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# Balancing the reagent suite to optimise grade and recovery

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**Abstract**

The recovery of Platinum Group Metals and Gold (PGM + Au) from the UG-2 reef of the Bushveld Complex is an interesting challenge when the selection and optimisation of the reagent suite is considered.

The UG-2 reef is characterised by two predominant gangue phases i.e. chromite and silicate, that have significantly different physical and chemical properties. A strategy needs to be devised to address concentrate grade that will reduce the recovery of gangue without significantly affecting the recovery of the valuable species.

Recovery of the valuable species is complicated by the fact that PGM + Au occurs as a variety of different minerals having varying chemical and physical properties. The operating strategy has to consider the characteristics of the valuable mineral species and maximise recovery while meeting stringent grade specifications.

Laboratory tests are conducted to illustrate the effect of the various flotation parameters. Applications of the findings on existing concentrators are discussed illustrating the need for a better understanding of the contribution of the various mechanisms occurring in the flotation cell. The paper demonstrates the significance of entrainment in the recovery of both valuable species and gangue species, and the need for a greater understanding of this non-selective sub-process on overall circuit performance.

This paper forms part of a postgraduate study through the University of Cape Town into the development of a mechanistic model for the entrainment process. Although much work has been done in this study of the effect of various other parameters on the flotation of UG-2 ore, this paper focuses on the effect of frother, depressant and water on the flotation results.


*Keywords:* Precious metal ores; Froth flotation; Flotation reagents; Process optimisation

## 1. Introduction

In optimising a flotation plant the metallurgist has to consider the effect of various parameters on the recovery and grade of the precious metal. In some cases the scenario is complicated by the presence of a gangue phase that has severe consequences in the downstream processing of the flotation concentrate.

The metallurgist is faced with the challenge of balancing the operating parameters so as to produce a high grade valuable mineral concentrate of low mass without compromising the concentrate with unacceptably high contaminant content. In so doing the metallurgist must consider the various sub-processes that occur in a flotation cell, and understand the effect of the various parameters on these sub-processes.

The objective of this paper is to describe such a scenario in the production of Platinum Group Metal (PGM) concentrate from the UG-2 reef, a topic that is the focus of much development on the Bushveld Complex in South Africa.

Laboratory tests are conducted to illustrate the effect of frother, depressant and solids concentration on the flotation results. Together with aeration rate and froth depth these parameters are commonly the most varied in the operation of a flotation concentrator.

The findings of the testwork and the quantification of the effect of the parameters on the behaviour of the various species have been realised on existing operations in the optimisation of the concentrate grade and recovery.

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### 1.1. The UG-2 orebody

The UG-2 ore is a platinum-bearing chromitite ore that contributes a growing proportion of the Platinum Group Metal production from the Bushveld Igneous Complex in Northern South Africa (McClaren and de Villiers, 1982). This ore is ideal for the study of entrainment as it contains varying proportions of two major gangue phases (chromite and pyroxene) that have significantly different physical and chemical properties.

The ore contains trace amounts of base metal sulphides, that, despite their low concentration, are of importance as they frequently occur is association with many of the PGM-bearing minerals. The copper (occurring primarily as chalcopyrite) and nickel (occurring primarily as pentlandite or pyrrhotite) grades of the ore are typically 0.005% and 0.025%, respectively.

### 1.2. Processing of UG-2 ore

As illustrated in Fig. 1 the first metallurgical stage in the production of Platinum Group Metals and Gold (PGM + Au) is the production of a concentrate as feedstock to the smelter. The smelter–converter stage is followed by a refining stage for the production of primarily copper and nickel, and a further refining stage for the production of the individual PGM + Au metals.

The conventional concentrator circuit is illustrated in Fig. 2. This is commonly referred to as an MF2 circuit. The particle size of the feed to the primary flotation circuit is typically 35% passing 75 μm and that of the feed to the secondary circuit is typically 75% passing 75 μm. The conventional flotation stages typically consist of rougher, cleaner and recleaner stages.

There are a number of variations to this circuit including the cleaner cell configuration, the destination of the cleaner tailing stream and separate secondary processing of the chromite- and silicate-rich streams.

Feed grades to the concentrator range from 4 g/t to 5.5 g/t. Final concentrate grades range from 120 g/t to in excess of 300 g/t. The higher concentrate grade is driven by the availability of smelter capacity and some producers cannot cope with the high concentrate tonnage at the low grades.

Flotation of PGM + Au from UG-2 ore was developed from a classical base metal sulphide flotation recipe. This has proven successful even though the base metal sulphide grades are relatively low. Much work is and has been done to understand the mechanisms for the recovery of the PGM-bearing minerals.

A typical reagent suite for UG-2 flotation consists of an activator ($CuSO_4$), collector (SIBX), depressant (carboxy methyl cellulose) and frother (DOW200) (Overbeek et al., 1984).

### 1.3. Considering the sub-processes in flotation

It has been widely accepted that the process of flotation is a combination of a number of individual sub-processes. Simply, the process whereby solids and water are transferred from the pulp phase to the froth phase can be described by considering the sub-processes of true flotation and entrainment (Bradshaw et al., 2005). A further sub-process whereby some of the solids and water return from the froth phase to the pulp is termed drainage.

True flotation can be described as the selective chemical sub-process where hydrophobic minerals are attached to the bubbles rising through the pulp. Entrainment is described as a non-selective physical sub-process where solids and water is transferred to the froth in the bubble lamellae and bubble interstices.

In assessing the results of flotation tests the metallurgist must consider the interaction of the various sub-processes and the effect of these processes on the response of the various minerals in the ore.

### 1.4. Challenges in processing UG-2 ore

The PGM + Au recovery from UG-2 ore across the Bushveld Complex varies from 75% to +90%. The differences in recovery can be attributed to a number of factors including differences in mineralogy, plant capacity and operating philosophy.

Apart from recovery a major challenge in the processing of UG-2 is the chromite ($FeCr_2O_4$) grade in the final concentrate. High chromite grades (>5%) have severe implications in the smelter and are normally met with severe penalties. Some smelters may refuse to accept such concentrate.

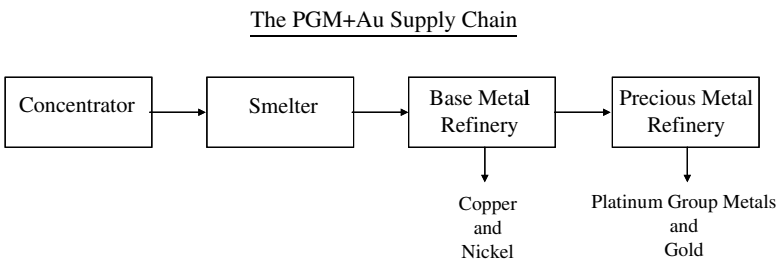


Fig. 1. The Platinum Group Metal supply chain.