Geometallurgy of tailings: Unveiling the next generation of mineral resources

A. Parbhakar-Fox[1,2]

1. Senior Research Fellow, W.H. Bryan Mining & Geology Research Centre, University of Queensland, Indooroopilly, QLD 4068, Australia
a.parbhakar-fox@uq.edu.au

2. Adjunct Senior Researcher, CODES, University of Tasmania, Private Bag 79, Hobart, TAS, 7001. Australia.
anita.parbhakar@utas.edu.au

INTRODUCTION

Never before have the challenges of mine waste management been so important to ensure ongoing progress and development of mining operations with licence to operate now ranked as the number 1 business risk facing the mining and metals industry (Ernest Young, 2018). Societal expectations increasingly demand the sector to commit and contribute to community, government, employees and environment needs beyond the life-of-mine. This includes realistic planning for the ongoing management of mine waste storage facilities and their eventual closure. Too few global examples of successful mine closure exist for a myriad of reasons, the most important of which is the poor approach to the chemical and physical characterisation of mine waste (e.g., waste rock, tailings, slag and spent heap leach materials). Ultimately, these data inform the engineering design for the long-term storage of these waste materials. If they are not well designed then there is strong potential to induce acid and metalliferous drainage (AMD) whereby sulphides contained in mine waste oxidise (Dold, 2017) or catastrophic structural failures can occur as demonstrated at the Brumadinho Dam, Brazil in January 2019. AMD is characterised by low pH, high sulphate and metals which negatively impact on the water quality of the receiving environment (Dold, 2017; Naidu et al., 2019). Once AMD generation has started, stopping and manage it is technically challenging, costing mining operations and government bodies many millions of dollars to actively manage (Naidu et al., 2019). For example, the mining industry in Tasmania was established in the late 1800s with activities focussed in the west and north east of the state with a range of commodities including gold, copper, lead, zinc, silver and tin sought (Walshe et al., 1995). Today, hundreds of historic mine waste features remaining on the land surface (Figure 1) many of which require ongoing management. But, maps like this should not be viewed as only conveying the distribution of acid forming materials, they also provide the location of concentrated outcrops of, often fine grained, sulphides. When considering the advances made in metallurgical processing technologies since the deposition of historical (i.e., late 1800s) waste and the changing thirst for commodities (i.e., increased demands for cobalt, lithium and REEs; Grandell et al., 2016) there is strength in the business case for mining waste. By adopting a geometallurgical characterisation approach (defined in Dominy et al., 2018) to mine waste this can be better defined as this extended abstract summarises using a case study example from Western Tasmania, Australia.

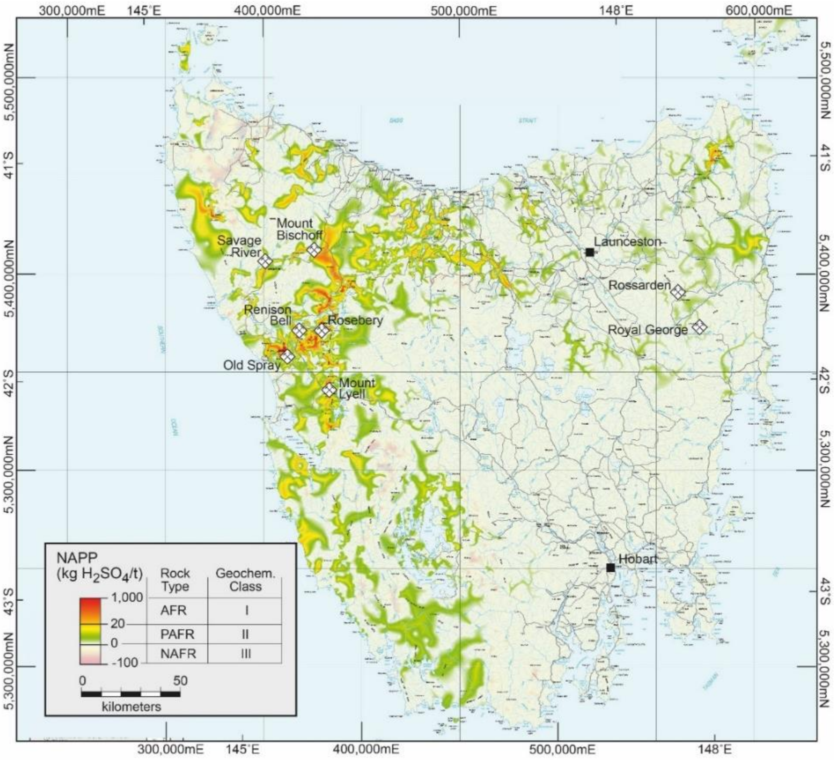

FIG 1 –Distribution of net acid producing potential (NAPP) materials identified at surface in Tasmania (redrawn from Mineral Resources Tasmania, 2001). Abbreviations: AFR, acid forming rock; PAFR, potentially acid forming rock; NAF, non-acid forming rock.

METHODOLOGY

Mine tailings were collected from the Old Tailings Dam (OTD), located at the Savage River iron-ore mine, Western Tasmania (Figure 2). At this site approximately 38 Mt of mine tailings were deposited from 1967 to 1985 and have since been actively generating AMD (Jackson and Parbhakar-Fox, 2016).

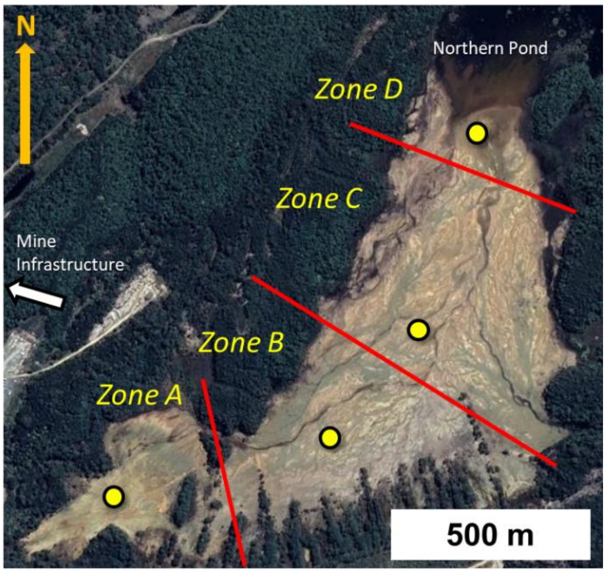

FIG 2 –Aerial image of the Old Tailings Dam, Savage River (location shown in Figure 1), with sampling locations on each Zone shown in yellow (Image from Google Earth).

Tailings were subjected to a geometallurgical characterisation approach as outlined in Figure 3. In summary, bulk samples (20 kg) were collected from four different zones across the OTD as defined in Jackson and Parbhakar-Fox (2016) and subjected to chemical (acid base accounting, chemical assay), mineralogical (X-ray diffractometry, scanning electron microscopy, mineral chemistry (laser ablation ICPMS). A composite of these materials was then prepared and subjected to metallurgical test work (flotation and biooxidation) as described in Parbhakar-Fox et al. (2018) with additional chemical and mineralogical analyses performed to track the characteristics of the reaction products to enable further experimental optimisation.

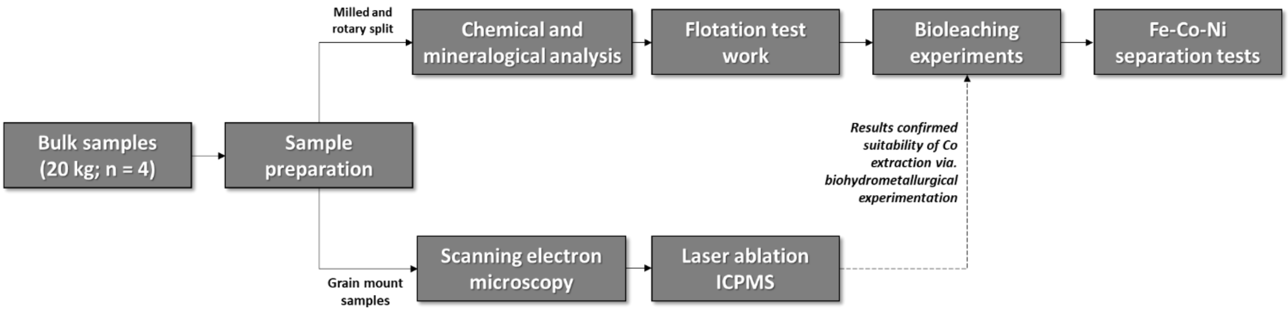

FIG 3 –Geometallurgical approach to tailings characterisation adopted in this study.

RESULTS

Parbhakar-Fox et al. (2018) present these results in full so only a summary is provided here. Bulk mineralogy analysis measured 7 wt. % pyrite with the remainder comprising hornblende, chlorite, albite and talc. Mineralogically, the composite is considered potentially acid forming (PAF) as there is a notable absence of carbonate minerals. To confirm this, static tests reported a NAPP value of 214 kg H_2SO_4/t and a net acid generation pH of 2.3 classifying it as PAF. Chemical assay of the composite reported a head grade of 360 ppm Co, 325 ppm Ni and 1,400 ppm Cu.

Pyrite chemistry analysis reported up to 27,800 ppm Co (avg. 2,460 ppm; n = 143) and up to 12,360 ppm Ni (avg. 1,960 ppm; n = 143) with both observed as refractory therefore confirming the suitability of these tailings to bioleaching. Copper in pyrite is present as < 10 µm chalcopyrite microinclusions. Flotation was performed using a methyl isobutyl carbinol (MIBC) frother and potassium amyl xanthate (PAX) collector and produced a 70.5% pyrite concentrate with talc also having concentrated from 1 wt. % to 17 wt. %. In the new tailings stream 2 wt. % pyrite was measured therefore classifying this as PAF. Biooxidation using the commercially available BIOX® culture (comprising *Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidans and Leptospirillum ferrooxidans*) was performed using a 9K medium at pH 1.5–1.6 and 40 °C. A continuous stirred tank approach was adopted with total oxidation occurring in 14 days leaching 99% Co. The metallurgical waste produced was dominated by jarosite and gypsum. The pregnant liquor solution was subjected to precipitation experiments with Co and Fe effectively separated at pH 3. Further separation of Co from Ni and Cu was not achieved despite oxidation experiments, therefore the final liquor was oxidised with sodium hypochlorite to produce the intermediate saleable product cobalt hydroxide.

DISCUSSION AND CONCLUSIONS

By adopting an integrated laboratory based 'source to recovery' experimental methodology opportunities for further processing optimisation are afforded. For example, Co loss was experienced in these experiments during the flotation step due to the presence of talc which is hydrophobic (Beattie et al., 2006). Effective depression of talc is achievable using polysaccharides as they adsorb to the surface making it hydrophilic preventing bubble-particle capture (Cheng et al., 2019). Thus, this modification will be made in the next iteration of test work. Detailed mineralogical studies are mandatory to select appropriate metallurgical processes (Goodall, 2008) as assays alone do not reveal this information, therefore, mineral chemistry analysis is an integral part of a geometallurgical approach. In the case of this study, if LA-ICPMS had not been performed then a more conventional method for metal recovery from pyrite (i.e., roast and/or leaching) may have been adopted which ultimately would yield lower recovery. Gwénaëlle Guezennec et al. (2017) explored the control of dissolve oxygen in bioleaching experiments identifying an optimal concentration of 4 to 13 ppm when using a 51% pyrite concentrate. In these experiments the range was 1.43 to 10.76 ppm with a 71% pyrite concentrate thus, future test work should consider increased this to accelerate sulphide oxidation rate. This case study example demonstrates that by adopting a geometallurgical approach to characterising acid generating sulphide-bearing historical and legacy sites. Breaking the source-pathway-receptor pollutant linkage chain at the source, rather than treating the pathway or managing the receptor can unlock value through identifying additional or new commodities. Other sites in Tasmania are now adopting this, with new research projects exploring geometallurgical properties of tailings currently being undertaken at Copper Mines Tasmania, Rosebery and Macquarie Harbour. Outcomes from these studies, with the financial benefits clearly articulated (i.e., cost-savings through the reduction of environmental liabilities in perpetuity), should be widely disseminated to encourage a national, if not global, paradigm shift in how the industry view tailings- from waste to future exploration targets.

ACKNOWLEDGEMENTS

The author wishes to thank students and staff at the ARC Transforming the Mining Value Chain Research Hub for their assistance in this research. Special thanks go to Sibele Nascimento, Laura Jackson, Le K'ng and Johanna van Balen who actively participated in Theme 3 (Minimising Geoenvironmental Risks) with the scope of their individual research projects having contributed to the discussion section of this extended abstract.

REFERENCES

BEATTIE, D.A., HUYNH, L., KAGGWA, G.B.N., RALSON, J., 2006. The effect of polysaccharides and polyacrylamides on the depression of talc and the flotation of sulphide minerals. Minerals Engineering, v. 18, p. 598-608.

CHENG, L., ZHANG, W., SONG, S., LI, H., 2019. A novel method to improve carboxymethyl cellulose performance in the flotation of talc. Minerals Engineering, v. 131, p. 23-27.

DOLD, B., 2017. Acid rock drainage: A critical review. Journal of Geochemical Exploration 172, 120-132.

DOMINY, S.C., O'CONNOR, L., PARBHAKAR-FOX, A., GLASS, H.J., PUREVGEREL, S., 2018. Geometallurgy – A route to more resilient mine operations. Minerals 8, 1-33.

ERNEST YOUNG, 2018. Risk in mining 2019-2020 https://www.ey.com/en_gl/mining-metals/10-business-risks-facing-mining-and-metals, accessed 01/03/2019

GOODALL, W., 2008. Characterisation of mineralogy and gold deportment for complex tailings deposits using QEMSCAN. Minerals Engineering, v. 21, p. 518-523.

GRANDELL, L., LEHTILA, A., KIVINEN, M., KOLJONEN, T., KIHLMAN, S., LAURI, L.S., 2016. Role of critical metals in the future markets of clean energy technologies. Renewal Energy, v.95, 53-62.

GWENALLE GUZENNEC, A., JOULIN, C., JACOB, J., ARCHANE, A., IBARRA D., BUYER, R.D., BODENAN, F., D'HUGHES, P., 2017. Influence of dissolved oxygen on bioleaching efficiency under oxygen enriched atmosphere. Minerals Engineering, v.106, p. 64-70.

JACKSON, L.M., PARBHAKAR-FOX, A., 2016. Mineralogical and geochemical characterisation of the old tailings dam, Australia: Evaluating the effectiveness of a water cover for long-term AMD control, Applied Geochemistry, v.68, 64-78.

MINERAL RESOURCES TASMANIA. 2001. Geochemical distribution of potentially acid forming rocks hosting abandoned mines in Tasmania. http://www.mrt.tas.gov.au/mrtdoc/map_catalogue/map_public/111156_1/aciddrain3.pdf

NAIDU, G., RYU, S., THIRUVENKATACHARI, R., CHOI, Y., JEONG, S., VIGENSWARAN, S., 2019. A critical review on remediation, reuse and resource recovery from acid mine drainage. Environmental Pollution, v.247, p. 1110-1124.

PARBHAKAR-FOX, A., GLEN, J., RAIMUNDO, B., 2018. A Geometallurgical approach to tailings management: an example from the Savage River Fe-ore mine, Western Tasmania, Minerals, v.8, doi:10.3390/min8100454

WALSHE, J., HEITHERSAY, P., 1995. Toward an Understanding of the Metallogeny of the Tasman Fold Belt System. Economic Geology, v 90, p. 1382-1401.