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Estimating Geometallurgical Risk in Undeveloped Complex Orebodies

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ABSTRACT

Demand for most commodities is projected to grow in future and is unlikely to be met by discovery and recycling alone. The implied supply gap will need to be met by existing undeveloped orebodies which have not reached production due to a variety of technical, environmental and social challenges. The SMI is developing a database of undeveloped orebodies and the challenges that they face preventing their development. In the geometallurgical space it is possible to integrate a range of datasets to assess factors such as variability in ore and waste characteristics, amenability to waste rejection and the presence or absence of deleterious elements. These factors are estimated by integrating data from a range of sources including commercial mineral deposit databases, more geologically-focused and deposit type-specific databases, company technical reports and academic publications. The derived information can be used in turn to assess and prioritise research and development strategies to address these challenges. This will be illustrated using the example of over 300 undeveloped copper orebodies representing approximately 1 billion tonnes of copper metal resources. In this database there are clear examples where the key impediments relate to lack of variability, excessive variability and prohibitive levels of deleterious elements, providing a strong basis for continued development of more robust, geologically realistic and high resolution geometallurgical tools to address these challenges.

INTRODUCTION

Analyses of future mineral demand show that there is a shortfall in many commodities which will not be met by new discoveries and recycling (eg Ali et al 2017). Known and underveloped Complex Orebodies (locked up due to Environmental, Social, Governance or Technical challenges) represent a significant source of additional potential supply to meet this shortfall. The aim of this contribution is to assess the role of geometallurgical complexity in undeveloped copper orebodies, to better assess the potential opportunities associated with innovations in this area.

METHODOLOGY

The analysis of geometallurgical risk used as a starting point a database of 308 undeveloped copper deposits extracted from the S&P Market Intelligence database. Deposit information within the database is based on mining company public filings and related public domain information. The deposits were chosen on the following basis:

- A resource of greater than or equal to 500,000 tonnes of copper metal; and
- An activity status which did not include the terms "Operation", "Expansion", "Commissioning" or "Construction Started"

Deposits in the database matching these criteria amount to approximately 1 billion tonnes of copper metal

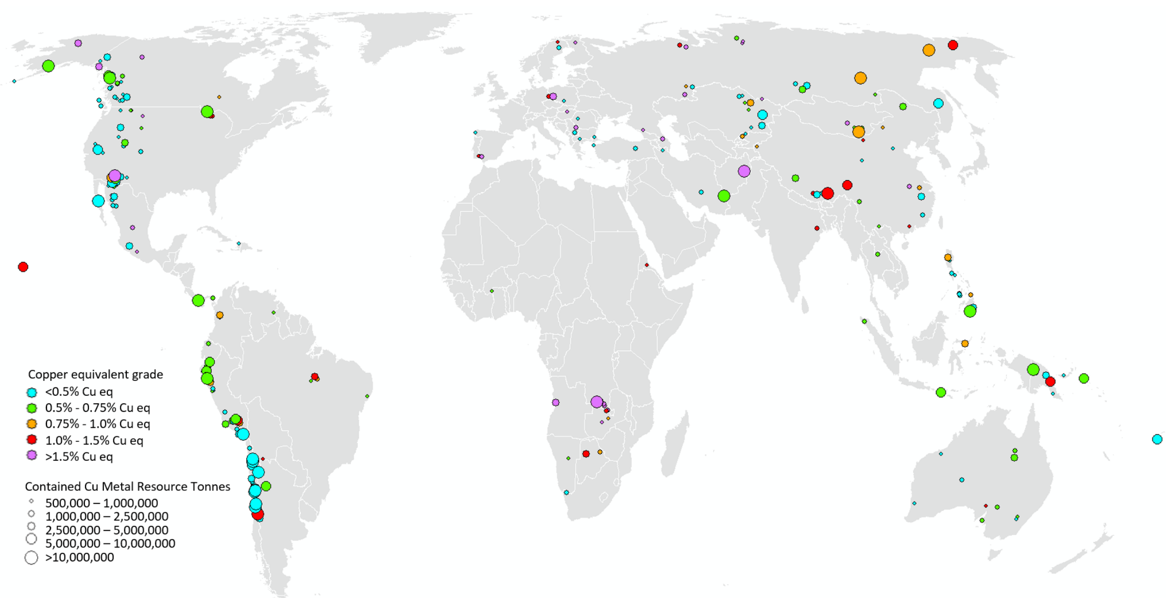

Figure 1 Locations of Cu deposits in the database, sized by tonnage and coloured by copper grade

The distribution, copper equivalent grade (based on copper and gold) and resource in tonnes of copper metal are shown in Figure 1. Proxies were developed to asses several criteria relating to potential project development risks, including Copper Grade, Water, Tailings, Variability, Permitting, Legal, Local Community, Land Pressure, Poverty, Arsenic, Biodiversity and Infrastructure. The subset of these risk areas considered for the analysis of geometallurgical risk included Mineral Variability, Grade Variability, Arsenic, and Tailings.

Mineral Variability

The rationale behind the assessment of mineral variability as a potential geometallurgical risk is the assumption that a deposit with multiple copper minerals and several different mineralized zones will be inherently more variable in its processing response than a deposit in which all the copper is contained in a single copper mineral and within a single identified zone. From a geometallurgical point of view, the complexity of a deposit with multiple copper minerals and zones is likely to be greater, so the proxy used to assess this factor was a simple count of minerals and zones for each deposit. Each zone was treated separately, so if a single mineral occurred in multiple zones it was counted multiple times. A Cu grade-tonnage cascade plot color-coded by mineral variability is shown in Figure 2.

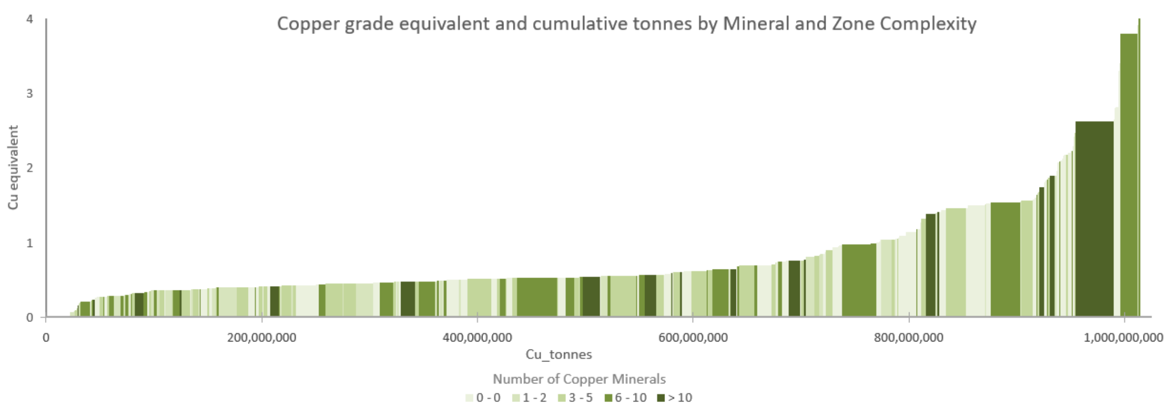

Figure 2 Cu grade-tonnage cascade plot color-coded by mineral variability

Grade Variability

One of the factors which can potentially contribute to the viability of a mining operation is the presence of grade heterogeneity at an exploitable scale (eg Claassen, 2016). Should this variability not be present at a scale which can be documented in a block model or mining unit, it becomes important to assess the potential for waste rejection strategies at a sub-mining unit scale (eg Walters, 2016). This factor was assessed by making a comparison of resource cut-off grade and average grade for deposits in which both measures were recorded. Of the 308 deposits in the database, 143 had cut-off grades which were recorded in the database or available from other public sources.

The ratio of resource Cu grade to resource Cu cut-off grade is shown in Figure 3 for the 143 deposits for which information was available. Given that grades in most mineral deposits approximate a lognormal distribution (eg Rossi and Deutsch, 2014), a low ratio of average grade to cut-off grade implies that most mining blocks within the deposit show grades close to the cut-off grade. Of the 143 deposits for which there was data, 65 showed a resource grade of less than 0.75% Cu and low to moderate variability. In such cases, the identification and exploitation of grade heterogeneities at sub-mining unit scale is likely to be important.

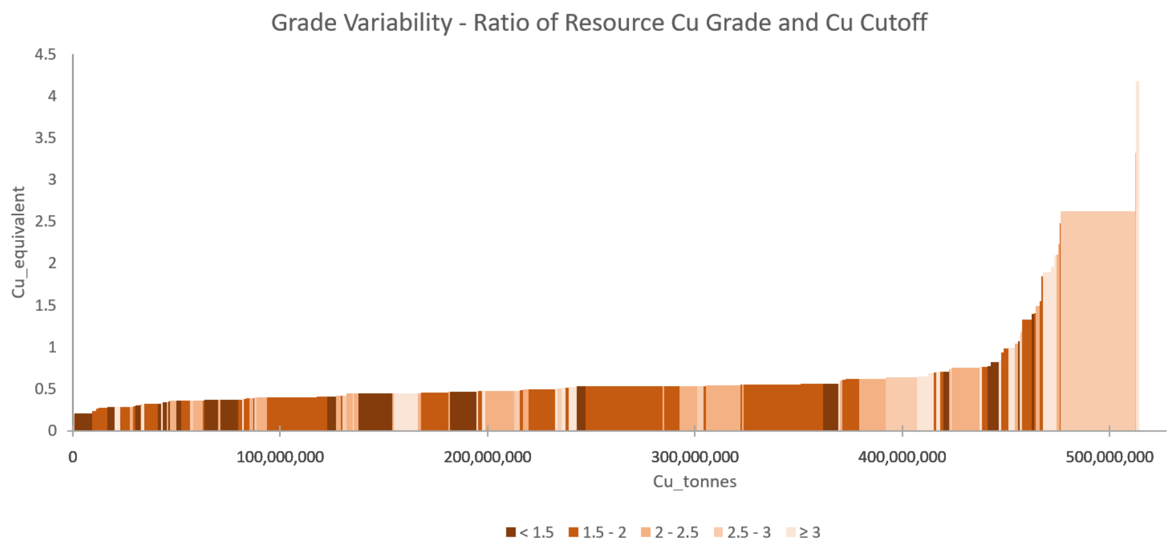

Figure 3 Cu grade-tonnage cascade plot color-coded by grade variability

Arsenic Risk

The increase in arsenic contents of ores and concentrates in world copper supply is now well-documented (eg Schwartz et al, 2017). This increase has also coincided with the introduction of more stringent regulations against contamination by arsenic and other deleterious elements (eg Voisin 2012) and a decreasing willingness from smelters to accept high-arsenic concentrates (eg Smale, 2017).

Arsenic risk was assessed within the database by carrying out a keyword search for the occurrence of a series of keywords relating to arsenic, arsenic minerals, and the occurrence of commonly arsenic-bearing mineralization styles. It is important to note that the assessment of arsenic risk is likely to be an underestimate, as the sources of data are based on public filings from companies who are only obliged to release potentially negative information relating to their assets when they have been judged to be material to the share price of the company. Keywords used and number of matches encountered in this analysis are as follows: arsenic (6); arsenopyrite (5); enargite (18); high sulphidation (11); and tennantite (17). The distribution of deposits, colour-coded by the degree of occurrence of arsenic-related keywords, is shown in Figure 3.

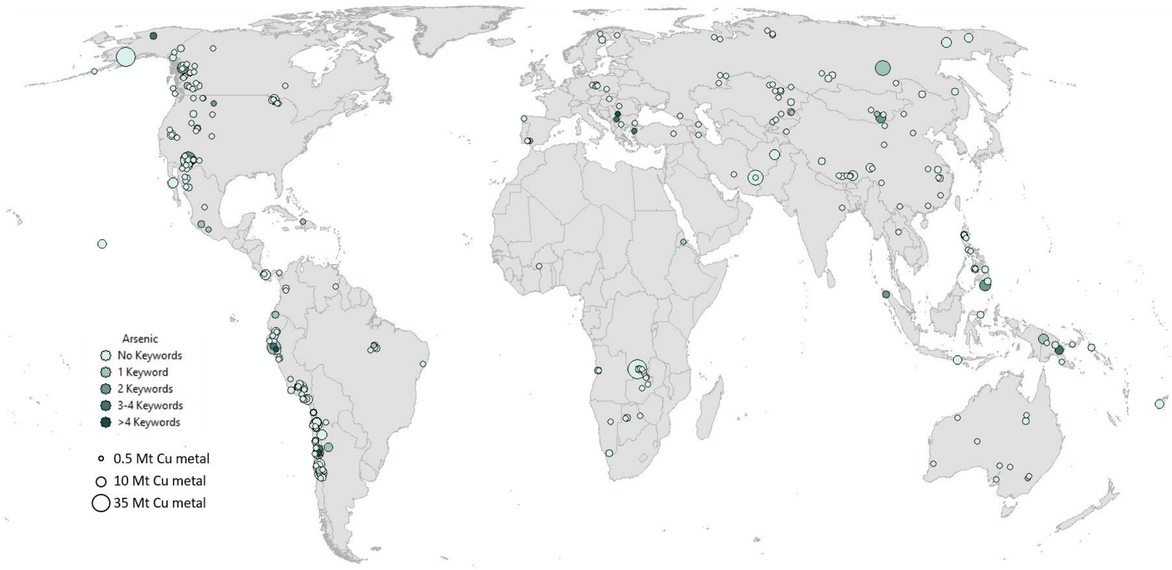

Figure 3 Distribution of copper deposits, colour-coded by the degree of occurrence of arsenic-related keywords

Tailings Risk

As competition for water and societal opposition to large wet tailings facilities increase, the need for dewatered tailings disposal is becoming more apparent (eg Hore and Luppnow, 2014). As the application of dry stacked tailings penetrates the copper industry, the need for a better understanding of the geometallurgical factors influencing filtration performance is of increasing importance.

The proxy for tailings risk in the database was developed using a combination of factors:

- A measure of seismic risk as documented by the Global Seismic Hazard Assessment Program (http://www.seismo.ethz.ch/static/GSHAP/index.html);
- A measure of local Topographic Roughness Index (Amatulli et al, 2018); and
- A measure of local flood incidence derived from the Aqueduct Water Risk Framework database (Reig et al, 2013)

The measure of tailings risk was defined as the maximum of the normalised values of the three measures detailed above, on the premise that any of the three could potentially contribute to high tailings risk without the contribution of the other factors (Figure 4).

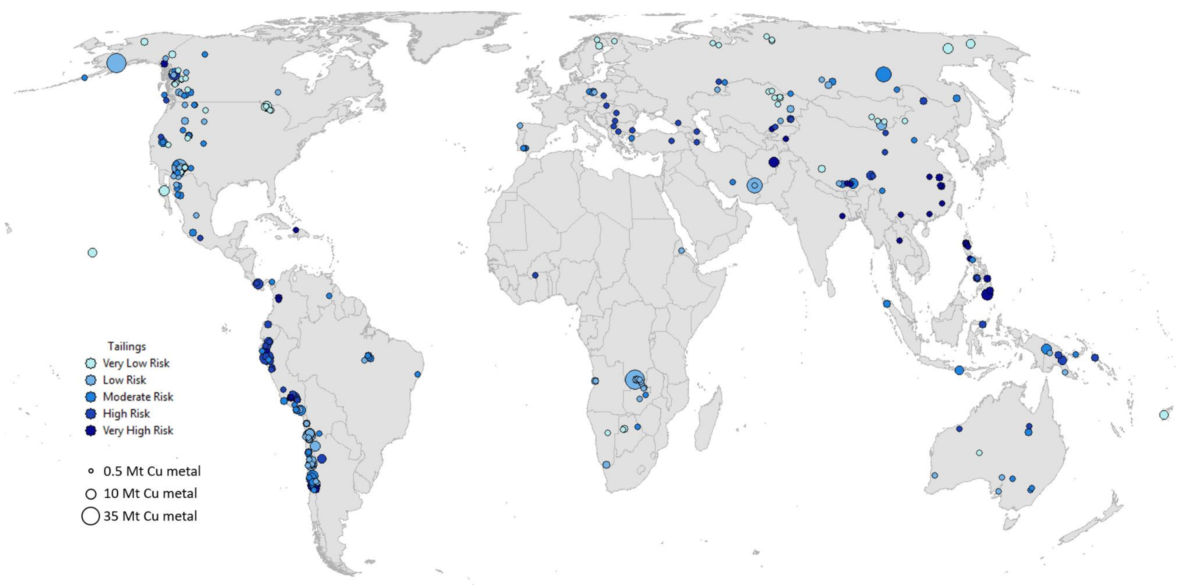

Figure 4 Distribution of copper deposits, colour-coded by the degree of tailings-related risk

RESULTS AND DISCUSSION

The four proxies investigated indicate significant levels of risk associated with undeveloped copper orebodies. In the area of mineral complexity, approximately 65% of the undeveloped tonnes of copper metal (just under 650 million tonnes of Cu metal) occur within deposits in which copper occurs in 3 or more minerals or zones. In the database, 90 deposits accounting for 385 million tonnes of Cu metal have below-median (0.77%Cu) grade and display mineral variability above the median for the dataset. Considering risks around low variability, approximately 54% of the copper tonnes for which both a cut-off and grade were defined had a sub-median copper grade and a grade/cut-off ratio of less than or equal to 2. This implies that more than half of the undeveloped copper tonnes in the data set have the potential to benefit from sub-mining unit scale waste rejection. Analysis of the arsenic results suggests that approximately 225 million tonnes of the undeveloped copper metal in the database are in deposits in which arsenic minerals are noted to occur, though it should be emphasized that this estimate is likely to be a minimum. Analysis of the tailings risk proxy data shows a significant number of deposits (97 out of 309 deposits, accounting for about 35% of the Cu tonnes in the database) which show both high Mining Water Risk from the Aqueduct Database (Reig et al 2013) and above median tailings risk based on the seismic-topographic-flood proxy, accounting for approximately 350 million tonnes of copper metal in the database.

CONCLUSION

Analysis of a database of undeveloped copper orebodies shows that they contain significant risks in the areas of mineral variability, low grade variability, deleterious elements and risks associated with conventional tailings. Geometallurgical investigations have the potential to mitigate all of these risks, and clearly form part of the mix of technological solutions which will be required in order to unlock mineral supply associated with complex orebodies. Depending on the proxies considered, the aspects of complexity related to geometallurgical considerations apply to 25% to 65% of the undeveloped copper tonnes in the dataset, providing a strong economic impetus for further innovations in this area.

REFERENCES

Ali, S.H., Giurco, D., Arndt, N., Nickless, E., Brown, G., Demetriades, A., Durrheim, R., Enriquez, M.A., Kinnaird, J., Littleboy, A., Meinert, L.D., Oberhänsli, R., Salem, J., Schodde, R., Schneider, G., Vidal, O., Yakovleva, N., (2017) 'Mineral supply for sustainable development requires resource governance'. *Nature* 543, 367-372.

Amatulli, G., Domisch, S., Tuanmu, M., Parmentier, B., Ranipeta, A., Malczyk, J. and Jetz, W. (2018) 'A suite of global, cross-scale topographic variables for environmental and biodiversity modeling', *Scientific Data*, 5, 180040

Claassen, J.O., (2016) 'Testing for heterogeneity in complex mining environments'. *Journal of the Southern African Institute of Mining and Metallurgy* 116, 181-188.

Hore, C., Luppnow, D., (2014) 'Karara Iron Ore TSF - design considerations for a large scale dry stack facility', *Tailings and Mine Waste 14, Keystone, Colorado*, p. 1-11.

Reig, P., Shiao, T. and Gassert, F. (2013) 'Aqueduct Water Risk Framework', Working Paper. Washington, DC: World Resources Institute. (Available online at http://www.wri.org/publication/aqueduct-waterrisk-framework)

Rossi, M.E., Deutsch, C.V., (2014) *Mineral Resource Estimation*. Dordrecht : Springer Netherlands : Imprint: Springer.

Smale, D., (2017) *Impurities: Regulatory Trends, Markets and Technologies.* 15/12/2017, https://www.ecometales.cl/wp-content/uploads/2017/03/1.Don-Smale-Presentation.pdf

Voisin, L., (2012) *New Strategies for the Treatment of Copper Concentrates with High Arsenic Content in Chile*. http://mric.jogmec.go.jp/public/kouenkai/2012-11/briefing_121108_5new.pdf

Walters, S.G., (2016) *Driving Productivity by Increasing Feed Quality Through Application of Innovative Grade Engineering® Technologies*, CRC Ore, Brisbane, https://www.crcore.org.au/images/CRC-ORE/papers/Walters-S-2016-Grade-Engineering-Whitepaper.pdf