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The application of modifying factors to the Merensky Reef and UG2 chromitite layer, Bushveld Complex

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The application of modifying factors to the Merensky Reef and UG2 chromitite layer has a number of challenging aspects as the deposits are tabular and consist of a number of separate geological layers that are grade bearing.

The important aspects or modifying factors in respect of the mineral reserve estimation include mineral tenement and other legal facets, mining method, mining cut, dilution with grade bearing material, mining and geological losses, marginal cut offs, recoveries, mine design and scheduling (including geotechnical and ventilation aspects), required infrastructure, PGE proportions, associated base and precious metals and the feasibility of the project or mine. One of the overarching principles is that the mineral reserve must demonstrate feasibility.

The declaration of the mineral reserve should not be considered as simply the application of modifying factors to convert the mineral resource into a mineral reserve. It is rather the application of suitable tenement, geological, mining engineering, metallurgical, economic, social and environmental expertise to the mine design and scheduling of the proposed operation. Furthermore, the mineral resource and reserve should be revisited on a regular basis as modifying factors change as mining operations mature and variations are made to the original mine design parameters.

These deposits require specialist treatment by the Competent Person(s) when declaring the mineral reserve. A critical aspect is the lower grade material adjacent to the main grade bearing lithologies either immediately above (hangingwall) or below (footwall) the mineralization. It may therefore be necessary to re-estimate the mineral resource and apply the selected mine design and scheduling to the mineral reserve estimation.

The paper will describe the application of modifying factors to the Merensky Reef and UG2 chromitite layer emphasizing relevant issues in the process to convert mineral resource to mineral reserve and highlighting examples from experience together with proposed solutions.

Keywords: mineral reserves, modifying factors

Introduction

The ultimate requirement of a mine is to have an orebody that can be extracted at a profit. The investor and operator need to be able to quantify the quantity and quality of the ore and then develop suitable strategies to fund and extract it. Sound investment or operational decisions must be based on relevant and reliable information. A mineral reserve estimation is therefore critical to demonstrate the merit of a mining project, for the successful management and operation of a mine.

The intention of this paper is present some of the technical aspects or parameters that are considered important when undertaking a mineral resource to mineral reserve conversion with special reference to the Merensky Reef and UG2 chromitite layer. The parameters are presented in a generic way but are based on actual cases.

Geology

Regional geology

The largest, best-known and economically most important layered intrusion is the Bushveld Complex, which was intruded about 2 060 million years ago into rocks of the Transvaal Supergroup, largely along an unconformity between the Magaliesberg quartzite of the Pretoria Group and the overlying Rooiberg felsites. The total estimated extent of the Bushveld Complex is 66 000 km, about 55% of which is covered by younger formations (Figure 1).

The mafic rocks of the Bushveld Complex host layers rich in platinum group elements (PGE), chromium and vanadium, and constitute the world's largest known resource of these metals and are collectively termed the Rustenburg Layered Suite (RLS). The RLS has been divided into five zones known as the Marginal, Lower, Critical, Main and Upper Zones. The Critical Zone is characterized by regular rhythmic layering of cumulus chromite within pyroxenites, anorthosites, norites and olivine-rich rocks. It hosts virtually all economic mineralization encountered in the Bushveld Complex.

The first economically significant cycle from a PGE perspective is the UG2 chromitite layer. The UG2 chromitite layer is probably the largest PGE resource on earth. It occurs between 15 m and 400 m below the

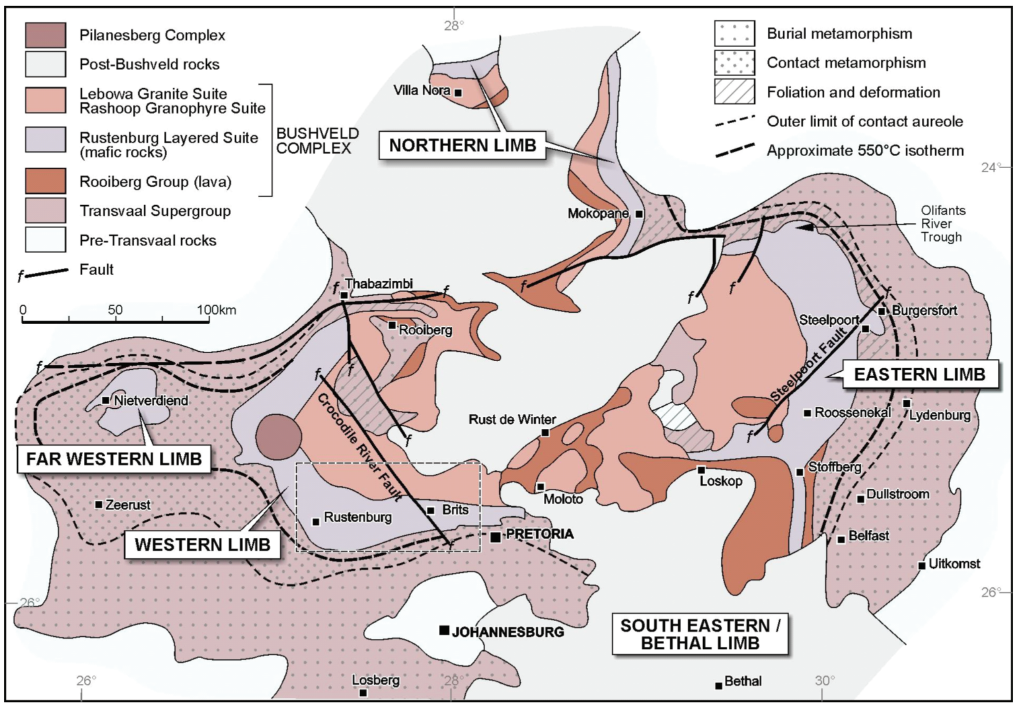

Figure 1. Simplified geology of the Bushveld complex

Merensky Reef. The UG2 chromitite layer can be traced for over 280 km along strike and dips varies from 10º at Rustenburg to 26º in the north-western lobe, with a segment in the north-eastern lobe having a dip of 65º.

The other important cycle, the Merensky cycle, is situated near to the top of the Critical Zone. The Merensky Reef can also be traced along strike for 280 km and is estimated to contain 60 000 t of PGE to a depth of 1 200 m below surface. The dip of the Merensky Reef is similar to the dip of the UG2 chromitite layer.

The major geological features that affect the Merensky Reef and UG2 chromitite layer are faults, dykes, potholes and mafic/ultramafic pegmatites. Potholes are features of subsidence or erosion where the igneous layer is absent or occurs at a lower elevation in a modified form. Typically the PGE concentration and the thickness of the layer are modified. Poor ground conditions may be associated with potholes and pothole edges.

The Merensky Reef and UG2 chromitite layer are currently mined at depths of up to 1 800 m below surface.

Merensky Reef

The Merensky Reef is typically a feldspathic pegmatoidal pyroxenite, bounded top and bottom by thin chromitite layers. The chromite layers have variable thicknesses up to some 5 cm with one being thicker than the other and the other chromite layer being generally thinner or absent. The pegmatoidal feldspathic pyroxenite (pegmatoid) contains interstitial subhedral pyrrhotite and chalcopyrite blebs. The pegmatoid consists of cumulus bronzite crystals, typically 10–20 mm in diameter. The plagioclase feldspar is interstitial.

The immediate hangingwall is a feldspathic pyroxenite (bronzite) typically 1–2.25 m thick, which grades upwards into a norite. Phenocysts of diopside (±20 mm) are present within the feldspathic pyroxenite. The hangingwall typically contains sulphides (pyrrhotite and chalcopyrite) for some 50 cm from its basal contact with the Merensky Reef. The footwall characteristics are variable including noritic, anorthostic and harzburgitic footwalls.

The grade profile is concentrated around the pegmatoidal feldspathic pyroxenite with the highest PGE concentration on associated with the chromitites. Sulphide mineralization extends into both the immediate hangingwall and footwall. In some cases the PGE mineralization characteristics of the Merensky Reef can be correlated with the nature of the footwall. For instance, where the footwall is noritic, the PGE mineralization does not typically extend more than a few centimetres into the footwall, whereas when the footwall is an anorthosite, fine grained sulphides are frequently present with good PGE mineralization for approximately 40 cm and more erratically to about a metre below the lower chromite layer. The PGE encountered in this horizon are predominantly PGE-iron alloys and PGE-sulphides.

UG2 chromitite layer

The UG2 chromitite layer typically consists of a basal pegmatoidal feldspathic pyroxenite (up to 0.5 m thick) which frequently contains chromite stringers and which is overlain by the main chromite layer (30–140 cm thick). A middling pyroxenite of a few centimetres to 6 m separates the main chromite layer from the alternating chromitite and pyroxenite layers commonly referred to as the leaders or triplets.

The UG2 chromitite layer is a consistently developed mineralized horizon in the Bushveld Complex. The UG2 chromitite layer is the only chromitite layer where significant mining for PGE takes place. The PGE are associated with sulphides that are interstitial to the chromite grains. The mineralized zone itself is defined by the sharp basal contact with the footwall pyroxenite. The 3PGE +Au (Pt, Pd, Rh) concentration of the UG2 chromitite layer ranges from 2.5 ppm to 6.6 ppm, and is generally dominated by platinum-palladium (‘Pt-Pd’) sulphides.

Modifying factors

The basis for a reliable mineral reserve is a reliable mineral resource. The reliable mineral resource is underpinned by reliable data and professional interpretation of that data. There is thus a requirement for first-class interpretation and estimation to be supported by high-quality data. The declaration of the mineral reserve also requires a high degree of technical and professional expertise to ensure an appropriate conversion of the mineral resource into a mineral reserve.

A reliable mineral reserve must include appropriate recognition and application of the knowledge of geology, mineralization type, grade distribution, mine design, metallurgy, costs, revenue, as well as marketing, environmental, legal, social and governmental aspects to determination of economic viability. The challenge with the Merensky Reef and UG2 chromitite layer is to apply the required specialist knowledge of these parameters to the deposit. The rigid adherence to procedure and method should not be applied but rather a sensible understanding of the significant and impact of each parameter on the mineral reserve estimation. In utilizing this type of approach, the uncertainties in the modifying factors are mitigated. The final results therefore should be referred to as an estimate not a calculation.

Mineral tenement and legal facets

Due to the changes in South African legislation in respect of mineral title, the declaration of a mineral reserve has been potentially difficult. The SAMREC code requires that there is a reasonable expectation of extraction. This must include the reasonable expectation of the granting of a prospecting right or mining right.

This aspect of the declaration can be problematic in that there is a significant backlog at the Department of Mineral Resources (DMR) with approvals taking as long as a year to obtain. It therefore important that the Competent Person to be aware of the tenement status of the project.

In experience of the authors, questions have to be asked of the mineral title applicant and sufficient confidence obtained from this person or entity that they are confident in securing the necessary mineral tenement for eventual mining. The applicant may need to provide documentation indicating that the application has been lodged and that the application has a realistic chance of success, i.e. the application is the first or only one if it has not already been granted. However, there is no guarantee that the applicant will be granted the right for which he has applied. The authors are aware of situations where a client provided all the necessary documentation and indications that the application would be successful; however, the application was subsequently refused. High profile legal disputes continue to occur far too often and remain an issue for the South African mining industry.

Mineral tenement must include not only mineral and mining rights but other terms of acquisition or participation in the property such as existing contracts, options, royalties or other conditions; surface rights; water usage license; servitude and surface infrastructure; and social responsibilities. Lack of diligence in any of the above can influence mineral resources and/or mineral reserves. A mining project may be affected negatively due to the lack of certainty in respect of the mineral right as it relates to potential mineral reserves or it could be a fatal flaw for the party concerned. Other items of a legal nature may involve the acquisition of water or electricity.

Geological losses

Geological losses, which affect the declared tonnage, fall into two categories namely: where the mineralized horizon or reef is not developed and where it is poorly developed to the extent that mining would be either dangerous or inefficient. The common geological features that influence the UG2 chromitite layer and Merensky Reef are potholes, dykes, faults and mafic pegmatites. Where a dyke, fault or mafic intrusion affects the reef, the reef will typically be absent or associated with poor ground conditions. These losses are often accommodated in the declaration of a mineral resource. Where potholes or faults may affect the reef by changing its elevation or its characteristic (thickness, dip, strike), it may be inefficient or impractical to mine, except where the block is large enough to support the required development and the mineralized horizon is sufficiently developed. The Competent Person needs to establish where this situation may be present and consider whether it would be reasonable to extrapolate the geology into these areas and of the potential effect it may have on mining both practically and economically.

Where a pothole is intersected in a borehole it may be possible to estimate its size based on the width to depth ratio. The maximum size of the pothole would be limited by the adjacent borehole intersections. However, it is likely that the intersection drilled is not at the centre of the pothole but to the one side. Local (or regional knowledge) of the aspect ratio of a pothole will assist in interpreting its size and position. Suitable mine planning would then be possible to optimize the mineral reserve.

The declaration of losses associated with the mine design (mining losses) is required in addition to the geological losses where the mineralization is absent.

Mining losses

Mining losses are the losses that are as a direct result of the implementation of the mine design on the deposit. The most common example is strike or dip pillars required for support in the stopes. The consideration must include the mining method, mining rate, geotechnical considerations, mine design characteristics, equipment selected, ore and grade control methods, hydrological considerations, ventilation, personnel requirements, and plant recovery. Pillars required for regional support, crown pillars between underground and open pit need also to be included here.

Another critical source of mining loss is sweeping efficiencies specific to mineral content. The Merensky Reef should have a better efficiency compared to UG2 chromitite layer as water can be used where as with the latter the risk of mudrushes usually prohibits the use of water to assist with sweepings. Therefore the technique and quality of sweepings on the two reefs cannot be the same and therefore the mining efficiency cannot be the same.

The determination of mining loss may be undertaken when all the potential excavations have been designed and optimized. The tonnage of non-mineralized material included with the mineralized material (Merensky Reef or UG2 chromitite layer) can then be determined. It is best if the full design is evaluated rather than applying a factor. The application of suitable mine design and scheduling provides an accurate determination of these associated losses.

Typical mining losses occur due to the following:

- Under break, material left behind in the stope caused by deviated blast holes
- Quality and efficiency of sweepings

- Inefficient mining due to the loss of reef caused by faulting or potholing
- Inefficient mining due to the geometry of the stope and the local geological features
- Safety requirements of additional support adjacent to major geological features, e.g. dykes
- FOGs that cannot be removed from the stope.

Mining cut

The combination of a good understanding of the geology and the grade distribution are fundamental to the mineral resource, particularly for the Bushveld Complex where the mining cut can vary to include or exclude lower grade material depending on the selection of the mining method. The grade histogram (Figure 2) is a method of compiling the data, relative to an identifiable geological marker, so as to provide a vertical distribution across the mineralized horizon and its immediate hangingwall and footwall. This method allows for the analysis of the grade distribution enabling mine planners to decide on the appropriate mining cut. This method has been developed and applied successfully in different formats on the existing Bushveld platinum mines.

The understanding of the grade relationships will govern the selection of the mining method and the adoption of the optimal mine design, as diluting material below the economic cut-off are included in the material to be mined. Attention to the geology is vital for recognition of salient features that control the spatial distribution, variability and continuity of the mining cut, e.g. facies determination, the effect of geological disturbances, such as potholes and mafic intrusions.

The Merensky Reef in particular is not a single lithology that is platiniferous with the immediately adjacent lithologies being barren but rather a highly mineralized envelope associated with the pegmatoidal feldspathic pyroxenite and less mineralized lithologies immediately adjacent to it. The distribution of PGE is typically up to a metre away from the highly mineralized pegmatoidal feldspathic pyroxenite with some erratic values being recorded several metres from the pegmatoid (Figure 2). When considering the appropriate mine design, the inclusion of low grade material can be considered advantageous.

In the determination of the mineral reserve it is therefore necessary to define the optimal mining cut and apply a suitable mine design to the mineral reserve estimation. A conversion of a mineral resource may therefore not be applicable, as the mineral resource may be declared over lithologies that may be included or excluded for the envisaged mining method depending on the criteria such as mine design, mining equipment or mining efficiency. The lithologies adjacent to the mineralized part of the Merensky Reef are generally mineralized, albeit it at a lower level, and may therefore contribute to the revenue of the mining cut. The grade characteristics for these lithologies needs to be determined in order for the appropriate grades and tonnages to be applied to the mine design and therefore should be incorporated in the mineral reserve. It is therefore envisaged that a re-estimation of the mineral resource for material not typically included in a mineral resource e.g. the immediate hangingwall and footwall to the mineralized horizon.

With reference to the UG2 chromitite layer, the knowledge of the grade distribution of the hangingwall stringers and middling pyroxenites needs to be well understood and may need to be determined independently so that the necessary application of rock engineering to the mining cut can be considered (Figure 3). The application of specialist knowledge in connection with the hangingwall is the assessment of the competency of the hangingwall beam. The UG2 chromitite layer has very prominent hangingwall jointing which when mined can cause real issues in respect of falls of ground and breaking point for mining. In general the support of the poor hangingwall of the UG2 chromitite layer is difficult and dangerous. When there is considerable emphasis on safe mining, the Competent Person may need to examine and asses, with the assistance a suitably experienced geotechnical engineer, the potential for hangingwall failure. The scenarios should be tested to determine whether it is practical, safe and economic to undermine and/or support the leader layers where they would, if included in the mining package, excessively dilute the grade of the main chromitite layer due to falls of ground or breaking on the chromite/pyroxenite parting. The rule of thumb has been that the grade of the leaders will support the equivalent thickness of the middling pyroxenite. In the declaration of a mineral reserve, this rule of thumb must be properly tested.

The grade distribution into the immediate hangingwall and footwall can be determined and then used in the determination of the grade of the mining cut and the head grade. The UG2 chromitite layer maybe quoted or declared with some consideration for the immediate footwall which is frequently pegmatoidal and significantly mineralized for some 20 cm below the bottom reef contact. The amount of footwall material included in the mineral reserve should be determined after consideration of the geology, grade distribution, mining method, metallurgy and economic factors.

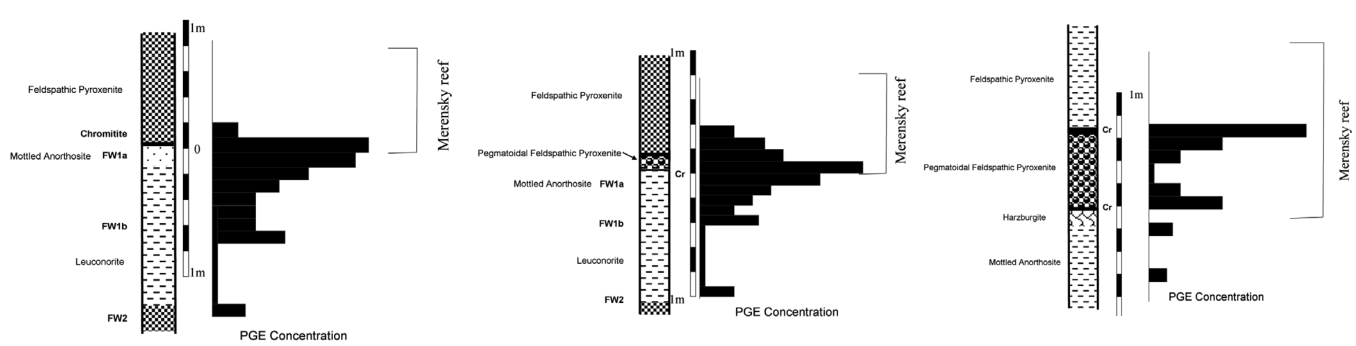

Figure 2. Schematic representation of the grade distribution of the Merensky Reef

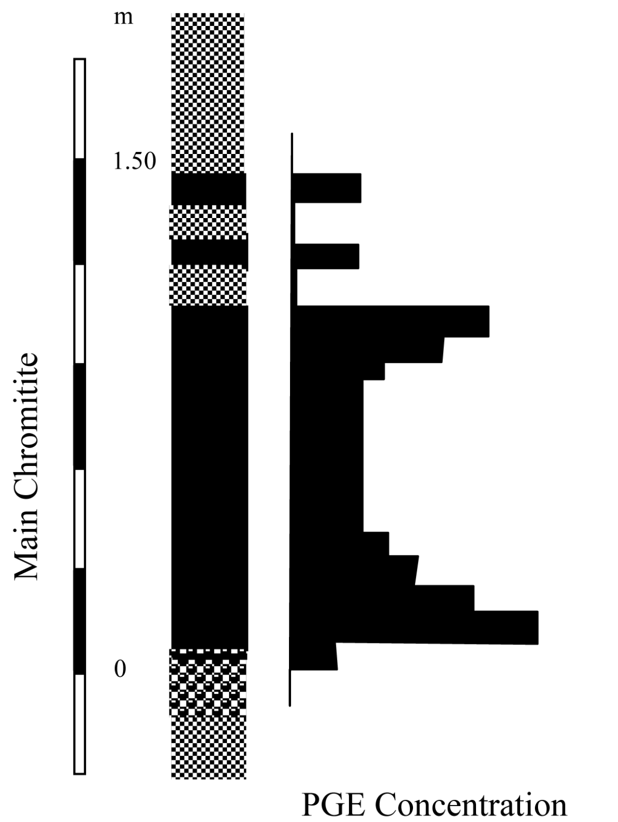

Figure 3. Schematic grade histogram of the UG2 chromitite layer

Underground logistics

Level spacing and stope back lengths may seem irrelevant; however, for interlevel spacing increase beyond the traditional 40 m to 90 m range, some mine designs being planned on 150 m to 200 m backlengths, logistics becomes a bigger issue. Longer backlengths not only influence productivity but also influence the number of stope orepasses. Necessitating longer box holes beyond the recommended and common practice in the 50 m to 70 m range. Logistics are further complicated by the timing to develop these longer ore passes.

Marginal cut-offs

Although the current paradigm is that almost all of the platiniferous reefs are payable, careful consideration must be given to the application of economic factors to the mineral reserve estimation. The application of the cut-off value should be based on profitability rather than achieving a 'hurdle rate'. The Competent Person must know what the anticipated cut-off grade for the mine or project would be. This would be based on the Competent Person's knowledge of similar operations within the Bushveld Complex. Once an initial mineral reserve has been completed, the mine designer may optimize the mine design by inclusion of a marginal cut-off.

The marginal cut-off should ideally be linked to the ability to recover metal. The current metallurgical technology can recover in the concentrator metal as low as a head grade of 0.5–0.7 g/t 3PGE+Au. The marginal grade should therefore be above this estimated cut-off as any additional material sent for concentrating would be expected to remove metal from the concentrate to accompany the tonnes with less grade than the lower cut off the tailings.

The application of the marginal cut-off is relevant to the consideration of the mining cut. If the additional material outside of the mineralized part of the reef has a grade lower than the marginal cut-off, it will effectively remove metal from the better mineralized material during the processing of the ore.

Metallurgical

The definition of a mineral reserve is taken to include any beneficiation of the raw product that might take place prior to, or during, the metallurgical process, and the application of discount factors such as mine or mill 'call factors'. The mineral reserve declared for many Bushveld mines or projects, however, generally exclude metallurgical factors. This is probably due to the historical secrecy of the rates of recovery of the concentrators and refineries and the complexity/multi-stage metallurgical process required to recovery all of the PGE and associated base metals. This does provide a similar basis to compare mineral reserves. Despite this an investor from another commodity may not appreciate that no account has been taken of the recovery of a concentrator or refinery. It can be argued that one needs to consider what the final product of a particular mine is, i.e. run of mine ore or concentrate or refined production in line with the relevant off take agreements.

Toll processing is becoming more of a common practice considering the high costs of establishing concentrator or smelting facilities. The mineral reserve estimation needs to take cognizance of the specifics of the plant feed as penalties are typically applied for contaminants, such as excessive chrome.

Mineral resource conversion generally presupposes that a detailed mineralogical study has been conducted, a process design has been established from a quantative study. Mineralogical aspects include liberation study size and degree of liberation of target minerals from gangue constituents, other valuable minerals, trace elements and contaminants. This data will assist in the process design of comminution and selection of appropriate process selection.

Ventilation, heat, and refrigeration

In platinum mines heat is a major source of concern especially as mining progresses deeper. This heat transfer is directly proportional to the area of rock face which is exposed to the airflow. It is the environmental engineer's responsibility to keep air temperatures to an acceptable level and reject temperatures of 27ºC are often specified. The use of mechanized equipment can add significantly to this heat load as well as water fissures for which cooling and pumping must be provided. As mining progresses deeper the costs of cooling influence on the resource reserve conversion process. If neglected previously declared mineral reserves may in fact to be found uneconomic once ventilation and refrigeration costs are appropriately applied to the mine design.

Mine design

Conventional

Conventional stoping is a commonly mining method applied on mines in the Bushveld Complex. Key areas to be considered are planned dilution, for example achieving a minimum stoping width, gully development and other in-stope excavations. Although planned dilution is usually well understood, unplanned dilution is often underestimated and affects the run of mine grade. Overbreak of the planned stoping width and gully, falls of ground, and the improper of tipping of hoppers are a major source of unplanned dilution.

Mechanized

Key considerations for mechanized mine designs is the amount of dilution introduced due to minimum mining height requirements, and footwall cutting to cater for roadways. Other sources of dilution can be additional waste development for conveyor belts, loading points and reverse bays for mobile equipment. Waste can also be sourced from the simultaneous loading of waste and ore into truck or on to conveyor belts. Failure to properly account for dilution can lead to the overestimation of run of mine head grade. The selection of mining equipment needs to be appropriate for the geology and grade distribution of the reef. An associated factor is that as the size and quantity of machines in a confined space increase so does the ventilation requirement which has an associated cost.

Open-pit mining

In recent years numerous open-pit operations on the UG2 chromitite layer and Merensky Reef have been established. Experience now exists as to the most appropriate way to mine, apply grade control and treat these ores. Typical knowledge that has been gained includes high wall stability, suitable highwall and sidewall slopes, most efficient mining method, suitability of mining fleets, planned and unplanned dilution aspects. This knowledge needs to be applied by the Competent Person.

One of the significant features is the ability to effectively mine potholes and other geological disturbance. It is practical to mine small potholes of 20 m diameter even 3–4 m deep, as the mining method and equipment can accommodate the variation on the reef geometry. This allows a significant improvement in the extraction ratio and when the thicker reef within a pothole is considered, the benefits are even greater. These features should be applied to optimize an operation and should therefore be incorporated into the mineral reserve estimation.

Variation across project/mine

The geology and grade profile of the Merensky Reef and UG2 chromitite layer can be expected to change across a project or mine. If the mineral resource does not attempt to address this variation, the Competent Person needs to be sure that the potential variation in geology or grade has been adequately addressed in the mine design and scheduling. Where facies change or characteristics of the grade histogram vary along strike or down dip, these need to be adequately accounted for in the estimation and declaration of a mineral reserve. If necessary a variety of mining methods, pillar designs, etc. needs to be applied across a mine or project.

As an example, the Eland Platinum Mine, which is underlain by the UG2 chromitite layer, has three different facies areas. Each has had to be handled differently as the mining approach required is related primarily to thickness and grade. The approach taken was to determine which facies was present at each point in the deposit and apply the appropriate mine design and scheduling in the determination of the mineral reserve. In the relatively small area where the reef is too thick for the selected mining method and machinery, the mineral resource has been re-estimated for a truncated width prior to application of mine design and scheduling.

The distribution and frequency of potholes can have a significant effect on the mineral reserve declared and the Competent Person needs to understand the distribution and frequency of the potholes from previous mining, or if the information is available, from adjacent mines. In the case of a project, it may be necessary to estimate the position or potential probability of intersecting a pothole.

Infrastructure

Existing mining operations are typically located in areas of developed infrastructure. New projects are being developed in areas with generally poor infrastructure and often insufficient water or power resources. The Competent Person must be cognizant of these aspects of the potential to mine. The feasibility should account for sufficient capacity where required to provide access, housing, power, water, etc. to the project area. Where water needs to be sourced from third party sources, proper provisions must be made to transport the water to site and the operational cost needs to be included in the feasibility. This requirement should not be underestimated, as many projects fail to adequately address this issue in terms of timing, quantity and cost.

PGE proportions

The PGE proportions is the ratio of the Pt, Pd, Rh and Au concentration to the total 3PGE+Au concentration. The distribution of the PGE is a significant influence on the revenue generation. This together with the base metals should be properly estimated. One of the important aspects is the method applied to the weighting of the metals based on length of intersection and density of the lithology.

The revenue determination needs to use the best estimate of the individual metal concentrations and the consideration of the metal prices needs to be cognizant of the potential for increases and decrease in these metals prices in the short and medium term.

Base metals and minor PGEs

The base metal contribution, especially nickel, can have a material bearing on the feasibility of a project. Nickel can contribute as much as 15% to the revenue of a project. The various aspects of the base metal concentrations need to be understood. Of particular importance is the ability to process the nickel of the orebody. For instance, the nickel in the UG2 chromitite layer is primarily in the chromite crystal structure and therefore difficult to recover.

Where the PGE concentrations are low (typically <2 g/t), the project may in fact be viewed as a base metal project with PGE credits. This has been the view of some of the project that have identified Platreef or Platreef-like deposits e.g. on the southern portion of the Northern Limb of the Bushveld Complex.

Although the other PGE (e.g. Ru, Os, Ir) are seldom considered of sufficient significance to assay and estimate, it would be prudent to have an appreciation of their potential contribution to the revenue of the mine or project. This is especially true when one of these metals has a volatile price. The appreciation of the concentration, market and price could change the Competent Person's view on whether to include them in the feasibility determination.

Grade control

Typically, new projects or mines consider mining a low grade deposit. Whereas pushing the technical envelope is desirable, the practical requirements of sufficient and suitable technical support must not be overlooked, particularly in the grade control and sampling departments. Management will be required to make critical decisions during the life of the mine and should be able to make these decisions based on sound technical data and interpretation. The feasibility should include all best practice aspects of grade control, sampling and ongoing surface and underground drilling.

Feasibility

A mineral reserve estimate represents the collation of work carried out by numerous professional disciplines and must be able to demonstrate feasibility. The SAMREC code (2007) requires a feasibility study be completed to at least a prefeasibility study level of accuracy.

In demonstrating feasibility the following are considered necessary:

- Mining method and mine design
- Mining equipment, staffing levels, operational protocols, etc
- Capital and operating costs
- Processing method(s) to be used, equipment, plant capacity and personnel requirements
- Estimated recovery (proportion of material sent to the processing plant that will be recovered) whether based on historical information, laboratory test, or pilot-plant results
- A reconciliation of mine to mill production and mine production to mineral resource/mineral reserve estimates.

Market

Although the Competent Person is not required to have a definitive understanding of the market, it must be considered important in assessing whether the economic factors being considered are appropriate to the deposit in question. The potential for over or undersupply of a particular metal in the future could influence the approach to the mine design and ultimately the mineral resource mineral reserve estimation.

Classification

The investor or stakeholder is extremely interested in the classification of the mineral reserve. The examination of all the factors that may affect the classification is likely to be an iterative process where increasingly rigorous assessment is applied to each, and reassessments of each, in order to attain greater confidence and higher rank in the mineral reserve classification. Where the application of appropriate methods has been completed in the mineral reserve estimation, the categorized mineral reserve can be confidently declared.

Conclusions

The conclusions drawn are that the UG2 chromitite layer and Merensky Reef are unique orebodies and require specialist treatment by Competent Person when declaring the mineral reserve. An important aspect is the lower grade material immediately above (hangingwall) and below (footwall) the orebody. It may be necessary to re-estimate the mineral resource and apply the selected mine design and scheduling to the mineral reserve estimation.

The declaration of the mineral reserve should not be considered simply as the application of modifying factors to convert the mineral resource into a mineral reserve. It is rather the application of suitable tenement, mining engineering, geological, economic, metallurgical, social and environmental expertise to the mine design and scheduling of the proposed operation.

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