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The PGM flotation predictor: Predicting PGM ore flotation performance using results from automated mineralogy systems

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ABSTRACT

Performance of froth flotation recovery plants for platinum group minerals (PGMs) is usually monitored by means of routine chemical assays of samples taken at various locations in the plant. Whilst these assays can alert the plant metallurgist to variations in recovery, the reasons for changes in recovery are not adequately revealed by the assay results. Assay-by-size analyses can help to diagnose whether PGM and/or base metal sulphide (BMS) liberation issues exist, but do not provide any information on mineralogical changes in the plant feed material.

The flotation performance of an ore is determined by its mineralogy. Mintek's Mineralogy Division is currently developing PGM flotation prediction software that uses data from automated mineralogy systems to provide valuable information to the plant metallurgist. Each PGM-bearing particle detected by the automated mineralogy system is individually evaluated. Particle floatability, based on the mode of occurrence of the PGM, the proportion of floatable component/s and the composition of constituent minerals in each PGM-bearing particle is calculated. These data provide a direct output that highlights the metallurgical properties and recoverability of the PGM-bearing particles in samples gathered from strategic locations in the recovery plant.

1. Introduction

Automated mineralogy systems generally use a combination of scanning electron microscope (SEM), backscattered-electron (BSE) images, image analysis, and energy dispersive spectrometry (EDS), to provide very useful data that cannot be obtained from other analytical techniques, particularly in complex ores. Common results outputs include relative abundance of minerals (modal analysis), liberation characteristics of valuable minerals, mineral grain and particle size, and mineral association data. These results can help to pinpoint mineralogical changes in an ore that can often affect mineral recoveries. If these mineralogical changes can be quantified with a reasonable degree of confidence, then the effect of these changes can be compensated for in the recovery plant.

The terms "mineral grain" and "mineral particle" are used frequently in this paper. It is important to distinguish between the two. A mineral grain is a homogenous unit of pure mineral. A mineral particle is made up of one or more mineral grains. In the case of a pure, liberated mineral, the terms "grain" and "particle" are equivalent.

In ores that contain platinum group minerals (PGMs), the plant feed material generally contains less than 10 ppm of platinum group elements (PGEs). The low PGE grade makes it virtually impossible to provide statistically meaningful PGM data by using traditional manual techniques. Automated SEM/EDS systems help to alleviate this problem by searching several polished sections per sample in unattended runs. Potential PGM-bearing particles are located by means of the high BSE intensity produced due to the high average atomic number of PGE-bearing minerals, and are identified by means of automated EDS analyses, performed on the constituent mineral grains in the PGM-bearing particles. Analysis results are saved to a database during the automated runs.

Results from automated mineralogy systems are typically presented as tables or charts that summarise particular sample characteristics, and represent the total population or a specific sub-set of analysed mineral particles in the sample. To reliably determine floatability from mineralogical data, however, each analysed mineral particle needs to be individually evaluated. The reason for this is that more than one particle characteristic often needs to be considered to determine floatability. For example, a liberated PGM grain would be expected to float, but might not if its grain size is either very small or very large. In the case of composite particles, floatability depends on the minerals present, the grain size, association and mode of occurrence of each of these minerals, and the total particle size (Chetty et al., 2009). These individual particle data are written to the results database during analysis, but are usually not resolved in the pre-defined tables

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and charts produced by the system's data processing software. The "grains table" within the automated SEM results database provides a source of individual PGM-bearing particle data required for interrogation by the flotation predictor.

Similar approaches to predicting floatability and recovery of ores using mineral particle properties determined by automated SEM systems have been documented (Evans et al., 2011; Evans, 2010; Ford et al., 2007; Hunt et al., 2008; Lotter et al., 2003; Wightman et al., 2010, 2008). These, however, apply largely to base metal sulphide recovery, and do not involve the development of custom designed software to interrogate the mineralogical data. The methodology discussed in this paper is a simple approach, which has been developed to cater specifically for South African Bushveld PGM ores with typical feed grades of less than 10 g/t. The concept has been implemented as a VBA module within Microsoft Excel, which can accept PGM mineralogical data from any of the current automated SEM platforms.

2. Producing an input file for the flotation predictor

The "grains table" produced by the automated SEM system is extracted from the sample results database, and is used to determine individual PGM grain and PGM-bearing particle characteristics. The first step is to determine the mode of occurrence of the PGM in each PGM-bearing particle. This is achieved by means of a Microsoft Excel spreadsheet, using a visual basic for applications (VBA) macro. The macro automatically classifies each PGM-bearing particle into one of six pre-defined mode of occurrence classes, described in Table 1 and illustrated in Fig. 1.

Mineral ID and grain measurement data are also captured from the grains table. Grain areas are used to calculate a liberation index for each PGM-bearing particle. This measure of PGM grain liberation is calculated by dividing the area of potentially floatable component (*PGM* + *BMS*) by the total area of the particle (*PGM* + *BMS* + *gangue*). The resultant figure will range between 0 and 1, the latter indicating either a liberated PGM grain, or a binary particle containing PGM and BMS only. In contrast, the liberation index of a PGM grain totally enclosed within a BMS-barren silicate particle (low probability of flotation) will approach zero. Mineral ID, particle liberation index, grain and particle size, and PGM mode of occurrence for each PGM-bearing particle are used to produce a file that contains all of the necessary particle data to be interrogated by the flotation predictor software.

3. Flotation predictor operation and data flow

The PGM flotation predictor predicts PGM recovery by producing an output based on the physical properties of all PGM-bearing particles detected in the sample. These properties include mode of occurrence of the PGM (as per descriptions in Table 1), the floatability of minerals associated with the PGM, liberation index (i.e. proportion of floatable component in the particle), and particle/grain size. By classifying PGM-bearing particles into five classes that contain particles expected to float within particular time intervals, a recovery–time profile is produced. If desired, a flotation model can then be applied to this profile to determine flotation kinetics for the PGM bearing particles. The current version of the flotation predictor estimates fast and slow floating PGM fraction percentages and flotation rate constants by fitting the predicted recovery profile to the Kelsall flotation model (Kelsall, 1961) using a non-linear regression procedure. A simplified flow chart of the flotation predictor operation is provided in Fig. 2.

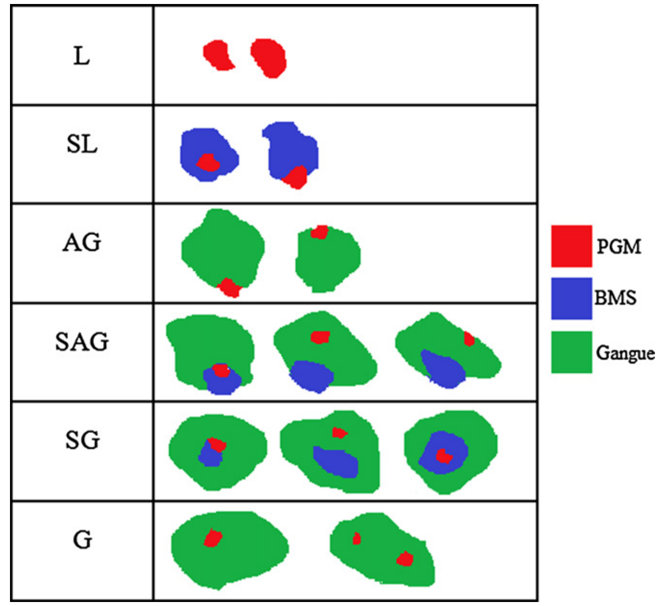

Fig. 1. PGM-bearing particle mode of occurrence classes.

The flotation predictor user interface, illustrated in Fig. 3, allows the user to set various flotation parameters prior to calculation. These include minimum and maximum particle sizes, choice of gangue minerals considered to be hydrophobic under the flotation conditions used, and liberation index cut-off values for AG and SAG class composite particles. SAG class liberation index cut-off values vary for the different BMS species, as the different BMS species have different floatability characteristics (Wiese et al., 2007; Penberthy et al., 2000). Initial "default" flotation parameter values are provided when the flotation predictor is run, and can be easily restored at any stage. These values are based on particle characteristics observed in samples generated by laboratory scale test-work that has been performed on various South African PGM ores. The parameters can be adjusted to suit a particular recovery plant, or circuit within that plant, according to mineralogical properties of PGM-bearing particles observed in representative samples of feed, concentrate and tailings gathered from the plant or circuit in question. The flotation predictor can thus produce results similar to those obtained from laboratory-scale rate tests from a full-scale operating plant. Once the plant feed has been properly characterised, the predictor output can be used as a diagnostic tool for routine plant monitoring and troubleshooting. Recovery via

Table 1
PGM-bearing particle mode of occurrence classes.

PGM mode of occurrence class	Description
L	Liberated PGM
SL	PGM associated with BMS only (i.e. a binary PGM–BMS particle)
AG	PGM attached to silicate or oxide gangue (i.e. PGM exposed at particle perimeter)
SAG	PGM associated with BMS attached to silicate or oxide gangue (i.e. BMS exposed at particle perimeter)
SG	PGM associated with BMS locked within silicate or oxide gangue (i.e. no exposure of BMS or PGM at particle perimeter)
G	PGM locked within silicate or oxide gangue (i.e. no exposure of PGM at particle perimeter)