

An industrial scale study of the floatability and rejection of fine minerals and pyrrhotite in ug2 PGM tailings deposits when using different reagent combinations

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High-grade platinum group mineral (PGM) deposits are being depleted, making tailings treatment operations increasingly viable. The feed to tailings operations is laden with fine minerals that were not beneficiated during the initial flotation processes; driving the need for additional research focussing on recovering fines while producing a product of saleable grade. A concentrator plant in the Bushveld Ingenious Complex receiving UG2 concentrator tailings as feed was investigated. The concentrator used sodium isobutyl xanthate (SIBX) and a novel fines-collector (FOC), HOSTAFLOT 9023 to recover PGMs by means of flotation. The flotation of individual minerals was investigated across the size range of -10 µm to +150 µm. The optimal flotation size range (10 - 150 µm) was divided into five fragments.

Chalcopyrite, pentlandite and pyrrhotite were identified as valued minerals for this study. The loss of valued minerals to tailings was evaluated across the entire size spectrum. Losses of valued minerals were quantified as too small to float (< 10 µm), too large to float (>150 µm), locked to a depressed gangue mineral or locked to a naturally hydrophilic mineral. Pyrrhotite is a very difficult mineral to float in a PGM flotation circuit and losses as pyrrhotite to tailings are significant. It was found that pyrrhotite losses as fines were significantly less in the presence of the novel HOSTAFLOT 9023. Talc, enstatite, pyroxene, quartz, feldspar, amphibole, mica and chromite were identified as gangue minerals for this study. The presence of gangue minerals in the concentrate was investigated and attributed to either entrainment, entrapment, locking to a value mineral or being a natural floating mineral in the system. Floatability and entrainment of the different gangue minerals were measured against the type of flotation collector used. It was found that less naturally-floating talc, enstatite, and pyroxene reported to the concentrate when using the novel fines-collector, resulting in an improved concentrate grade and less chromite in the concentrate.

Keywords: PGM tailings, fines-collector, chalcopyrite, pentlandite, pyrrhotite

INTRODUCTION

Platinum group minerals (PGMs) refer to minerals containing platinum group elements (PGEs). The PGEs (platinum, palladium, rhodium, iridium, ruthenium) and gold make up the typical basket in UG2 production. UG2 also contains small quantities of copper and nickel. The highly complex nature of UG2 platinum group mineralisation necessitates the use of a simpler model when evaluating the flotation behaviour of these minerals. Grain size, liberation and association are the main factors that influence mineral floatability. (Chetty, Gryffenberg, Lekgetho, & Molebale, 2009).

The typical feed of a UG2 tailings retreatment concentrator contains Pt, Pd, Rh and Au (referred to as 4E), typically at < 1ppm 4E PGEs, and the meaningful analysis of PGMs to do a statistically relevant study is very difficult and time consuming (Bushell, 2012). The PGE content in the ultra-fine region is more than eight times that of the content in the coarser fraction, and the copper and nickel values are also higher in the fines region, indicating that PGMs are associated with base metal sulphides (BMS) (Von Gruenewaldt & Hatton, 1987). The analysis of BMS is easier and more cost effective when compared to that of PGMs. Flotation of PGMs is based on bulk sulphide flotation principles, and the analysis of the flotation behaviour of BMS can therefore predict the flotation behaviour of PGMs, such that helpful suggestions can be made to improve the recovery of PGEs on this basis (SGS Mineral Services, 2004). PGE sulphides and PGE base metal sulphides account for 48 – 86% of all PGMs in UG2 ore (Rose, Viljoen, & Mulaba-Bafubiandi, 2018). When considering PGM floatability, PGM association with BMS is claimed to be of the same importance, if not more, than liberated PGMs (Chetty, Gryffenberg, Lekgetho, & Molebale, 2009).

Pyrrhotite, pyrite, pentlandite, chalcopyrite and intergrowths thereof are the BMS that host the PGMs. The dominant BMS being pentlandite occurring at 45 – 48%, along with chalcopyrite (19 – 24%), pyrite (9 – 27%) and pyrrhotite (1 – 22%) (Rose, Viljoen, & Mulaba-Bafubiandi, 2018). Pyrrhotite is the slowest-floating mineral (Mishra, Viljoen, & Mouri, 2013) and will be the most likely to report to tailings – suggesting that losses of PGMs during the flotation of UG2 ore may be directly associated with the poor flotation characteristics of pyrrhotite (Rose, Viljoen, & Mulaba-Bafubiandi, 2018). The UG2 reef has smaller grain sizes when compared to the Merensky reef, and this is one of the beneficiation challenges explaining why the UG2 reef was only exploited many years after being discovered (Pentberthy & Oosthuysen, 2000). Valued mineral losses during flotation in the beneficiation of PGMs are mainly contributed to fines and ultra-fines. Different sized particles display different flotation behaviour when exposed to different flotation chemicals, and particles < 10 µm are (ultra-fines) are often lost in flotation. For example, sodium isobutyl xanthate (SIBX), used as primary sulphide flotation collector on the majority of PGM plants in South Africa, is not effective to prevent losses as fines and as pyrrhotite (Corin, McFadzean, Shackleton, & O'Connor, 2021). Because most PGM grains in UG2 ore occur in this ultra-fine region it is important to use collectors that are more effective at collecting fines. Indeed, fines recoveries are improved when a dithiophosphate (DTP) co-collector is dosed in addition to the conventional SIBX for these ores. The PGEs (platinum and especially palladium) that also occur in these finer fractions, showed improvements in recovery when a co-collector was dosed (Corin, McFadzean, Shackleton, & O'Connor, 2021). When dosing Clariant's novel HOSTAFLOT 9023 to a run of mine (ROM) UG2 ore, platinum recoveries were similar to recoveries when SIBX was dosed, and the Pt grade increased – at a lower mass recovery (Engelbrecht, Jordaan, & Cloete, 2022). Considering that Pt occurs in the -10 µm region, this is to be expected when targeting fines.

The losses of PGEs as fines and the losses as PGEs associated with pyrrhotite called for the development of an appropriate flotation reagent that can successfully address these losses on a tailings retreatment concentrator. The development in sulphide flotation reagents has been slow, and in the case of PGMs, not close to what is required when considering the surging basket prices and retreatment potential. New reagents for these types of problems are being developed according to technical and environmental standards and a 2-3% volume increase per annum is predicted (Pearse, 2005).

MATERIALS AND METHODS

Ore and mineral grouping

A concentrator treating tailings from a ROM UG2 operation in the Bushveld Igneous Complex in the Kroondal/Marikana area in South Africa was used to evaluate the performance of two different collectors. A novel fine ore collector (HOSTAFLOT 9023) developed specifically for fines recovery and improved pyrrhotite recovery was measured against SIBX during a 29-day plant trial. The mineralogy of the ore indicated it contained 0,38% sulphides (Cu, Ni, Fe and other sulphides); 27,92% talc; enstatite and pyroxene; 23,23% quartz and feldspar; 4,58% amphibole and mica, and 42,42% chromite. Analytical results obtained on the head samples indicated 0,94 g/t 4E PGMs, traces of Cu, 0,09% Ni, 12,34% Fe, 0,01% S, 13,14% Cr, 19,20% Cr₂O₃. Analysis of 4E PGM was carried out by fire assay, while the other

elements were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). The major oxide determination for the %Cr₂O₃ was done using lithium metaborate/tetraborate fusion. The minerals in this study will be grouped into copper-, nickel-, iron- sulfides. Cu sulfides will be referred to as chalcopyrite, Ni sulfides will be referred to as pentlandite and Fe sulfides will be referred to as pyrrhotite. The base metal sulfides are regarded as the valued minerals in this study. Gangue minerals are grouped as talc, enstatite and pyroxene; quartz and feldspar; amphibole and mica; chromite; and other gangue.

Reagents

The novel fine ore collector (HOSTAFLOT 9023) that is recommended for the specific application of recovering fine sulphide minerals and improving the recovery of pyrrhotite was supplied by Clariant. The collector performance was measured against a xanthate, SIBX, that forms the baseline for all test work. The HOSTAFLOT 9023 ore collector has certain characteristics when compared to conventional xanthates that makes it a promising reagent in PGM tailings-operations. These characteristics include that particles <25 µm are targeted, high selectivity towards chalcopyrite and pentlandite, improved recovery of pyrrhotite, lower mass pulls and lower dosages. This reagent is recommended for PFM tailings-operations and can be dosed on the cleaners as a grade enhancer.

Sampling conditions and procedures

The tailings-retreatment concentrator used for this study employs double-stage milling followed by flotation. This is an arrangement referred to as mill-float-mill-float (MF2). The flotation section has a standard rougher/cleaner/recleaner cascade configuration with final concentrate being pulled from the re-cleaner cells. Composite samples of the feed, final concentrate and final tails were taken on site. The composites of the feed, tail and concentrate were collected three times daily for 29 days to make up the sample examined in this study. The concentrate stream was manually sampled and in each case the sample cutter width was at least three times the size of the largest particle present in the stream (>400 µm). A spare volume of 50% was accounted for to make sure the cutter did not overflow. The cutter cut the full width of the respective stream at a constant velocity. The feed and tails streams were sampled by a pneumatically driven, flow through cutter on site.

Table I. Basic conditions for flotation on the tailings retreatment sites

Condition/parameter	Value
Flotation feed density	>1,38 g/ml
pH _{flotation}	Natural
Collector	SIBX, HOSTAFLOT™ 9023
Collector dosing point 1	Primary mill discharge
Collector dosing point 2	Secondary rougher feed tank
Collector dosage (g/t)	150 g/t SIBX 70 g/t HOSTAFLOT™ 9023
Collector strength	SIBX 40% HOSTAFLOT™ 9023 100%
Frother	PPG 200
Frother dosage (g/t)	5 g/t
Depressant	CMC
Depressant dosage (g/t)	100 g/t

Analyses were performed on the mineral groups by Quantitative Evaluation of Materials by Scanning Electron Microscopy (QEMSCAN). Each sample was split in a coarse and fine fraction and analysed separately by using 6µm and 3µm point spacing respectively. Mineral occurrence was investigated across seven size fractions and classified as too small to float, optimal flotation size and too large to float. Particles classified as too small to float are smaller than 10 µm. Well sized particles are in the size range between 10 and 150 µm. These particles are considered as being in the optimal size range for flotation. This range can be further expanded to 10 – 25 µm, 25 – 50 µm, 50 – 75 µm, 75 – 100 µm and 100

- 150 μm to have more detailed information on the size fractions in which particles occur. Particles larger than 150 μm are considered too large to be recovered by flotation.

Calculated Recovery

The calculated recovery in this study was determined using the standard metallurgical recovery formula shown as equation 1 because only the feed (f), concentrate (c) and tails (t) assays were available and not the mass fractions as in a single flotation experiment.

$$R = \frac{100c(f-t)}{f(c-t)} = \text{recovery \%} \quad [1]$$

This recovery represents the ratio of the weight of metal or mineral value recovered in the concentrate to 100% of the same constituent in the heads or feed to the process and is expressed as a percentage.

Results and discussion

This section presents and discusses results of the effect of the novel fine ore collecting reagent on the flotation performance in an industrial scale UG2 tailings retreatment plant.

Tailings Plant Feed (TPF) Analysis

The calculated assay of the TPF is 0,95 g/t 4E PGM and 19,20% Cr_2O_3 . An assay by size fraction was done to determine where the majority of PGMs were located. The assay by size for the UG2 TPF is given in Table II.

Table II. Assay by size for TPF

Size (μm)	Mass %	4E g/t	PGM location
+ 106	11,29	0,50	6%
+ 75	12,65	0,83	11%
+ 53	4,37	1,05	5%
+ 38	20,89	0,83	18%
- 38	50,80	1,10	60%

As can be seen in Table II, more than 60% of the PGMs in the feed occur in the <38 μm fraction. The TPF originates from an upstream run-of-mine (ROM) UG2 concentrator. The number of fines in the TPF stream indicates major losses as fines in the upstream process. The mineral analysis of the tailings retreatment feed produced trace amounts of chalcopyrite, 0,02% pentlandite, 0,36% pyrrhotite, 23,23% quartz and feldspar, 27,92% talc, enstatite and pyroxene, 4,58% amphibole and mica, 42,42% chromite and 1,48% other minerals. The amount of pyrrhotite in the TPF is much higher when compared to other BMS (chalcopyrite and pentlandite). This is indicative of poor pyrrhotite flotation performance in the upstream UG2 ROM concentrator, where pyrrhotite is the least abundant mineral in the fresh feed. Figure 1 compares the relative abundance of the value minerals is a typical ROM feed to that of the occurrence in the tailings plant feed studied in this paper. The abundance of pyrrhotite emphasises the opportunity to increase value mineral recoveries by targeting pyrrhotite.

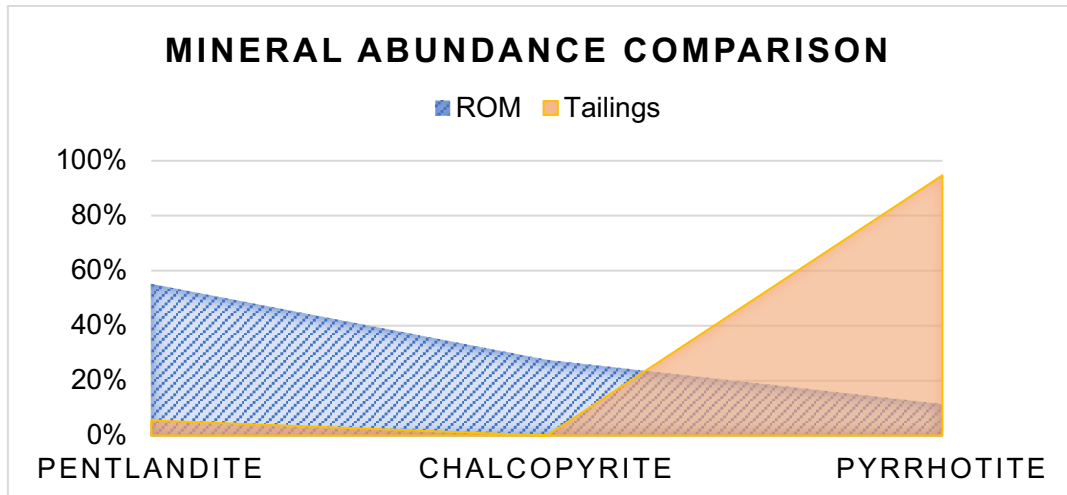


Figure 1. Mineral abundance comparison between ROM and tailings ore.

The value minerals in the TPF are identified as chalcopyrite, pentlandite and pyrrhotite.

Three percent of the chalcopyrite in the TPF are liberated. All the liberated chalcopyrite occurs in the 0 – 10 µm fraction. Ninety-seven percent of the chalcopyrite are locked to gangue mineral- and base metal sulphide particles. Table III reports on the locked chalcopyrite particles:

Table III. Chalcopyrite liberation in TPF

Chalcopyrite	Size Range ($x = \text{particle}$)	
Liberated	3%	0 – 10 µm
Locked	97%	
	15%	0 – 10 µm
	82%	10 µm > x > 150 µm
	0%	> 150 µm
<i>Locked to:</i>		
Chromite	20%	< 25 µm
Quartz and feldspar	63%	25 µm > x > 150 µm
Talc and enstatite	9%	10 µm > x > 100 µm
Amphibole and mica	4%	50 µm > x > 75 µm
Other BMS	4%	0 – 10 µm

Chalcopyrite is locked with chromite in the fine fraction. Chromite is a non-floating mineral in this reagent system but might report to the concentrate due to entrainment. Most (63%) chalcopyrite in the optimal size (10 – 150 µm) fraction is locked to quartz and feldspar. Quartz and feldspar are non-floating minerals in this system. This might mean losses of chalcopyrite occur due to locking with non-floating gangue minerals. Nine percent of chalcopyrite is locked to talc and enstatite, a natural floating gangue mineral in this system. It is predicted that the talc and enstatite locked to chalcopyrite will report to concentrate, unless depressed. Four percent of the chalcopyrite is locked to amphibole and mica, which acts as a middling in this system. Four percent of the chalcopyrite is locked to other BMS in the fines fraction and should report to concentrate. No oversized chalcopyrite was found in the TPF.

Sixteen percent of the pentlandite in the feed is liberated and all liberated particles occur in the fine region. Eighty-four percent of the pentlandite is locked. Table IV shows the liberation results for pentlandite in the TPF:

Table IV. Pentlandite liberation in TPF

Pentlandite	Size Range ($x = \text{particle}$)	
Liberated	16%	0 – 10 μm
Locked	84%	
	23%	0 – 10 μm
	51%	10 $\mu\text{m} > x > 150 \mu\text{m}$
	10%	> 150 μm
<i>Locked to:</i>		
Chromite	46%	< 25 μm
Quartz and Feldspar	8%	> 150 μm
Talc and Enstatite	26%	> 150 μm
Amphibole and Mica	7%	> 150 μm
Other BMS	12%	0 – 10 μm

It is noteworthy that there are pentlandite particles present in the coarse fraction. Ten percent of pentlandite occurs in the +150 μm region, and most locking with quartz and feldspar, talc and enstatite and amphibole and mica occurs in this region. Particles > 150 μm are considered too large to float, and it is predicted that these particles will report to the tails. Forty-six percent of the locked particles were locked to chromite in the finer fraction (<25 μm). Chromite is a non-floater in this system, but due to the fine nature of the particles, chromite might still report to the concentrate due to entrainment. The large amount of talc and enstatite locked to pentlandite (26%) suggests a possible sticky froth that might lead to entrapment of oversized gangue minerals in the concentrate. Twelve percent of all locking of pentlandite occurs with other BMS in the fines region.

Twenty-five percent of pyrrhotite in the TPF is liberated and occurs in the fines region. Thirty-four percent of pyrrhotite is locked in the fines region and 41% is locked in the optimal sized region. Overall, the pyrrhotite occurs as very small particles. The liberation of the pyrrhotite in the TPF is analysed in Table V:

Table V. Pyrrhotite liberation in TPF

Pyrrhotite	Size Range ($x = \text{particle}$)	
Liberated	25%	0 – 10 μm
Locked	75%	
	34%	0 – 10 μm
	41%	10 $\mu\text{m} > x > 150 \mu\text{m}$
<i>Locked to:</i>		
Chromite	73%	< 25 μm
Talc and Enstatite	15%	< 25 μm
Amphibole and Mica	1%	< 25 μm
Other BMS	11%	0 – 10 μm

Considering how fine the pyrrhotite particles interlocked with chromite are, it is predicted that an increased pyrrhotite recovery might also cause a slightly increased chromite recovery. This means that if more pyrrhotite reports to the concentrate, the % Cr₂O₃ might also increase. The increase in % Cr₂O₃ should not be of such a value that it negatively impacts the concentrate sent to the smelter, resulting in penalty fees. The benefit in the pyrrhotite recovery should thus outweigh the negative aspect of chromite recovery. Even though it is known that fines and ultra-fines are the most difficult particles to recover, all liberated BMS and BMS associations in the TPF occur in these fractions. The 4E PGM occurrence (60%) in the finer fraction confirms the association with chalcopyrite, pentlandite and pyrrhotite. It then makes sense that this should be the area targeted by a flotation collector in a tailings operation.

Losses to tailings plant tails (TPT)

Based on the feed composition, losses were predicted on fines, both as oversized pentlandite and as pyrrhotite. Table VI indicates the conditions that the concentrator operated on, and the assay results obtained for 4E PGMs and Cr₂O₃:

Table VI. Operating conditions and tails analysis

Conditions	Description	Overall Dosage	4E PGM Assay	% Cr ₂ O ₃
Scenario 1 (Xanthate operation)	SIBX as primary collector	150 g/t	0,76 g/t	13,37%
Scenario 2 (FOC operation)	HOSTAFLOT™ 9023 as primary collector	70 g/t	0,80 g/t	13,54%

The difference in 4E PGM assay values for the two conditions falls within a 95% confidence interval and is seen as nearly similar. The losses as fines were investigated for both scenarios and will be discussed in Table VII – Table XII.

Table VII compares the occurrence of value minerals in the TPT as mass totals (wt%) for the two scenarios:

Table VII. Comparison of valued mineral mass total in TPT

Primary Reagent →	SIBX	HOSTAFLOT™ 9023	Comparison of losses	Relative Increase
Valued Mineral ↓	Mass Total (Wt%)			
Chalcopyrite	0,003	0,002	▼	- 67%
Pentlandite	0,019	0,012	▼	- 63%
Pyrrhotite	0,333	0,211	▼	- 63%

An improvement can be seen in the recovery of chalcopyrite, pentlandite and pyrrhotite when using the HOSTAFLOT 9023 as primary reagent relative to SIBX. The losses as fines are shown in VIII:

Table VIII. Losses as fines to the TPT

Primary Reagent → Valued Mineral ↓	SIBX	HOSTAFLOT™ 9023	Losses	Relative Increase
<i>Chalcopyrite</i>	0,07%	0,04%	--	--
<i>Pentlandite</i>	2,65%	1,26%	▼	- 47%
<i>Pyrrhotite</i>	57,23%	38,74%	▼	- 67%

The amount of pentlandite and pyrrhotite (wt%) losses as fines are reduced when using the HOSTAFLOT 9023. The most significant reduction was seen in the loss as fine pyrrhotite. This is also consistent with the reduced amount of overall pyrrhotite lost as seen in Table VII.

Minerals in the tailings plant concentrate (TPC)

The gangue minerals reporting to the concentrate are quartz and feldspar, talc, enstatite and pyroxene, amphibole and mica and chromite. Any other gangue minerals are referred to as other minerals. The mass distributions (wt%) of the concentrates are given in Table XV for both the SIBX and the HOSTAFLOT 9023 tests.

Table IX. Mineral composition of the TPC (wt%)

	Mass Total (Wt%)		
	SIBX	HOSTAFLOT™ 9023	
Total valued minerals	0,48	1,49	▲
Quartz and feldspar	10,55	11,08	--
Talc, enstatite and pyroxene	53,25	47,24	▼
Amphibole and mica	7,84	9,65	--
Chromite	29,09	26,44	▼
Other	1,44	1,46	--

The mass total (wt%) of the valued minerals in the TPC increased significantly when using the HOSTAFLOT 9023. The increase was mainly due to the improved recovery of pyrrhotite. The increase in pyrrhotite recovery is very promising. The calculated recoveries of pyrrhotite when using SIBX and the HOSTAFLOT 9023 are compared in Table X:

Table X. Pyrrhotite calculated recovery and fines recovery

<i>Pyrrhotite</i>	SIBX	HOSTAFLOT™ 9023	
<i>Calculated Recovery</i>	30,57%	48,14%	▲
<i>Fines Recovery</i>	44,28%	51,43%	▲

The calculated recovery for pyrrhotite is higher when using the HOSTAFLOT 9023 when compared to SIBX.

Talc, enstatite and pyroxene are the main gangue minerals in the TPC. The usage of the HOSTAFLOT 9023 also resulted in a reduction of natural floating talc, enstatite and pyroxene in the concentrate. These minerals are naturally hydrophobic, and when they are dominant in the concentrate, they cause a thick, sticky froth. This type of froth structure can contribute to entrapment of coarse gangue minerals and minerals that are naturally hydrophilic due to poor drainage. Table XI shows the results for talc, enstatite and pyroxene in the TPC.

Table XI. Talc, enstatite and pyroxene distribution in the TPC

<i>Talc, Enstatite and Pyroxene</i>	SIBX	HOSTAFLOT™ 9023	
Mass Total (wt%) in TPC	53,25	47,24	▼
< 10 µm	10,18	8,82	▼
10 - 150 µm	42,51	37,98	▼
> 150 µm	0,57	0,44	▼

The HOSTAFLOT 9023 reduced the percentage of talc, enstatite and pyroxene in the TPC across the entire size range. That is indicative of a collector that is more selective against talc.

It would be expected that the chromite in the TPC should also be less since there should be better froth drainage. This is the case as indicated by Table XII:

Table XII. Chromite distribution in the TPC

<i>Chromite</i>	SIBX	HOSTAFLOT™ 9023	
Cr ₂ O ₃ assay	14,39	12,9	▼
Mass Total (wt%) in TPC	29,09	26,44	▼
< 10 µm	12,42	11,48	▼
10 - 150 µm	16,66	14,96	▼
> 150 µm	--	--	

The amount of chromite in the TPC decreased when the HOSTAFLOT 9023 was used. This suggests that the reduced amount of talc, enstatite and pyroxene recovered to the TPC when using the HOSTAFLOT 9023 might have contributed to less entrainment of chromite fines and better drainage of well sized liberated chromite particles.

CONCLUSIONS AND RECOMMENDATIONS

This investigation has shed light on the probable reagent type preference of fines in the PGM tailings retreatment industry. Losses in ROM UG2 concentrators occur as fines, as confirmed by the analysis indicating that 60% of the 4E PGMs in the TPF are smaller than 38 µm. Pyrrhotite is also more abundant in the TPF, indicating difficulty floating this mineral upstream. The recovery of valued mineral fines and pyrrhotite should be improved, and one novel fine ore collector (HOSTAFLOT 9023) that showed promise on this type of material was investigated in this study. The HOSTAFLOT 9023 not only has a lower dosage rate, no reagent make-up and reduced human interaction, but it also delivers a higher recovery of finer, difficult to float minerals. The HOSTAFLOT 9023 recovers a reduced amount of talc, enstatite, and pyroxene to the concentrate, indicating a collector that is more selective against talc. That is very promising considering the need to depress these gangue minerals on Merensky type of ores. The chromite recovered to the TPC decreased when the HOSTAFLOT 9023 was used. Lower talc, enstatite, and pyroxene appear to be correlated to lower chromite. Chromite is a naturally hydrophilic mineral and should only occur in the concentrate as an ultrafine entrained mineral, as an entrapped oversized mineral or as a mineral floating naturally due to interlocking with a hydrophobic mineral.

It is suspected that the chromite in the TPC decreased because the concentrate, and therefore the froth, had less of the main gangue minerals (talc, enstatite, and pyroxene). This could have resulted in a froth that allowed for better drainage of well-sized, liberated chromite and promoted less entrainment of ultrafine chromite particles. When investigating the valued mineral losses to the tails, there was an overall improvement using the HOSTAFLOT 9023. Less fines were lost to the tails, and pyrrhotite, mostly occurring as fines, was better recovered. It would be beneficial to do assays by size on the tail and concentrate streams, as well as feed. It would also be beneficial to test the scenario where SIBX and the HOSTAFLOT 9023 are dosed concurrently on the concentrator. The Cu/Ni response to the

HOSTAFLOT 9023 should also be assayed. The HOSTAFLOT 9023 not only has a lower dosage rate, no reagent make-up and reduced human interaction, but also delivers on the goal to recover finer, difficult to float minerals. This magnifies the importance of investigating the wide selection of novel reagents available that can not only address processing concerns, but also reagent handling, logistics, toxicity, environmental issues and costs.

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REFERENCES

- Bulatovic, S. (2003). Evaluation of alternative reagent schemes for the flotation of platinum group minerals from various ores. *Minerals Engineering*, 931-939.
- Bushell, C. (2012). The PGM flotation predictor: Predicting PGM ore flotation performance using results from automated mineralogy systems. *Minerals Engineering*. Retrieved from <http://dx.doi.org/10.1016/j.mineng.2012.02.016>
- Cabri, L. (1981). Platinum-Group Elements: Mineralogy, Geology, Recovery. *CIM Special Volume 23*.
- Chander, S., & Nagaraj, D. (2007). Flotation Reagents, Flotation. *Encyclopedia of Separation Science*.
- Chetty, D., Gryffenberg, L., Lekgetho, T., & Molebale, I. (2009, October). Automated SEM study of PGM distribution across a UG2 flotation concentrate bank: implications for understanding PGM floatability. *The Journal of The Southern African Institute of Mining and Metallurgy*, 109, 587.
- Corin, K., McFadzean, B., Shackleton, N., & O'Connor, C. (2021). Challenges Related to the Processing of Fines in the Recovery. *Minerals*, 11, 533. Retrieved from <https://doi.org/10.3390/min11050533>
- Engelbrecht, S., Jordaan, P., & Cloete, J. (2022). Investigating the recoveries and grades of individual platinum group and precious metals when alternative collector chemistries are used on UG2 ore. *Minerals Engineering*, 179.
- Mishra, G., Viljoen, K., & Mouri, H. (2013). Influence of mineralogy and ore texture on pentlandite flotation at the Nkomati nickel mine, South Africa. *Minerals Engineering*, 54, 63-78. doi:10.1016/j.mineng.2013.04.009
- Pearse, M. (2005). An overview of the use of chemical reagents in mineral processing. *Minerals Engineering*, 18, 139-149.
- Pentberthy, C., & Oosthuyzen, E. M. (2000). The recovery of platinum-group elements from the UG-2 chromitite, Bushveld Complex - a mineralogical perspective. *Mineralogy and Petrology*, 68, 213-222.
- Rose, D., Viljoen, K., & Mulaba-Bafubiandi, A. (2018). A mineralogical perspective on the recovery of platinum group elements from Merensky Reef and UG2 at the Two Rivers mine on the Eastern limb of the Bushveld Complex in South Africa. *Mineralogy and Petrology*, 112, 881-902. Retrieved from <https://doi.org/10.1007/s00710-018-0594-7>
- SGS Mineral Services. (2004). PGM ORE PROCESSING AT IMPALA'S UG-2 CONCENTRATOR IN RUSTENBURG, SOUTH AFRICA. *Technical Paper*, 02. Retrieved from <https://www.sgs.com/-/media/global/documents/technical-documents/sgs-technical-papers/sgs-min-tp2004-02-pgm-ore-processing-at-ug-2-concentrator-in-south-africa.pdf>
- Von Gruenewaldt, G., & Hatton, C. (1987, September). Platinum-group metals-a resource in the tailings of chromium mines in South Africa. *Journal of the South African Institute of Mining and Metallurgy*, 87(9), 265-268.



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Metallurgist
Clariant

Shani grew up in a mining community and developed a passion for process metallurgy, specifically in the PGM and chrome sectors.

She has 14 years' experience in a production environment. This includes the full beneficiation process from crushing, milling, flotation and thickening.

She is highly proficient in investigating complex-mineralogy's for different ore bodies on processing plants and have done mineralogy studies and analysis for most existing concentrator plants in the SSA region in PGMs, copper, nickel, and chrome.

She has a special interest in being a mentor and inspiration to young students and metallurgists and gives her assistance in the initiation and completion of technical projects on site.

She has a proven ability to use applied research, data analysis and problem-solving skills to establish the root cause of production related issues, as well as heading investigations.

She is a published author and believes that she can make a positive contribution to the metallurgical mining community in her country and beyond.

