Machine learning at a gold-silver mine: a case study from the Ban Houayxai Gold-Silver Operation

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BACKGROUND INFORMATION ON THE OPERATION AND DEPOSIT

The Ban Houayxai Gold-Silver Operation is a producing asset for Australian-based copper and gold producer, PanAust Limited. The Operation lies within PanAust's 2,600 square-kilometre Phu Bia Contract Area in northern Laos. Commencing production in 2012, Ban Houayxai is operated by PanAust's Lao-registered company, Phu Bia Mining. PanAust owns a 90 per cent interest in Phu Bia Mining. The Government of Laos owns the remaining 10 per cent.

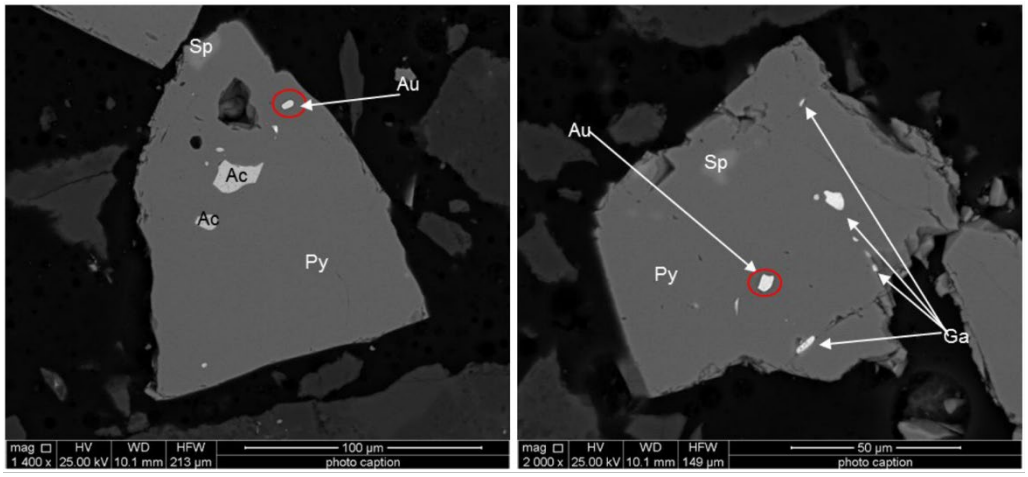
The Operation mines an intermediate sulphidation epithermal gold-silver deposit and comprises an open-pit feeding ore to a conventional carbon-in-leach process plant. Metallurgical recoveries for gold and silver are approximately 75-85 per cent and 55 per cent respectively. To year-end 2017, the Operation had poured 0.65 million ounces (oz) of gold and 4.7 million oz of silver. The Ban Houayxai Ore Reserve supports a mine life of approximately four years from the end of 2017.

The Ban Houayxai deposit is in an early Permian volcano-sedimentary unit which is part of a late Carboniferous to early Permian (310–270 million years ago) volcanic-plutonic sequence of the Truong Son Fold Belt. The deposit formed when hot saline (240–415°C, 2.7–13.0 weight per cent NaCl equivalent) fluids ascended from a geologically fertile island arc porphyry into overlying volcanics along a fault or faults in the early Permian (290–256 million years ago) (Manaka *et al.,* 2014).

DIFFICULTY OF PREDICTING TAILS GOLD GRADE AND GOLD RECOVERY

The Ban Houayxai Gold-Silver Operation has experienced intermittent periods of lower than expected metallurgical recoveries due to gold locked inside sulphides and silicate minerals. The amount of gold locked in sulphides is typically between 0.1 to 0.15 g/t, while the gold locked in silicates varies between 0.02 to 0.2 g/t and up to 1g/t. Feed head grades vary between 0.6 to 1.6g/t gold with an average grade of 0.8g/t. Intermittent periods of less than 50 per cent gold recovery over 1 to 3 days have been experienced when tailings gold grades have unexpectedly increased. The lower recoveries have not had a material impact on the Operation but it is desirable to understand the issue and predict areas that may have low recoveries.

Gold locked inside sulphides has been previously identified as 1-4 micron sized droplets of gold and electrum (Figure 1). This size is well below the typical grind size of 150 microns. The gold locked in silicates is unobserved but interpreted to be similar in nature. Increased sulphide and silica locked gold are limited to the fresh, unweathered rocks. Petrographic and geochemical studies have failed to clearly identify any correlated properties that could otherwise allow discrimination of poor recovery areas. The lack of a clearly identifiable reason for high gold content in tails/low gold recovery was the motivation for using the MAXTA® model.



Py – pyrite
Sp – sphalerite
Ga – galena
Au – gold/electrum
Ac – acanthite

Photomicrograph of sulphides from the tailings at Ban Houayxai that contain tiny grains of gold and silver; once the sulphides have oxidised by weathering these grains are liberated and can be recovered

FIG 1 – Gold and silver deportment in sulphides found in tailings

HOW THE MAXTA® MODEL HAS BEEN USED TO SOLVE THE PROBLEM

The MAXTA model identified existing estimated variables in the Mineral Resource block model that could be used to predict areas with poor recovery. Two years or 10 million tonnes of ore was integrated and analysed between 2016 and 2018. This period coincided with the mining and processing of fresh unweathered ore. The variable of interest to predict was the gold grade in the tailings. The actual tailings gold grade data came from 1,211 twelve hourly composite samples taken from the processing plant, which were spatially linked to the geological block model from which statistically significant predictors were determined. The machine learning part of the study was the spatial linking of the Mineral Resource block model to the tailings grades. This can be difficult, given the complexity of tracking material through stockpiles. For the case at Ban Houayxai this problem was reduced (but not eliminated) by a high proportion of direct tipping of the trucks of ore straight from the pit into the crusher. The high proportion of direct feed improved the predictive properties of the model.

RECONCILIATION AND PREDICTIVE PROPERTIES OF THE RESULTS

The significant predictors for high tails grade gold were determined by linear regression and filtered based on knowledge and experience. The significant predictors were higher grades of copper, lead and zinc and a higher acid neutralising capacity of the rock (a proxy for the presence of carbonate veins). The model variable ‘veinag’ improved the grade predication accuracy, where ‘veinag’ is a proxy for the higher silver grades greater than 13g/t silver. The topography variable also assisted in improving the model accuracy, explained by the more intense weathering of the exposed blocks. These predictors made sense, given what is known from geological studies of the deposit but their combination to predict the tailings grade was not obvious. A graph of the predicted versus actual tailings gold grade is provided in Figure 2, which demonstrates the ‘predicted’ outcome of tailings grade versus the actual measured tailings grade from the plant. The adjusted r-squared value of 0.36, or correlation coefficient of 0.6, indicates that the predictions are good but not perfect. The result is considered acceptably strong to act as an indicator to identify areas which will have high tailings gold grades. The results also made sense when reconciled back against qualitative observations from the Operation, which gave confidence in the result.

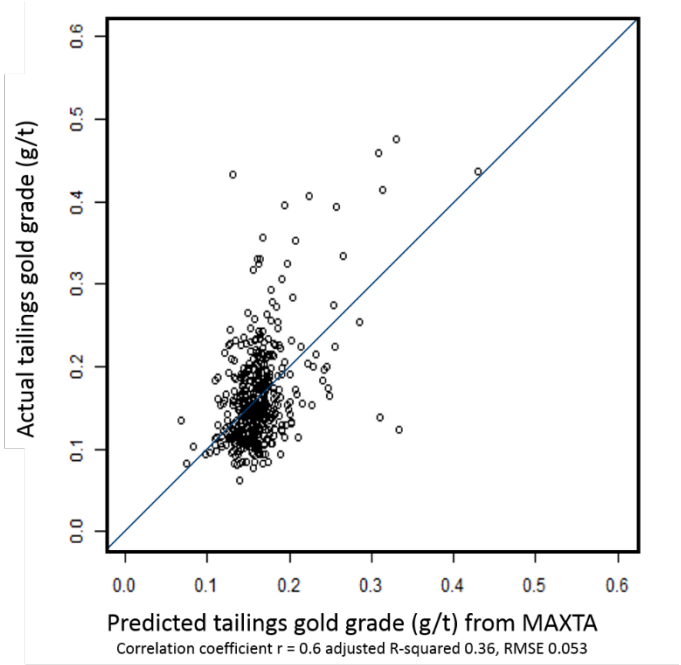


FIG 2 – Tailings gold grade, actual plant measured grade versus MAXTA predicted grade

FURTHER USES, NEXT STEPS AND LESSONS LEARNED

The MAXTA model has been used to identify the areas that have possible problematic gold recovery. The method used existing data and was not guided or informed by prior knowledge of the locations or characteristics of low recovery areas. No new tests were performed; in this case, the plant acted as the testing device. The study was rapid, taking less than 4 weeks, and relatively cheap compared to a drill program which only tests a relatively miniscule amount of material. The MAXTA model has been further developed to provide both a direct estimate of the tailings gold grade as well as a probability that a block will have a high tails grade. The benefit of the probabilistic approach is that it produces an outcome of quantified mining risk, which is the main objective of this approach.

Further applications of the MAXTA model are being investigated. The integrated data includes drill and blast data, data from the process historian and other plant assays. This makes the MAXTA model amenable to analysis by multiple disciplines for inexpensive scenario testing. As an example, a multi-disciplinary exercise would be to optimise the design of drill and blast (burden, spacing and design powder factor) to suit certain rock types (uniaxial strength, Young's modulus and fabric, gold deportment), which can then be fed into the plant with ideal mill settings (power draw, motor temperature, noise levels, recirculating load, etcetera) and processed with ideal settings (pH, cyanide levels, reagents, etcetera).

The MAXTA model, being a digital twin of the Operation, effectively provides information for risk analysis, cost improvement studies, analysis and 'what if' simulations for various scenarios, justification for resource allocation and developing strategies for the amelioration of negative events such as breakdowns. It is a step along the path towards whole-operation optimisation.

REFERENCES

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