De Beers Venetia Mine Cut 4 Slope Optimization

J.N. Ekkerd  De Beers Venetia Mine, Musina, South Africa
M.R. Ruest  De Beers Group Services, Johannesburg, South Africa
N.E. Rankhododo De Beers Venetia Mine, Musina, South Africa

Abstract

The country rock assemblages at Venetia are part of the Limpopo Mobile Belt and mainly consist of metamorphic and intrusive igneous rocks. A dominant S2 foliation cross cuts all the geology which results in an anisotropic rock mass strength. The interaction between the brittle jointing and foliation also locally impacts on bench stability and subsequent bench performance. The slope design is therefore highly dependent on the orientation of the pit slopes relative to structural features.

In 2009 a revision and optimisation of the business plan was undertaken of which one aspect was the review of the slope angles and design sectors. The acceptance criteria, as recommended by the Guidelines for Open Pit slope Design (Read & Stacey, 2009) were used by De Beers to determine the acceptable level of risk for the optimisation programme. The optimisation programme consisted of an extensive field data collection campaign and Geotechnical modelling. The Geotechnical domain model was subsequently updated based on the results of the field data collection programme. The updated design considered the orientation of the pit slopes relative to the foliation; consisted of a bench, inter-ramp and overall slope analysis and conforms to internationally recognized acceptance criteria.

1 Introduction

1.1 Location

Venetia Mine is situated south of the confluence of the Shashi and Limpopo rivers, 80 km West of Musina and 36 km North-east of Alldays in South Africa. See Figure 1. Venetia is an open pit, truck and shovel operation which commenced full production in 1993. Mining began on the Cut 4 design in 2006 with a final planned open pit depth of approximately 500m below surface at a maximum waste stripping rate of approximately 50 million tonnes per annum. The two most economical kimberlite pipes (K01 and K02) are currently being mined in a single open-pit operation. See Figure 4. Venetia Mine employs a split shell mining method to strip waste and mine the associated ore. The split shell mining sequence is preferred since it allows for the merging of successive shell designs resulting in waste deferment and advancing revenue, leading to improved NPV and cash flow. In the current plan, the mining sequence for the different split pits is as follows: Cut 3, Cut 4 North and Cut 4 South.

1.2 Geology

Venetia Mine is located within the in the Central Zone of the Limpopo Mobile Belt, South Africa. Lithologies within and surrounding the Venetia Mine comprise a ‘gneissic package’ (12 lithologies) and a ‘metasedimentary package (6 lithologies). The ‘gneissic package’, representing the Malala Drift Group in the core of the large E-to ENE-trending synform consists of: (a) biotite-bearing quartzofeldspathic gneiss (BBG); (b) biotite schist (BS) and (c) amphibolite/amphibolitic gneiss (AM). Metasediments exposed in the pit comprise fuchsite and fuchsite-muscovite quartzite (FQ), metapelite (PHY) and marble (MBL). Current exposures of these are restricted to the SW and NW parts of the pit, although relatively thicker layers of metasediment outcrop further to the north and south of the mine (Barnett, 2003; Rigby et al, 2011). Dolerite sill and dykes, pegmatite intrusions and the
kimberlite intrusions cross cut the above-mentioned metamorphic units. For Geotechnical engineering purposes the lithologies are grouped into five packages: Gneiss, Metasediments (No Marble), Marble, Intrusive (Dolerite and pegmatite) and Ore (kimberlites). See Figure 2.

The Venetia kimberlites are situated within a large F3 synform, which is asymmetrical and south-verging. The site is characterised by four main deformation events (D1 – D4). The first deformation event is not resolvable, although it may have consisted of the juxtaposition of gneissic and metasedimentary units. The second generation of planar fabric (termed S2) forms the dominant foliation at Venetia. This foliation is largely parallel to gneissic and metasedimentary contacts. The orientation of S2 across the pit accords with the orientation of the E-W trending synform in Gumbu Group metasediments. (Rigby et al, 2011). A fold axial plane (FAP3) subdivides the large F3 synform into, firstly, a northern block wherein S2 and lithological contacts are steeply N-dipping. The northern limb of the synform is vertical to overturned and thereby steeply north-dipping, although no stratigraphy or way-up indicators per se are present to definitively confirm this. Secondly, a southern block wherein S2 and lithological contacts are moderately N-dipping may be defined. The southern limb is also north-dipping, although this has a shallower or more moderate dip, compared to the north limb. The exact form of the hinge zone of the large F3 synform is unknown (Basson, 2011). See Figure 3.

The number of phases of deformation through which many of the faults and joints have been reactivated makes it difficult to create a reliable genetic model for the joint sets. The orientations of some of the sets do imply that they have been formed and reactivated at the same time as the faults during the brittle phase of the Limpopo Belt’s development, post-2Ga (Barnett, 2003). Historically four main joint sets have been identified and termed J1, J2, J4 and J6. Review of recent slope failures and extensive pit mapping indicated that the J2, J4 and J6 sets are still present within the current exposures. J6 is associated with the NW trending fault system. J2 and J4 are pervasive in the rock mass and the dip and strike varies slightly depending on the domain. See Figure 3. In summary a dominant S2 foliation cross cuts all the geology which results in an anisotropic rock mass strength and impacts on stack and overall slope performance. The interaction between the abovementioned brittle jointing and S2 foliation in turn also locally impacts on bench stability and subsequent bench performance. The slope design is therefore highly dependent on the orientation of the pit slopes relative to structural features.
Figure 2. Country rock map of the pit showing the major package boundaries, major structures and fold axial plane (Basson, 2011).

Figure 3. Lower hemisphere stereographic projections showing the distribution of the brittle jointing and S2 foliation in the North and Southwest Domain.
1.3 Hydrogeology

Inflows into the pit generally occur from the fault zones and geological contacts. The passive groundwater inflow to the current pit is estimated at about 600m$^3$/day. See Figure 2 for the major structures intersecting the pit. The overall hydraulic conductivity of the metamorphic country rocks is very low – less than 0.001m/day. In such rocks, active dewatering from perimeter of the pit will not be successful in reducing the relatively small amount of passive inflow to the pit. No significant water bearing structures that would constitute targets for dewatering boreholes have been encountered to date (Atkinson & Shchipansky, 2008).

Groundwater modelling and pore pressure monitoring has however indicated that some natural depressurisation of the highwalls has already occurred and will continue to occur as the pit deepens due to de-stressing or relaxation of the rock mass behind the highwalls (Atkinson & Shchipansky, 2008). This has been factored into the slope design.

2 Geotechnical model

2.1 Domains

The analysis was conducted on the c4v25 and c5v5 pit designs for Cuts 4 and 5 respectively and consisted of overall slope and inter-ramp analyses. The initial boundaries only considered the main structural domains and were crosscutting major geological boundaries. Subsequent updates to the pit shell necessitated the review of the domain boundaries. See Figure 4.

The domains are primarily based on the dominant orientation of the primary metamorphic fabric, lithological boundaries and the overall stability performance of the pit slope. The positions of the domain boundaries are approximate and change with depth, pit face position and orientation. The boundaries are continually repositioned with further in pit mapping and exploratory diamond drilling. The boundaries were based on the Cut 4 V27 pit shell.

Thus considering the above the pit can be divided into the following domains.

- **North Domain:** The foliation is steeply dipping into the face. The main failure mechanisms in this domain are toppling (in upper weathered units only) and wedge type failures. For design purposes the East and North domains have been combined (Contreras, 2008). In the East of this domain the S2 foliation angles are oblique to the pit wall. This is a favourable relationship between the metamorphic fabric and the pit walls.
- **Southeast Domain:** This is a transitional zone between the South domain and North domain. The difference in strike between the S2 foliation and pit walls are in excess of 20 degrees. Local wedge failure can however still occur. This domain was added at the end of 2008 by the design consultant after a review of the domain boundaries was requested by the site (Armstrong, 2008).
- **South Domain:** In this sector the foliation and the pit wall are parallel to each other. The dominant failure modes are planar, wedge and step-path type failures along the foliation. This domain is dominated by the rocks from the Tina-Liezal Shear zone and consist mainly of rocks from the Gneiss Package.
- **South-southwest Domain:** This domain is characterised by both a change in rock type (Metasediments) The S2 foliation changes in dip direction and as a result the pit walls and foliation are still parallel to each other in this domain. Planar failure is still the dominant failure mechanism. This domain is within the Metasediments.
- **West-southwest Domain:** This is a transitional domain between the North and South-southwest domains. Historically this domain has the lowest rock fall history and the difference in strike between the pit walls and foliation is in excess of 40 degrees. Localised wedge failure can still however occur.
• Kimberlite Domain: This domain is holistically used for all the kimberlites in the pit. This domain is characterized by slumping and/or circular failures. See Figure 4.

Figure 4. The geotechnical domains in the Venetia Pit. The blue, green and black line demonstrates the evolution of domain boundaries in 2008, 2009 and 2010 respectively.

2.2 Rock mass data

From the previous section it is evident that the geology is complex and that various potential failure mechanisms are present. In order to mitigate this potential hazard approximately 800 boreholes have been drilled in and around the pit of which 141 were dedicated Geotechnical and Dewatering investigation boreholes. The drilling programme is backed by an extensive in pit mapping campaign. The database currently consists of approximately 6400 Geotechnical samples. Using this data the geological units were divided into various geotechnical units. The rock mass rating for the major applicable Geotechnical units are given in Table 1. The country rock units are in the fair to good category.

Table 1. Rock Mass Ratings (RMR; Laubscher, 1990) and Uniaxial Compressive Strength (UCS) for the major geotechnical units and domains in the pit

<table>
<thead>
<tr>
<th>Geotechnical Units</th>
<th>Domains</th>
<th>RMR</th>
<th>UCS (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gneiss Package</td>
<td>North, South East, South</td>
<td>65</td>
<td>132</td>
</tr>
<tr>
<td>Metasediment Package</td>
<td>South-Southwest, West-Southwest</td>
<td>57</td>
<td>140</td>
</tr>
<tr>
<td>Marble Package</td>
<td>Not exposed</td>
<td>60</td>
<td>125</td>
</tr>
<tr>
<td>Dolerite</td>
<td>All Domains</td>
<td>57</td>
<td>267</td>
</tr>
<tr>
<td>K01 RVK Kimberlite</td>
<td>Kimberlite</td>
<td>63</td>
<td>29</td>
</tr>
<tr>
<td>K01 DVK Kimberlite</td>
<td>Kimberlite</td>
<td>74</td>
<td>134</td>
</tr>
</tbody>
</table>
3 Optimisation

3.1 Scope

In 2009 a revision and optimisation of the business plan was undertaken of which one aspect was the review of the slope angles and design sectors. The acceptance criteria, as recommended by the Guidelines for Open Pit slope Design (Read & Stacey, 2009) were used by De Beers to determine the acceptable level of risk for the optimisation programme. The following main opportunities were identified:

- **Southern Slopes**: Initially the design was based on only two domains (North: mined at 56 degrees, South: mined at 40 degrees). The 40 degree design assumed a slope striking parallel to the foliation. The mine design recently changed for economic reasons which resulted in changes to the orientation of pit slopes. The kinematic impacts and/or benefits of these changes have never been assessed. A transition between the North and Southern domain was included in 2008 but this study was not extended to the rest of the pit. See Figure 2

- **North Slope Design**: The current North Slope Design are based on the slope design studies undertaken by SRK Consulting on behalf of Venetia mine in 2008 (Contreras, 2008). The analysis indicated that steeper stack angles are achievable in this portion of the slope however a lower slope angle was recommended due to the perceived rock fall risk and the mining practices at the mine. The rock fall risk was however not quantified.

- **Stack angle per ore type**: No stack angle existed for the ore types intersected at the bottom of the pit and the country rock angles were applied to the kimberlite ore. This resulted in a significant amount of ore not being extracted from pit bottom.

3.2 Southern slopes and transition zones

The South slope is designed, principally, considering the kinematic planar failure on the dominant S2 foliation fabric and is designed at 40°. The design was based on the Cut 4v25 shell; however the Cut 4 pit shell was updated and redesigned in 2009. Since the previous Cut 4 design, 5 benches have also been developed in Cut 4 South. The newly exposed faces and geometrical changes (New shell: Cut 4 V27) necessitated the review of the slope angle in this portion of the pit in 2009. For this purpose approximately 1.8 km of scan line mapping was conducted in that quadrant of Cut 4 South. The historic South domain were also grouping major geotechnically distinct geological packages which is not recommended according to the Open Pit Design Guidelines (Read & Stacey, 2009). See Figure 2 and 4. It was also noted that bench performance in the Southern slope could be isolated to distinct areas. Thus the historic Southern Domain was divided into additional domains considering bench performance, slope orientation and geology: See Figure 4 and Figure 5.

- **South Domain, Gneiss and Tina-Liezel Shear Zone**, Dip direction approximately 15 degrees in Cut4V27, poor bench performance

- **SSW: Metasediments**, Dip direction approximately 46 degrees in Cut 4V27, poor bench performance. Eastern boundary is the contact between Gneiss and Metasediments.

- **WSW: Metasediments**, Dip direction approximately 67 degrees in Cut 4V27, good bench performance, Northern contact with the Gneiss.
A complete bench, inter-ramp and overall slope analyses were performed for the two domains by Itasca. Benchscale analyses were performed on the new domains by Itasca using kinematic wedge-and-planar analysis tools, developed by Itasca: SWISA and PFISA. The bench-scale analyses were used to determine an acceptable inter-ramp angle for each design sector based on the available structural-orientation data for the SSW and WSW design sectors. Based on the results of the bench scale analyses, inter-ramp configuration analyses then were performed for each design sector, to determine stack angles for the new domains. Analysis where conducted for 12m and 15m bench heights. (Strouth, 2009)

The acceptance criteria for the bench scale analysis were defined as a probability of failure (PoF) of 20% and a minimum factor of safety (FOS) of 1.1. (Strouth, 2009) The acceptance criteria that were used are consistent with the recommendations of the Open Pit Design Guidelines (Read & Stacey, 2009). The results of the bench-scale configuration analyses are summarized in Table 2.

Table 2. Results of the bench scale and stack analysis (Strouth, 2009).

<table>
<thead>
<tr>
<th>Design Section</th>
<th>Bench Height (m)</th>
<th>Min. Bench Width (m)</th>
<th>Resulting Stack Angle (deg)</th>
<th>Previous Stack Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSW</td>
<td>12</td>
<td>14.0</td>
<td>41</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>17.5</td>
<td>41</td>
<td>40</td>
</tr>
<tr>
<td>WSW</td>
<td>12</td>
<td>9.0</td>
<td>53</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>11.0</td>
<td>54</td>
<td>40</td>
</tr>
</tbody>
</table>

An inter-ramp configuration analysis was performed by using SWISA, PFISA. The inter-ramp joint cohesion and friction angle were assumed to be the deterministic joint-strength values calculated by Contreras (2009) for the Metasediment Package unit. (Strouth, 2009) The inter-ramp analyses are based on the inter-ramp angle results determined from the bench-scale analyses. The limiting acceptable value of the probability of failure (PF) was defined as 15% for the Probability of Failure and 1.2 for the Factor of Safety (FOS). The acceptance criteria that were used conform to the recommendations of the Open Pit Design Guidelines (Read & Stacey, 2009). See Table 2. The inter-ramp angle (crest-to-crest) was found to be controlled by the bench geometry for both Southwest design sectors. The analysis indicated a maximum acceptable inter-ramp angle of 41° for the SSW design sector, for both 12 m and 15 m bench heights; and for the WSW design 53° and 54° degrees for 12 m and 15 m bench heights respectively.
An overall slope stability analysis was only conducted for the WSW domain because the proposed inter-ramp angle was significantly higher than the previous inter-ramp angle (increased from 40 to 53 degrees). Overall slope analysis where conducted by Itasca using the finite difference code FLAC on a representative design section, with a ubiquitous joint model. The FLAC solution is efficient and fast compared to UDEC at this scale and gives a valid answer for slip along foliation and was deemed the most appropriate tool for the analysis. For conservative modelling purposes, it was assumed that the apparent dip of the foliation in the analysis section coincides with the real dip, i.e. 41 degrees. (Gomez, 2010) The water pressure conditions were simulated in the model and two alternatives were considered:

a) Phreatic surfaces defined using a criterion previously applied by SRK in the Cut 4 and 5 studies (Contreras, 2008)
b) Pore pressure distributions obtained from an existing hydrogeological model developed by Itasca Denver in 2008 (Atkinson & Shchipansky, 2008).

The analyses performed by Itasca using both sets of data showed that the simplified approach described in alternative a) yields lower factors of safety for the slopes and was therefore conservatively applied in the model. (Gomez, 2010) Various overall angles where analysed as part of a sensitivity study. See Table 3. The factors of safety could be considered as high for the overall slope; however stack stability dictates the maximum achievable slope angle in this domain. It is thus unlikely that steeper overall slopes can be achieved in this domain.

Table 3. Results of the overall slope analysis (Gomez, 2010).

<table>
<thead>
<tr>
<th>Case</th>
<th>FoS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall angle = 41°</td>
<td>1.63</td>
</tr>
<tr>
<td>Overall angle = 44°</td>
<td>1.51</td>
</tr>
<tr>
<td>Overall angle = 48°</td>
<td>1.37</td>
</tr>
</tbody>
</table>

3.3 Northern slope

In 2008 slope stability analyses for overall and stack slope scales were performed with the programme SLIDE (Rocscience, 2002), using the limit equilibrium methodology. Selected results of these analyses were verified with a stress-deformation analysis using the programme PHASE2 (Rocscience, 2008). The stability of various angles for the North Slope was assessed for each combination of stack height and in general, the criteria used for acceptable factor of safety were 1.5 for overall slopes and 1.2 for stack slopes.

The effect of the foliation on the stability of the South Slopes was considered by assuming anisotropic rock conditions with the direction of the weaker strengths derived from the geological model. The analysis of the North Slope indicated that a 58 degree angle is within the required factor of safety (1.2). However based on previous berm retention due to poor blasting practices an angle of 56 degrees (120m maximum stack height) was recommended for the North Slope. No quantitative analysis was undertaken to define the rock fall potential and/or maximum stack angle.

In 2008 two sets of strength parameters were estimated to correspond to deep (>50m, D=1 and σ3max=1.0 MPa) and shallow (<50m, D=1.3 and σ3max=0.5 MPa) rock mass conditions. The criteria for shallow rock mass conditions was reduced by using the parameters for deep rock mass using stress reduction factors of 2.2 for the cohesion and 1.3 for the Tan(φ) term. (Contreras, 2008) Effectively average minus one standard deviation uni-axial compressive strength was applied. The values for the 2008 study are given in Table 4. The authors could not duplicate the best-fit Mohr-Coulomb values using conventional Hoek Brown criterion (Hoek, 2002).
An update of the Geotechnical Model was undertaken in 2009 (Barnett and Russo, 2009). The values for the 2009 update were used by the authors to generate equivalent Mohr Coulomb parameters from the Hoek Brown criterion (Hoek, 2002). Conservatively average minus one standard deviation UCS and GSI were applied. See Table 4.

Table 4. Rock mass properties used to derive Mohr Coulomb equivalent parameters using the Hoek Brown criterion (Hoek, 2002).

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Geotechnical Unit</th>
<th>UCS (MPa)</th>
<th>UCS St. Dev (MPa)</th>
<th>UCS applied (MPa)</th>
<th>RMR</th>
<th>GSI applied</th>
<th>mi</th>
<th>σ3max (MPa)</th>
<th>D (KPa)</th>
<th>c (KPa)</th>
<th>Φ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contreras (2008)</td>
<td>Gneiss Package</td>
<td>125</td>
<td>65</td>
<td>73</td>
<td>60</td>
<td>54</td>
<td>12</td>
<td>0.5</td>
<td>1.3</td>
<td>307</td>
<td>33</td>
</tr>
<tr>
<td>Barnett et al. (2009)</td>
<td>Gneiss Package</td>
<td>132</td>
<td>55</td>
<td>77*</td>
<td>65</td>
<td>60</td>
<td>13</td>
<td>0.5</td>
<td>1</td>
<td>208*</td>
<td>45*</td>
</tr>
</tbody>
</table>

* Derived by authors.

The geometry of the 2008 models, including the phreatic surfaces, were duplicated in SLIDE. Two sensitivity analyses on the stack angles for the North Domain were conducted by applying the values derived by Contreras (2008) and the newly generated strength values from the 2009 dataset. Applying average minus one standard deviation UCS and GSI values resulted in a factor of safety of 1.23 for a 63 degree stack. The sensitivity analysis demonstrated that rock strength is not the dominant factor that controls the maximum stack angle in the North Domain. See Figure 6.

Figure 6. Sensitivity analysis showing the results of stack analysis using the two sets of properties.
Review of fall of ground data indicated that rockfalls are prevalent in the North Domain. This was mainly due to steep wedges forming between the J2 and J4 joint sets. Subsequently poor blasting resulted in the catch berms not being retained and thus the catch berms did not act as an effective control to mitigate the rock fall risk. The definition as described by Ryan and Prior (2000) was used to define the actual catch berm width for the benches in the North domain. See Equation [1] for the definition of the percentage catch berm:

\[
\% \text{ Catch berm} = \frac{\text{actual catch berm width}}{\text{design catch berm width}} \times 100
\]

From the results it is clear that blasting has improved resulting in a significant increase in catch berm potential (\% Catch berm). It was therefore deemed appropriate to re-evaluate the angle for the North domain. See Figure 7.

For this purpose an extensive study was undertaken in order to define the major joint sets and S2 foliation in the North domain. The study consisted of an extensive pit mapping programme and review of the current drill hole dataset. The orientation of the dominant joint sets and S2 foliation in the North Domain as defined by the study is given in Table 5.

<table>
<thead>
<tr>
<th>Set</th>
<th>Dip (Degrees)</th>
<th>Dip Direction (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St. Deviation</td>
</tr>
<tr>
<td>J2</td>
<td>73</td>
<td>5</td>
</tr>
<tr>
<td>J4</td>
<td>75</td>
<td>6</td>
</tr>
<tr>
<td>J6</td>
<td>52</td>
<td>7</td>
</tr>
<tr>
<td>S2 Foliation</td>
<td>58</td>
<td>16</td>
</tr>
</tbody>
</table>

Bench-scale analyses were conducted using the SWISA to determine the maximum berm width and subsequent stack angle for the North Domain. Analyses were conducted for 12m and 15m bench heights. The same methodology as defined by Itasca (Strouth, 2009) in 2009 to define the maximum stack angle for the South-
Southwest and West-Southwest domains was applied. The bench-scale results are given in Figure 8. The results indicate that a maximum stack angle of only 62 degrees can be achieved in the North domain irrespective of the results presented in Figure 6. Thus the ability to retain rock falls controls the maximum achievable stack angle in the North Domain and not rock strength.

![Maximum Stack Angle](image)

Figure 8. SWISA bench-scale analysis for 12 and 15m bench heights showing that a maximum stack angle of only 62 degrees can be achieved in the North Domain.

### 3.4 Stack angle for ore

There is a major contrast in the strength properties between the various kimberlite types ranging from 29 to 132 MPa for the RVK and DVK kimberlite respectively. See Table 1. No stack angle existed for the ore types intersected at the bottom of the pit and the country rock angles were applied to the kimberlite ore. This resulted in a significant amount of ore not being extracted from pit bottom (Ore in south mined at 40 degrees = country rock angle). See Figure 9.

DVK kimberlite forms the final benches at the bottom of the Cut 4 V27 pit shell. SRK was requested in 2009 to update the design and to determine a stack angle for the kimberlite ore (DVK) at the bottom of the V27 pit shell. The results indicated that the DVK sub-unit corresponds to a stronger type of kimberlite when compared with the properties of the average undifferentiated kimberlite. However, to allow for the potential degradation with time of this rock type the average parameters based on the full KIM database were selected for the stability analysis. It is assumed that these parameters would better represent the long term strength conditions of the DVK sub-unit. A stack angle of 56 degrees (crest-crest) with a maximum stack height of 60m was recommended (Contreras, 2009). This resulted in the stack angle being increased in the south of the ore body from 40 to 56 degrees.
Figure 9. A section through the V27 shell showing the various kimberlites and how waste angles were applied to the ore.

4 Summary

Domains at Venetia were for the first time designed from the bench scale and upwards and conform to the acceptance criteria as stipulated in the 2009 Open Pit Design Guidelines (Read & Stacey, 2009).

The stability of the pit walls in the Southern domains are controlled by their orientation in relation to the major S2 foliation. The bench and inter-ramp kinematic analysis indicated that steeper angles are viable where there is a major difference in strike between the S2 foliation and pit walls. In contrast the stack angles in the North domain are not controlled by the S2 foliation and/or rock mass strength. Here the interaction between brittle jointing controls the maximum catch berm and subsequent stack angle.

The proposed updates will be applied to future pit shells. A desktop study undertaken by the mine’s planning section to determine the financial impact of increasing the stack angle indicated that a one degree change in slope angle results in a potential saving of US$ 50 million.

5 References


