Machine Learning-Driven Geometallurgical Evaluation of the Lowermost Manganese Bed in the Kalahari Manganese Field, South Africa

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The Kalahari Manganese Field (KMF), located in the Northern Cape, South Africa, boasts a significant portion, approximately 77%, of the world's known land-based manganese reserves. The focus of the study is on the lower most Mn seam at one of the Mn mines, containing ore of lower grade (<36 wt% Mn), situated in the eastern portion of the KMF.

Using a random forest regression (RFR) algorithm, predictive models were developed to quantify the relationships between ore textures, geochemical characteristics, and comminution behaviour. Six drill cores logged at 50 cm intervals were analysed using XRF data, with textural variations serving as key predictive variables. The Mn content was successfully predicted using ore textures, achieving a high correlation ($R^2 = 0.92$), with "Massive" and "Hematite Lutite" textures contributing most to model accuracy.

This predictive model has direct implications for underground mining optimization. By integrating machine learning into geometallurgical workflows, mining operations can refine ore classification and extraction strategies, reducing off-seam mining and minimizing waste. The model enables real-time decision-making, reducing reliance on costly and time-consuming laboratory analyses.

Comminution behaviour, assessed through relative crushability tests using a jaw crusher, highlighted mineralogy as the dominant factor influencing grindability. Manganese oxide-rich textures exhibit higher crushability, guiding efficient processing strategies.
By leveraging textural analysis and predictive algorithms, this study supports sustainable mining practices through improved resource utilization, operational efficiency, and cost reduction. Machine learning-driven ore classification enhances mine planning, ensuring targeted extraction and extended mine life.