

# Valuation of a mineral resource that has a compound metal content distribution: an example based on the Merensky Reef at Wesizwe Platinum Limited's Pilanesberg project

D.R. YOUNG

*The Mineral Corporation, South Africa*

Drilling exploration over the Wesizwe Platinum Limited's Pilanesberg Project has identified the Merensky Reef at depths varying from 594 m to 1 552 m depth. Merensky Reef thickness varies from 0.05 m to 3.63 m and contains PGE(4) mineralization above a cut-off grade of 1.0 g/t over intersection widths of 0.95 m to 2.63 m.

Four distinct facies types have been identified over the property, viz. 1) Normal Merensky Reef, generally 1.2 m thick, bounded by thin top and basal chromitite layers and composed of upper feldspathic pyroxenite and lower feldspathic olivine pegmatoids containing base metal sulphide mineralization overlying poikilitic anorthosites. 2) Single chromitite Merensky Reef, generally 0.15 m thick and usually devoid of internal silicate material, overlying variable stratigraphy containing significant base metal sulphide mineralization. 3) Detached Merensky Reef, generally 1.0 m thick, bounded by thin top and basal chromitite layers and composed of feldspathic pyroxenite or pyroxenite containing base metal sulphide mineralization overlying Merensky Pyroxenite. 4) Normal footwall Merensky Reef, generally 1.8 m thick, bounded by thin top and basal chromitite layers and composed of feldspathic pyroxenite containing base metal sulphide mineralization overlying norites also containing significant base metal sulphide mineralization.

The PGE(4) content's (g/m<sup>2</sup>) distribution for the global intersection data appears to be lognormal, and conversion to lognormal space produces a near normal distribution which could be interpreted as a compound lognormal distribution. The mean PGE(4) contents estimated by these three different distributions are the same, and thus do not impact on the contained metal. Data for the Normal Merensky Reef facies type are sufficient to indicate that a normal distribution is followed for this facies type, and therefore does not need to be transformed to log space for estimation of the mean and the 90% confidence limits.

A global evaluation based on all of the data is compared with a facies-weighted evaluation. The latter method is noted to provide a better definition of the associated estimation errors and thus potential classification of Mineral Resources. A valuation of \$20.95 for Inferred and \$41.90 for Indicated PGE(4) ounces is applied to both of the evaluations and compared. The global evaluation is considered to over-value the project by approximately 40%, thus indicating that valuations based on global summary sampling data that have a compound distribution may be materially flawed, and that cognizance of the underlying geology is crucial for unbiased valuation.

## Introduction

Wesizwe Platinum Limited (Wesizwe) has recently identified the occurrence of Merensky and UG2 Reef underlying its Pilanesberg Project via a diamond drilling exploration programme. The Pilanesberg Project lies immediately to the south of the Pilanesberg Complex on the southern portion of the farm Ledig and the northern portion of the farm Frischgewaagd, Northwestern Province, South Africa (Figure 1).

The Merensky Reef in this area occupies its normal stratigraphic position within the Upper Critical Zone (SACS, 1980) that underlies the Main Zone which forms the outcrop of the Pilanesberg Project. No outcrop of the Merensky or UG2 Reefs occurs in the project area. Intersections of Merensky Reef have been found at depths of between 1 552 m and 594 m below surface, and the separation between the Merensky and underlying UG2

Reefs varies from 18 m to 50 m.

Four facies types with differing average widths and mineralization profiles are recognized for the Merensky Reef. Also the average percentage of the platinum group elements, Pt, Pd, Rh as well as Au (PGE(4)), comprising the total for each facies type, is different.

This paper describes the differing facies types and mineralization styles as well as providing an analysis of the statistics and certain of the Geostatistical parameters for the contents of the Merensky Reef PGE(4) in terms of g/m<sup>2</sup>. Evaluation of the mineral resources of the project have been estimated by two methods, one based on a global estimate of all of the data and the other based on a weighted facies model approach, the classification of the mineral resources is discussed and a valuation based on contained PGE(4) ounces for the two methods and their classification is presented.

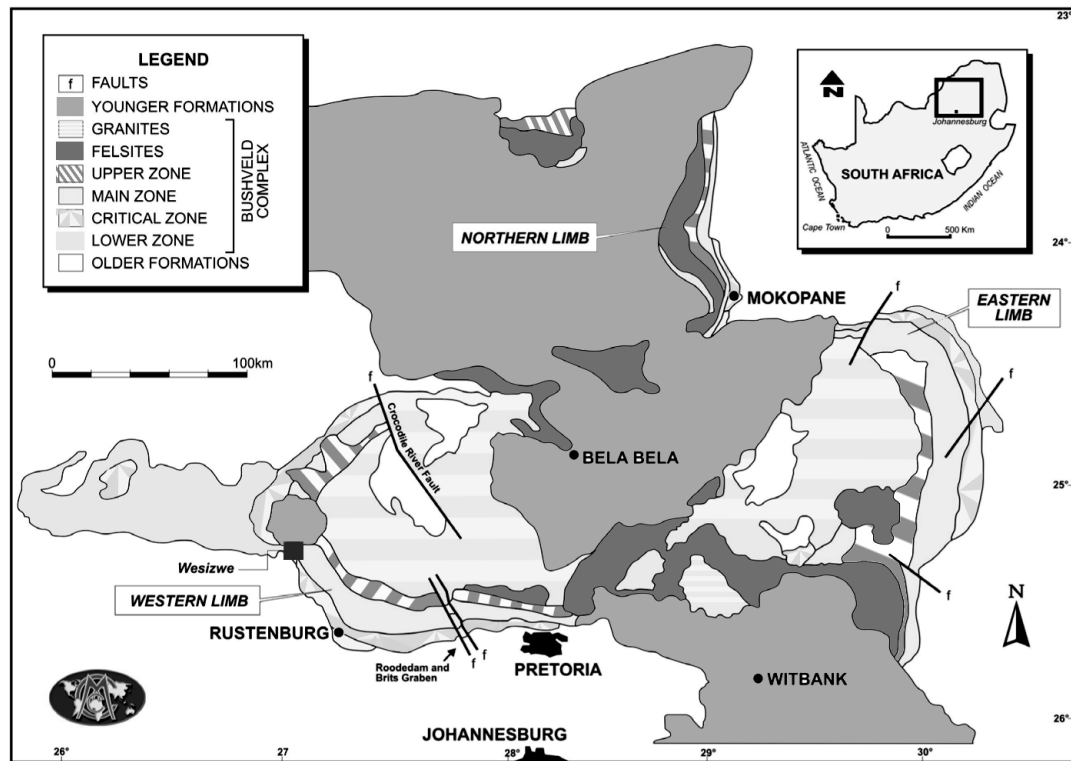


Figure 1. Location plan of the Pilanesburg Project

### Regional Merensky Reef descriptions

In the Western Limb, the Merensky Reef exhibits significant variations in lithology and grade. It was originally subdivided into the Rustenburg facies and Swartklip facies (south and north of the Pilanesberg Complex) respectively by Wagner (1929). Numerous features distinguish these facies, including the abundance of olivine-rich cumulates and thinner 'pre-Merensky' units (UG1 and UG2) in the Swartklip facies (Maier and Eales, 1997). Viljoen (1994) has further subdivided the Rustenburg facies into five sub-facies. The Merensky Reef within the Swartklip facies has been subdivided into normal reef sub-facies and regional pothole sub-facies.

The Merensky Reef Unit is the most regular and complete cyclic unit within the Critical Zone. The terms 'Merensky pegmatoid', 'Merensky pyroxenite' and 'Merensky chromitite' have been used to describe the various layers comprising the Merensky Reef. The Merensky Reef is located between 60 m to 100 m below the top of the Critical Zone and grades upward through the cycle into norite, a 'spotted' anorthosite and, finally, into a 'mottled' anorthosite (at the top of the cycle). Many variations to this profile are noted regionally, and the following are of particular impact in the Western Limb of the Bushveld Complex:

- In the Rustenburg area, a coarse-grained pegmatoidal layer is located between two chromitite stringers at the base of the Merensky pyroxenite (e.g. the Band C Reefs of Impala Platinum Mine)
- At Anglo Platinum's Union and Amandelbult Sections, the Merensky Reef is an olivine-rich harzburgite pegmatoid with chromitite stringers both above and below the reef
- At Lonmin's Western Platinum Mine, the chromitite stringers occur at the base and near the top of the pyroxenite, and only the top stringer is mined.

The following distinctive types of Merensky Reef are recognized regionally and referred to as facies.

#### Normal (or pegmatoidal) reef

This reef-type is a coarse-grained to pegmatoidal phase of feldspathic pyroxenite contained between two thin chromitite layers and located at the base of a 2–10 m thick equigranular feldspathic pyroxenite unit. The width of the pegmatoidal phase is in the order of 15–25 cm and each of the chromitite layers is typically 0.1–5.0 cm thick.

An accumulation of disseminations of chromite, base metals and precious metal sulphides accompany the pegmatoidal phase, with some dispersion into the immediate hangingwall and footwall sequences. Generally, these base metal sulphides occur as interstitial particles in a silicate matrix of pyroxene and plagioclase. The precious metals occur as discrete particles, in close association with the base metals sulphides, and as internal inclusions within the silicate and oxide components of the host rocks.

The normal reef type is generally located above the poikilolithic anorthosite, which varies between 5–30 cm in thickness. This, in turn, is underlain by a noritic sequence some 10 m thick.

#### Pothole Merensky Reef

The Merensky Reef can be found resting on a footwall horizon lower than normal in the stratigraphic succession. These depressions are referred to as potholes. The width and depth of the potholes are highly variable. In many instances, the Merensky Reef rests on the first resistant anorthosite horizon, whereas in other cases it can cut through significant thicknesses of the footwall succession.

Within the broad classification of pothole reef, three sub-categories are recognised: contact-type reef; pothole-type reef; and lens-type reef. A schematic geological section is presented in Figure 2.

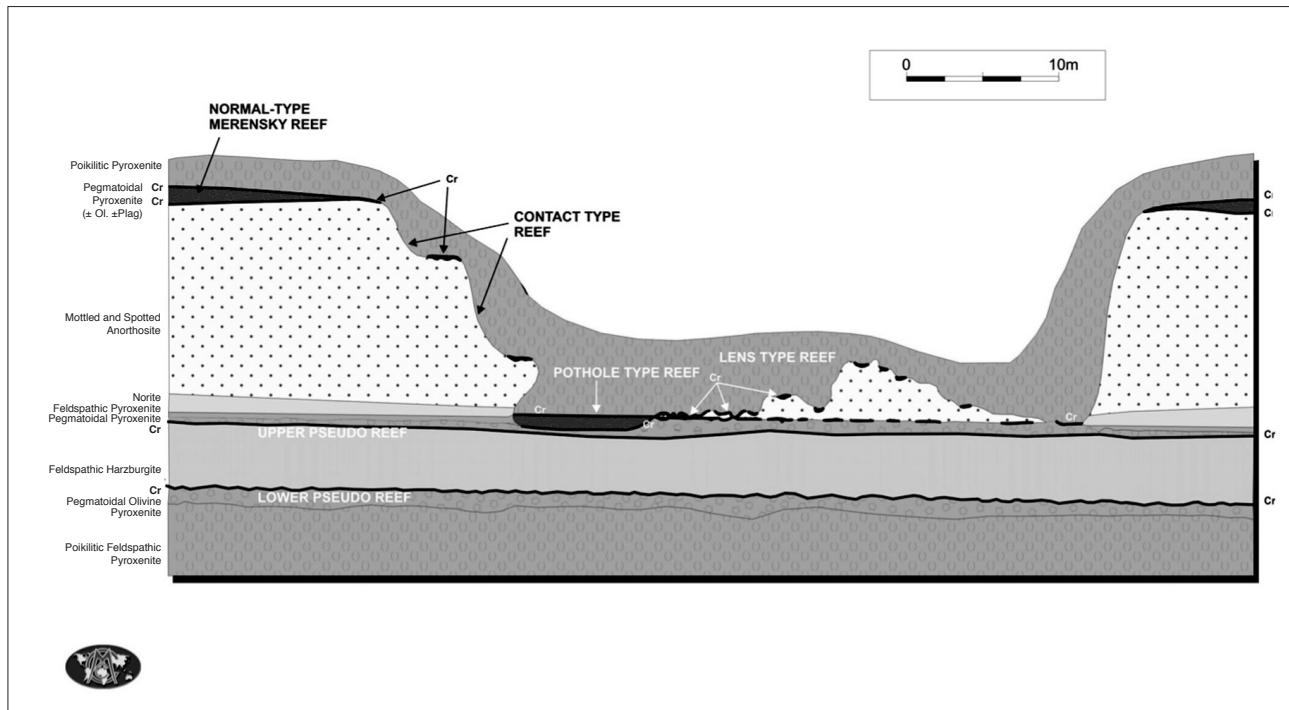


Figure 2. Geological scheme of reef type classification as employed at Union Section (after Viljoen *et al*, 1986).

Work by Carr *et al.* (1994 and 1999) at Western Platinum Mine indicates that the sites of pothole formation on the Merensky Reef can be related to steeply-dipping footwall structures. It is proposed that potholes were initiated at the sites of the footwall structures and developed by down-dip synmagmatic extension of the footwall crystal mush in response to tension deformation caused by the loading effects of major new magma additions. As a generalization it is also noted that the distribution of potholes on one stratigraphic level is not necessarily superimposed on other stratigraphic levels (i.e. potholes in the Merensky Reef are not necessarily underlain by potholes in the UG2 Reef).

#### Wide Merensky Reef

Leeb-du Toit (1986) and Viljoen and Hieber (1986) report on isolated cases of anomalously thick Merensky Reef at Impala Platinum Mine and Rustenburg Section of Rustenburg Platinum Mines respectively. At Impala Platinum Mine, on the farm Doornspruit 106 JQ, a typical Merensky pyroxenite overlies a pegmatoidal pyroxenite, varying from 0.9–2.5 m in thickness, and is bound on the top contact by a 5 mm thick chromitite layer. A 10 mm thick second chromitite layer occurs within the pegmatoid some 7 cm below the upper chromitite. No information is provided on vertical grade distribution. At the Paardekraal Shaft of Rustenburg Section, a wide reef area occurs where the pegmatoidal pyroxenite attains a thickness of 180 cm. The distribution of PGE(4)'s within this unit is lower and the top chromitite is ubiquitous, whereas the basal chromitite becomes inconsistent. This type of reef is reported as being top-loaded and having mineralization extending into the footwall rocks.

A similar wide Merensky Reef is depicted for the modelled mineral resource width over portions of the farm Styldrift 90 JQ, which occurs directly to the east of the Pilanesberg Project. This characterization is based on

information taken from the Royal Bafokeng Resources website ([www.rbr.co.za](http://www.rbr.co.za)).

Viljoen *et al.* (1986) report on a wide Merensky Reef occurring at Union Section of Rustenburg Platinum Mine. However, care must be taken in interpreting these data. The Merensky Reef at Union Section is generally a pegmatoidal feldspathic pyroxenite and harzburgite, with upper and lower chromitite layers overlying a poikilitic anorthosite. The highest concentration of PGE(4) mineralization is associated with the upper chromitite layer. The width of the Merensky Reef at this locality ranges from 10 cm in the south to more than 700 cm in the north portion of the mine, but the economic mineralization is focused over 100 cm from the top chromitite contact. In the wider areas, the grades would appear to be somewhat diluted over the top 100 cm, but are mined only over approximately 100 cm.

#### Merensky Reef underlying the Pilanesberg project

The Reef comprises four broad types. These have been named in accordance with the regional nomenclature as follows

- **normal reef** (approximately 1.2 m thick): This reef type is bounded by narrow top and basal chromitite layers, and composed of an upper feldspathic pyroxenite pegmatoid and lower feldspathic olivine pegmatoid. The basal chromitite lies on a poikilitic anorthosite and the overlying rocks are medium grained feldspathic pyroxenites. Macroscopic base metal sulphide mineralization is restricted to the pegmatoids and to a few centimetres into the overlying feldspathic pyroxenites. This is very similar to the Normal/Pegmatoidal Merensky Reef already described from Impala and Rustenburg. However, the width is much greater at the Wesizwe project.

- **single chromitite reef** (0.15 m thick): This reef type is similar to the contact reef (Figure 2) in that it is only a few centimetres wide and generally a single chromitite layer with minor internal silicates. No pegmatoid is developed. It lies on footwall rocks from FW1 - FW6 (Leeb-du Toit, 1986) and is overlain by feldspathic pyroxenite. Macroscopic base metal sulphide mineralization occurs in the underlying anorthosites and norites, as well as in the overlying feldspathic pyroxenites for a few centimetres. The single chromitite reef is similar to the Contact Merensky Reef as described at Union Section (Figure 2). The large-scale area this facies type occupies (south-west of the Normal Reef, Figure 10) its variable footwall (Table I), and data obtained from Platinum Group Metals (RSA) (Pty) Limited (March 2006), suggest the format of an onlapping relationship towards the south west and eventually sub-outcrops against the Main Zone.
- **detached reef** (1.0 m thick): This reef type is a pegmatoid of feldspathic pyroxenite or pyroxenite bounded by top (ubiquitous) and basal (usually) chromitite layers. It generally overlies several metres of fine - medium-grained pyroxenite and is overlain by feldspathic pyroxenite. Macroscopic base metal sulphides are generally restricted to the material between the chromitite layers. It is similar to the

normal reef type described at Union Section, but usually has a basal chromitite layer.

- **normal footwall reef** (approximately 0.67 m thick): This reef type is bounded by two chromitite layers that define the upper and lower surfaces of the Merensky Reef. The intervening material is either feldspathic pyroxenite pegmatoid or pyroxenite that contains macroscopic base metal sulphide mineralization. The footwall is generally composed of olivine norites of FW7 (Leeb-du Toit, 1986) which also contain significant PGE(4) mineralization recognised macroscopically by the presence of base metal sulphides. The area comprising of this reef type (south - west of the single chromitite reef, Figure 10) is interpreted as a continuation of the onlapping relationship towards the south-west and suboutcrops against the Main Zone.

#### Isopach data

The general stratigraphy encompassing the Merensky Reef has been scrutinized, and a detailed stratigraphy has been developed based largely on that developed by Leeb-du Toit (1986). The core for the Merensky Reef intersections from the drillholes contained in Table I has been scrutinized and the measurements of various stratigraphic units taken. This has allowed the potholed Merensky Reef intersections to be

**Table I.**  
**Stratigraphic marker thickness (intersection widths) – Merensky Reef**

| Drillhole No | Merensky Pyroxenite Width (m) | Merensky Reef Width (m) | Distance between Merensky Reef and FW6 (m) | Distance between Merensky Reef and UG2 (m) | Footwall (FW) to Merensky Reef | Merensky Reef Type Classification |
|--------------|-------------------------------|-------------------------|--------------------------------------------|--------------------------------------------|--------------------------------|-----------------------------------|
| WL 1/07      | 4.78                          | 1.32                    | 18.21                                      | 35.93                                      | FW1                            | Normal                            |
| WL 1/03      | 4.56                          | 1.95                    | 12.49                                      | 32.56                                      | FW1                            | Normal                            |
| WL 2/13      | 16.59                         | 0.77                    | 0.00                                       | 37.99                                      | Merensky Pyroxenite            | Detached                          |
| WL 2/50      | 11.07                         | 0.54                    | 12.58                                      | 25.36                                      | Merensky Pyroxenite            | Detached                          |
| WL 2/06      | 7.99                          | 0.63                    | 0.00                                       | -                                          | Merensky Pyroxenite            | Detached                          |
| WL 2/03      | Not Intersected               |                         |                                            |                                            |                                | Faulted Out                       |
| WFA01        | 3.54                          | 1.58                    | 13.06                                      | 40.91                                      | FW1                            | Normal                            |
| WFA03        | 3.85                          | 1.19                    | 12.35                                      | 37.06                                      | FW1                            | Normal                            |
| WFA04        | 3.77                          | 0.05                    | 0.00                                       | 18.04                                      | FW6                            | Single Chromitite                 |
| WFA05        | Not Intersected               |                         |                                            |                                            |                                | IRUP                              |
| WFA14        | 3.29                          | 0.76                    | 0.28                                       | 33.41                                      | FW5                            | Normal Footwall                   |
| WFA47        | Not Intersected               |                         |                                            |                                            |                                | Hole Abandoned                    |
| WF23         | 4.04                          | 1.21                    | 10.77                                      | 34.98                                      | FW1                            | Normal                            |
| WF02         | 4.24                          | 1.75                    | 12.86                                      | 36.80                                      | FW1                            | Normal                            |
| WF01         | 4.88                          | 1.26                    | 13.18                                      | 47.75                                      | FW1                            | Normal                            |
| WF07         | 3.96                          | 1.39                    | 13.30                                      | 37.67                                      | FW1                            | Normal                            |
| WF09         | 5.05                          | 1.67                    | 12.39                                      | 42.70                                      | FW1                            | Normal                            |
| WF08         | 2.98                          | 0.86                    | 13.31                                      | 40.51                                      | FW1                            | Normal                            |
| WF79         | 5.29                          | 3.63                    | 13.44                                      | 41.34                                      | Merensky Pyroxenite            | Detached                          |
| WF61         | 1.84                          | 0.28                    | 13.86                                      | 50.45                                      | FW1                            | Normal                            |
| WF60         | 2.25                          | 2.25                    | 14.90                                      | 40.70                                      | FW1                            | Normal                            |
| WF68         | 4.28                          | 0.21                    | 8.81                                       | 46.72                                      | FW1                            | Single Chromitite                 |
| WF69         | 0.44                          | 0.18                    | 8.75                                       | 31.64                                      | FW1                            | Potholed                          |
| WF71         | 2.73                          | 0.05                    | 5.75                                       | 38.60                                      | FW3                            | Single Chromitite                 |



interpreted as distinct from the regional onlapping intersections. The results of these measurements and classifications are also contained in Table I.

#### Bafokeng Rasimone platinum mine joint venture exploration data

Certain exploration data from the exploration campaigns conducted by the Bafokeng Rasimone Platinum Mine Joint Venture (BRPM JV), particularly over the farms Styldrift and Frischgewaagd, have been made available to Wesizwe (Figure 3). The data are in an electronic format and include drillhole collar positions, geological logs, down-the-hole survey results, sampling positions, and assay results. Due to the agreement between Wesizwe and Anglo Platinum (acting on behalf of the BRPM JV), these data cannot be made public. However, they have been employed for mineral resource estimates where applicable and the lithological data have made it possible for this information to be classified in the facies scheme developed for the Pilanesberg Project.

#### Mineralization and vertical platinum distribution

The analytical data for Wesizwe Merensky Reef have been compiled in a database that enables the average platinum grade and Pt:Pd ratios (for 1 cm slices relative to a chromitite layer at a 0 cm reference point) for each

Merensky Reef type to be derived. The results are portrayed in histogram format (Figures 4–7).

The effect of significant platinum mineralization in the footwall rocks is not a new style of mineralization. Viljoen and Hieber (1986) discuss the effect of significant base metal sulphide mineralization associated with pyroxenite oikocrysts within anorthosite for up to 60 cm below the Merensky Reef at the Townlands and Boschfontein sections of Rustenburg Platinum Mine.

The Normal reef (Figure 4) is seen to have virtually no Pt mineralization below the basal chromitite layer, but minor Pt mineralization extends into the overlying feldspathic pyroxenites. The average width of the Pt mineralization above a cut-off of 1.0 g/t is 225 cm, and it can be seen to be top-loaded. Also, the Pt:Pd histogram depicts Pd-rich PGE mineralization at the base, which becomes enriched with respect to Pt towards the top chromitite contact and above.

The Single chromitite reef (Figure 5) is noted to have significant Pt mineralization contained in the underlying anorthosite rocks as well as in the overlying feldspathic pyroxenites. The average width of the Pt mineralization above a cut-off of 1.0 g/t is 230 cm, and it can be seen to have a mineralization peak over the chromitite layer as well as one in the hangingwall. Also, the Pt:Pd histogram depicts a near constant ratio of approximately 2:1 apart from the upper Pt peak and chromitite layer which are Pd-poor.

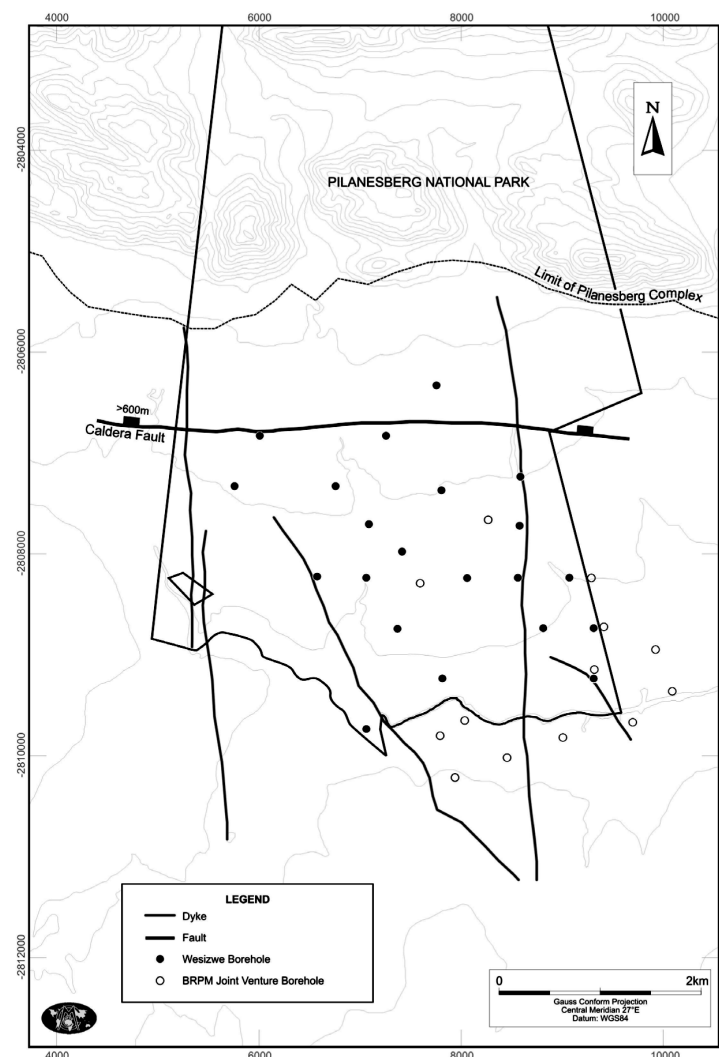


Figure 3. Drill hole location plan

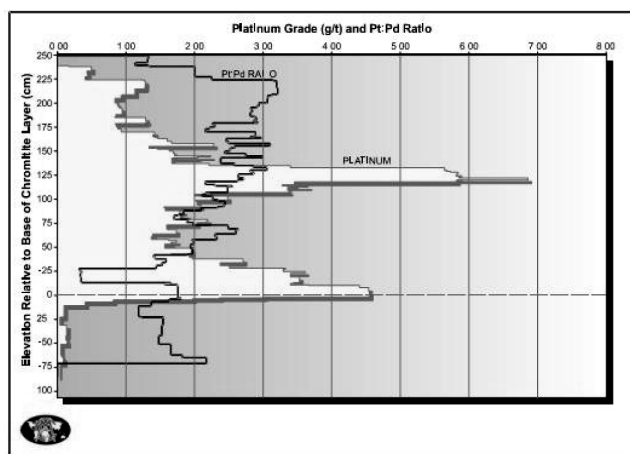


Figure 4. Normal Merensky Reef - vertical platinum grade distribution relative to the basal chromitite layer and platinum to palladium ratios.

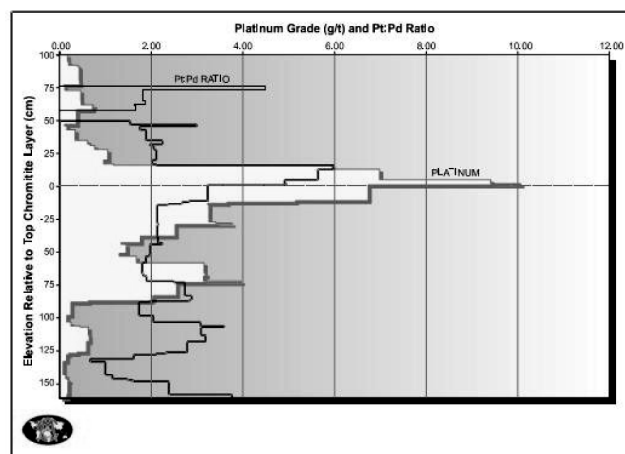


Figure 6. Detached Merensky Reef - vertical platinum grade distribution relative to the top chromitite layer and platinum to palladium ratios

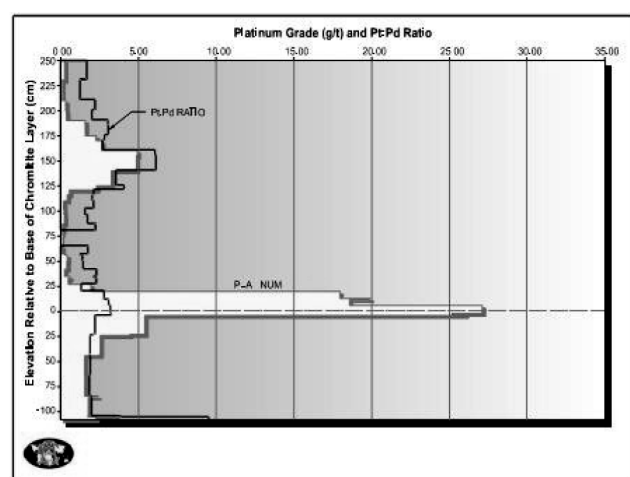


Figure 5. Single chromitite layer Merensky Reef - vertical platinum grade distribution relative to the basal chromitite layer and platinum to palladium ratios

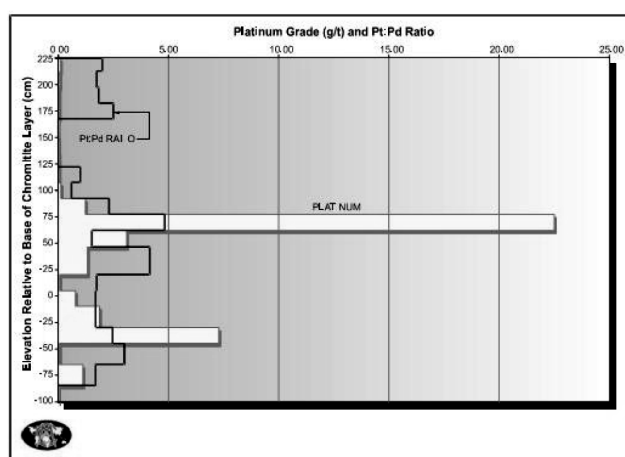


Figure 7. Normal footwall Merensky Reef - vertical platinum grade distribution relative to the basal chromitite layer and platinum to palladium ratios

The Detached reef (Figure 6) is noted to have the Pt peak at the top chromitite layer and a lesser one over the basal chromitite layer, which may form the base of the mineralization. Mineralization into the hangingwall rocks does occur. The average width of the Pt mineralization above a cut-off of 1.0 g/t is 110 cm and the Pt:Pd ratios peak over the chromitite layers.

The Normal footwall reef (Figure 7) is noted to have an upper and lower Pt peak. The average width of the Pt mineralization above a cut-off of 1.0 g/t is 120 cm. It can be seen to have the peak of Pt mineralization over the upper chromitite layer as well as one in the footwall rocks. The Pt:Pd histogram depicts an overall enrichment in Pt above the 2:1 ratio.

## Statistical data

### Discussion

In the evaluation of layered two-dimensional ore bodies at the exploration stage, samples are taken via drillholes

oriented normal to the layering. Assays are performed on samples generally of 15 - 20 cm length taken across the orebody, ensuring that samples at the boundaries are not sampling material extraneous to the orebody. An average thickness and metal content per drillhole intersection can be calculated based on length weighting and, if necessary, density weighting. In this manner the variation in the metal content and orebody thickness over the project area can be ascertained.

The variable that the evaluation is performed upon is the width and metal content (length multiplied by grade) of each drillhole or a de-clustered average of deflections. In the cases where there is variation in density, either within the layering or regionally due to horizontal variations, then assaying of the density of each sample needs to be made (Krige, 1981). The metal content average for each drillhole intersection would then be based on the length multiplied by density multiplied by grade weighting, resulting in an average grade per unit area. The width would be multiplied by the density, producing a tonne per unit area. These two variables are employed for evaluation of the orebody

(Rendu, 1978). The notion that grade is a regional variable is applicable only if the orebody is of constant width and density (Krige, 1981).

The assays performed on each Wesizwe sample were for Pt, Pd, Rh, Au, Cu, Ni, and density. In this paper only the PGE(4) are considered. Where no density data are available the length weighted average per intersection is accepted. However, in the regional evaluation, densities per facies type (based on acceptable data) are applied to the intersections.

### Results - global evaluation

The histogram of the PGE(4) g/m<sup>2</sup> for all the intersections is displayed in Figure 8. The distribution is seen to be positively skewed (skewness of 1.04), with a possible underlying lognormal distribution. A three-parameter lognormal average has been estimated after Rendu (1978) by transformation of the data into lognormal space. The histogram of the transformed data is contained in Figure 9, which has a skewness of -0.4984 and a kurtosis of 3.4157. As this is not a perfectly normal distribution in lognormal space, a compound lognormal distribution after Sichel (1973) was tested. In this case the test conditions required for a compound lognormal distribution,  $B_2(x) \geq \frac{1}{2}[3B_1(x)+6]$ , were met, but did not yield a significantly different mean PGE(4) g/m<sup>2</sup> (Table II).

Variography of all of the data has been completed in the GS+ (Geostatistics for the Environmental Sciences) environment in lognormal space. The deflection data have also been analysed to ascertain the nugget effect. A single structure spherical anisotropic variogram with a range of 500 m is interpreted, with a nugget effect of 60% of the total variance.

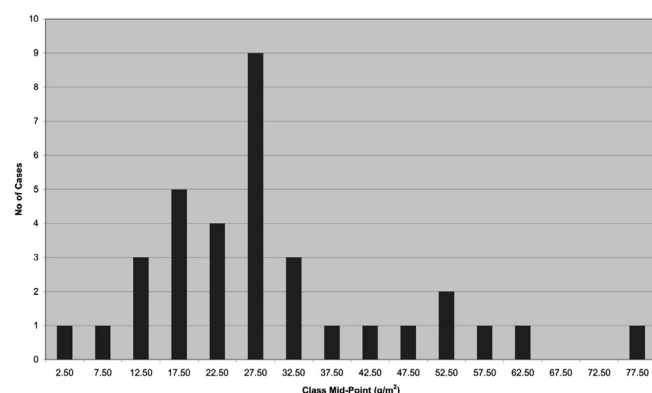


Figure 8. Merensky Reef PGE(4) g/m<sup>2</sup> distribution for the Pilanesburg project in normal space

Table II  
Global Merensky Reef evaluation results

| Parameter                                             | Value  |
|-------------------------------------------------------|--------|
| Arithmetic Mean (PGE(4) g/m <sup>2</sup> )            | 30.07  |
| Arithmetic Mean (width -cm)                           | 153    |
| Arithmetic Mean (tonne/ m <sup>2</sup> )              | 4.80   |
| Compound Lognormal Mean (PGE(4) g/m <sup>2</sup> )    | 30.06  |
| Lognormal Mean (PGE(4) g/m <sup>2</sup> )             | 30.06  |
| Upper 90% Confidence Limit (PGE(4) g/m <sup>2</sup> ) | 35.23  |
| Lower 90% Confidence Limit (PGE(4) g/m <sup>2</sup> ) | 26.92  |
| Estimation Error of PGE(4) (g/m <sup>2</sup> )        | 13.82% |

As the drillholes are spaced generally in excess of the variogram range of 500 m and the nugget effect is high, the average lognormal g/m<sup>2</sup> mean (Rendu, 1978) is employed to evaluate the project without taking cognizance of the facies distribution. The 90% upper and lower confidence limits of the three-parameter lognormal distribution are calculated to obtain an estimate of the likely error associated with this method, to assist in classifying the mineral resources as per the SAMREC Code (2000). The results of this evaluation are provided in Table II.

Based on an estimation error calculated in this manner, the mineral resources of the total project area could be classified as Indicated, as the error is less than 25% (boundary taken for Inferred) and greater than 10% (boundary taken for Measured).

### Results - Facies Evaluation

Based on the facies identified by geological scrutiny of the core, the different facies are noted to occupy definitive geographic areas that can be evaluated separately (Figure 10). Unfortunately only the Normal Merensky Reef has a substantial number of data (19) to justify the drawing of any statistical conclusions. Each of the other facies types has only 5 intersections.

Figure 11 contains the histogram of the PGE(4) g/m<sup>2</sup> contents for the Normal Merensky Reef, where it can be seen to have a near-normal distribution (skewness=0.931 and kurtosis=3.59 - normal space). Thus the evaluation of the Normal Merensky Reef can be based on the arithmetic average of the data.

Variography of the Normal Merensky Reef data has been completed in the GS+ environment in normal space and the deflection data have been analysed to ascertain the nugget effect. A single structure spherical anisotropic variogram with a range of 500 m is interpreted, with a nugget effect of 50% of the total variance.

As in the case of the global data, the borehole intersection spacing for the Normal Merensky Reef is also generally in excess of 500 m. Thus the average g/m<sup>2</sup> is employed to evaluate the Normal Merensky Reef facies. The 90% upper and lower confidence limits based on Student's t (Spiegel, 1972) are calculated to obtain an estimate of the likely error associated with this method to assist in classifying the mineral resources according to the SAMREC Code (2000). The results of this evaluation are provided in Table III.

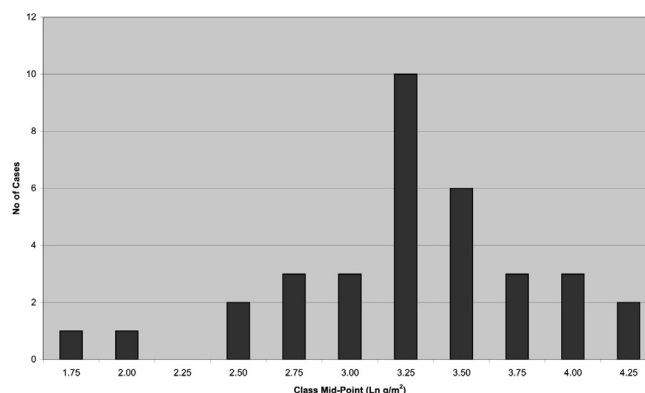


Figure 9. Merensky Reef PGE(4) g/m<sup>2</sup> distribution for the Pilanesburg project in lognormal space

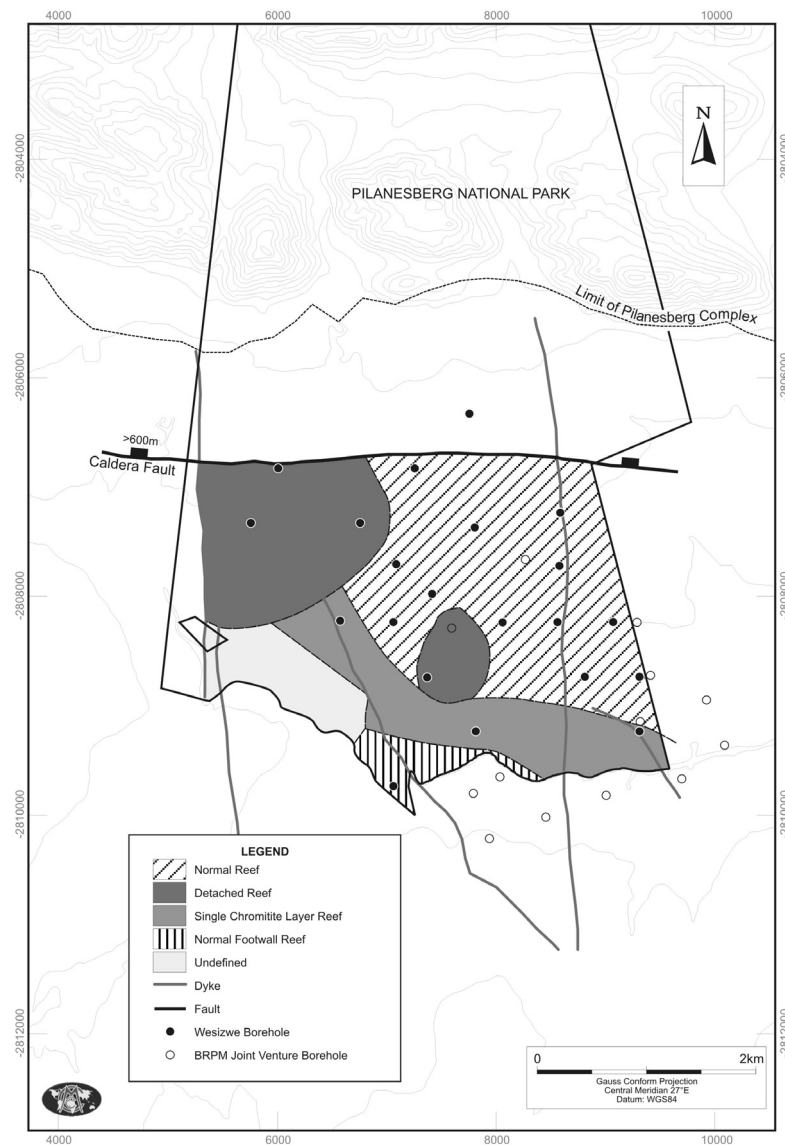


Figure 10. Merensky Reef facies distribution plan

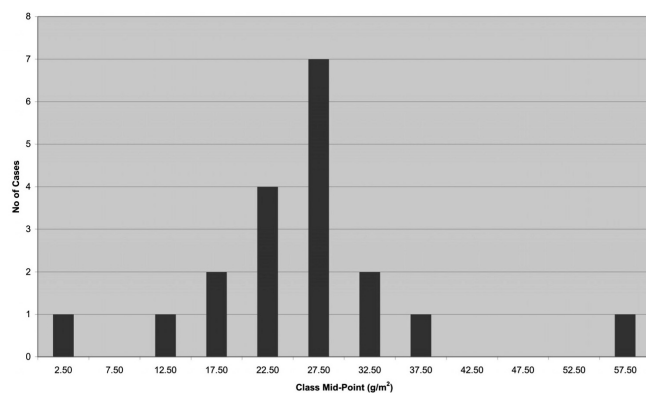


Figure 11. Normal Merensky Reef PGE(4) g/m<sup>2</sup> distribution for the Pilanesburg project in normal space

Table III  
Normal Merensky Reef evaluation results

| Parameter                                             | Value  |
|-------------------------------------------------------|--------|
| Arithmetic Mean (PGE(4) g/m <sup>2</sup> )            | 26.82  |
| Arithmetic Mean (width -cm)                           | 149    |
| Arithmetic Mean (tonne per m <sup>2</sup> )           | 4.66   |
| Upper 90% Confidence Limit (PGE(4) g/m <sup>2</sup> ) | 31.32  |
| Lower 90% Confidence Limit (PGE(4) g/m <sup>2</sup> ) | 22.29  |
| Estimation Error of PGE(4) g/m <sup>2</sup>           | 16.84% |

Based on an estimation error calculated in this manner, the Mineral Resources of the Normal Merensky Reef could be classified as Indicated as the error is less than 25% (boundary taken for Inferred) and greater than 10% (boundary taken for Measured).

Figure 12 contains the PGE(4) g/m<sup>2</sup> distribution of the Detached, Normal footwall and Single chromitite Merensky Reefs. Within the constraints of the limited data available, the only conclusions that can be drawn from this graph are that the Detached Facies type probably forms a normal distribution at relatively lower PGE(4) contents than either of the other facies types, and that the Normal footwall facies type has a narrower distribution than the Single chromitite facies type.

The average PGE(4) contents (g/m<sup>2</sup>) and other parameters for these facies types are contained in Table IV. Included in this table are the results of the average weighted deflection variance data which provide nugget effect results without the analyst's having to complete variograms. The Detached and Single chromitite facies results are as would be expected, albeit the Single chromitite facies has the lowest nugget effect of all. The Normal footwall facies is anomalous in that the average weighted deflection variance is greater than the average de-clustered variance. This is not



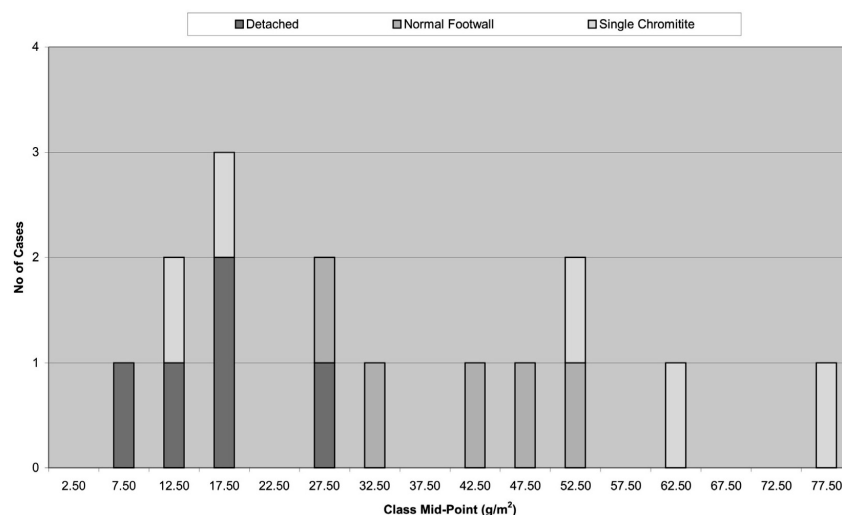


Figure 12. Detached normal footwall and single chromitite Merensky Reef PGE(4) g/m<sup>2</sup> distribution for the Pilanesberg project in normal space

Table IV.  
Detached, normal footwall and single chromitite Merensky Reef evaluation results

| Parameter                                              | Detached | Normal Footwall | Single Chromitite |
|--------------------------------------------------------|----------|-----------------|-------------------|
| Arithmetic Mean (PGE(4) g/m <sup>2</sup> )             | 17.34    | 40.83           | 44.43             |
| Arithmetic Mean (width -cm)                            | 113      | 186             | 179               |
| Arithmetic Mean (tonne per m <sup>2</sup> )            | 3.56     | 5.87            | 5.50              |
| Upper 90% Confidence Limit (PGE(4) g/m <sup>2</sup> )  | 24.21    | 49.73           | 70.72             |
| Lower 90% Confidence Limit (PGE (4) g/m <sup>2</sup> ) | 10.48    | 31.94           | 18.15             |
| Estimation Error of PGE (4) g/m <sup>2</sup>           | 39.57%   | 21.79%          | 59.15%            |
| Classification                                         | Inferred | Indicated       | Inferred          |
| Nugget (Percentage of total variance)                  | 51.87%   | 824.21%         | 10.01%            |

the result of an outlier, but is a nugget effect seen in each intersection. This facies type is interpreted as being best evaluated by a large number of samples without the application of geostatistics.

Based on the estimation errors, the mineral resources have been classified as either Inferred or Indicated given, the 25% estimation error boundary between the classes.

### Valuation

A valuation of the project based on contained PGE(4) ounces has been conducted to indicate the error that can be associated with a valuation based on the global evaluation, in comparison with the preferred facies evaluation. The facies areas have been applied in the latter case, and in all cases a 27% geological loss has been applied. The results of evaluations based on the two methods are depicted in Table V.

The difference in the contained PGE(4) is only 6% for the two method. However, the classification based on estimation error for the facies model allows greater resolution of the areas with higher estimation error (Inferred) from those with lower estimation error (Indicated).

Wesizwe Platinum has no assets apart from its mineral rights, thus the value of the share relates directly to its attributable *in situ* PGE (4) ounces. The market

capitalization of Wesizwe Platinum on 7 June 2006 was ZAR861.716 million, and at an exchange rate of US\$1=ZAR6.7584 and a declared attributable Inferred Merensky and UG2 Reef Mineral Resources estimation of 6.015 million ounces PGE(4), equates to an *in situ*, value of US\$20.95 per PGE(4) ounce, i.e. the shareholders value of the *in situ* PGE (4) ounces.

It should be noted that the current mineral resources of the Pilanesburg Project do not contain any in the Indicated category owing to various factors that the Competent Person has invoked to preclude their inclusion. Further drilling is currently in progress to remedy this situation.

Based on a database available to The Mineral Corporation that supplies data on the trading of *in situ* gold mineral resources, the Inferred mineral resources are noted to trade at an approximate 50% discount of the Indicated and Measured Mineral Resources at any particular gold price. Thus the employment of US\$20.95 to the Inferred Mineral Resource PGE(4) ounces and twice this value of US\$41.90 for the Indicated mineral resources is in the author's opinion not unreasonable for a comparison of this nature. The results of the Merensky Reef valuation of the Pilanesberg Project area are contained in Table VI.

From the results contained in Table VI, the valuation for the global evaluation based on all of the data is 40% overvalued compared with the facies model evaluation. This is a significant overvaluation.

**Table V**  
**Comparison of evaluation methods**

|                                             | Global Evaluation | Facies Model |
|---------------------------------------------|-------------------|--------------|
| Average Contents (PGE(4) g/m <sup>2</sup> ) | 30.06             | 28.29        |
| Average Tonne per m <sup>2</sup>            | 4.80              | 4.57         |
| 90% Upper Limit(g/m <sup>2</sup> )          | 35.23             | 40.13        |
| 90% Lower Limit(PGE(4) g/m <sup>2</sup> )   | 26.92             | 19.34        |
| % Error                                     | 13.82%            | 31.60%       |
| Tonnage                                     | 31,750,006        | 30,257,211   |
| Grade (g/t)                                 | 6.26              | 6.18         |
| M ozs PGE(4)                                | 6.393             | 6.015        |
| Inferred Resources                          | 0%                | 48%          |
| Indicated Resources                         | 100%              | 52%          |

**Table VI**  
**Merensky Reef valuation comparison for the two estimation methods**

| Resource Type | Value Applied (US\$ M) | Global Estimate (US\$ M) | Facies Model (US\$ M) |
|---------------|------------------------|--------------------------|-----------------------|
| Inferred      | \$20.95                | \$0.00                   | \$60.04               |
| Indicated     | \$41.90                | \$267.85                 | \$131.97              |
| <b>Totals</b> |                        | <b>\$267.85</b>          | <b>\$192.00</b>       |

## Conclusions

The Wesizwe Pilanesberg Project is underlain by Merensky Reef of variable facies type, the most prolific being the Normal type. The facies types are recognised by the macroscopic geology as well as by the differing Pt mineralization profiles.

The distribution of the PGE(4) content in terms of g/m<sup>2</sup> for all of the data, irrespective of facies types, has a near lognormal distribution with a high additive constant, but could be considered a compound lognormal distribution. The mean PGE (4) g/m<sup>2</sup> based on these distributions was the same.

The distribution of the PGE(4) content in terms of the g/m<sup>2</sup> for the Normal Merensky Reef facies has a near - normal distribution, and the distribution of the Detached Merensky Reef facies is probably similarly distributed. The PGE(4) g/m<sup>2</sup> distribution of the Normal footwall and Single chromitite Merensky facies is not known because there is insufficient data.

The nugget effects of each facies type are different. However, the variogram ranges of the global data and the Normal Merensky facies type are similar at approximately 500 m.

Classification of the mineral resources based on the estimation errors for the 90% confidence limits, taken as half of the confidence limit range divided by the mean and expressed as a percentage, provides differing mineral resources classifications for the estimates based on the global data and the facies - weighted data.

A valuation based on the global estimate evaluation overvalues the *in situ* Mineral Resources of the project by 40% when compared with the facies evaluation method.

It is concluded that when valuing similar projects on summary sampling data that has a compound distribution, a large unknown error in the value assigned to the project may result if no cognizance is taken of the underlying geology.

## Acknowledgements

The author is indebted to the management of Wesizwe Platinum Limited for permission to use their exploration data in this paper. Thanks must go to Mpho Tshukudu for formatting and editing the manuscript, and Colin Bleach for the illustrations and presentation media. Winfred Assibey-Bonsu provided assistance with the Compound Lognormal distribution theory.

## References

- CARR, H. W., GROVES, D. I. and CAWTHORN, R. G. Controls on the Distribution of Merensky Reef Potholes at the Western Platinum Mine, Bushveld Complex, South Africa: Implications for Disruptions of the Layering and Pothole Formation in the Complex. *South African Journal of Geology*, vol. 97, 1994. pp. 431–441.
- CARR, H. W., KRUGER, F. J., GROVES, D. I. and CAWTHORN, R. G. The Petrogenesis of Merensky Reef Potholes at the Western Platinum Mine, Bushveld Complex: Sr-Isotope Evidence for Synmagmatic Deformation. *Mineralum Deposita*, vol. 34, no. 4, 1999. pp. 335–347.
- KRIGE, D. G. Lognormal-de Wijsian Geostatistics for Ore Evaluation. SAIMM Monograph Series No. 1. 1981.
- LEEB-DU TOIT, A. The Impala Platinum Mines. In *Mineral Deposits of Southern Africa. II*. Annhauser, and Maske, S., eds. Geological Society of South Africa, Johannesburg. 1986.
- MAIER, W. D., and EALES, H. V. Correlation within the UG2—Merensky Reef interval of the Western Bushveld Complex. *Bull. Geol. Surv. S. Africa*. 1997. p. 120.
- Platinum Group Metals (RSA) (Pty) Limited. Updated Resource Estimation for the Western Bushveld Joint Venture Projects 1 and 2. SEDAR Lodgement, www.sedar.com. 2006.
- RENDU, J. M. An Introduction to Geostatistical Methods of Mineral Evaluation. SAIMM Monograph Series no. 2. 1978.
- SAMREC. South African Code for Reporting of Mineral Resources and Mineral Reserves. South African Mineral Resource Committee (SAMREC) Under the Auspices of the SAIMM. March 2000.
- SICHEL, H.S. Statistical Valuation of a Diamondiferous Deposits. *Journal of the SAIMM*. Feb 1973.
- South African Committee for Stratigraphy (SACS). Stratigraphy of South Africa. Handbook, Geological Survey of South Africa. 1980.
- SPIEGEL, M. R. *Schaum's Outline Series – Theory and Problems of Statistics*. McGraw-Hill Book Company. 1972.
- VILJOEN, M.J., DE KLERK, W.J., COETZER, P.M., HATCH, N.P., KINLOCH, E.D. and PEYERL, W. The Union Section of Rustenburg Platinum Mines Limited, with reference to the Merensky Reef. In *Mineral Deposits of Southern Africa. II*. Annhauser, and Maske, S., eds. Geological Society of South Africa. Johannesburg. 1986.
- VILJOEN, M.J. and HIEBER, R.W. The Rustenburg Section of Rustenburg Platinum Mines Limited, with references to the Merensky Reef. In *Mineral Deposits of Southern Africa. II*. Annhauser, and Maske, S., eds. Geological Society of South Africa, Johannesburg. 1986.
- VILJOEN, M.J. A review of the geological variations in facies and grade distribution of the Merensky Reef, Western Bushveld Complex, with some mining implications. *Proceedings 15th Annual CMI Conference*. SAIMM. 1994.
- WAGNER, P. A. *The Platinum Deposits and Mines of South Africa*. Oliver and Boyd, London. 1929.