

QUANTIFICATION OF PLATINUM GROUP METAL ENRICHMENT IN THE FINES ASSOCIATED WITH PLATINUM MINING

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INTRODUCTION

The measurement of tonnage and grade is the current means of estimating the metals in the ore to be delivered to the Metallurgical Extraction Plant. The Mine Call Factor reports the discrepancy between metals called for and metals accounted for and this includes the losses associated with fines produced during blasting. Over a period of time metal accounting of the ore flow stream and grade comparison along the route should verify where the losses occur and the extent thereof.

Factors responsible for these losses can be divided into:

- those attributable to the inherent physical characteristics namely relative size and mode of occurrence of the mineralization and;
- mining induced factors arising from the drilling, blasting, cleaning and transport of the ore to the plant.

The principles of fluid dynamics provide insight into the role of water in transporting and depositing minerals and metal fragments in hydrological traps.

The study undertaken focused mainly on the Merensky reef although UG2 had to be considered in the blend obtained in the haulages and within the mud.

1. PGM MODE OF OCCURRENCE WITHIN THE MERENSKY REEF.

Mode of occurrence refers to the inherent physical characteristics.

A recent study done by the Department of Geological Sciences of the University of Cape Town at Northam Platinum had as its subject the mineralogical, textural and geochemical characterisation of the Merensky reef types.

Photomicrographs of rock specimens were taken. Microscopic techniques including transmitted light microscopy and reflected light microscopy were applied in achieving the images below. The images show the positioning and relative size of the PGM's within the surrounding mineral.

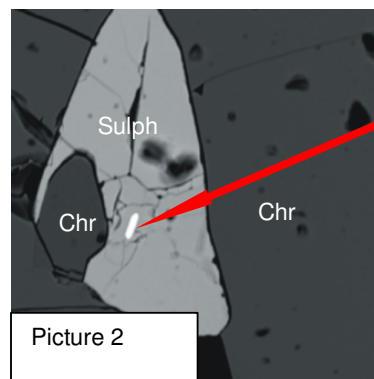
PGM's were observed as follows:

- PGM mineralization is closely associated with sulphides and chromitites.
- Decoupling of PGM's from sulphides take place near chromitites.
- The combined mode of occurrence of the PGM's result that more than 50% of PGM's occur at base metal sulphide and silica grain boundary contacts.
- 25% of the PGM's occur as inclusions in base metal sulphides.
- 10% of the PGM's occur at base metal sulphide and chromite contacts.
- The remaining 15% of PGM's occur as triple point junctions within chromite in chromitite stringers as small inclusions within silicates.
- 50% of the Platinum occurs in a band from 10cm above the chromitite to 10cm below the chromitite.

(The PGM's are the little white specs delineated within the surrounding minerals).

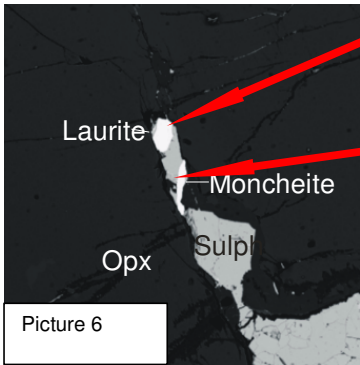
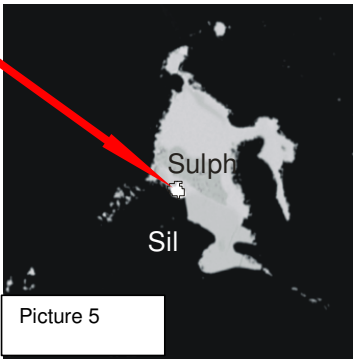
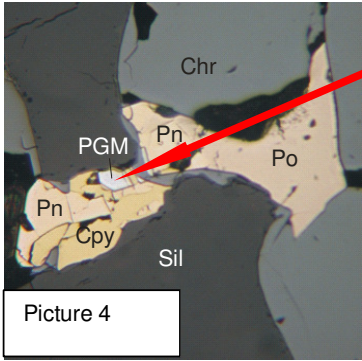
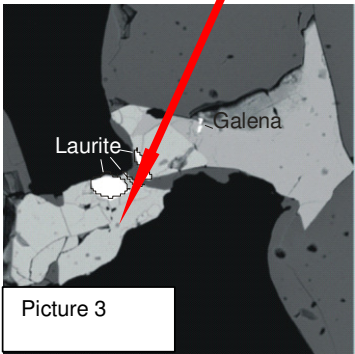
5.2.1 PGM's included in Base Metal Sulphide. (25%)

Pictures 1 and 2



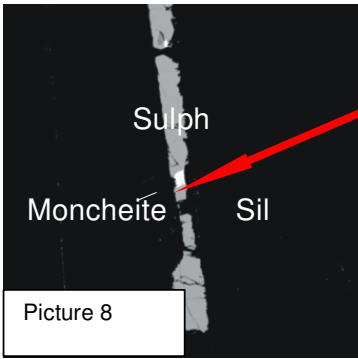
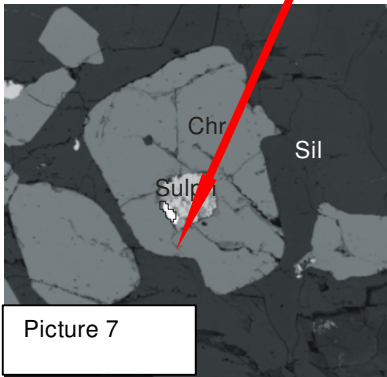
5.2.2 PGM's on Base Metal Sulphide / Silicate boundary (50%)

Pictures 3 - 6



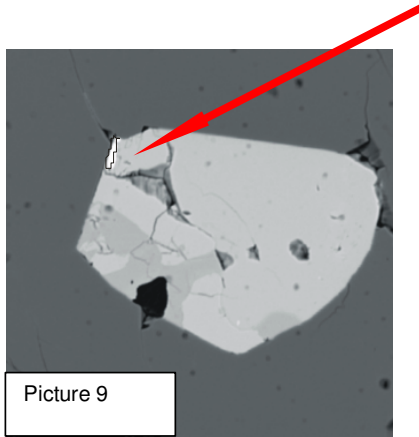
5.2.3 PGM's locked in Chromitite and PGM's in fractures (15%)

Pictures 7 and 8



5.2.4 PGM's at Base Metal sulphide and Chromite contacts (10%)

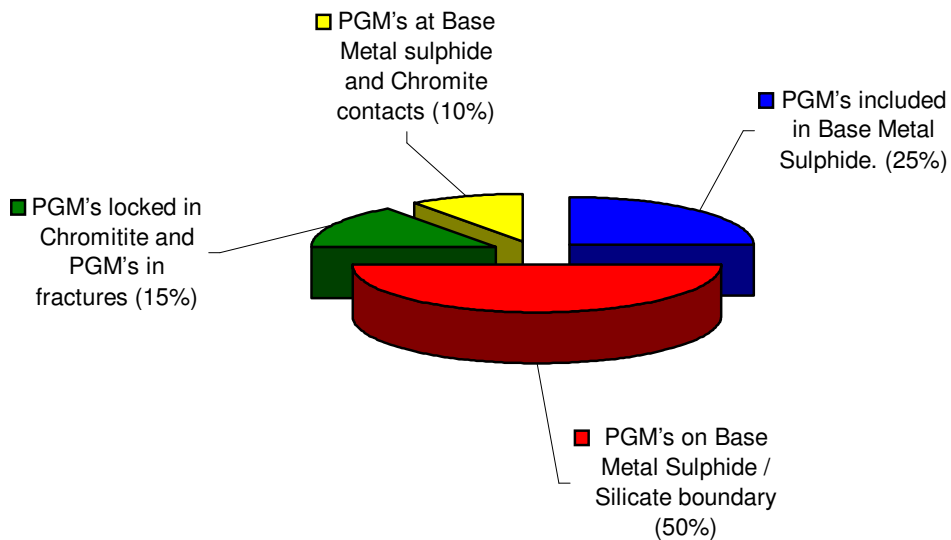
Picture 9



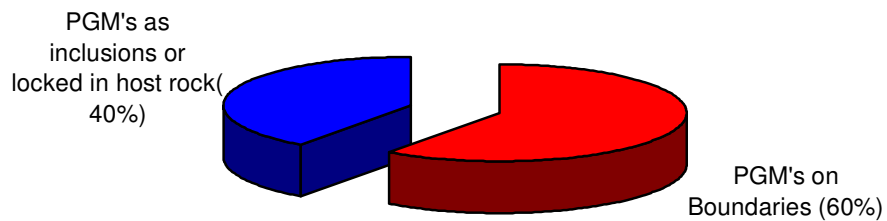
PGM relative size and mode of occurrence can be observed – Both these parameters support the thought that mineral losses are incurred because of physical characteristics as well as the method of extraction and removal.

(The imaging and analysis of these micrographs were done at the Department of Geology, University of Durban Westville.)

PGM's Mode of Occurrence % of Total.



Ratio between inclusions and Boundary Grain Modes of Occurrence.



The most abundant type of occurrence of PGM's is loose and on the boundaries. On breaking the rock the probability of separation of these finer particles is most likely.

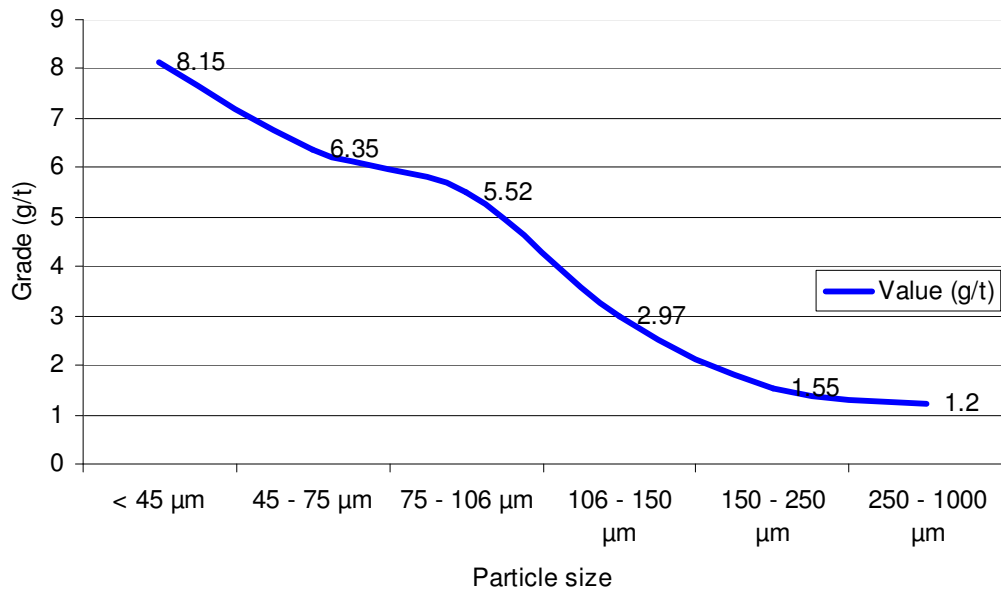
2. PGM SIZE DISTRIBUTION.

2.1 Flotation feed results.

A study undertaken by Knoetze and Van Vuuren in 1994 to determine the size grade relationship of broken rock did not consider particles <3,5mm.

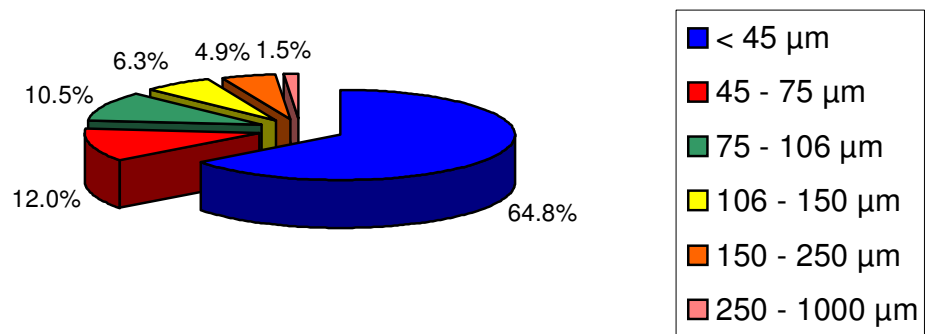
In order to determine the status of the <3,5mm fractions bulk sample feed results were analysed and the following was observed:

Value relative to particle size.



- The highest grade was in the smallest fraction <45μm.

% PGM's occurrence in relation to particle size.



- 64,8% of the PGM's occur in the <45μm range.
- Not only is the highest grade in the smallest fractions but the PGM's also concentrate here (PGM grain size is in this range).

2.2 Drill Core Laboratory analysis.

Drill Core analysis revealed the following:

Within the reef band, where the different PGM minerals occur, they are surrounded by:

Orthopyroxene, Feldspar, Biotite, Clinopyroxene, Sulphides, Chromite, Olivine.

These surrounding minerals range in size depending on the mode of occurrence.

Gangue mineral particle size ranges (note: mm).

Mineral	Size (mm)
Orthopyroxene	3.0 – 20.0
Feldspar	Interstitial
Biotite	0.1 – 4.8
Clinopyroxene	Interstitial and rims on Chromitite
Sulphides	0.1 – 3.8
Chromite	0.1 - 8.0
Olivine	3.0

PGM's refers to Cooperite, Moncheite, Laurite, Sperrylite, Braggite, Niggliite and Rustenburgite of which the following was observed in the P2 sample that was analysed.

PGM Particle size ranges (Note: μm)

Mineral	Size (μm)
Moncheite	10 – 29.5
Cooperite	5 – 36
Laurite	5 – 53
Braggite	8.5 – 37.5
Niggliite	6.5

A comparison of the smallest and biggest particles of the host rock to that of the PGM's shows that PGM's are from twice as small to more than 3000 times smaller than the surrounding minerals. The value spread confirms that most PGM's are smaller than $45\mu\text{m}$.

Grain size distribution of a combination of the different Merensky reefs skew towards $10\mu\text{m}$ with a peak of between 8 and $16\mu\text{m}$.

The range within which the PGM's were found is between 10µm and 70µm.

3. **ROCK SIZE AND GRADE RELATIONSHIP.**

Merensky value spread.

Source	No. of samples	Ave. width (cm)	Ave. value (g/t)	% Difference to the mean face value
Hanging wall	4786	18	2.86	39.78
Top Chrome Band	3571	11	23.79	330.88
Between Chrome bands	2520	31	5.76	8.011
Bottom Chrome band	2508	10	16.2	225.31
Foot wall	4786	56	4.51	62.73
AVERAGE ON FACE		126	7.19	

Metal grades within the Merensky reef (measured over the face width) are not evenly distributed. Results obtained from samples over a period of 2 years are summarised in the table below.

Grade disparity.

Stope face grades are consistently lower than shaft head grades. Measured over a period of ten years, this difference averaged 12.26%.

A portion of this percentage is recovered by mud pumping. Unfortunately a significant amount of metals still remains trapped underground.

Rock size and grade relationship.

In May, 1994, A.F. Knoetze and A.A. van Vuuren undertook a study to determine the relationship between the gradual attrition of the broken rock in the transport process to the plant and the values associated with different rock sizes. The hypothesis was that the gradual attrition of rock size causes losses in value.

Samples were taken from different locations along the transport route of ore from the same working stope.

The following locations were chosen:

- The stope panel,
- The store ore pass and;
- The reef belt.

The samples were screened into the following size distribution:

- >50mm
- 12 – 50mm
- 5 – 12mm
- 3.5 – 5mm
- <3.5mm

Knoetze and van Vuuren confirmed important relationships.

Face sample values of that taken in the Chrome bands are 2 – 3 times higher than the average values of the samples taken over the total reef width. Higher values were closely related to the chrome content of the samples taken.

Although the PGM grade is lower in the <3.5mm fraction than that of the 5 – 12 mm fraction the chrome content is more than double that of the latter fraction.

The relationship of high chrome content and high sample value in the smaller fraction sizes was not evident – which indicates that there has been a loss of value.

Greater losses of PGM's occur in the smaller ore fractions than the larger fractions.

The percentage of smaller fraction ore increases along the transport route thus increasing the probability of value losses even further. The >50mm portion of the total mass is halved between the stope ore pass and the reef belts.

In essence the study confirmed the following:

- Rock size is reduced progressively from the face to the reef belts.
- There is a loss in value between the stope face and the plant. Although the magnitude varies, the difference is significant.
- Greater value is associated with the smaller rock fractions.
- Higher values are not observed with higher chrome content in the smaller fractions as is expected which confirms losses of PGM's, which were associated with the chrome.

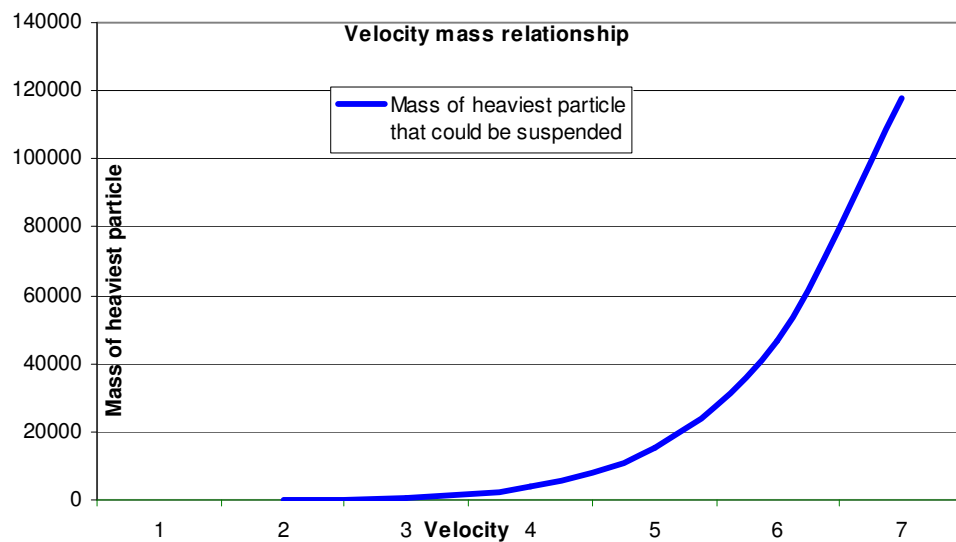
4. THE ROLE OF WATER AS TRANSPORT MEDIUM.

The Sixth Power Law

The mass of a particle not only determines its transportability but also stands in a specific relation to the velocity of flow.

The mass of the largest particle that can be lifted is to the power of 6 to the factor by which the velocity increases. For example: should the velocity increase 3 times, the mass of the largest particle that could be picked up would be 3 to the power of 6 or 729 times greater in mass. The maximum size of particles that could be picked up is called competence.

Velocity Mass relationship.



$M(\text{max}) = m(\text{previous max})$

$M = \text{mass}$

X – factor by which the velocity increases or decreases
(Flip Hjulstrom 1930 Sweden).

Hydraulic sorting.

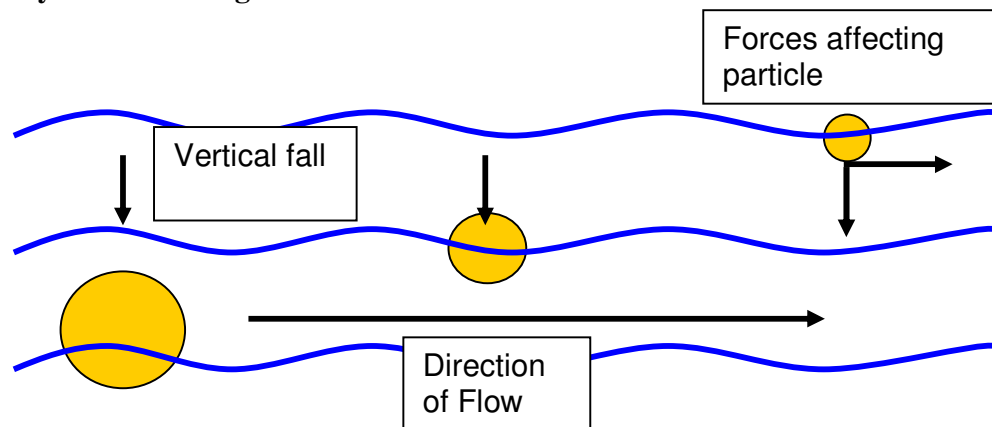
As the velocity and boundary shear stress decreases, the water current can no longer continue carrying the load and deposition of particles (sediment) takes place.

Finer sediment travels faster and further than coarser sediment. Hydraulic sorting takes place over the distance of flow. The finer the particles, the lower the velocity required to maintain these particles in suspension. At the same velocity before settlement can take place, the particles need to flock together to form larger aggregates that combine and settle because of their greater weight.

As the velocity reduces, particles will start to settle out under their own weight.

Hydraulic sorting takes place because finer particles are picked up faster and travel further than coarser particles.

Hydraulic sorting.



5. POSSIBLE MEASURES LIMITING LOSSES.

The factors that cause PGM losses are identified and can be listed as follows;

- Mode of occurrence
- Size of PGM particles
- Transport
- Fragmentation
- Water

As noted, certain factors are given and cannot be altered. These factors are the mineralogical, textural and geochemical characteristics of the rock established during the formation of the rock. Understanding this provides the opportunity to alter our mining strategies in order to negate these with the least probable losses. Fine losses can however not be seen in isolation as various factors need to be considered in achieving maximum metals recovery with the available resources.

Probable measures that need to be considered:

- Stop excessive use/abuse of water in the stopes.
- Implement face winch cleaning where viable.
- Minimise handling frequency of blasted ore in order to retain the larger fragment sizes as far as possible.
- Stick to a drilling pattern that will minimize excessive breakage of chromite.
- Select an explosive that meets both requirements – strength and fragmentation control.
- A vamping schedule should be followed removing all rock from mined out areas.
- The vamping of Cross cuts to footwall depth needs investigation.
- Drains should be cleaned out frequently.
- The water drainage system should be such that minimum fines are deposited en route to the Settlers.
- The mud retrieval strategy at the Settlers should be such that losses are minimised.
- Belt cleaners must be used to clean all belts and the fines must be put back into the ore flow system.

CONCLUSION.

- PGM's are much smaller than the gangue minerals.
- PGM's are liberated with ease during blasting.
- Due to the PGM's mode of occurrence within the gangue mineral the ore handling process is conducive to further breakdown of the rock lumps and metal losses.
- PGM's are more prevalent in the Chrome seams, which are more brittle and prone to break down to smaller sizes.
- Water will pick up and carry the PGM's with greater ease than gangue mineral and will also deposit these further down the ore flow route than gangue mineral.
- PGM's lost in the initial breaking and transfer need not be lost altogether as large percentages could be recovered through vamping and mud recovery strategies.

There is no so called enrichment of fines in the stope but rather enrichment of the mud en route due to the action of water.

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