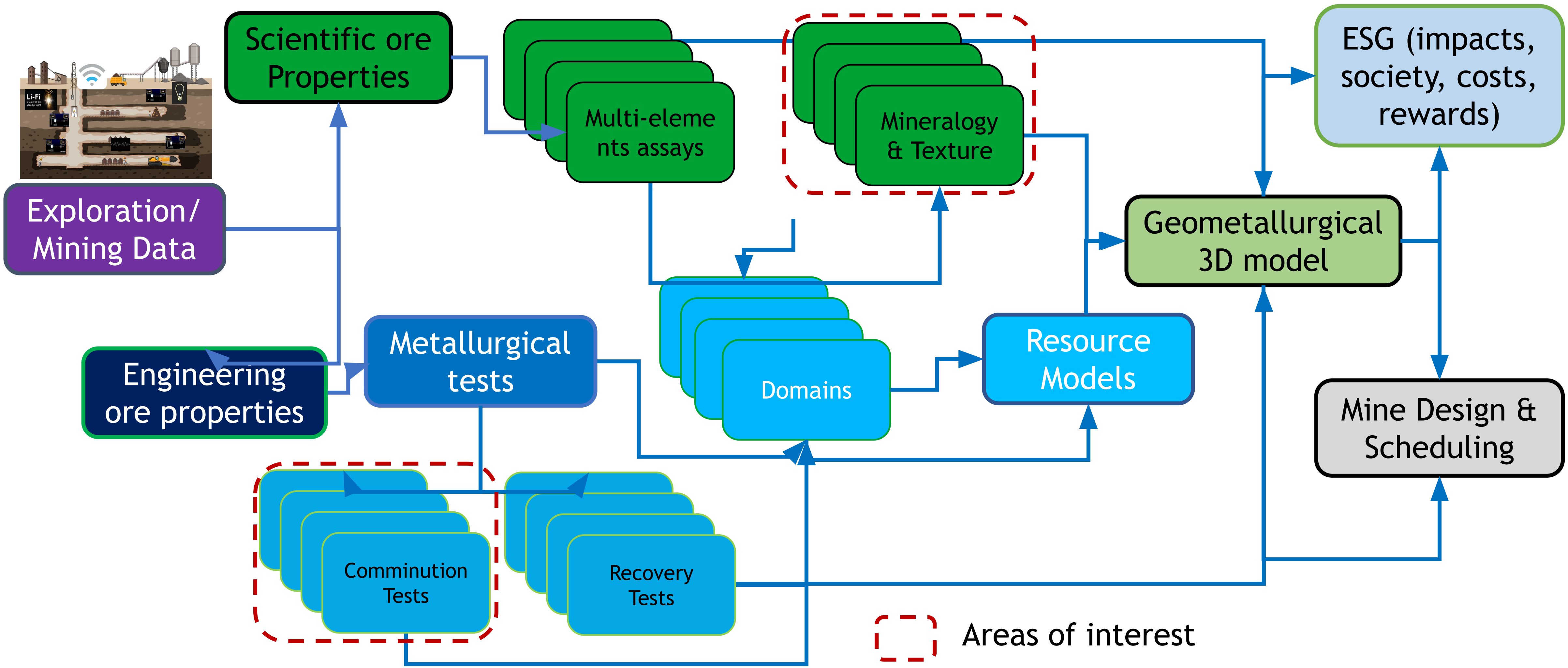
Introduction

- Comminution consumes up to 50% of concentrator energy
- It is challenging to prediction its performance due to heterogeneous ore mineralogy, texture and breakage behaviour
- Conventional comminution models rely on trial-and-error lab tests, ignoring mineralogical effects
- Therefore, we aim to link mineralogy, comminution and Monte Carlo simulation to forecast energy requirements and mineral liberation

Objectives: → Assess mineralogical and textural variability → Evaluate impact on comminution → Apply Monte Carlo simulation for energy prediction

Napier-Munn, 2015; Jeswiet and Szekeres, 2016, Alex

Geometallurgy Workflow Overview



Geological Context

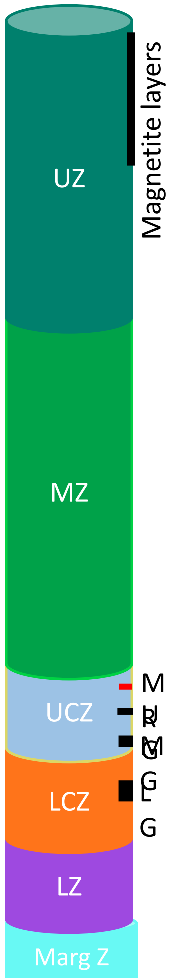
a

b

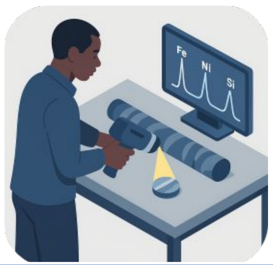
- Drill cores were collected from Impala Bafokeng and subjected them into multi-stage mineralogical and chemical analysis

Workflow

Core



Characterisation and Experimental Testwork



Pre-comminution analysis

- HSI
- pXRF
- TIMA

Comminution tests

- Wet Rod-Mill
- Rod-Work index

Post-comminution characterisation

- TIMA
- Metallurgical tests
- MC Simulation

ML Textural Analysis

Preprocessing

- Image Normalisation
- Denoising
- Contrast enhancement

Feature Engineering

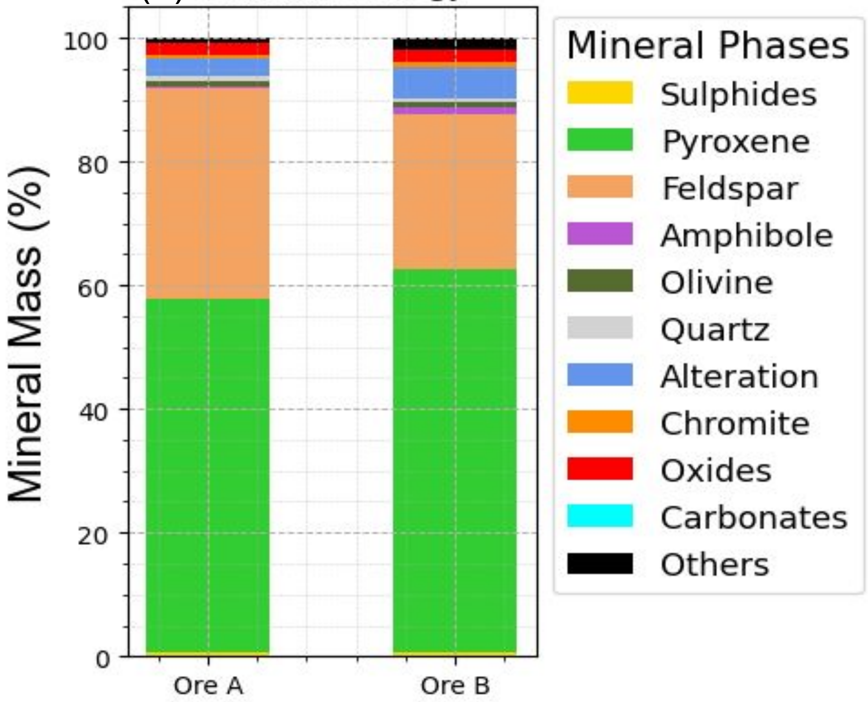
- Local Binary Patterns
- Scharr gradient operator

Region Adjacency Graph Merging

- Boundary gradient < 0.10
- Intensity difference < 0.05
- LBP texture difference < 0.08

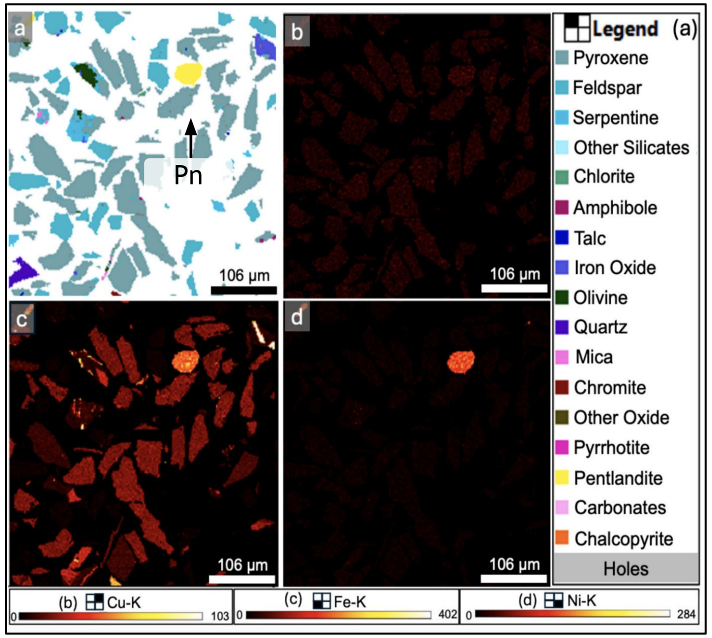
Automated Mineralogy: TIMA Results

(a) Bulk Mineralogy



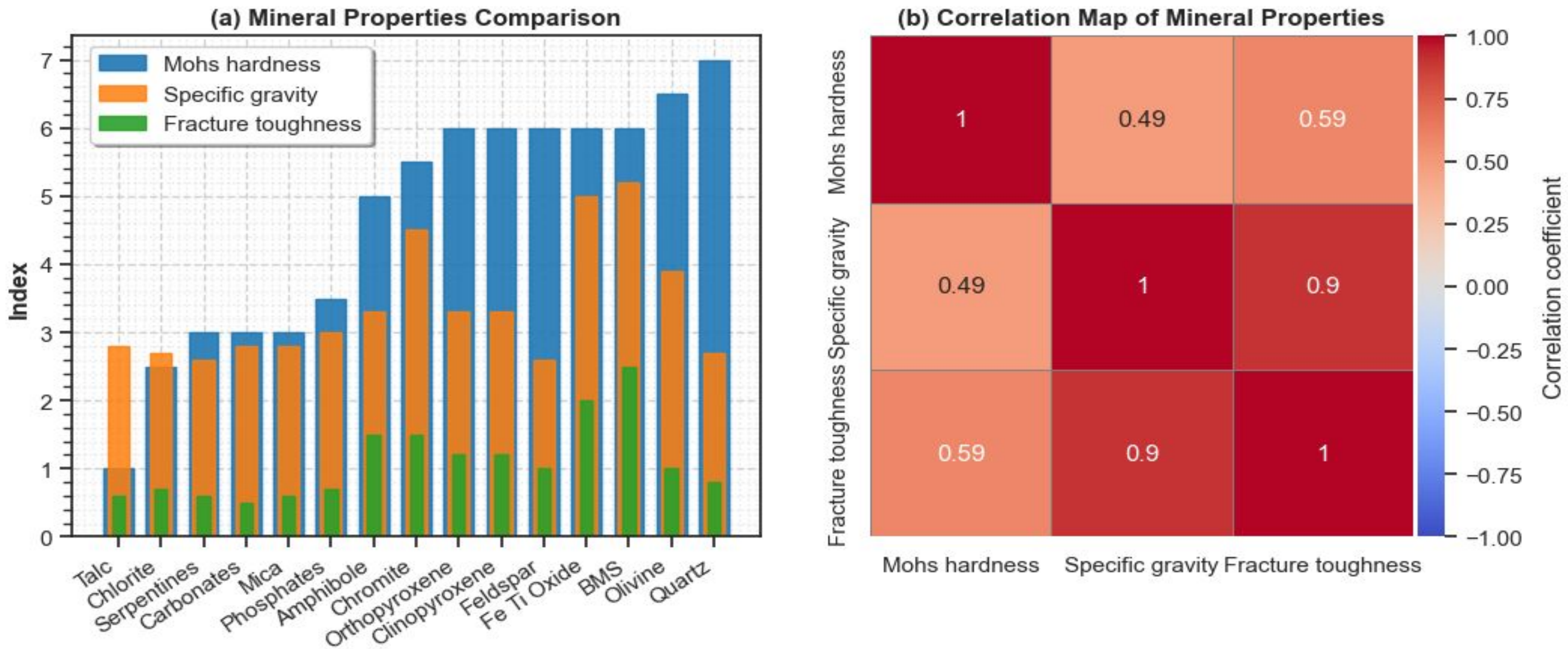
(b) Pre-comminution mineralogy

(c) Post-comminution mineralogy



- Pyroxenes and feldspar are the most dominant silicates, accounting for 91.2 wt.%, 87.4.0 wt.% in Ore A and Ore B, respectively.
- Pre-comminution mineralogy provides inherent ore texture and shows that PGMs are hosted in sulphide minerals.
- Post-comminution mineralogy shows that sulphide minerals are liberated.

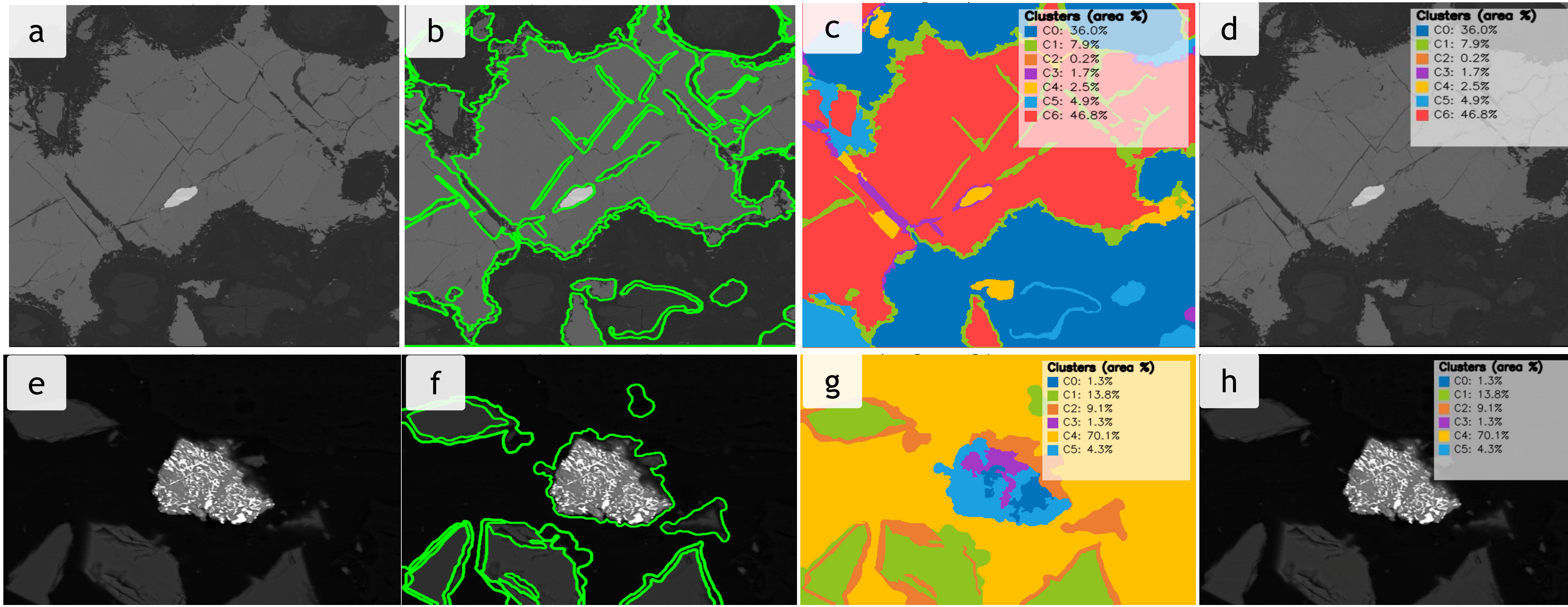
Mineral Properties and Their Influence in Comminution



- Influence of mineral properties in comminution in decreasing order: Fracture Toughness > Mohs Hardness > Specific Gravity

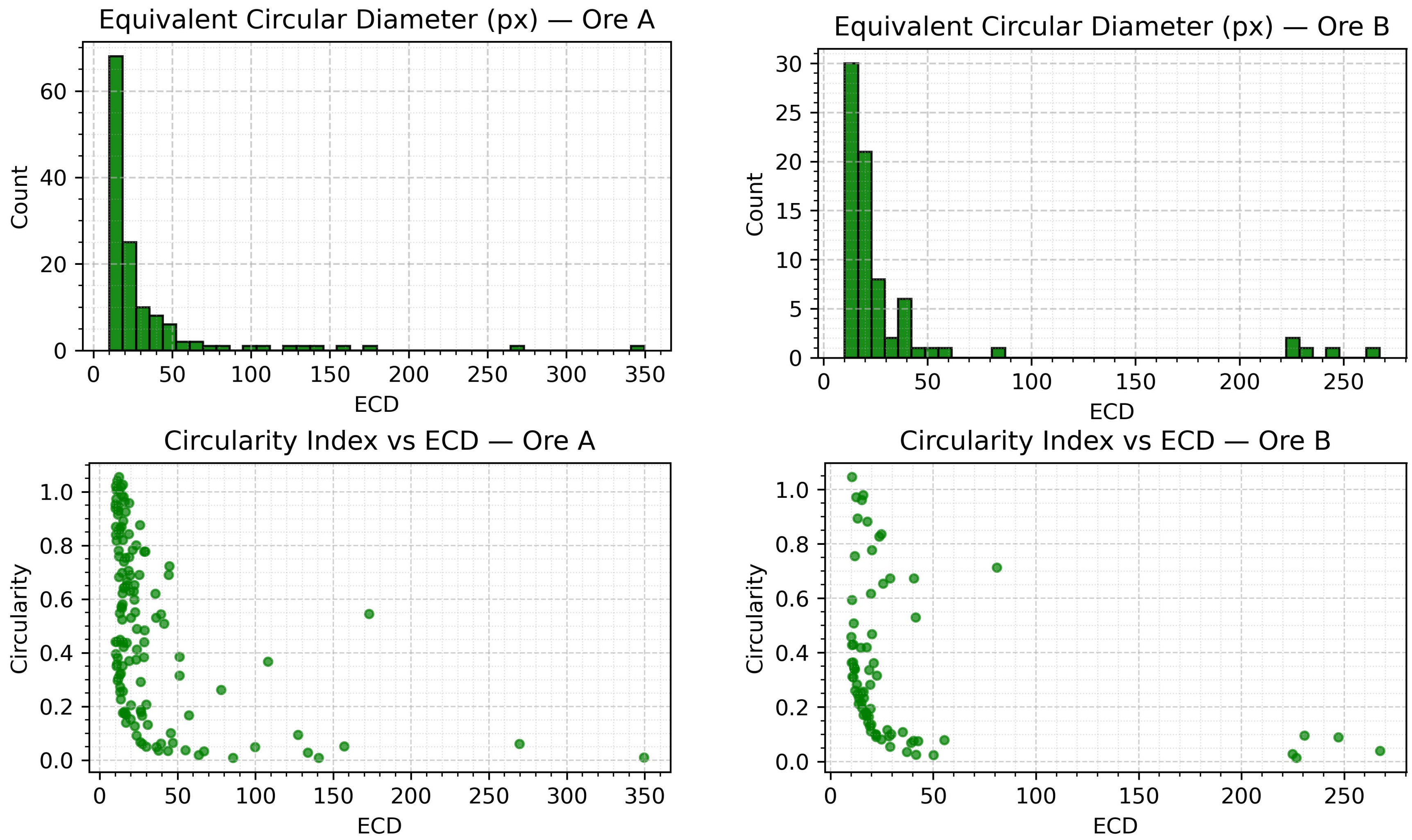
Tromans and Meech, 2004; Broz et al., 2006; Whitney et al., 2007

Texture: Mineral Grain Segmentation



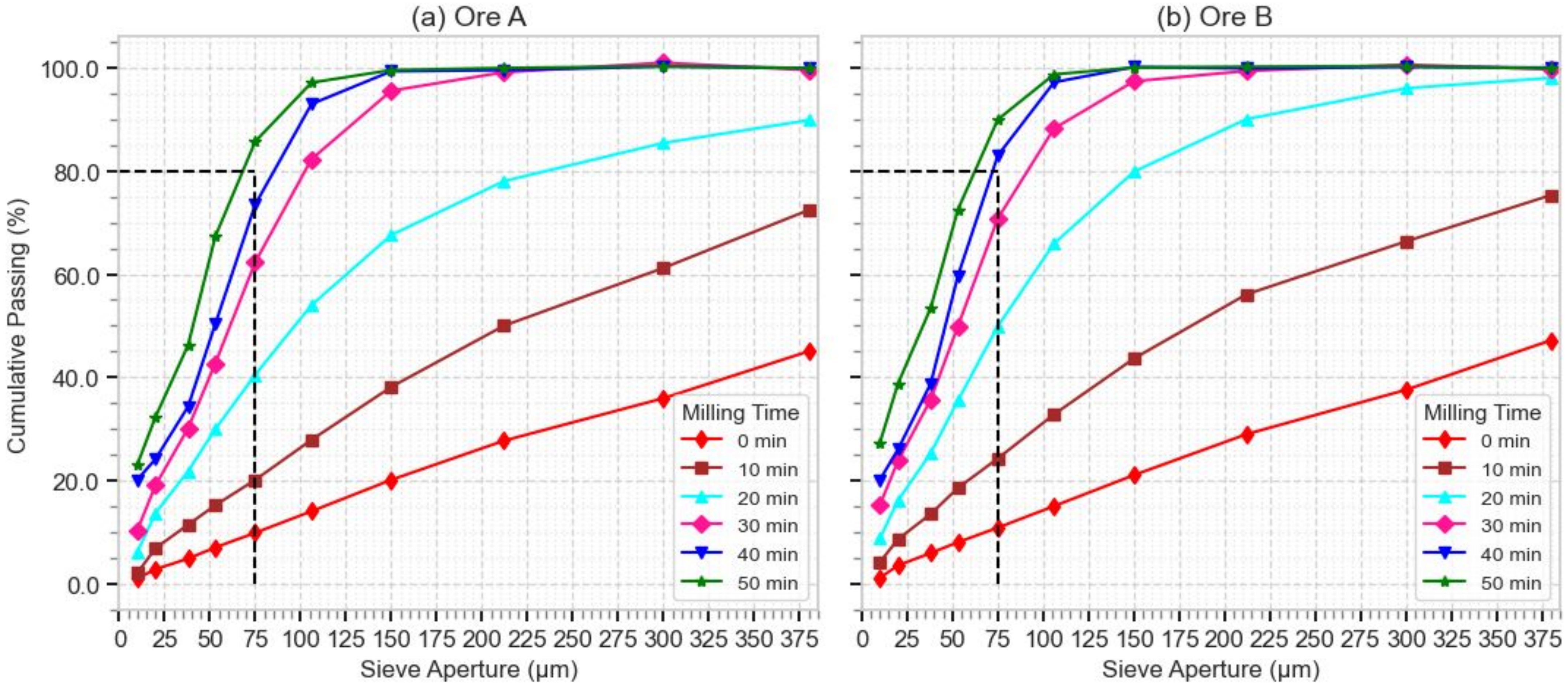
- Unsupervised ML mineral grain segmentation accurately mapped ore texture (green contours) and used BGMM auto-K to cluster grains based on there Boundary gradient < 0.10; Intensity difference < 0.05 and LBP texture difference < 0.08

Mineral Morphometric Analysis



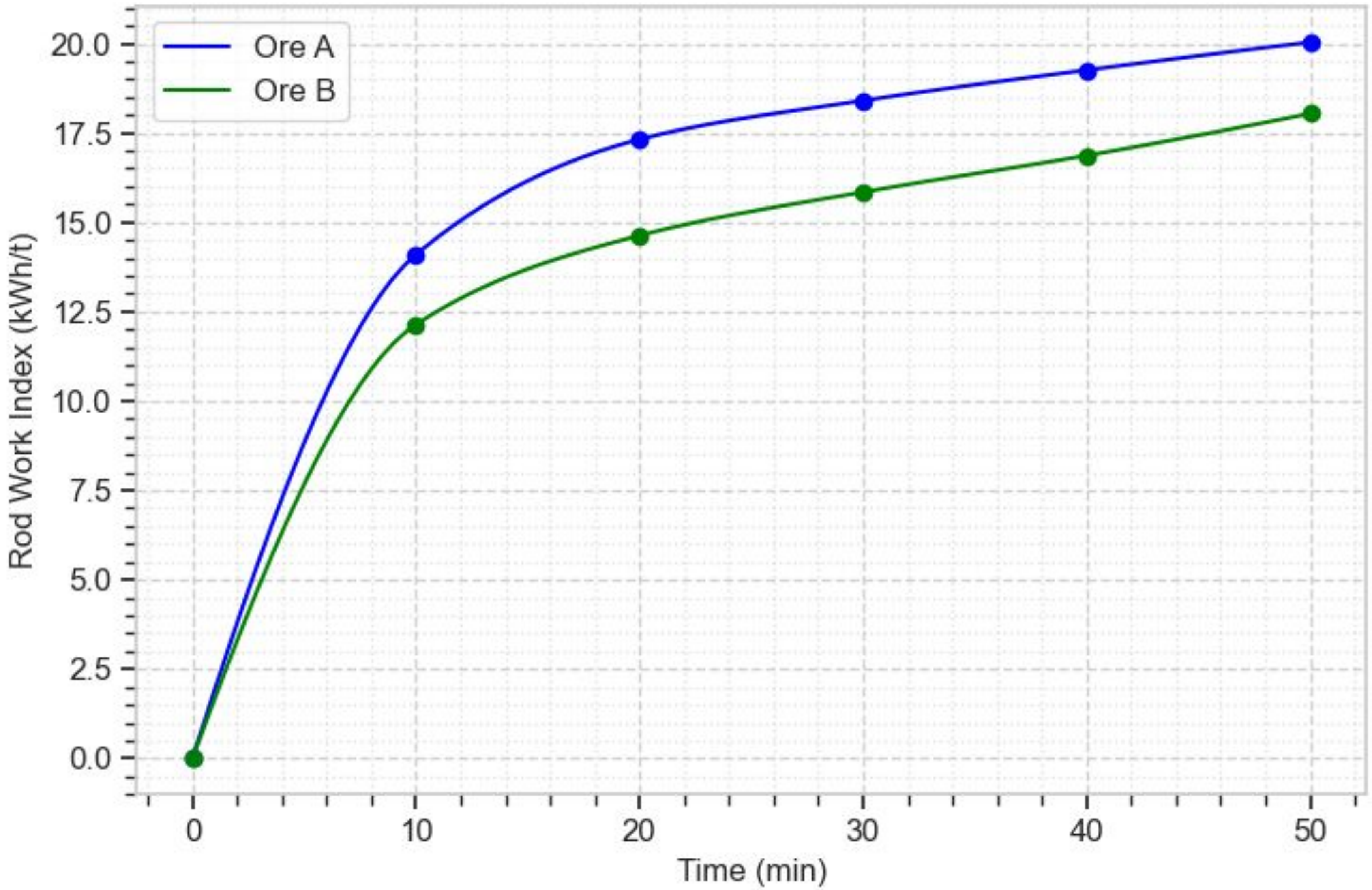
- Ore A have wider ECD (10–350) and more circularity index compared to Ore B with ECD ranging from 10 to 260

Comminution Laboratory Tests

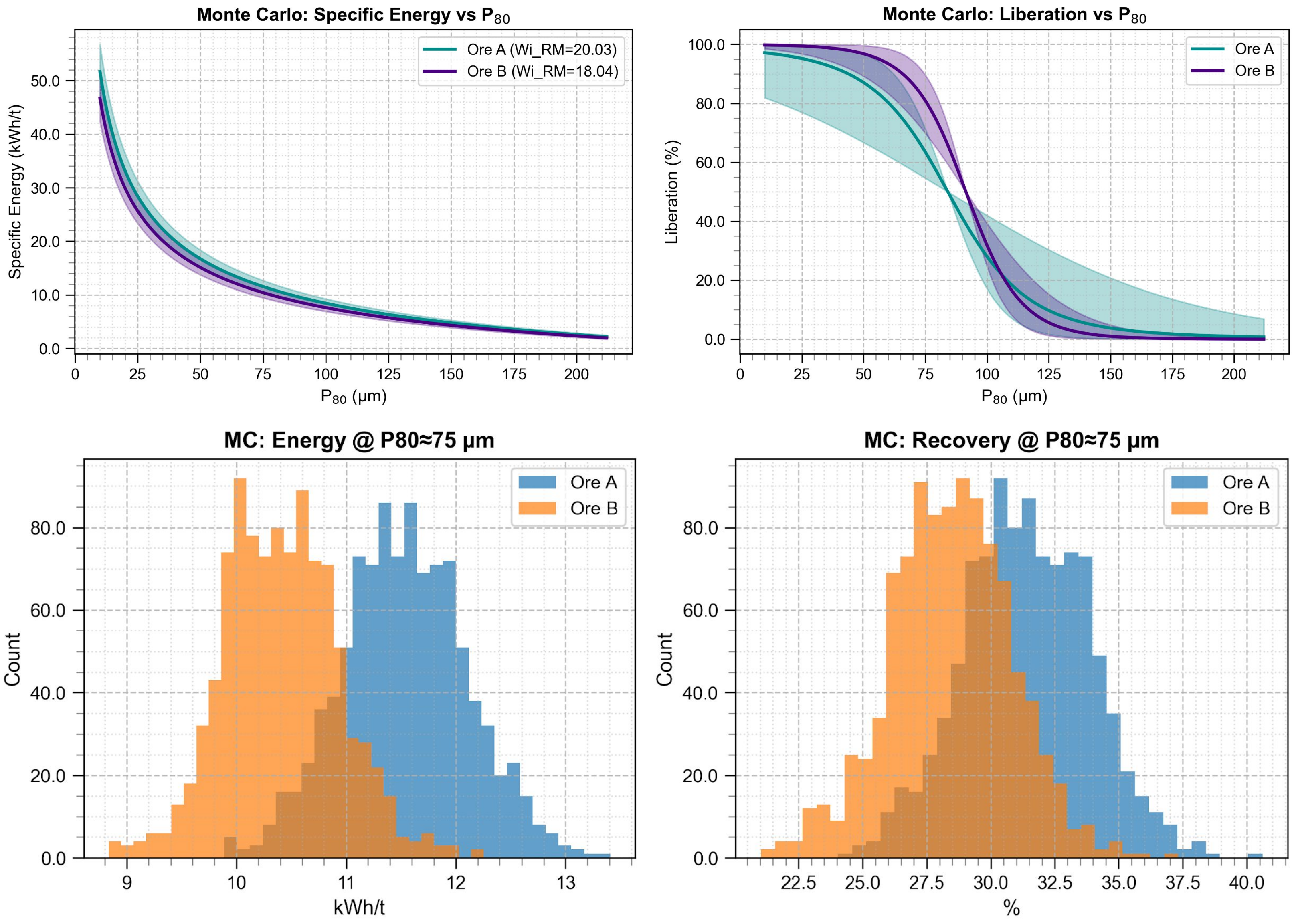


- Ore A is more resistant to comminution than Ore B, with 75% vs 85% passing 75 μm in 40 min

Calculated Rod-Work Index



Monte Carlo Simulation



Mineralogy–Comminution Insights

Mineralogy and texture controls ore grindability, enabling energy forecasts

Microscopic observations allows for prediction of large-scale comminution behaviour

Grain size and morphology variations influence energy use and flotation performance

Uniform and circular grains in Ore A promote consistent breakage; Ore B’s irregular grains promotes selective fracture

Conclusion & Takeaways

ML-based mineral grain segmentation provides fast, cost-effective and real-time high-resolution textural data

Monte Carlo simulations capture ore variability, improving confidence in energy and liberation forecasts

Integrating mineralogy, comminution and probabilistic modelling enables data-driven optimisation of energy use and metal recovery

The approach promotes accurate comminution prediction and informs downstream ore processing synergy

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Sibanye Stillwater

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