Applied Geological Techniques for the Evaluation of Kimberlitic Tailings Mineral Resources: the case of Orapa and Letlhakane mines, Botswana

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Introduction

As primary kimberlite and secondary (alluvial and eluvial) diamond deposits become depleted, and new discoveries become increasingly elusive, diamond mine houses have turned to tailings mineral resources (TMR), as a way of prolonging the life-of mines. TMR diamond resources have the advantages of easy accessibility, low cost mining and crushing, and unique finer diamond size frequency distribution (SFD). Tremendous growth in the global diamond price and demand in the last few decades, have heighted the focus on TMR deposits. In addition, the technological advancement in diamond processing technology, have also increased the interest in eploiting this type of diamond deposits. To failitate the conversion of the tailings deposits into resources for exploitation, there has been increasing need for new geological knowledge relating to TMR geology and evaluation techniques.

Debswana have developed innovative methods for optimizing the sampling and evaluation of TMRs. These have aided the successful execution of TMR evaluation campaigns at Orapa and Letlhakane mines. This presentation demonatrates that applied geo-techniques deriving knowledge from kimberlite deposit evaluation and sediment analysis, can be applied to effective sample optimization and sampling evaluation of TMRs.

Origins of TMRs

The TMR deposits are formed as coarse residue from the Dense Medium Separation (DMS) during treatment of kimberlitic ore. The original processing plants were inefficient either during communition, screening, DMS concentration, and recovery, resulting in sub-optimal diamond recovery, and therefore loss of diamonds to the tailings. The TMR deposits were modified by mining and treatment processes of blasting, blending, stock-piling, crushing, screening, DMS concentration, tailings conveyance and spreading, and prolonged exposure to weathering elements, once they are deposited as TMRdumps. The TMRs are therefore complex deposits characterized by unique geology (mineralogical composition and diamond distribution), that often are not comparable to the original kimberlite source. The coarseness of the TMRs are dependant on the original DMS plant screen cut-offs sizes applied in separating the DMS feed from the slimes and slurry, screeening efficiency, and kimberlite resistance to weathering.

TMR Geo-chronological Model

In order to optimize the TMR sampling and evaluation plan, knoweldge of the TMR formation and deposition mechanisms is required. The geo-chronological model outlines how the TMR deposit was grown over time, including an indication of the kimberlite ore source and the treatment window when the particular TMR zone was grown. Modern mine planning systematically plan for the TMR dumps to ensure preservation of the TMRs for future potential exploitation. This entails conducting ground preparation prior to dumping, conveyance layouts, determining dump heights, advancement rates and directions. This ensures the TMR is preserved from waste contamination. The TMR geo-chronological model allows for correlation of the TMR geology to the original mined kimberlite ore source and grade. In addition, the TMR geo-chronological zones could be correlated to the treatment window when the ore was processed. The residual diamond grade could therefore, be inferred on the basis of the run-of-mine ore grade treated through the plants and the processing plant recovery efficiency at the time when the ore was treated.

Sample Optimization

An accurate TMR growth model (geo-chronological model) is a key input to the sample optimization and forms the basis of determining the optimum sampling grid spacing, individual sample sizes, sample support, and sample lift intervals. In addition, the TMR features such as the angle of respose and internal layering are influnced by particle mechanics and dynamics. As the individual particles roll, creep and slump forming the angle of repose, there is particle segregation and sorting, that affect the diamond grade and size frequency distribution within the TMR.

A systematic approach was adopted during the sample optimization study. A geo-chronological model was constructed taking into consideration the angle of repose of the deposit. The model was used to establish the critical distance spacing of vertical drill-holes that is required in order to seamlessly and uniquely sample a different time zone of the deposit. The critical distance spacing of vertical drill-holes was related to the height of the deposit and the angle of repose, and was calculated using trigonometry.

The sample optimization determined the appropriate sampling techniques and tools, the expected diamond recoveries per sample, the predicted diamond size frequency distribution, the optimal individual sample size, the optimal sample intervals, the sampe grid dimensions, sample quality atndards, and sample plant treatment efficiency paramenter targets for diamond liberation, screening, concentration, and recovery, and diamond bottom cut-off sizes to be applied in evaluation campaigns.

Granulometry and historical production efficiency factors were used to derive a desktop TMR residual grade. The average TMR base elevation was calculated and set as a constant datum for aligning the samples. The angle of repose of the TMR deposit was also calculated based on the dump profile. The analysis of the TMR elevation along the growth timeline was conducted in order to determine the critical sample drill-hole spacing required for time-line overlap of adjacent drill-holes, and the number of sample lift intervals required. The sample configuration was then determined to ensure adequate sample support. The outcome of the above approach was a sample configuration aligned to the direction of the TMR growth. This made it possible to estimate the anticipated total sample tonnes and the total sample carats, based on drill-hole configuration, sample sizes and global TMR estimated grade and density. The number of drill-holes and samples that would deliver the confidence criteria for an indicated resource category (both grade and revenue) were determined through simulation. In addition,

Geological Analysis and Interpretations

A number of applied geo-techniques were utilized in analysing and interpreting the TMR geological units for internal geology modeling. The primary data was obtained from drilling using a BG36C Auger drill rig with a 1.5m diamtere bucket. Auger drilling was undertaken using 15m sampling lift height, on optmized 60 x 60m 5-spot grid for Lethlakane and 100 x 100 m 5 spot grid for Orapa mine. Each sample size (lift) weighed between 48 to 60 tonnes, depending on the moisture content and level of weathering. The primary purpose of the sampling was for recovery of diamond grade SFD fro resource estimation and for geological analysis. Geological analysis of the recovered samples was conducted using both qualitative and quantitative methods. Qualitative methods involved physical obervation geological sample logging. Residual kimberlite features in the TMR were analysed for mineralogy, grain size, colour, intensity of weathering, and composition of xenoliths (mantle and crustal rocks). Quantitative analytical methods included particle size distrinution (PSD) and constituent analyses. The PSD of each sample were derived from sieving the samples through a successive suite of sieves, which ranged from +32mm to -1mm apperture. A PSD ratio analysis based on Cum sum +8mm / Cum sum-8mm fractions, was used to differentiate between TMR coarse unit (HZ2) and TMR finer unit (HZ1). Recovered sub-samples above +4mm and above, were each analysed for constituent composition. This involved identifying the different constituent rock types by weight of each sample. The limitation on the quantitative data set was the bias introduced by preferential weathering of weaker minerals and their reconstitution into the finer sieves sizes. On the other hand, the harder minerals were preferential enriched in the corser fractions. The mineral constituent data was useful in the interpretation of the diamond grade data, where dilution was correlated with grade data. The PSD was used in the interpretation of SFD grade data, as coarser diamond SFD was expected in coarse samples.

Metallurgical settling tests analsysis data from TMR samples mapped the olivine alteration trends within the TMR. No serpentine was found in older deeply weathered TMR (HZ1), but serpentine was abundant in the newer less weathered competent TMR (HZ2), with values ranging between 1.1 to 11.2 % in the -5 micron fraction. The smectite (montimorillonite) distribution results were inclonclusive, as no definte treands (corelation) existed between smectite content and the level of weathering exhibited in the older HZ1 and newer HZ2 units. The density results showed relatively higher density values obtained from less weathered and more competent newer HZ2, compared to lower values obtained from the older highly weathered HZ1.The diamond liberation (diamond lock-up) analysis based on comparisons of diamond recoveries from samples treated without recrushing and audit samples treated with additional recrushing, showed higher diamond lock-up in competent newer HZ2 and lower diamond lock-up in highly weathered and less comptenet HZ1. The following diamond lock-up profiles were established from the 3 Orapa TMR units: HZ1 (<10%), HZ1/HZ2 (10 to 20%), and HZ2 (>20 to 32%). The diamond lock-up profiles were used as further validation of the interpreted TMR geo-zones. The strong correlation between the different data sets (quantitative (PSD), metallurgical data (settling tests), density, qualitative data (observation logs), and liberation data (diamond lock-up profiles) provided confidence in differentiating TMR geological units for internal 3D geological modeling.

3-Dimensional Geological Models

Based on the interpreted TMR geological units, 3-D geology models were developed. The Letlhakane mine TMR geology model example is presented below:

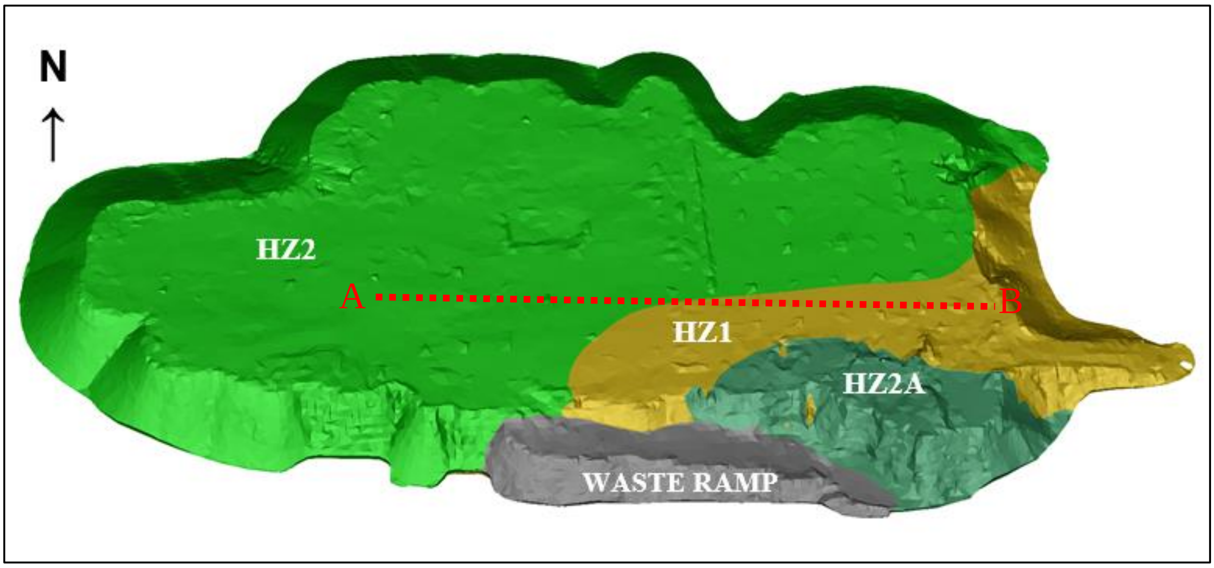

Figure 1: Final 3-Dimensional Geological model of the Letlhakane mine TMR

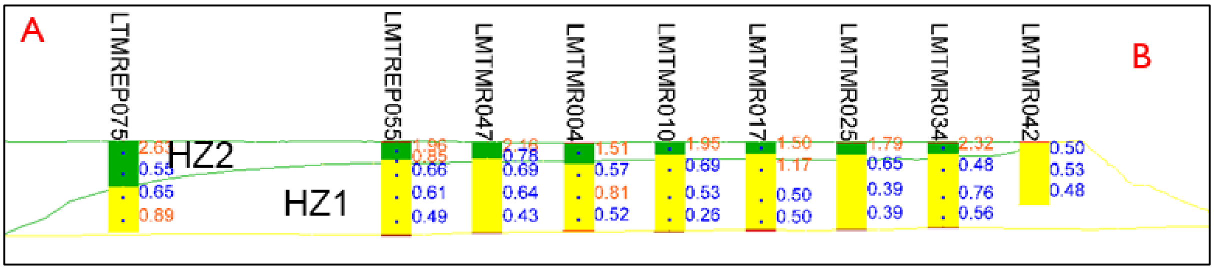

Figure 3: Section A- B showing strong correlation between PSD Ratio data and the Letlhakane mine TMR geological model