Geotechnical and risk analyses for the positioning of shafts at the Wesizwe Platinum project

by

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deur

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DECLARATION

I, **Vannessa Clark-Mostert** hereby declare that this dissertation/thesis that I hereby submit for the Degree MSc EARTH SCIENCE PRACTICE AND MANAGEMENT (ESPM) at the University of Pretoria is my own work has not previously been submitted by me for a degree at this or any other university.

Signature: ______________________ **Date: ________________**

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Handtekening: __________________ **Datum: _______________**

SUMMARY

Geotechnical and risk analyses for the positioning of shafts at the Wesizwe Platinum project

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Co-Supervisor: Professor M.F. Handley

Department: Geology

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The Wesizwe main and ventilation shaft positions are sited within an almost square block formed by four faults. The shaft positions were not sited within the centre of gravity of the Wesizwe lease area. This is due to factors related to the local community and various environmental issues. It was decided to position the shaft in the current block as geological and rock engineering confidence was high in regard to the structures within the area, and the shaft position was falling within the allowable distance radius from the nearby community and river boundary.

A seismic survey, conducted on the area, indicated a near vertical fault. The fault, which has a 30m throw, occurs approximately 50m north of the position at which the main shaft was site. It was suggested that this fault, which was a reinterpretation of the northern boundary fault, would have a negative effect on the rock mass behaviour in the shafts.

Previously it was noted that the shaft level breakaways and geotechnical borehole information do not correlate. A 20m vertical discrepancy was observed between the planned Merensky breakaway and the Merensky position indicated by drilling. The logical interpretation was that this was due to faulting and a note was sent out to make the project team aware of this 20m discrepancy. This was again brought to the team’s attention upon the release of the seismic study interpretation indicating a 30m fault in this area.

Geotechnical logging had already been done on the diamond drill holes sunk at the positions indicated for the Wesizwe Main and Vent Shafts. The rock mass ratings indicated that these positions were favourable and that the rock mass of the shafts can be referred to as “Good Rock”. To determine what the geotechnical character of the fault was, four boreholes (WF01, WF049, WF059 and WF090) were geotechnically logged at the predicted depths of the fault intersection.

Two zones carrying less competent ground were identified near the fault intersection positions as was indicated by the seismic interpretation. By combining the zones into one area of less competent ground it was found that the affected area does not exceed a vertical influence of 58m, and has a minimum vertical influence of 25m. The rock mass in these affected areas are overall rated as “poor rock” to “exceptionally poor rock”. The rock quality designation (RQD) ratings for the affected area fall between 36 to 52 %.

A decision needed to be reached as to whether the shafts would be developed at the positions indicated, or whether a new area needed to be selected for the main and ventilation shaft positions. This decision was reached by combining all available information and weighing the risks related to the options. From this study, a general approach to shaft positioning for platinum projects was formulated.

SAMEVATTING

Geotegniese en risiko analise vir die bepaling van skag posisies vir die Wesizwe Platinum projek

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Die Wesizwe hoof - en ventilasieskag posisies is geposisioneer binne ‘n vierkantige blok wat gevorm word deur vier verskuiwings. Die ligging van die skagte is nie geposisioneer volgens konvensionele voorskrifte nie, wat gewoonlik die middelpunt van die bepaalde projek se permit area sal wees nie. Die Wesizwe skagte is hoofsaaklik as gevolg van sosiale en omgewings voorskrifte geplaas. Die spesifieke blok was op besluit aangesien die vlak van informasie in die gebied aansienlik hoër was as vir die res van die permit area en dit was die toelaatbare afstand van die nabye gemeenskap en rivier grens.

Na afloop van ‘n 3D seismiese ondersoek oor die area, was dit duidelik dat daar ‘n verskuiwing met ‘n 30m gooi, ongeveer 50m noord van die gekose hoofskag posisie was. Die veronderstelling was gemaak dat die verskuiwing ‘n onwelkome invloed op die gesteente gedrag in die omgewing van die skag sou hê. Hierdie was egter net ‘n herinterpretasie, van geologiese boorkern resultate.

Op die 21ste van Augustus 2007, was hierdie verskuiwing reeds bemerk as gevolg van die verskil tussen die beplande Merensky Rif wegbreek posisie en die boorkern posisie. Die interpretasie van ‘n 20m verskuiwing was toe reeds gemaak.

Geotegniese analise op die hoof – en ventilasieskagte het aan gedui dat die posisies gunstig was, en dat die skagte gesink sou word in “goeie rotsmassa”. Geen verskuiwing was binne die boorkern opgetel nie.

Die seimies resultate het vier boorgate uitgesonder wat moontlik die verskuiwing raak geboor het. As voorsorgmaatreels is hierdie verdere vier boorkerns geotegnies geannaliseer naamlik WF01, WF049, WF059 en WF090.

Twee zones van slegte grond is geidentifiseer naby die seimies aangeduide verskuiwing posisie. Die posisie het ‘n effek radius van tussen 25 tot 58m gehad. Die analise van die geaffekteerde posisies is geklassifiseer as “slegte rotsmassa” tot “baie slegte rotsmassa”. Die “rock quality designation (RQD) vir die geaffekteerde area het tussen 36 tot 52 % geval.

‘n Besluit aangaande die skuif van die huidige skag posisies moes geneem word. Dit het geskied deurmiddel van ‘n in diepte studie van die informasie wat reeds beskikbaar was en risiko analise van die situasie. Hierdie studie het dus tot `n algemene metode van skagpositioneering gelei.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation	Description
<	$x < y$ means x is less than y.
>	$x > y$ means x is greater than y.
Ablast	Blasting adjustment for MRMR
Ajo	Joint Orientation adjustment for MRMR
Aweath	Weathering adjustment for MRMR
cm	Centimetre, a unit of length equal to one hundredth of a metre.
D0	Main diamond drill borehole, D1 would be deflection 1 etc.
FF	Fracture Frequency
IRMR	In-situ rock mass ratings
IRS	Intact Rock Strength
IRUP	Discordant Iron Rich Ultramafic Pegmatites
Ja	Joint Alteration
JCW	Joint Condition and Water
Jn	Joint Number
Jr	Joint Roughness
Js	Joint Spacing
Jw	Joint Water
m	Metre, the basic SI unit of length, equivalent to approximately /1.094 yd or /39.37 in.
mamsl	Metres above mean sea level
MPa	Mega Pascal, a unit of pressure or stress equal to one Newton per square metre.
MPRDA	Minerals and Petroleum Resources Development Act
MRMR	Laubsher's Mining Rock Mass Rating
PERT	Programme Evaluation and Review Technique
Q	Barton's Rock Tunnelling Index
RMR	Rock Mass Rating
RQD	Rock Quality Designation
SRF	Stress Reduction Factor
UCS	Uniaxial Compressive Strength
UG1	Upper Group 1
UG2	Upper Group 2

1 INTRODUCTION

Before and during any mine planning and scheduling for concept and feasibility studies, the position of the main shaft and its associated infrastructure must be indicated, as companies doing shaft sinking require it as part of their safety procedures. Not only can unforeseen structurally complex ground be a safety hazard during sinking, but also could lead to even bigger complications when the shaft starts producing and access is compromised. The mineshaft can be regarded as the most crucial element to mining success as its main purpose is to provide access to mineral resources below surface for successful extraction. The shafts planned for the Wesizwe Ledig platinum project are to be sunk to provide access to and ventilation for mining operations on the Merensky and UG2 platinum reefs situated in the Upper Critical zone of the Rustenburg Layered Suite of the Bushveld Complex.

According to most literature regarding the positioning of shafts, the centre of gravity (middle point of an area) of the lease area is usually chosen. This is mainly due to the practicality of the arrangement, as the whole area to be mined will thus be equally accessible. Of course, other factors also dictate the decision such as the shape and dip of the ore body, structural features, surface topography, economic and financial viability. Normally the final decision is therefore a combination of these factors, ensuring the optimal accessibility to the ore body, in a structurally sound area, with adequate mineralization (suitable grades).

In the case of the Wesizwe Ledig Platinum project, the encroaching community of the town Ledig mainly affected this assessment of the Main Shaft location and not on the aspects that normally dictate such a decision.

The Department of Mineral Resources (DMR) required a distance of at least 800m to be kept between the community and the proposed mining operations, otherwise the community was required to be relocated at the cost of the mining company. In this case, the management of Wesizwe Platinum decided that the cost of moving the community could lead to the failure of the project. It was therefore opted to site the Main Shaft position in an area that was the correct distance away from the community, but where they at the time had limited to fair knowledge of the structural constraints of the ore body.

The Wesizwe Main and Ventilation shaft positions were sited within an almost square block constrained by four faults (Figure 1). Two vertical geotechnical boreholes were drilled in the Main and Ventilation shaft positions. These holes were logged geologically and geotechnically and the rock mass ratings indicated that these positions were favourable and that the rock mass of the shafts can be referred to as “Good Rock”.

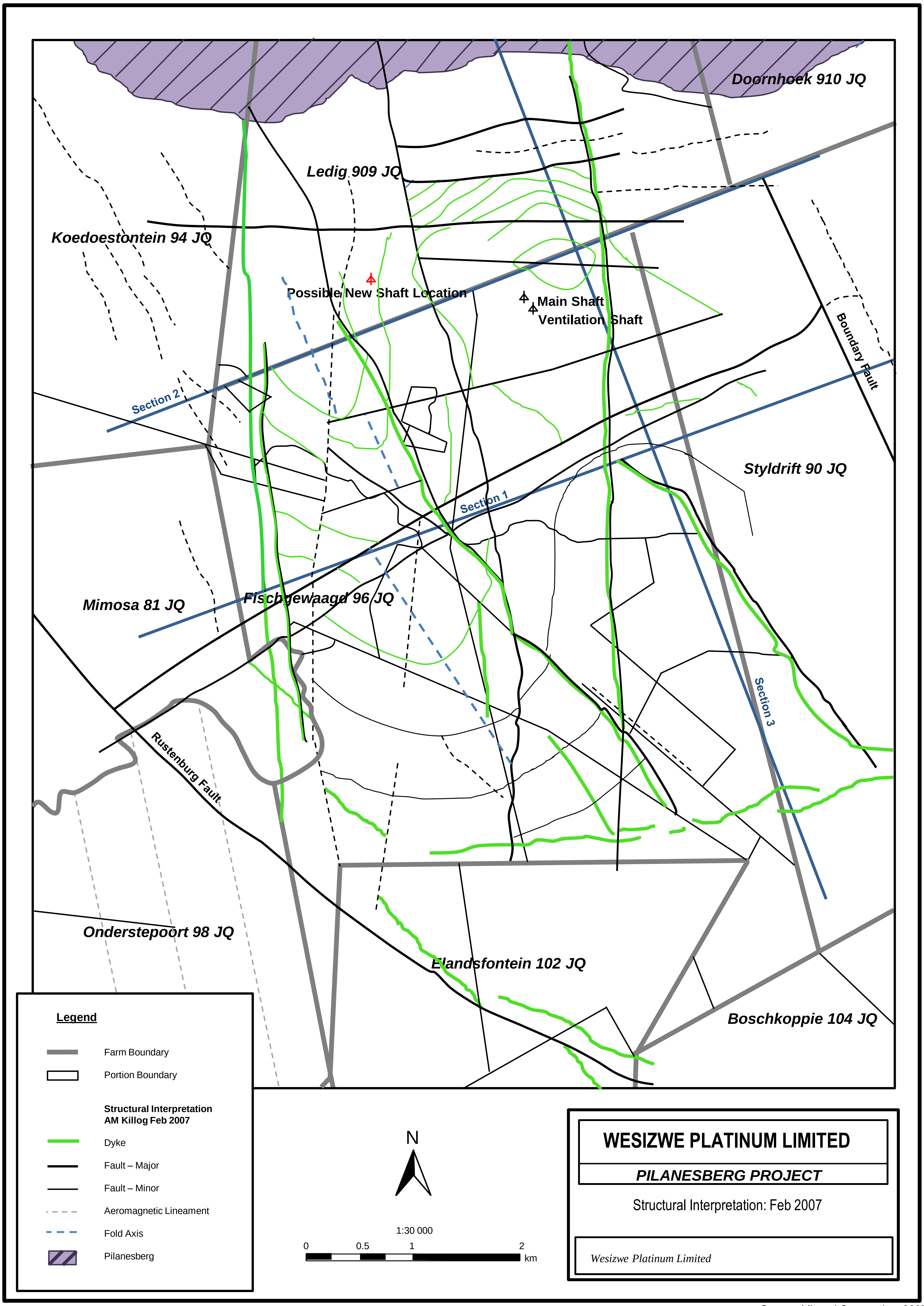
However, a three-dimensional seismic survey conducted over the area indicated a near vertical fault, with a roughly 30m vertical throw, positioned approximately 50m horizontally to the north from the Main Shaft position. It was suggested that this would influence the rock mass behaviour of the shafts. Drilling confirmed this reinterpretation of the structural model, repositioning the fault marking the northern boundary of the “shaft block”.

To determine the geotechnical character of the fault and it’s radius of influence, four boreholes (WF01, WF049, WF059 and WF090) were identified that intersected the fault (Figure 2). These were geotechnically logged at the predicted depths of the fault intersection. Two zones carrying bad ground were identified near the fault intersection positions as was indicated by the seismic interpretation.

From the rock mass ratings, combining the two zones of bad ground conditions that were picked up, the affected area does not exceed a vertical (down-hole) distance of 58m, and has a minimum vertical influence of 25m down hole. The rock mass in these affected areas was overall rated as “poor rock” to “exceptionally poor”. The rock quality designation (RQD) ratings for the overall affected area fall between 36 to 52 %. This area was considered hazardous ground, not suitable to house any major shaft infrastructure and it was established that either the shafts had to be repositioned or the infrastructure had to be rotated around the main shaft barrel to face in a more southerly direction to avoid any major shaft developments in this ground.

Knowing the facts in regard the structural situation of the shaft area, a decision had to be reached as to whether the shafts should be developed at the positions currently indicated, or whether a new area had to be selected for the main and ventilation shaft positions.

It was decided to use a risk analysis matrix in order to reach a conclusion on whether the current positions were acceptable or not. Factors such as the safety risk, time delay, monetary limitations, rock mass quality, structural knowledge, risk management techniques and community issues were reviewed and rated by a panel of experts in various mining related fields, The risk analysis results were therefore based on a combination of expert opinion, knowledge and experience. The analysis outcome was used to reach the final decision in regard the final acceptable positions for the Wesizwe Main and Ventilation shaft positions.



Source: Mineral Corporation, 2007

Figure 1: Map showing major structures. Faults are indicated in black, dykes in green and fold axes by blue lines.

Figure 2: Google Earth imge showing the positions of the boreholes that intersected the fault (note the town of Ledig to the west and lease boundary in red to the east).

1.1 DEFINITIONS

1.1.1 Bunton:

*"A steel or timber element in the lining of a rectangular shaft." (*Parker, 2003)).

1.1.2 Discordant Iron Rich Ultramafic Pegmatites (IRUPs):

"Iron-rich ultramafic pegmatites – these rocks are typically intruded into the Rustenburg Layer Suites, generally after the main mineralised layers were formed. They can replace the normal stratigraphic sequence over extensive areas, and can have a greater or lesser effect on the mineralised layers. They occur as pipes, dykes and sheets" (Allaby and Allaby, 1991).

1.1.3 Replacement pegmatoids:

These features are similar to IRUP's but are non-magnetic.

1.1.4 Lamprophyre

"A dark coloured, strongly porphyritic, intrusive igneous rock, containing abundant euhedral phenocrysts of biotite and /or amphibole which can be accompanied by phenocrysts of olivine, diopside, apatite, or opaque oxides, set in a mafic, felsic or glassy ground mass. Lamprophyres are found intruded as dykes and sills" (Allaby and Allaby, 1991).

1.1.5 Dolerite

"A dark-coloured, medium grained igneous rock which contains plagioclase feldspar of labradorite composition and pyroxene of augite or titanoaugite composition as essential minerals, and magnetite, titanomagnetite, or ilmenite as accessory minerals. Dolerites are commonly found in shallow level intrusions such as dykes, sills or plugs" (Allaby and Allaby, 1991).

1.1.6 Joint

"A discrete brittle fracture in a rock along which there has been little or no movement parallel to the plane of fracture, but slight movement normal to it" (Allaby and Allaby, 1991).

1.1.7 Fault

"Approximately plain surface of fracture in a rock body, caused by brittle failure, and along which observable relative displacement has occurred between adjacent blocks" (Allaby and Allaby, 1991).

1.1.8 Uniaxial/Unconfined Compressive Strength (UCS)

"The strength of a rock or soil sample when crushed in one direction (uniaxial) without lateral restraint." (Allaby and Allaby, 1991)

1.1.9 Rock Quality Designation (RQD)

RQD values are calculated from borehole core by adding the lengths of core greater than 10cm and dividing this by the total length measured, as shown by Equation 1 below.

$$RQD = \frac{\sum lengths\ of\ core > 10}{Total\ length\ of\ core} x100 \qquad \text{(Equation 1)}$$

1.1.10 Barton's Rock Tunnelling Index (Q and Q')

The Q-rating is determined by:

$$Q = \frac{RQD}{Jn} * \frac{Jr}{Ja} * \frac{Jw}{SRF} \qquad \text{(Equation 2)}$$

Where:

Q values range from 0.001 to 1000 on a logarithmic scale.

RQD is the rock quality designation derived from Equation 1.

Jn is the joint set number,

Jr is the joint roughness number,

Jw is the joint water reduction number,

Ja is the joint alteration number and

SRF is the stress reduction factor.

And

$$Q' = \frac{RQD}{Jn} * \frac{Jr}{Ja} \qquad \text{(Equation 3)}$$

Q' can be used where stress and water flow is already taken into account by numerical modelling, and therefore have become redundant.

1.1.11 Rock Mass Rating (RMR)

The RMR is calculated by adding together the values of the input parameters as shown in Table 1.

Table 1 Beniawski's RMR parameters.

Parameter	**Abbreviation**
Uniaxial compressive strength (UCS)	A1
Rock Quality Designation (RQD)	A2
Spacing of discontinuities	A3
Condition of discontinuities	A4
Groundwater conditions	A5
Orientation of discontinuities	B

RMR = A1 + A2 + A3 + A4 + A5 (Equation 2)

1.1.12 Mine Shaft

Excavation consisting of a vertical or sloping passageway for finding or mining ore or for ventilating a mine (Parker, 2003).

"Shaft means any tunnel having a cross-sectional dimension of 3.7 metres or over and a) having an inclination to the horizontal of 15 degrees and over; or b) having an inclination to the horizontal of less than 15 degrees but more than 10 degrees where the speed of traction may exceed two metres per second" (Mines Health and Safety Act, 1991).

1.1.13 Risk

*"An event, occurrence or situation that could have a negative influence (impact) on the achievement of a specific goal or objective" (*Basson, 2005).

1.1.14 Risk Identification

"Pre-determination of the potential external and internal risks associated with reaching a specific goal" (Basson, 2005).

1.1.15 Risk Analysis

"Analysis of possibilities and consequences that certain undesirable events can take place or situations can develop, and their influence on the achievement of a goal or a range of goals" (Basson, 2005).

1.3 Background

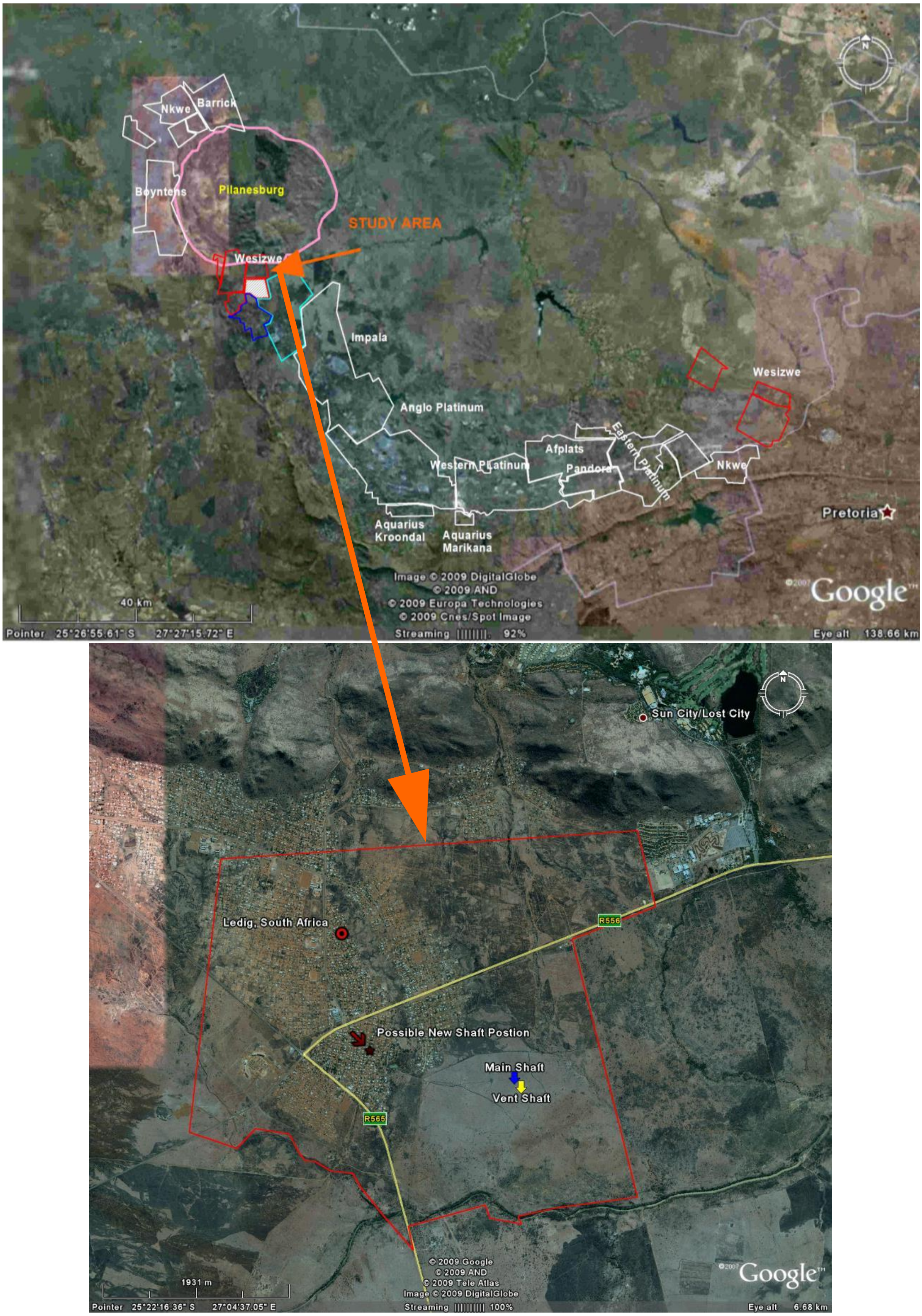
The Wesizwe Ledig Platinum project is a platinum group metals (PGM) project situated on the western limb of the Bushveld Complex. The project has undergone various study phases from exploration, to Scoping and Bankable feasibility studies. During these studies a high-grade orebody was defined capable of producing approximately 350 000 oz of PGM's per annum, at a mining rate of 230 000tpm, sustaining a 35 year life of mine (LOM). Mining production tonnages will consist of both the Merensky and UG2 reefs, with resources defined by 179 diamond drillholes, including 439 deflections.

During the Bankable Feasibility study phase a three-dimensional seismic survey was conducted to assist with the interpretation of structural deformation in the orebody. This survey was further done to ensure the correct placement of the main and ventilation shafts and other critical mining infrastructure. Before the survey, the study was considered complete, as geological, geotechnical, mine design & scheduling and supporting engineering services work was complete. The data received from the seismic survey redefined the structural environment, and particularly the area where the shafts were placed came under scrutiny. It was found that a fault structure previously interpreted as 80m horizontally from the main shaft position, was considerably closer at 50m. A re-evaluation of all the work done in this area was conducted including additional geotechnical interpretation work and a risk assessment.

This report describes the project area and the work surrounding the resultant conclusion on the shaft positionsand the related project risks.

1.3.1 Location

The Wesizwe Ledig Platinum project lease area is situated in the North West Province, Republic of South Africa, roughly 35km northwest of the town of Rustenburg (see Figure 2). The two northernmost farms, Ledig 909 JQ ("Ledig") and portions of Zandrivierspoort 210 JP ("Zandrivierspoort") are adjacent to the Pilanesberg National Park. The other farms that comprise the Exploration Properties are portions of Mimosa 81 JQ ("Mimosa"), and Frischgewaagd 96 JQ ("Frischgewaagd") (Figure 3). The nearest railway siding is at Boshoek, located approximately 12km to the south of the lease area. The properties are served by tarred roads and the Pilanesberg Airport is situated 8km to the east of the exploration properties.



Source: adapted from Wesizwe Platinum, 2007

Figure 3: Google image indicating the study area.

The majority of the Wesizwe exploration area is characterised by soil-covered, flat to gently undulating ground. The Elands River has a very wide flood plain, and forms the southern border of Portion 11 and parts of Portion 4 of Frischgewaagd and minor tributaries from both the north and south further join it.

The Pilanesberg Complex is located to the immediate north of the study area and defines a spherical mountainous terrain rising some 260m above the surrounding plains that have an average altitude of 1 059 mamsl. Most of the Pilanesberg Complex has been declared a nature conservation site, known as the Pilanesberg National Park. The surface of the Wesizwe Exploration Properties is mainly used as tribal farmland for pastoral and dry-land cultivation. The villages of Serosecha and Lekwadi have been developed on Ledig 909 JQ and Frischgewaagd 96 JQ, respectively.

1.3.2 Tenure

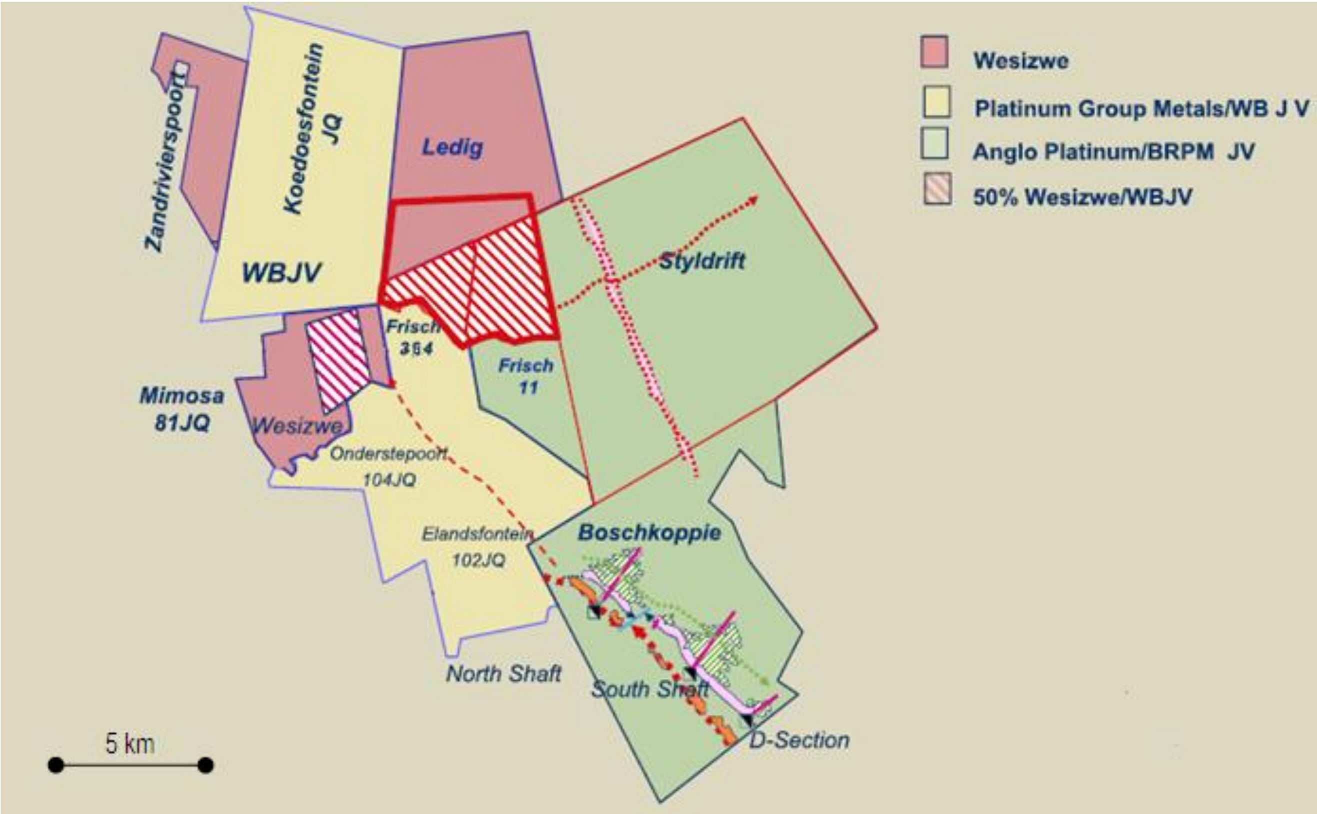
Wesizwe owns 100% of a subsidiary company, Bakubung Minerals (Pty) Limited ("Bakubung") and has placed all of their mineral title assets in this company. According to Hofmeyr Herbstein Gihwala Inc ("HHG") and Bell Dewar and Hall ("BDH") all agreements and necessary mineral rights are valid and enforceable, to the extent that such rights are necessary for execution of the exploration programme as proposed by Wesizwe and possible eventual mining.

1.3.2.1 **Mineral Rights**

Mineral Rights in South Africa are governed by the Minerals and Petroleum Resources Development Act (2002) ("MPRDA") as was circulated on the 1 May 2004. A transitional period between 1 May 2004 and 30 April 2009 was granted to bring unused mineral rights, prospecting and mining permit applications being considered, old order prospecting permits and old order mining permits into accord with the new legislation. In terms of the MPRDA, Wesizwe are in receipt of either new order converted prospecting rights or new order prospecting rights. The status of the Ledig and Frischgewaagd prospecting rights are contained in Table 2.

1.3.2.2 **Surface Rights**

Neither Wesizwe nor Bakubung own any surface rights, however, the Bakubung-Ba-Ratheo tribe ("Bakubung tribe"), who are major shareholders of Wesizwe, are the surface right owners of Ledig and Frischgewaagd (Portion 11), albeit that the ownership is held in trust by the Department of Land Affairs of the North West Province, which acts in accordance with tribal resolutions in matters regarding ownership of tribal land (Figure 4 and Table 2).



Source: Adapted Wesizwe Platinum, 2007

Figure 4: Location plan of the Wesizwe exploration assets.

Table 2: Wesizwe's mineral rights for the Pilanesberg project.

No	Farm Name	Portions	Minerals	Share of Minerals	Prospecting Right Number	Permit Type	Expiry Date
1	Ledig 909 JQ	Former portions 2 and 3	Platinum and associated metals, precious metals, base minerals and precious stones	100%	In notary Johannes Hendrik van Heerden's protocol 330	30 September 2010	Converted to new-order prospecting right
2	Ledig 909 JQ	Former portions 1,4,5 and 6	Platinum and associated metals, gold ore, nickel ore, copper ore, lead, zinc ore, diamond general, diamond Kimberlite, silver ore	100%	In notary Johannes Hendrik van Heerden's protocol 336	21 October 2010	Converted to new-order prospecting right
3	Frischgewaagd 96 JQ	Portion 11	Platinum and associated metals, precious metals, base minerals and precious stones	50%*	PP 45/2004	29 April 2010	Converted to new-order prospecting right
4	Frischgewaagd 96 JQ	Portion 3 and 4	Platinum group metals, gold, nickel, copper, lead, zinc ore, diamond (general), diamond (kimberlite) and silver ore	50%#	In notary Johannes Hendrik van Heerden's protocol 329	30 September 2010	New-order prospecting right

* *Remaining 50% held by Anglo Platinum*

\# *Remaining 50% held by WB JV*

WB JV Western Bushveld Joint Venture, in respect of which a 34% interest is held by Anglo Platinum, a 34% interest by PTM and a 26% interest by Africa Wide

Source: Wesizwe Platinum, 2005; Mineral Corporation, 2006a; Wesizwe Platinum, 2008

Note: "Permit Type" refers to the period validity of the permit.

1.4 Objectives of the study

The Wesizwe Platinum Project intillaly sited the position of their main and ventilation shafts, based on a low level of geological knowledge and reasons pertaining more too surface aspects, rather than technical factors. During the feasibility-stage of the Wesizwe Platinum Project it was determined that the position chosen for the vertical and ventilation shafts were situated within 50m of a major fault, which could affect the safety and stability of the proposed infrastructure. The fault was previously overlooked by geological logging and was only identified months later by geophysical work conducted on the mining lease area. Geotechnical boreholes drilled for the shaft position also did not intersect the fault and therefore the area was initially considered suitable.

Initially this block of ground was considered the most suitable based on the geological environment. Taking into account the vicinity of the shafts to the Pilanesburg, and the extensive amounts of geological structures already associated with the area and moving the shaft would be extremely difficult.

The author was tasked to:

- Review the geo-physical and geological information available.

- To analyse this information by using geotechnical rock mass classification to establish the risk related to the shaft postions and

- To trade-off all available information to determine an acceptable way forward.

Based on all of this information, a trade-off was conducted by means of a detailed risk assessment utilizing Delphi methodologies whereby technical expert opinion of the situation was utilised. The results of the geotechnical analysis and this risk assessment aid the process in determinining whether the shafts could remain at the current position and circumstance are mitigated by engineering, or whether these shafts had to be moved. Moving the shafts would result in complete re-engineering, and starting with pre-feasibility and feasibility stages from scratch.

The objective of this study was therefore to establish the definite position of the fault, to determine the possible effect on the main and ventilation shafts by reviewing all the geological, geophysical and geotechnical information available.

Further, this data was combined with risk analysis techniques to make an informed decision to re-site the shaft positions and re-engineer the project or to continue with the current project and mitigate the risk with appropriate engineering.

1.5 SCOPE OF THE STUDY

The study can be divided into two phases, each comprising data inputs to derive a conclusion. The first phase consists of intrepration of geological, structural, geotechnical and geophysical data interpretation. The focus was to understand all the aspects of the physical environment surrounding the shaft positions and to determine the potential related risk to the area. This first phase, and especially the geotechnical work is considered a quantitative risk analysis itself, as it gives measurable parmeters of the physical ground conditions surrounding the shaft areas

The second phase comprised the risk analysis, which used the information and knowledge derived during the first phase to analyse not only the risk related to the position of the shafts in the ore body, but also look at aspects affecting movement of the shafts as a whole. This is considered qualitative as the outcome is based on informed expert opinion, rather than measurable elements.

Based on these two phases the study included the collection and generation of the following data:

1.5.1 Geological data

Geological data are necessary to give a description of the environment and the rock types to be encountered, within the shaft cross-section.

1.5.2 Structural data

The structural data will put the shaft location in perspective to the major structures encountered in the area and the possible influence on the shaft structure. This data will also highlight the affect of the Pilanesberg on the geological setting.

1.5.3 Geophysical data

The geophysical data are vital in the risk analysis and the interpretation of the geological model. The three-dimensional seismic data combined with the structural and geotechnical data will form the basis from which major assumptions are being made in regard the suitability of the current shaft location and alternative locations.

1.5.4 Geotechnical data

The geotechnical data will provide rock mass quality and competency data, which are crucial for shaft design and support.

1.5.5 Risk Analysis data

The risk analysis will guide the final decision for positioning of the shafts and the project success. Use is made of the Delphi method, which relies on expert opinion to come to the final risk rating per element.

1.6 METHODOLOGY

In solving the main question as to what the ideal/most suited position for the Wesizwe Main and Ventilation shaft positions would be, various forms of data had to be collected and the methods were as described below (Figure 5).

Beforehand a desk study of the geological character of the area was conducted, and internally published reports on exploration results were examined. The geology of the adjacent area was studied by researching public domain data on the surrounding areas as well. The author has also worked on projects in the area such as Styldrift and Bafokeng Rasimone, and had previous experience to draw upon as well.

The project area is situated approximately 2.90km south from the Pilanesburg Complex and is structurally very complex. Influences from this intrusion can be seen in the form of faulting, jointing, and various types of intrusions including lamprophyres and dolerites. Further to this, the site is located close to the town of Ledig approximately 800m north from the main shaft position and the Elandsriver is located 1.76km to the south of the Main shaft position. The DMR conditions for granting the new order prospecting rights also determined that an 800m distance from Ledig and 1.6km distance from the Elandsriver had to be adhered too.

By looking at all these factors, the shafts could not be placed in the centre of gravity of the ore body as would normally be the case. This left very few options and the shaft positions chosen were the most suitable, adhering to all the requirements stated. The shafts were therefore placed by the project team in an area that would allow for succesfull reef extraction and adherence to DMR requirements.

Two geotechnical, diamond drill boreholes, 76mm in core diameter, were drilled at the planned shaft positions. It is important that these holes be drilled at a larger diameter than standard exploration cores, which is normally 36mm in core diameter. This is to ensure that rock types and structures are sufficiently presented, and joint fillings and contacts are adequately exposed. During drilling of a larger diameter core there will be less deflection and better core recovery, which is crucial in describing the rockmass charateristics. The core is also handled with the utmost care to provide intact core with undisturbed joint infillings and fractures. Drilling of shaft boreholes has become a minimum industry requirement to determine the rockmass charateristics to be expected as the shafts are developed, and this was therefore applied as a standard in the Wesizwe Ledig Platinum project.

The core was geotechnically logged as per accepted geotechnical standards (Laubscher, 1990 and pers communication H. Urcan), followed by geological logging. The data was captured in MS Excel, after which it was rated according to four accepted rock mass rating systems, and results correlated.

The results were used to access the suitability of the site to house major infrastructure and ore body access. The ratings were used to draw a downhole profiles by which rockmass caharcteristics was shown in depth and was used to highlighted problematic areas. This data was further prepared to be used in numerical modelling exersise for rock engineering support requirements and as a guide for contractors doing the shaft sinking work.

A three dimensional seismic reflection survey was carried out as a joint venture between Anglo Platinum, the Western Bushveld Joint Venture and Wesizwe in 2007. Anglo American Technical Division, Geosciences, completed a preliminary interpretation of this data and Rock Deformation Research Ltd (RDR) conducted the final interpretation of the seismic data. Dr. A. M. Killick reviewed the field interpretation and it was considered acceptable to be included in further modelling. The data was then merged with the existing structural model that was based on interpretations from borehole information.

This combined interpretation of structural and geophysical data lead to further investigation of a fault intersection close to the north of the main shaft position. This intersection was previously interpreted to be approximately 80m horizontal distance away from the shaft location, but the seismic data interpretation showed this to be closer at 50m. The Senior Mine Designer on the project team raised this as a concern, as major shaft infrastructure development was planned to the north of the main barrel position.

The three dimensional seismic information and drilled borehole positions were plotted together and four boreholes were identified that could possibly have intersected the fault at shallower elevations, and not necessarily at reef elevation. The Wesizwe geology department previously logged these boreholes geologically, but no evidence of a fault intersection was noted in the logs. The Engineering Geologist (also the author) on the project team requested that further work be conducted on this area. It was decided that the identified holes should be re-logged geologically and geotechnically, with particular focus at the depths indicated to have intersected the fault decided it. Detailed geological and geotechnical logging of these four boreholes was done by the author and the fault intersections identified and described.

Using the Delphi methodology the author led a group of experts through a risk analysis process based on available data. The Delphi method is a type of forecasting procedure that can be used when examination of a broad or complex problem is required by more than one knowledge field (Turoff and Linstone, 2002). In this case, the geological and geotechnical knowledge alone was not sufficient to draw a conclusion on the shaft positions. All aspects such as the social, environmental, rock engineering and finacial aspects had to be taken into consideration.

The author decided that a risk assessment workshop would be the most effective method, as it would incorporate all aspects related to the positioning of the shaft, but will result in a simplified, structured answer that could be communicated to the Client management. It would present data as a trade-off between the current shaft positions versus the selection of a new shaft position.Thus, expert opinion was combined taking to account the risk related to the rockmass as well as the other aspects related to the project to reach a decision on the shaft positions. This was considered acceptable by the Client represenatives as well as all the members of the project team, and would serve as the substantiating document further into the project life cycle.

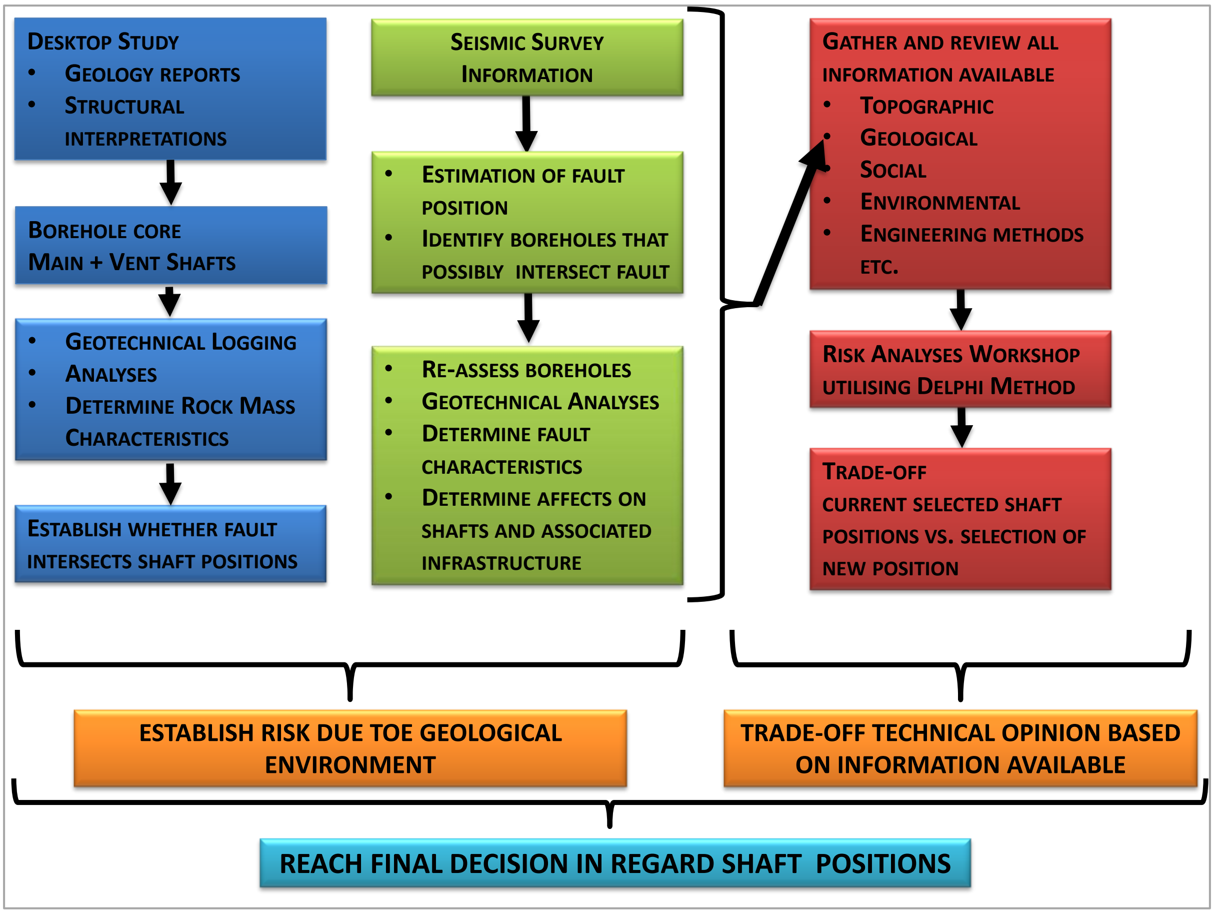


Figure 5: Research methodology used to solve research problem.

2 LITERATURE STUDY

A shaft can be defined as: "*…vertical or inclined openings sunk into the earth's crust in order to access mineral resources which are too deep to mine economically using open-cut methods or adit systems.*" Their main purposes are the following (Matunhire, 2007*):*

- *"To access an ore body"*
- *"To transport men and materials to and from underground workings"*
- *"For hoisting ore and waste from underground"*
- *"To serve as intake and return airways for the mine (ventilation)"*
- *"To provide a second egress as required by mining law"*
- *"Storage of nuclear waste"*

A more concise definition is: "*Shafts are the vertical or inclined openings through which men, supplies, ore and waste are transported. They are the chief surface openings during the development and operation of a mine*" (Lewis, 1956).

It should be noted that every shaft is unique due to difference in geology, influence of neighbouring shafts, mining methods and volumes required (Fourie, 1980). Often it is the amount of capital available and the market conditions for the commodity to be mined that will largely determine the approach to be taken.

When doing research on the positioning of shafts you come to the realisation that this is an aspect that is not getting the amount of attention it deserves. The favourite one-liner that exists is: "Place the shaft in the centre of gravity." Even when experts in the field are cornered with this question they will come back with the same answer. Here and there, literature refers to taking into account the depth, strike, dip and width of the ore body (Germishuis, 1986 and Hartman, 1992). Pondering this, you realise that apart from the resource, this is probably one of the most important aspects when it comes to mining. Where do you put the main entrance to your mineable reserve?

The Hard Rock Miners Handbook, by Jack de la Vergne, 3rd ed, 2003, p 82 states the following as a rule of thumb on shaft locations: *"The normal location of the shaft hoisting ore (production shaft) is near the centre of gravity of the shape of the orebody (in plan view), but offset by 200 feet or more."* And *"For a deep orebody, the production and ventilation shafts are sunk simultaneously and positioned within 100m or so of each other."*

Due to mistakes made in the past, a lot of attention has been given to the design of mineshafts and the support of various types of ground. As a good example, Lonmin conducted a full research programme on the effects of IRUP's on shaft and mine support infrastructure (Godden, 2000). Geotechnical and geophysical methods are used to give various rock mass classifications, and side-wall stability profiles for the shaft positions. In fact, it has become industry standard to drill geotechnical boreholes at shaft positions to make sure that the ground conditions to be encountered are manageable.

Even though all these techniques have been designed to ensure safer shafts, the final positioning is often still dictated by nature and the boundaries of the lease area. Due to the proximity of the Wesizwe mining lease area to the Pilanesberg complex, structural features associated with this intrusion are frequent. Faulting is a universal occurrence, thus there will always be a likelihood of intersecting these features during shaft sinking. Various mines have successfully managed similar situations as those encountered at Wesizwe. Some local examples of this include;

- Impala 20 shaft (Jagger, 2006)
- Harmony No.4 Shaft (Preston, 1983)
- Matjhabeng – Eland Shaft (Kruger, 2001 and Dunn & Menzies, 2005)
- Savuka Mine (Dunn & Menzies, 2005)
- Kloof GM (pers communication H. Urcan)
- West Driefontein (Gürtunca and Adams, 1991)
- South Deep (Bevan, 2007)
- Numerous Far West Rand gold mines (Venter, 1983 and pers communication H. Urcan)
- Numerous Bushveld Complex shafts (pers communication H. Urcan)

According to Jager and Ryder (1999) the following applies when taking the strategic decision on presence of fault intersection in the vicinity of shaft infrastructure:

"Normal faults displacing the reef in or close to the shaft by tens of meters have been successfully handled in the past, though a fair amount of waste stoping was required to safeguard the shaft installations…"

Every project is unique and although all of the technologies and skills are available to the Wesizwe project, one is still hesitant to make a final decision, that will influence an entire project for its total mine life without very careful consideration of the facts. Evert Hoek has stated *"… there are no simple universal rules for acceptability nor are there standard factors of safety that can be used to guarantee that a rock structure will be safe and that it will perform adequately. Each design is unique and the acceptability of the structure has to be considered in terms of a particular set of circumstances, rock types, design loads and end uses for which it is intended"* (Hoek, 1991).

Risk assessment is an effective means of identifying process safety risks and determining the most cost-effective means to reduce risk. Many organizations recognize the need for risk assessment, but most do not have the tools, experience and resources to assess risk quantitatively. The crux of this decision was to make use of a technique that would suit the purpose. *"Risk on any matter/project is normally interrelated and complex, but one could simplify it by analysing events separately, whilst keeping interactions in mind and adding up calculated results to arrive at a total value"* (Basson, 2005). Various methods exist such as:

- Sensitivity analysis
- Statistical analysis
    - Theory of probability
    - Simulation (Monte Carlo)
    - Three Values (PERT)
- Decision making tree
- Delphi-Method
- Personal Judgement
- Scenario analysis
- Trade-Off Analysis

Although the various rock mass ratings themselves can be considered as an indication of the risk involved in the sinking method and the stability of the shaft (Oosthuizen, 2004 and McGill and Theart, 2006), and these were favourable, it was necessary to put the client and other shareholders minds at ease.

Various quantitative and qualitative methods were assessed, and research was done on the methods used in the mining industry and other disciplines. Qualitative analysis appeared to have the largest following in general as it helps with the identification of assets and resources at risk, vulnerabilities that could allow the risks to be realised, as well as the safeguards that are already in place, and which could be implemented (Merrit, 2007).

The mining industry tends to prefer a more statistical approach when quantifying business risk. This may include Monte Carlo simulations, sensitivity analysis and cash flow models, as these methods tend to grasp the essence of the overall project situation and could potentially lead to better decisions in regard the project itself (Heuberger, 2005, McGill and Theart, 2006, Terbrugge *et al*, 2006 and du Plessis and Brent, 2006).

Not one of these methods can be considered as right or wrong, but cognisance should be taken of the project context when choosing a method. For Wesizwe it was decided that a qualitative method would be more appropriate and therefore the Delphi Technique in combination with a risk matrix, also known as a risk factor analysis, was used (Kindinger and Derby, 2000). Not only was the project team familiar with this type of "brainstorming" method, but it also provided a simplistic method with clear visual results that could be presented in a logical manner.

A risk matrix is a qualitative or semi-quantitative risk assessment tool, which enables you to rank various risks affecting a project or process (Ozog, 2002).

Risk matrices are easy to use, but unless they are designed properly, they can create liability issues and give a false sense of security. An effective risk ranking matrix should have the following characteristics (Ozog, 2002) according to Mr. Henry Ozog from ioMosaic Corporation (risk auditing and Assessment Company):

- *"Be simple to use and understand"*
- *"Not require extensive knowledge of quantitative risk analysis to use"*
- *"Have clear guidance on applicability"*
- *"Have consistent likelihood ranges that cover the full spectrum of potential scenarios"*
- *"Have detailed descriptions of the consequences of concern for each consequence range"*
- *"Have clearly defined tolerable and intolerable risk levels"*
- *"Show how scenarios that are at an intolerable risk level can be mitigated to a tolerable risk level on the matrix"*
- *"Provide clear guidance on what action is necessary to mitigate scenarios with intolerable risk levels"*

The Delphi concept may be viewed as one of the spinoffs of defence research. "Project Delphi" was the name given to an US Air Force-sponsored RAND Corporation study, starting in the early 1950's, concerning the use of expert opinion. The objective of the original study was to "*obtain the most reliable consensus of opinion of a group of experts ... by a series of intensive questionnaires interspersed with controlled opinion feedback."* (Dalkey and Helmer, 1963)

Through the experts applying their minds to the issues pertaining to the positioning of the shafts, and by taking into account the current situation and the proposed solution, a consensus was reached that satisfied both the client and the consultants. The decision could also be defended by logical interpretation and factual verification.

3 GEOLOGY

The proposed shaft is to access the Merensky- (MR) and UG2 reefs, contained within the Critical Unit, Rustenburg Layered Suite (RLS), Bushveld Complex. The study area is located on the Western Limb of the RLS, a mere 2.90km south of the Pilansberg Complex (Figure 6) in the Northwest province, South Africa. It is located north of the town of Rustenburg and south of Thabazimbi (Figure 6).

3.1 DELIMITATIONS

A comprehensive review of the RLS is beyond the scope of this study. A brief overview is presented of the Bushveld Igneous Complex (BIC), with specific focus only on the MR and UG2 as these units are the targets for development. This study also excludes other syn- and post-intrusives events.

3.2 PILANESBERG COMPLEX

The Pilanesberg Complex is a circular structure, which intruded into country rock of the Rustenburg Layered Suite, and Lebowa Suite granite in the east. The concentric nature of the intrusion is reflected in the surrounding topography and drainage patterns in the area (Verwoerd, 2006).

It is approximately 28km in east-west diameter, rising 300 to 600m above the surrounding surface elevation. The surface volcanics consist of inward dipping, dislocated remnants of phonolitic and trachytic lava flows, stratified volcaniclastic lacustrine sediments, debris flows, tuff, agglomerate and volcanic breccia (Verwoerd, 2006).

Ring faults have not been defined, but recent work in the area and work by Lurie (1973) suggests that the enire Complex is fault bounded. In addition, the Complex was adhered to subsidence followed by radial fracturing and a rotational fault that bisects the area (Verwoerd, 2006).

The Pilanesberg Complex has had a significant influence on the area of interest as it has resulted in many geological feautures being introduced such as faults, fractures, and intrusions. The local geological features follow the concentric discontinuity patterns created with the intrusion of the Pilanesberg, which makes interpretation challenging. Due to this, mining activities in this area are considered more challenging than other shafts projects within the Bushveld Complex

3.3 THE BUSHVELD COMPLEX

The Bushveld Complex is the world's largest layered intrusion. The Bushveld Complex, as exposed at current levels of erosion, consists of an eastern, a western and a northern limb, and is some seven to nine kilometres thick (see Figure 6). The southern limb or Bethal limb is not exposed. The large scale layering forms the basis for a subdivision, from bottom to top these zones are:

- Marginal Zone (MZ), comprised of norite,
- Lower Zone (LZ), consisting of pyroxenite and harzburgite,
- Critical Zone (CZ),consisting of pyroxenite and norite,
- Main Zone (MZ), consisting of norite, gabbronorite, a thin pyroxenite unit and overlying gabbronorite and the
- Upper Zone (UZ), consisting of a magnetite- and olivine bearing gabbronorite and the upper apatite, olivine-diorite layers.

A characteristic is that the layers are laterally continuous, except for minor downward magmatic erosional discontinuities known as potholes. This lateral continuity aids in the exploration, evaluation (of the economic sequences), mine planning and operation.

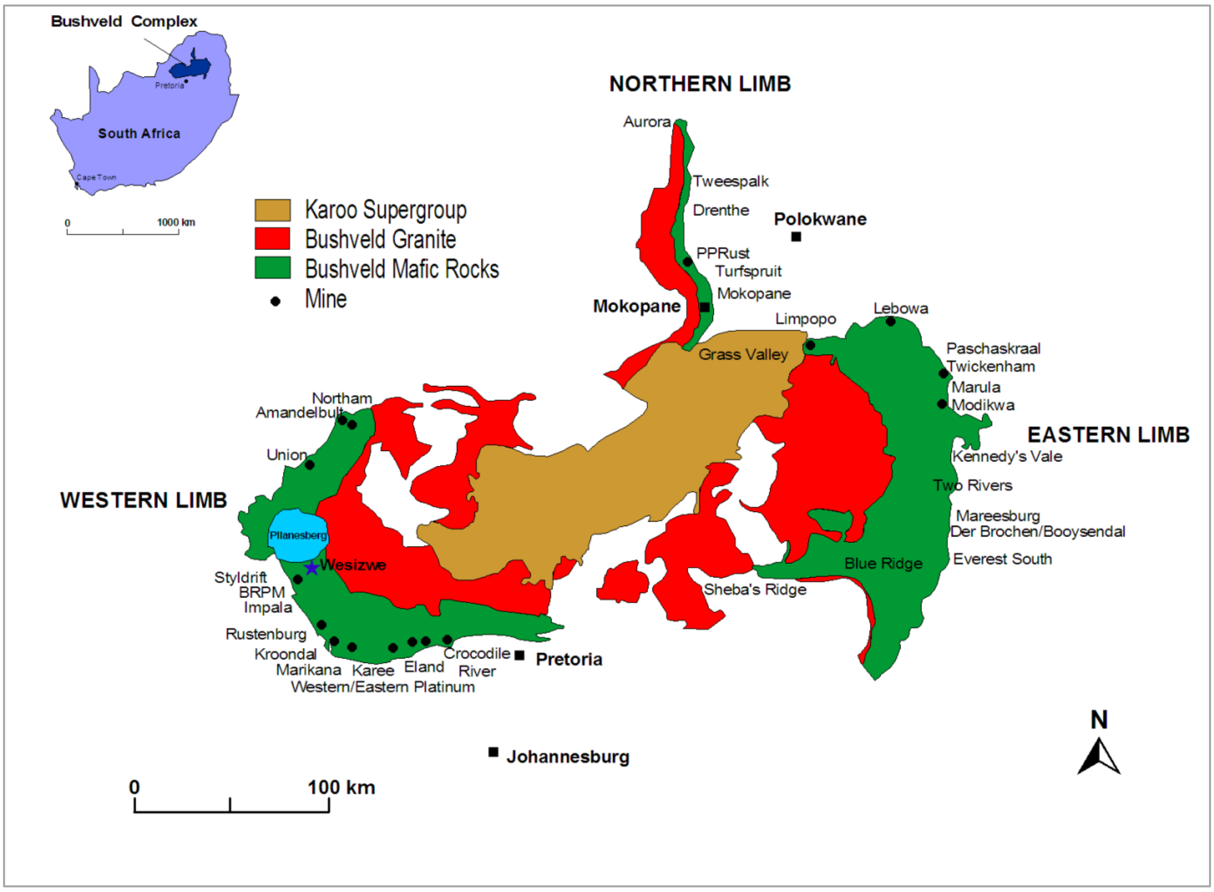


Figure 6: Geological map of the Bushveld Complex showing the distribution of the main platinum minining areas (Modified after Viljoen and Schűrmann, 1998).

3.3.1 Formation of the Bushveld Complex

In several respects the Bushveld Complex represents an end-member in layered complexes. Its aspect ratio is large (>1:40) for an igneous intrusion, giving it a thin saucer or funnel shape, in contrast to the more conical shape of the Skaergaard Intrusion, in the U.S.A, or the canoe shape of the Great Dyke of Zimbabwe. Furthermore, most of the Bushveld rocks contain extremely low abundances of incompatible elements, making it almost a pure cumulate (Viljoen and Schürmann, 1998).

Approximately 2000 Ma ago, a major magmatic event occurred, which resulted in vast volumes of molten mafic magma from the Earth's mantle, which was injected into an unconformity between the Magaliesberg Quartzite's and the Rooiberg Felsites into a sub-volcanic, shallow-level chamber (Cawthorn, 1999). This process, lasting for almost 500 million years and took the form of a series of pulses, which introduced successive units of magma, each differing from the magma preceding it. Some differentiation took place, due to minerals crystalizing at different temperatures and pressures, according to Bowen's reaction series. The net result of these processes was a clearly stratified compositional unit, the Rustenburg Layered Suite (Viljoen and Schürmann, 1998).

In contrast it is suggested by Kruger (2005) that the Bushveld Igneous Complex was intruded as a series of magmatic sills, with varying composition. These flat-lying sills intruded between the Rooiberg Felsites and the underlying Transvaal Supergroup sediments. The chamber could not extend through the capping of felsite and as a consequence expanded laterally.

The Rustenburg Layered Suite is mainly the result of slow cooling, during which silicate, oxide and sulphide minerals crystallized and sank to the bottom of the magma chamber to form texturally distinct layers. The removal of the more refractory minerals depleted or enriched the residual melt in various elements. Thus, the magma changed composition until solidification was complete. Elements such as the platinum group metals and base metals (nickel and copper), when in the presence of a sulphide phase, can become enriched to form predictable, mineralised horizons within the intrusion. In the case of the Bushveld Complex, magnesium rich rocks occur at the base of the intrusion and silica and iron-rich rocks at the top. (Maier, 2001)

The economically important UG2 Chromitite layer is found in the Critical Zone. (Figure 7). The Merensky Reef is located at the bottom of the Main Zone. The outcrops of these two units are near parallel to each other in a semi-circular arc. Both these units are targeted for platinum and related elements exploitation in both underground and limited open-cast operations. The UG2 and Merensky Reefs can be traced for many tens of kilometres where there are no physical breaks in the BIC outcrop, making economic potential evaluation very favourable (Cathorn, 1999).

The grades are variable, depending on position in the larger BIC and the specific character of the RLS on the different limbs. A summary of the grade distribution in the eastern and western limbs are presented in Figure 8.

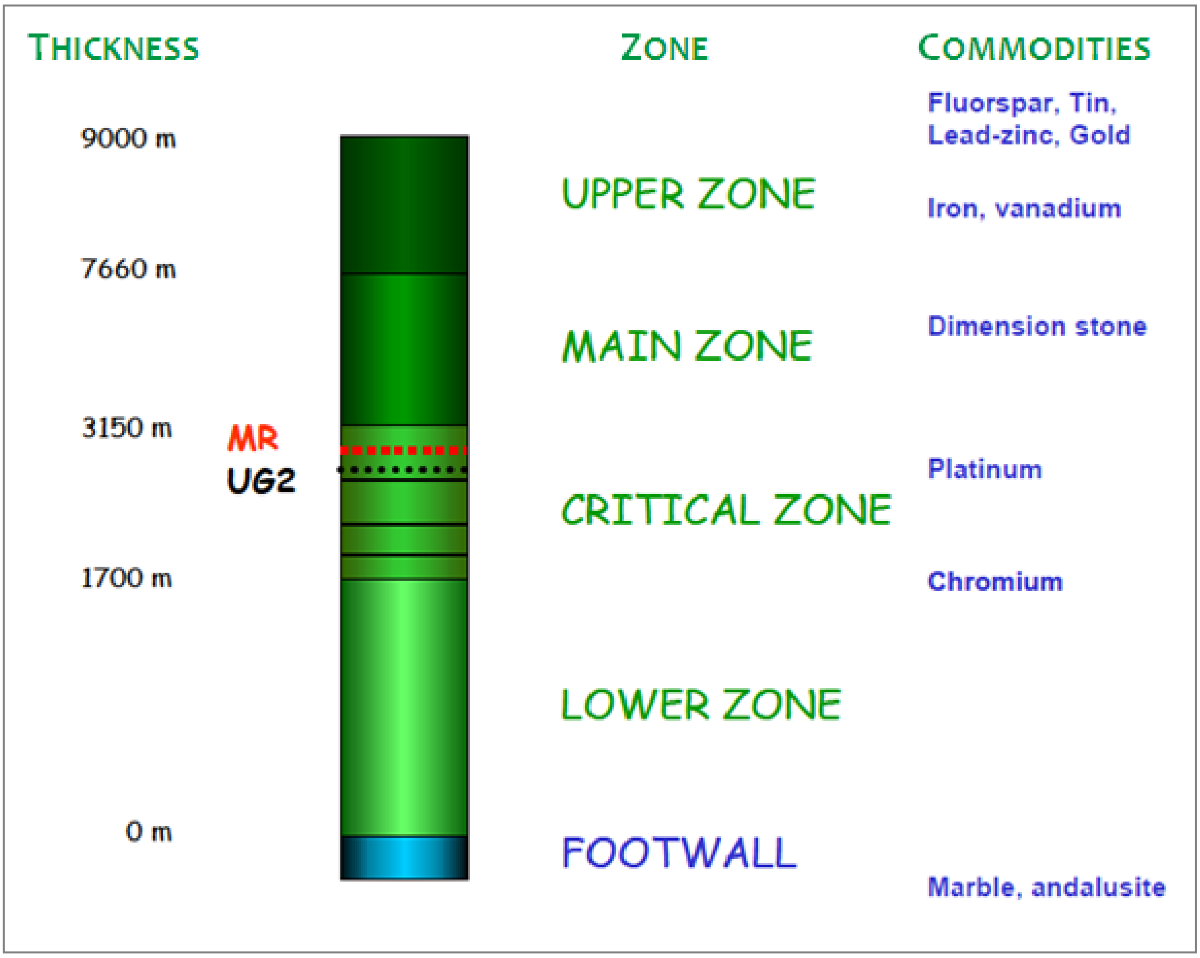


Figure 7: Generalised stratigraphy of the Bushveld Complex.

The westen limb of the BIC is sub-divided into a northern- and a southern section as a result of the later emplacement of the Pilansberg Complex (Cawthorn, 1999). The intrusion of the Pilansberg terminates the surface outcrop over a 25km area. The northern sector is defined in the northeast by the Crocodile River Fault and in the southwest by the Pilansberg Complex. The southern section extents from southeast of the Pilansberg Complex to east of the town of Brits.

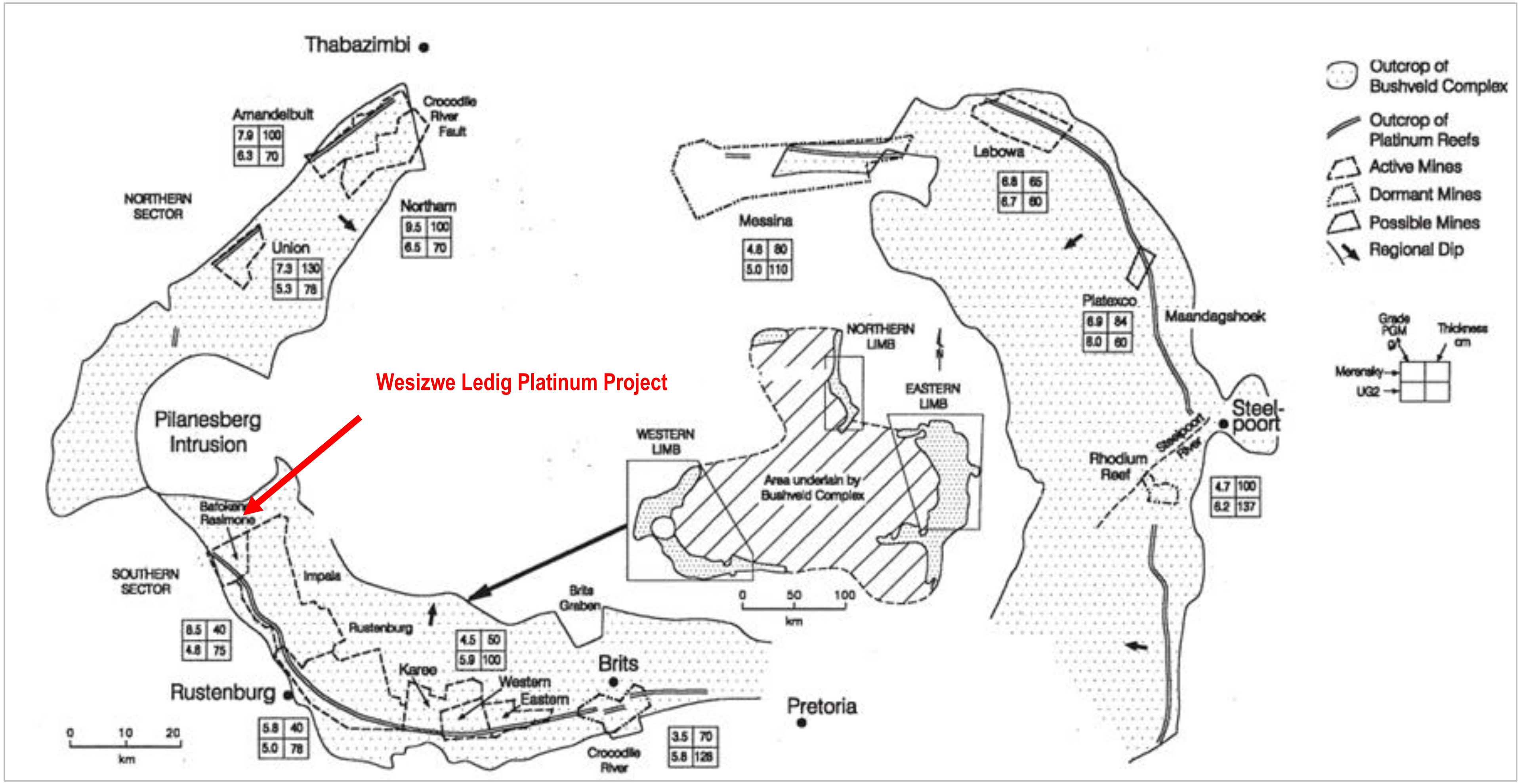


Figure 8: Generalised grade distribution of PGM's in the western and eastern limbs of the Bushveld Complex (Modified after: Cawthorn, 1999).

3.4 MERENSKY REEF

3.4.1 General

The Merensky Reef (MR) is a continuously developed lateral reef. Large variations occur in reef thickness, reef composition, as well as the relative position of the mineralisation within the reef which is very dependent on the location within the greater Bushveld Complex. The Merensky Reef is located 40 to 140 meters above the UG2 on the western limb, from north to south. (Cawthorn, 1999). In the northern section of the RLS's western limb, the MR has been found to be thicker to the north (Cawthorn, 1999). The general grade in the MR is presented in Figure 9.

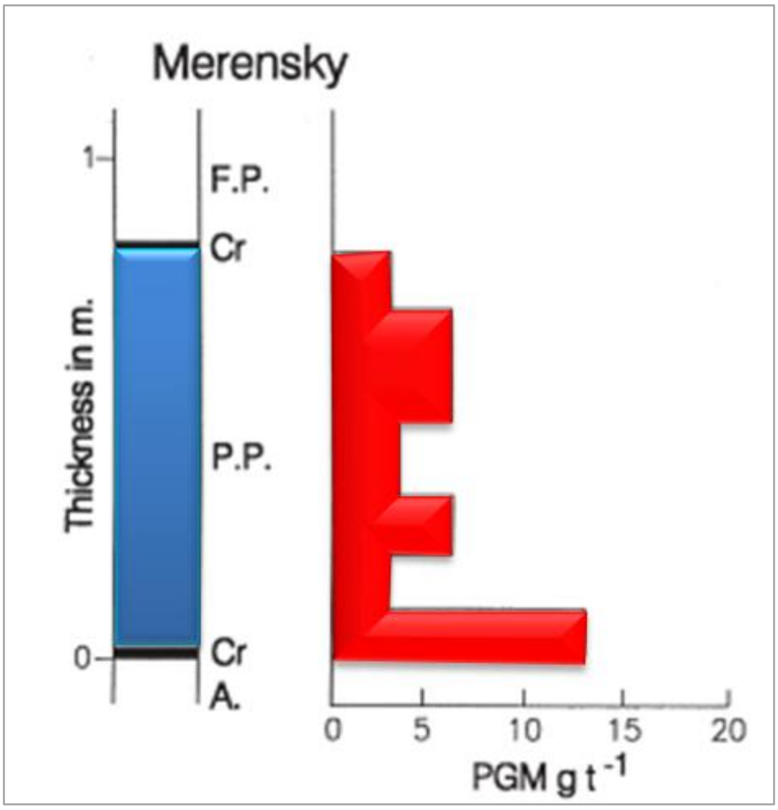


Figure 9: Generalised PGM grade through the Merensky Reef. A = Anorite, Cr = chromitite, F.P = Feldspathic pyroxenite. (Modified after: Cawthorn, 1999).

3.4.2 Wesizwe Ledig Merensky

The Merensky Reef at Wesizwe is a continuously developed lateral reef consisiting of fine to medium-grained pyroxenite, which continues into a pegmatoidal feldspathic pyroxenite, overlain and/or underlain by distinctive chromitite contacts. At the area of interest, the reef is intersected between 739.20 and 740.20m in depth from surface. Within the Lease area deposit, large variations occur in reef thickness, reef composition, as well as the relative position of the mineralisation within the reef that is very dependent on the location within the greater Bushveld Complex and the localised reef disturbances encountered.

The Merensky reef at the Wesizwe Ledig project comprises four broad types (Mineral Corporation, 2006a). These have been named in accordance with a descriptive nomenclature below.

Normal reef (approximately 1.23m thick): This reef type is bounded by narrow upper 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 similar to the Normal/Pegmatoidal Merensky Reef as described from Impala and Rustenburg. However, the width is much greater at the Wesizwe Ledig Platinum project.

Figure 10 depicts the nature of the Normal Reef as well as the other Merensky Reef types. The average mineralisation widths are also provided. (Mineral Corporation, 2006a)

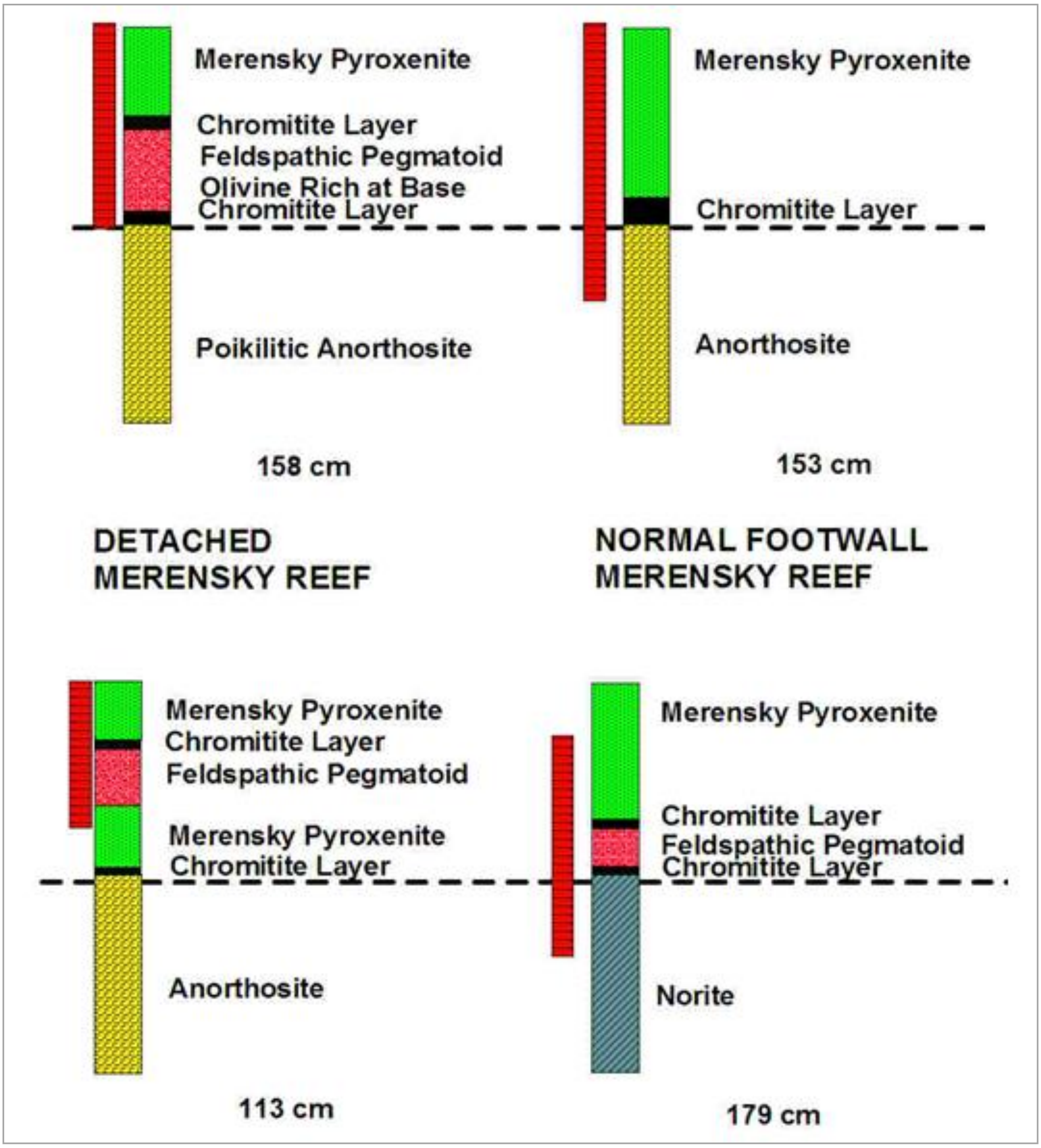


Figure 10: Merensky Reef types with location of mineralisation (red vertical bar) and average mineralisation widths (in cm below) (after Mineral Corporation, 2006a)

Single Chromitite Reef (approximately 0.07m thick): This reef type is similar to the Contact Type Merensky Reef, 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 to FW6 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. It is similar to the Contact Merensky Reef as described at Union Section. However, the pothole association implicit in this term at Union Section is not fully applicable to this reef type at Wesizwe, but it is transgressive towards the southwest. (Mineral Corporation, 2006a)

Detached reef (approximately 5.89m thick): This reef type is a pegmatoid of feldspathic pyroxenite and/or pyroxenite with an upper chromitite layer. It generally overlies several metres of fine to medium grained pyroxenite that has a basal chromitite layer, hence its thickness. It is overlain by feldspathic pyroxenite of the Merensky Pyroxenite unit. Macroscopic base metal sulphides are generally restricted to the material below the upper chromitite layer for a width of only 1.13m. It is similar to the Merensky Reef as described at Union Section. (Mineral Corporation, 2006a)

Normal Footwall reef (approximately 0.72m thick): This reef type is bounded by two chromitite layers that define the upper and lower surfaces of the Merensky Reef and the intervening material is either a feldspathic pyroxenite pegmatoid or a pyroxenite that contains macroscopic base metal sulphide mineralisation. The footwall is generally composed of olivine norites of FW7 that also contain significant PGE mineralization recognised macroscopically by the presence of base metal sulphides. This reef type is also transgressive towards the southwest. (Mineral Corporation, 2006a)

3.5 UG2 Reef

3.5.1 General

The UG2 reef is a platiniferous chromitite layer that it is generally underlain by a basal feldspathic pyroxenite pegmatoid and is overlain by chromitite layers/stringers termed the leader and triplets (see Figure 9). It has been shown that the UG2, like the MR decrease in grade from north to south (Cawthorn, 1999). It is however less marked than for the MR and compensated for by an increase in thickness. The general PGM grade distribution through the UG2 is presented in Figure 11.

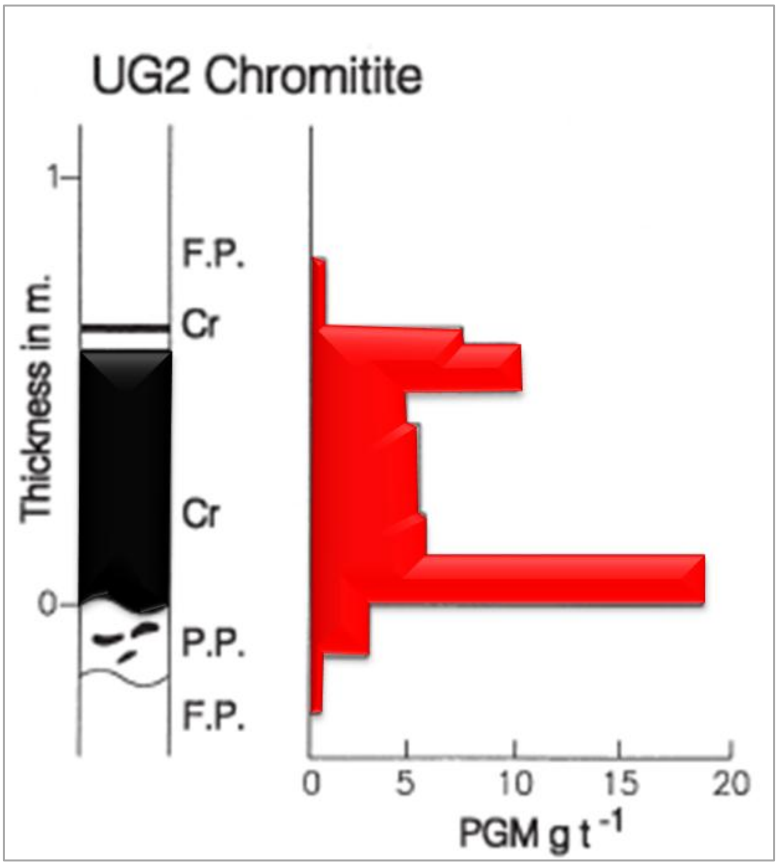


Figure 11: Generalized PGM distribution through the UG2 reef. F.P. = Felspathic Pyroxenite, P.P. = pegmatitic pyroxenite and Cr = chromitite. (Modified afterCawthorn, 1999)

3.5.2 Wesizwe Ledig UG2

The UG2 reef is a platiniferous chromitite layer intersected at 773.70 and 778.60m from surface, approximately 40.00m vertical distance from the Merensky Reef, in the area of interest. The UG2 is generally underlain by a basal feldspathic pyroxenite pegmatoid and is overlain by chromitite layers/stringers termed the leader and triplets (see Figure 12).

Most of the intersections encountered in the Wesizwe Ledig project have no basal pegmatoid but rather a feldspathic pyroxenite similar to the hangingwall rocks or a poiklitic anorthosite layer. The terms employed for the UG2 reef are restricted to Normal reef when it conforms to stable stratigraphic relationships and Regional Pothole reef when it is underlain by, or close to, the UG1 pyroxenite over a large area. The UG2 reef is also noted to be transgressive towards the southwest in a similar manner to the Single Chromitite and Normal Footwall Merensky reefs (Mineral Corporation, 2006a).

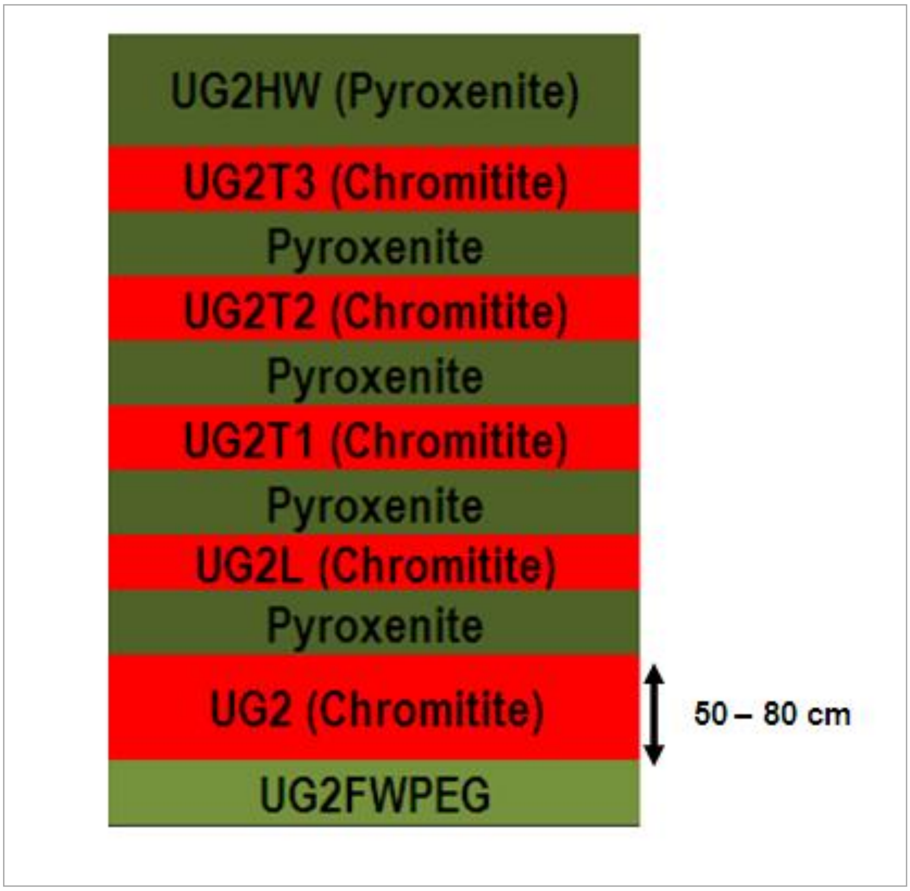


Figure 12: Idealised section through the UG 2.

3.6 Discontinuities

3.6.1 Dykes and Sills

Four major dykes were identified in the study area, with several smaller associated intrusions indicated from aeromagnetic data (Mineral Corporation, 2007). Two dykes striking northwest-southeast are emplaced 1.8 kilometers apart. The second set of dykes are located approximately 3 kilometers apart and has a general north-south strike. A number of smaller dykes and sills were picked up in the core.

The sills present in the study area were divided into three groups:

- Sill with a dip < 10°,
- Bridging sills with dips between 10° and 60° and
- Sills with dip > 10°.

The average sill thickness does not vary significantly. The occurrence of sills is greatest at a depth of between 600 and 650 mamsl. It is indicated from the core descriptions that the contact between the sills and host rock appear to be indurated (Mineral Corporation, 2007).

3.6.2 Iron Replacement Ultramafic Pegmatoid (IRUP)

A small number of Iron Replacement Ultramafic Pegmatoids (IRUP's) were intersected. The IRUP's thickness generally decreases with depth.

3.6.3 Faulting

The strike of faults in the study area was found to occur in three modes: 056°, 135° and 175°. It was determined that the average calculated distance between significant faults are 476 meters (Mineral Corporation, 2007). The density of faults with a small displacement is expected to higher relative to the significant faults considered in this study.

The estimate of fault distribution across the property is affected primarily by the borehole spacing and the finite vertical displacement on the faults. This is because the presence of faults is detected by the distortions in the apparent regional dip between two boreholes. A distortion of about 10° in apparent regional dip is required to reliably interpret the presence of a fault. In the core area part of the drill grid has been closed down to 250m intervals and only faults with displacements, or fault zones with cumulative displacements, of more than 40m vertical displacement would be reliably detected. In the peripheral area where drill spacing is only at 500m centres, faults will have to have finite vertical displacements of more than 85m to be reliably detected (Mineral Corporation, 2007).

4 ENGINEERING GEOLOGY

Two diamond drill boreholes were drilled at the positions of the planned Main shaft and Ventilation shaft as indicated in Figure 13 in relation to the Mining Lease area. These holes were geotechnically logged using TWP standard procedures, of which a condensed field guide is included in Appendix G, to define the rock mass character.

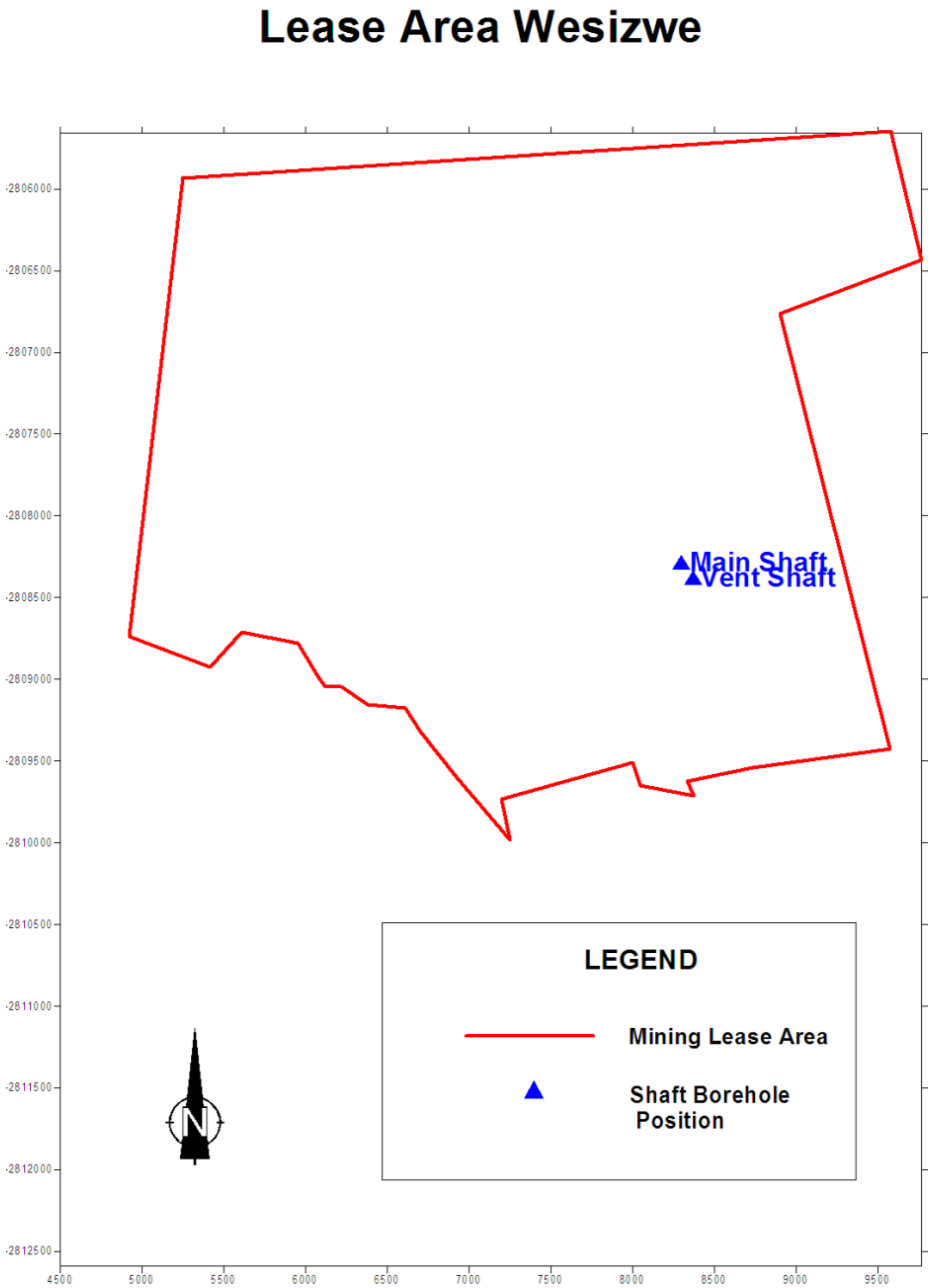


Figure 13: Lease area map for Wesizwe showing Main and Ventilation Shaft positions in relation to the Wesizwe Ledig Platinum project Lease area.

4.1 GEOLOGICAL FEATURES INFLUENCING ROCK MASS BEHAVIOUR

Due to the proximity of the lease area to the Pilanesberg, it is expected that the area will be dominated by deformation associated with the Pilanesberg intrusion. The deformation will determine the majority of the large and small-scale rock mass characteristics of the area. There are however many more local scale features that impact on the geotechnical characteristics of the shaft areas (Mineral Corporation, 2006b).

The information presented in this section examines this in detail. It is derived from geotechnical and geological logging done on the main and ventilation shaft boreholes.

4.1.1 Stratigraphy

The response to applied stresses will be different where the mechanical characteristics of adjacent rock layers are different. The variation will be the highest where the adjacent rocks are of a significantly different composition. This will most likely be the case close to the reef intersections, such as the Bastard Reef, Merensky Reef, UG2 succession, UG1 succession and MG succession, and intersections with intrusive structures such as dolerite dykes/sills, lamprophyre dykes and IRUPs. The middling between these intersections consists predominantly of norite and anorthosite, which are strong competent rocks.

The stratigraphic positions and thicknesses were determined from the geological and geotechnical logging of the mother holes (D0) for both the Main and Ventilation shafts (Table 3). Table 4 gives the amount of rock types present within each shaft position. Detailed stratigraphic logs were generated to allow the accurate assessment of the rock types at the two shaft positions.

Table 3: Summary of the significant stratigraphic layers and their positions as logged in the Ventilation and Main Shaft diamond drill cores

Stratigraphic Unit	Main Shaft		Vent Shaft	
	Depth (m)	Thickness (m)	Depth (m)	Thickness (m)
Bastard Reef	719.75	4.72	719.87	2.92
Merensky Reef	739.88	1.40	739.20	0.83
UG2 Triplet 1	777.93	0.01	778.64	0.60
UG2 Triplet 2	778.54	0.07	778.76	0.14
UG2 Triplet 3	778.66	0.16	778.96	0.09
UG2 Leader	778.85	0.08	Absent	
UG2 Main Seam	779.17	0.56	779.25	0.73
UG 1 Succession	795.34	2.60	793.39	2.81

Source: Clark-Mostert 2007

The reader is referred to Appendix A and Figure 30 for the full stratigraphy of the boreholes.

Table 4: Rock types present in the Main and Ventilation Shaft holes.

Rock Types	Main Shaft		Vent Shaft	
	Thickness (m)	% Present	Thickness (m)	% Present
Anorthosite	102.24	10.22	97.31	9.71
Chromitite	5.70	0.57	6.30	0.63
Dolerite	26.10	2.61	16.70	1.67
IRUP	6.52	0.65	233.54	23.30
Lamprophyre	5.73	0.57	0.00	0.00
Norite	780.88	78.06	596.38	59.50
Pegmatoid	18.97	1.90	0.57	0.06
Pyroxenite	34.65	3.46	40.07	4.00
Saprolite	19.6	1.96	11.5	1.15

Source: Clark-Mostert 2007

4.1.2 Structural Discontinuities

The lease area is dominated by various large scale geological discontinuities such as dykes and faults.

Four major dykes and numerous secondary dykes have been identified from the aeromagnetic and borehole data (Mineral Corporation, 2006a). Two major dykes approximately 1.8km apart, striking northwest – southeast (145^{o}) and two major dykes spaced 3km apart, striking north – south (175^{o}). Some sills related to the dykes have also been identified by the aeromagnetics, but these have been noted as dykes in the boreholes. Where the drillhole data is sufficient, the sills are indicated as polygons. It will however remain a geological risk throughout the life of the mine due to the frequency and unpredictability of the magma flows that formed these structures.

Various large, near vertical faults have also been interpreted from the aeromagnetic and borehole data. These strike roughly north-northwest to south-southeast and east-northeast to west-southwest (see Figure 1). It has been anticipated from the Mineral Corporation's structural analysis that a significant fault can on average be expected every 476m, depending on orientation (Mineral Corporation, 2006b).

The Main and Ventilation shafts are located within a discontinuity-bounded structural block which appears to be unaffected by any large structures (See Figure 1). Even though the block appears to be relatively intact, there are five rock types and structural features that could have a significant impact on shaft stability and safety. These are described in the paragraphs below.

Discordant Iron Rich Ultramafic Pegmatites (IRUP) – these rocks are typically intruded into the Rustenburg Layered Suite, after the main mineralised layers were formed. They can replace the normal stratigraphic sequence over extensive areas, and can have a greater or lesser effect on the mineralised layers. They occur as pipes, dykes and sheets. IRUPS can be expected to have a significant impact on the resources and cause complications during the mining process.

Godden (2000) reported that:

- IRUP's and their associated alteration haloes accelerate corrosion of exposed steelwork and installed steel support. Rapid corrosion of coated wire-mesh, pipes, rails, steel cables, shaft guides and buntons was observed. This had severe impacts on safety risks and had significant financial implications.

- It was recommended that the effect of IRUP's should not be underestimated, and where shaft steelwork is concerned, the affected areas be shotcreted as recommended, as it would make salt levels more manageable.

- To prevent, or reduce, the corrosion of shaft steelwork due to the galvanic effect it was recommended that the shaft column should be kept dry, drainage systems be monitored, and the shaft buntons should be isolated from the surrounding rock mass, so that there is no electrical connection.

Replacement pegmatoids are very much similar to IRUP's in the mode of formation and appearance, the main difference between them however is that the iron content is much lower, and that a replacement pegmatoid will appear as un-magnetised when a magnet gets run over the core. Often no distinction is made between the two rock types, as the overall effect on infrastructure stability is similar.

Lamprophyres are found intruded as dykes or sills, but often no distinction can be made in core samples. It is normally recognised by the dark wood-like oak colour and texture, which gets enhanced by exposure to oxygen and water (when face/end gets developed). Experience has shown that this rock mass can deteriorate from a fresh condition to totally weathered in as little as a year. This causes various problems as far as support and shaft infrastructure stability is concerned, as the rock layers merely disintegrates around support. These layers often have misleadingly good geotechnical ratings as it would occur as fresh rock in recently drilled core samples. Experience shows that the best management of these structures is to immediately shotcrete upon exposure (pers communication H. Urcan).

Doleritic dykes, sills and pipes are dark-coloured, medium grained igneous rock. These rocks are normally very strong and have excellent geotechnical ratings. They do however cause problems where encountered as they are often associated with groundwater, have movement associated with the layer (faulting), and in the case of sills often go undetected until the hangingwall collapses. In the Bafokeng Rasimone Mine, which is adjacent to the Wesizwe Ledig study area, hangingwall collapses have often been encountered due to sills not being adequately supported (pers communication K. Lomberg and M. Roberts).

Joints and faults are discontinuities in the rock mass along which either only slight movement has occurred, or where no visible displacement between two blocks of rock has taken place. In both cases similar problems are encountered in terms of hangingwall and shaft infrastructure stability. Where several of these structures are encountered at different angles to each other, it normally causes failure of the rock mass. An increase in frequency causes “blocky” ground which has proven to be difficult to support due to the decrease in competence of the rock mass.

Table 5 lists the intact rock strengths determined by Uniaxial Compressive strength (UCS) tests. Three tests were conducted per rock type, and were done by ROCKLAB in Pretoria (see full results in Appendix C).

Table 5: Rock strengths as determined by ROCKLAB by method of Uniaxial Compressive Strength Tests.

Rock Type	**UCS (MPa)**		
	Minimum	**Maximum**	**Average**
Anorthosite	174.63	234.17	207.43
Leuco Norite	151.35	155.72	154.02
Norite	235.18	275.50	256.29
Lamprophyre	52.86	68.77	58.36
IRUP	95.07	149.59	115.28
Pyroxenite	138.56	170.36	159.04
Merensky Reef	79.48	113.06	92.05
UG2 Chromitite	56.91	68.13	62.19

Source: Clark-Mostert 2007

It can be seen that the norite and anorthosite are strong to very strong rock, which is highly beneficial, as approximately 60-80% of the stratigraphy consists of these rock types (Table 4 and Appendix A).

4.1.3 Geotechnical Subdivisions

The following geotechnical groupings (Table 6) of the logged rock types have been generated based on the rock properties and geotechnical characterisation. This was done to simplify the interpretations and to make the data more manageable. It can be anticipated that the rock mass behaviour will not vary significantly within these groupings. This is due to consistant mineralogical composition, with only textural and minor abundance differences.

Table 6: Grouping of rock types.

Grouping	**Included Rock Types**
Anorthosite	Mottled Anorthosite Spotted Anorthosite Anorthosite
Norite	Leuco Gabbro Norite Mela Gabbro Norite Gabbro Norite Leuco Norite Mela Norite Norite Troctolite
Pyroxenite	Feldspathic Pyroxenite
Chromitite	Chromitite
Pegmatoid	Replacement Pegmatoid Pegmatoidal Feldspathic Pyroxenite
IRUP	Iron replacement ultramafic pegmatites
Lamprophyre	Lamprophyre
Dolerite	Dolerite
Saprolite*	Weathered Layer Soil Saprolite

Source: Clark-Mostert 2007

*Although saprolite represents weathered material, it was included in all the calculations for the sake of completeness.

4.2 GEOTECHNICAL CHARACTERISATION OF THE MAIN AND VENTILATION SHAFT POSITIONS

Processing of the data generated by geotechnical logging made it possible to examine basic trends of the various rock mass rating quantifications (Deere, 1964). These ratings are based on the characteristics of the intact rock and the discontinuities separating these fragments (Table 7). The spatial and stratigraphic characteristics of the different geotechnical subdivisions are described below.

Table 7: Summary of logged discontinuities.

	Core Logged (m)	Number of Discontinuities	Discontinuities per metre
Main Shaft	1000.41	2918	2.92
Vent Shaft	1002.37	2848	2.84

Source: Clark-Mostert 2007

Ratings of the different rock types in the various boreholes are given based on the depth from surface (indicated as 0m from collar to the length measured) of the rock types as logged by the Wesizwe Platinum geologists (Appendix A). This information formed the basis for the subsequent RMR, MRMR and Q ratings of the different portions of the Main and Ventilation Shafts.

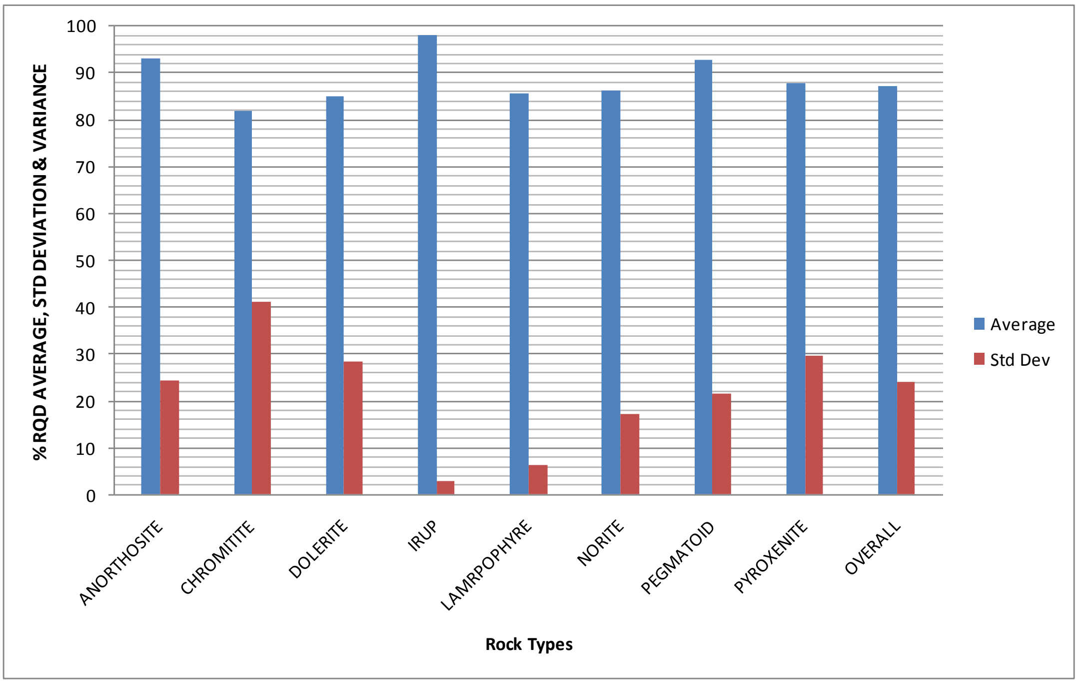
4.2.1 Rock Quality Designation Values (RQD), calculations and values

RQD values are calculated from borehole core by summing the lengths of core greater than 10cm due to natural discontinuities, and dividing this by the total length measured, as shown by Equation 1 below (Deere, 1964, and Deere and Deere, 1987).

$$RQD = \frac{\Sigma \text{ Lengths (in cm) of core} > 10\text{cm long}}{\text{Total length of core (in cm)}} \times 100\ \% \qquad \textit{(Equation 1)}$$

This allows the calculation of values for various parts of the borehole, such as different rock types. With the positions of the discontinuities recorded within the various boreholes, it was relatively simple to determine the lengths of core greater and less than 10cm and use this to determine the RQD for the different boreholes and rock-types within these boreholes (see Table 8). The weighted average per rock type and borehole take into account the varying lengths of the different types of rock and their different RQD values.

The statistical characteristics of the different rock groups are very similar in trend (Figure 14). This shows that although the stratigraphy within the boreholes is dominated by norites, the rock mass behaviour of the various groups is not lost in the overall evaluation of the boreholes. The higher standard deviation in the chromitite can be explained by the Main Shaft chromitite being affected by replacement pegmatoids close to the chromitite intersections.



Source: Clark-Mostert 2007

Figure 14: Statistical characterisation of the RQD values for Main and Ventilation Shafts.

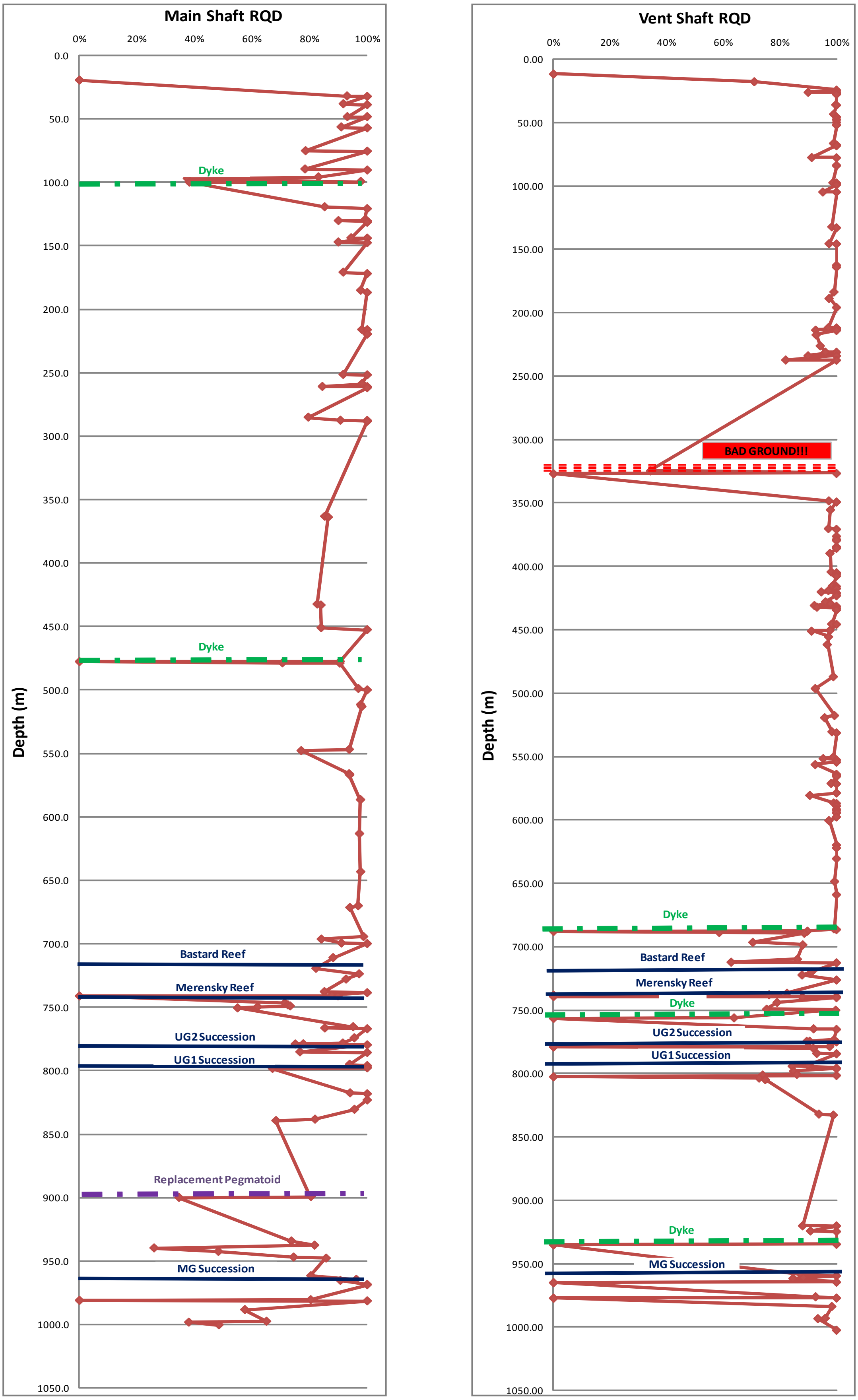
The RQDs are generally higher than 80%. Lower values are recorded in areas close to significant intrusions, the Bastard Reef, Merensky Reef, UG2 succession, UG1 succession and MG successions (Figure 15). This phenomenon is closely associated with contacts, the presence of chromitite stringers and a contrast in mechanical characteristics of the adjacent rock types. The differing response of the adjacent rock types would cause differential movement or weakening of pre-existing geological discontinuities.

Figure 15 is a plot of the RQD with depth for the Main Shaft and Ventilation Shaft. The detailed parameters at depth are given in Appendix B.

Table 8: Summary of rock types and RQD's.

Rock Type	**Main Shaft**		**Vent Shaft**	
	Length	**RQD**	**Length**	**RQD**
ANORTHOSITE	102.24	94%	97.31	91%
CHROMITITE	5.70	78%	6.30	86%
DOLERITE	26.10	83%	16.70	89%
LAMPROPHYRE	6.52	94%	-	-
IRUP	5.73	86%	233.54	98%
NORITE	780.88	87%	596.38	85%
PEGMATOID	18.97	93%	0.57	88%
PYROXENITE	34.65	84%	40.07	92%
SAPROLITE	19.6	-	11.5	-
OVERALL	1000.41	86%	1002.37	88%

Source: Clark-Mostert 2007



Source: Clark-Mostert 2007

Figure 15: Line graph of the Main Shaft and Ventilation Shaft RQD's with depth.

4.2.2 Discontinuity Spacing

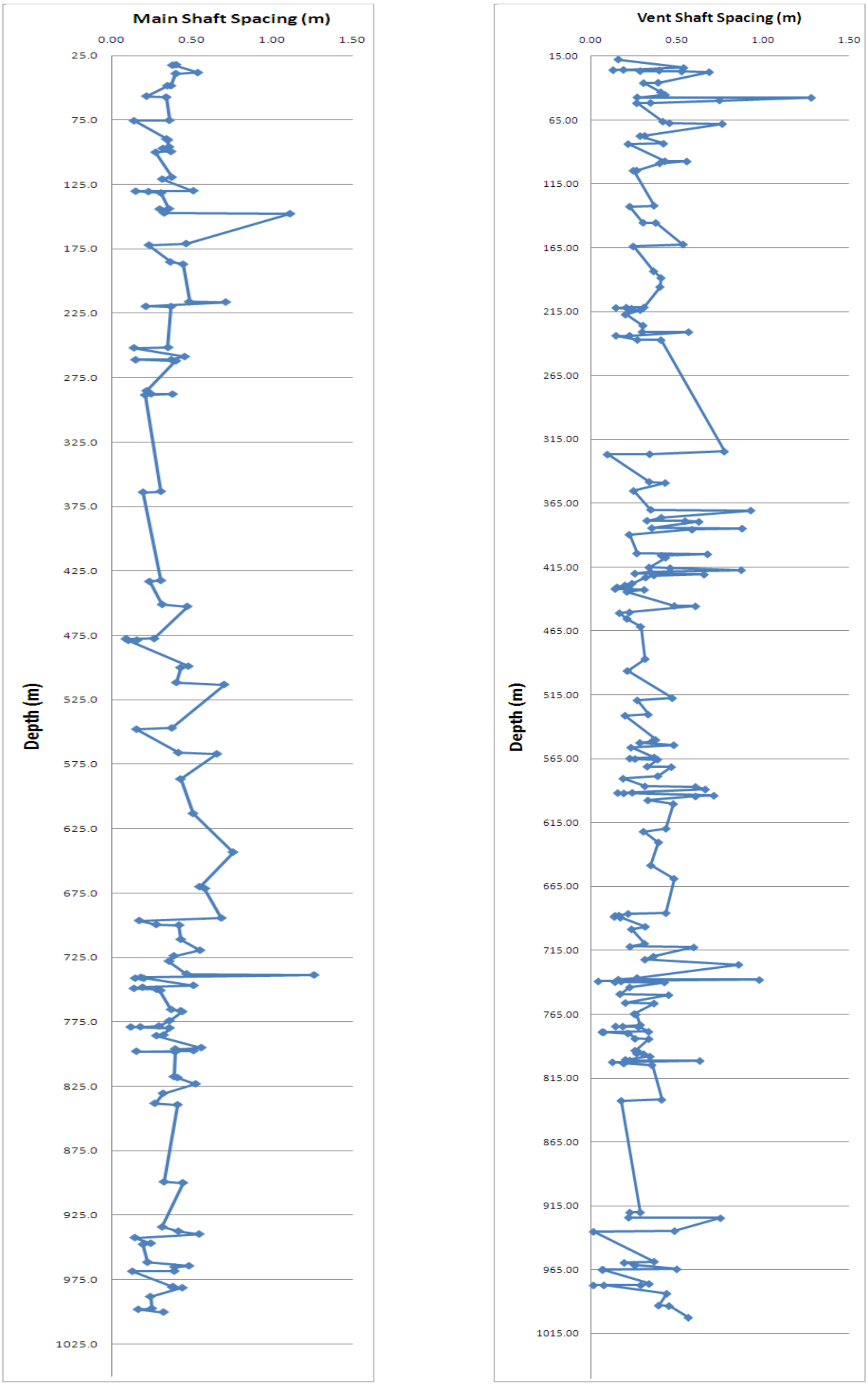
The average spacing of discontinuities for each rock-type in the different boreholes was determined. These results are shown in Table 9 and Figure 16. The raw data used to obtain these values can be found in Appendix B. The average spacing values are very similar for the various rock types and do not vary significantly between the two shafts, except for the pegmatoid spacing which has a difference greater than 50 %. No depth dependant changes are seen either, apart from the first 40m.

Table 9: Summary of rock types and spacing values.

Rock Type	Main Shaft		Vent Shaft		% Difference
	Length (m)	Spacing (m)	Length (m)	Spacing (m)	
ANORTHOSITE	102.24	0.53	97.31	0.36	33%
CHROMITITE	5.70	0.30	6.30	0.25	15%
DOLERITE	26.10	0.36	16.70	0.33	9%
IRUP	6.52	0.35	233.54	0.38	7%
LAMPROPHYRE	5.73	0.34	-	-	N/A
NORITE	780.88	0.37	596.38	0.41	10%
PEGMATOID	18.97	0.32	0.57	0.15	53%
PYROXENITE	34.65	0.41	40.07	0.36	13%
SAPROLITE	19.6	5.82	11.5	3.79	35%
OVERALL	1000.41	0.387	1002.37	0.394	0%

Source: Clark-Mostert 2007

When considering the significance of this information it is clear that the shafts are being sunk in good competent rock, which should overall have good ratings for RQD and the other rockmass classifications systems described in this document. From the percentage difference in discontinuity spacings it can be deducted that the rockmass is similary affected by discontinuities, with the pegmatoid intersections being more fractured in the Ventilation shaft, but less abundant, and thus no cause for concern.



Source: Clark-Mostert 2007

Figure 16: Line graph of the Main Shaft and Ventilation Shaft discontinuity spacings in depth.

4.2.3 Bieniawski's Geomechanics Classification, Rock Mass Rating (RMR), calculations and values

The RMR is calculated by summing the rank values of the input parameters in Table 10 as they would be determined from Table 11 (Bieniawski, 1976).

$$\boldsymbol{RMR = A1 + A2 + A3 + A4 + A5} \qquad \textit{(Equation 2)}$$

For the adjusted RMR' it changes to:

$$\boldsymbol{RMR' = A1 + A2 + A3 + A4 + A5 + B} \qquad \textit{(Equation 3)}$$

Table 10: Beniawski's RMR parameters.

Parameter	**Abbreviation**
Uniaxial compressive strength (UCS)	A1
Rock Quality Designation (RQD)	A2
Spacing of discontinuities	A3
Condition of discontinuities	A4
Groundwater conditions	A5
Orientation of discontinuities	B

Source: Bieniawski, 1976

Most of the discontinuity spacings are between 15 and 40cm. The condition of discontinuities considers length, the separation between joint walls, roughness of these walls, the infill and its weathering. The only sign of groundwater that has been observed was at a fractured area in the Main Shaft drill core at approximately 75.3m and is associated with a doleritic intrusion; it is thus very conservatively rated as damp even though the core was dry upon extraction. The remainder of the rock mass is described as completely dry. For both the Main Shaft and the Ventilation Shaft, the ratings for the tunnelling are considered to be fair to very favourable, down-grading the rating by -2 to -5.

Table 11 lists the possible values used in the calculations based on observed characteristics. Using these various rankings, the characteristics of the different rock types at various depths was determined. These results are shown in Table 12. Appendix B contains the raw data and analysis.

Table 11: Possible RMR inputs and ratings.

Rock strength (MPa)		**RQD (%)**		**Discontinuity spacing**		**Condition of joints**		**Groundwater**	
Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
>250	15	90 - 100	20	> 2m	20	Very rough, non-continuous, no separation, un-weathered wall rock	30	Dry	15
100-250	12	75 - 90	17	0.6 - 2m	15	Slightly rough, separation < 1mm, slightly weathered	25	Damp	10
50 - 100	7	50 - 75	13	20-60cm	10	Slightly rough, separation < 1mm, highly weathered	20	Wet	7
25 - 50	4	25 - 50	8	6-20cm	8	Slickensided or gouge or < 5mm, separation 1 - 5mm, continuous	10	Dripping	4
25 -5	2	< 25	3	< 6 cm	5	Soft gouge or continuous separation > 5mm	0	Flowing	0
1 - 5	1	-	-	-	-	-	-	-	-
< 1	0	-	-	-	-	-	-	-	-

Source: Bieniawski, 1976

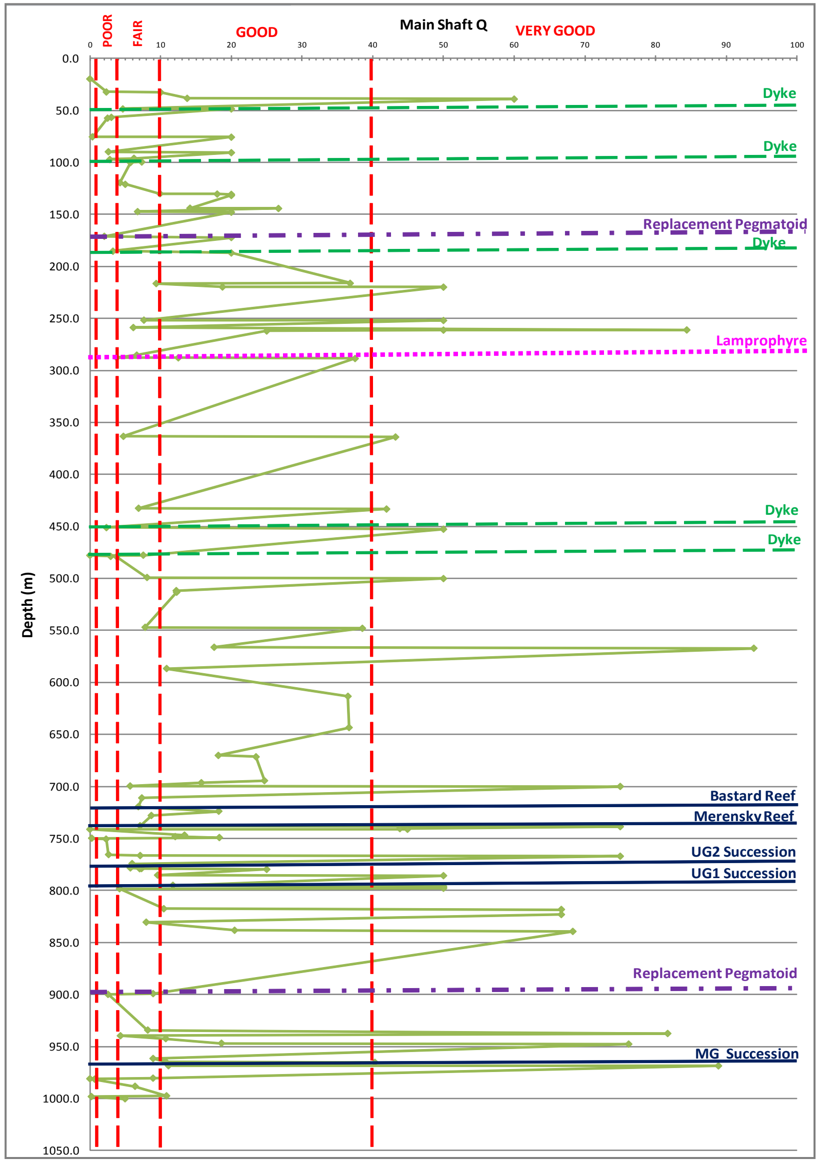
The results shown in Table 12 and Figure 17 show the calculated RMRs. The overall RMR for each borehole was calculated by multiplying the RMR of each rock type by its length in the hole and adding these values together and then dividing this by the total borehole length.

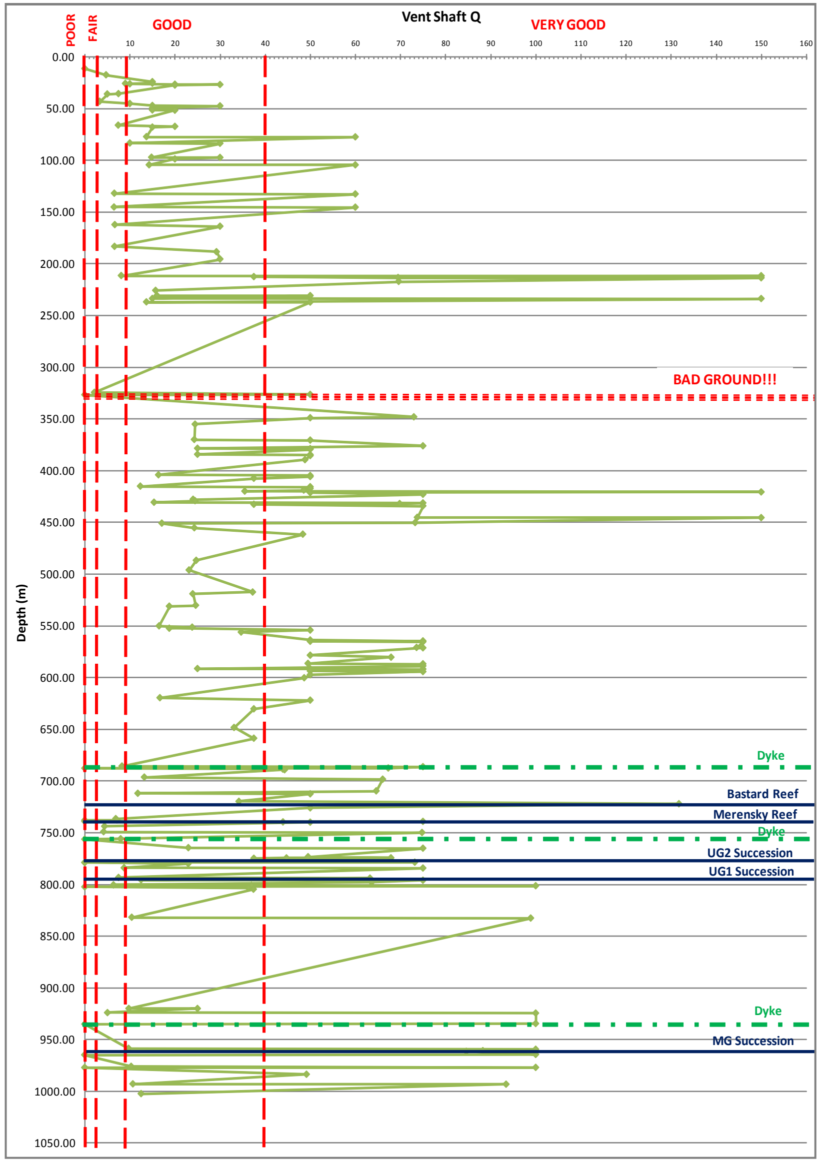
The average overall RMRs for the Main and Ventilation shafts were 76 % and 77 % respectively, thus indicating that the general rock mass at the shaft positions may be described as “Good Rock”.

Table 12: Actual RMR values for the rock types found in the Main Shaft and Ventilation Shaft.

Parameters		ANORTHOSITE		CHROMITITE		DOLERITE		IRUP		LAMPROPHYRE		NORITE		PEGMATOID		PYROXENITE		SAPROLITE	
		Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating
Rock strength		100 to 250	12	50 to 100	7	100 to 250	12	100 to 250	12	50 to 100	7	100 to 250	12	50 to 100	7	100 to 250	12	1 to 5	1
Fracture spacing	Main Shaft	0.53	10	0.3	10	0.36	10	0.36	10	0.4	10	0.37	10	0.32	10	0.41	10	3.792	20
	Vent Shaft	0.36	10	0.25	10	0.33	10	0.38	10	-		0.41	10	0.15	8	0.36	10	5.82	20
RQD	Main Shaft	94%	20	78%	17	83%	17	94%	20	86%	17	87%	17	93%	20	84%	17	0%	3
	Vent Shaft	91%	20	86%	17	89%	17	98%	20	-		85%	17	88%	17	92%	20	0%	3
Joint condition	Main Shaft	Slightly rough, separation < 1mm, slightly weathered	25	Very rough, non-continuous, no separation or weathering	30	Slightly rough, separation < 1mm, slightly weathered	25	Very rough, non-continuous, no separation or weathering	30	Slightly rough, separation < 1mm, slightly weathered	25	Slightly rough, separation < 1mm, slightly weathered	25	Slightly rough, separation < 1mm, slightly weathered	25	Slightly rough, separation < 1mm, slightly weathered	25	Soft gouge or continuous separation > 5 mm	0
	Vent Shaft	Very rough, non-continuous, no separation or weathering	30	Very rough, non-continuous, no separation or weathering	30	Very rough, non-continuous, no separation or weathering	30	Very rough, non-continuous, no separation or weathering	30	-	-	Slightly rough, separation < 1mm, slightly weathered	25	Very rough, non-continuous, no separation or weathering	30	Slickensided or gouge > 5 mm, separation 1 to 5 mm, continuous	10	Soft gouge or continuous separation > 5 mm	0
Groundwater	Main Shaft	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15
	Vent Shaft	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15	Dry	15
Orientation adjustment	Main Shaft	Tunnel - favourable	-2	Tunnel - fair	-5	Tunnel - favourable	-2	Tunnel - fair	-5	Tunnel - fair	-5	Tunnel - favourable	-2	Tunnel - favourable	-2	Tunnel - fair	-5	Tunnel - very unfavourable	-12
	Vent Shaft	Tunnel - favourable	-2	Tunnel - fair	-5	Tunnel - favourable	-2	Tunnel - fair	-5	-	-	Tunnel - favourable	-2	Tunnel - fair	-5	Tunnel - fair	-5	Tunnel - very unfavourable	-12
RMR	Main Shaft	**84**		**65**		**76**		**80**		**75**		**77**		**74**		**74**		**27**	
	Vent Shaft	**79**		**72**		**79**		**79**				**75**		**72**		**71**		**22**	
Class	Main Shaft	**I**		**II**		**II**		**II**		**II**		**II**		**II**		**II**		**IV**	
	Vent Shaft	**II**		**II**		**II**		**II**				**II**		**II**		**II**		**IV**	
Description	Main Shaft	**Very good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Poor rock**	
	Vent Shaft	**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Good rock**		**Poor rock**	

Source: Clark-Mostert 2007





Source: Clark-Mostert 2007

Figure 17: Line graph of the Main and Ventilation Shaft RMR ratings with depth).

4.2.4 Barton's Rock Tunnelling Index (Q), calculations and values

Using the geotechnical logs, Q-ratings were also calculated per borehole and rock type. The Q-rating is determined by (Barton et al, 1973):

$$Q = \frac{RQD}{Jn} * \frac{Jr}{Ja} * \frac{Jw}{SRF} \qquad \text{(Equation 4)}$$

And

$$Q' = \frac{RQD}{Jn} * \frac{Jr}{Ja} \qquad \text{(Equation 5)}$$

Q' can be used where stress and water flow is already taken into account by numerical modelling, and therefore become redundant.

Q values range from 0.001 to 1000 on a logarithmic scale. RQD is the rock quality designation derived from Equation 1. Jn is the joint set number, Jr is the joint roughness number, Jw is the joint water reduction number, Ja is the joint alteration number and SRF is the stress reduction factor. The input values and their ratings for these different factors are listed below in Tables 13 to 16, as well as a subset of stress reduction factors in Table 17.

Table 13: Evaluation table for joint number (Jn) ratings.

Number of Joint Sets	**Random Joints**	**J_n Rating**
Intact Rock	No random joints	0.5
Intact Rock	Few random joints	1
1 Joint set	No random joints	2
1 Joint set	Random joints	3
2 Joint sets	No random joints	4
2 Joint sets	Random joints	6
3 Joint sets	No random joints	9
3 Joint sets	Random joints	12
>=4 joint sets		15
Crushed rock, earthlike		20

Source: Barton et al, 1973

Table 14: Evaluation table for joint roughness (Jr) ratings.

Joint surface	Discontinuous	Undulating	Planar
Rough	4	3	1.5
Smooth	3	2	1
Slickensided	2	1.5	0.5
No rockwall contact	1.5	1	1

Source: Barton et al, 1973

Table 15: Evaluation table for joint alteration (Ja) ratings.

Gouge	Ja for joint separation (mm)		
	< 1.0	1.0 to 5.0	> 5.0
Tightly healed, non-softening, impermeable fill	0.75	-	-
Unaltered joint walls, surface stains	1	-	-
Slightly altered, non-cohesive or crushed fill	2	4	6
Non-softening slightly clayey, non-cohesive	3	6	10
Non-softening clay fill non-cohesive, with or without crushed rock	3	6	20
Softening or low friction clay, small quantities	4	8	13
Softening clay fill with or without crushed rock	4	8	13
Shattered or swelling clay gouge fill with or without crushed rock	5	10	18

Source: Barton et al, 1973

Table 16: Evaluation table for joint water reduction (Jw) ratings.

Groundwater conditions	Pressure (kPa)	Jw
Dry excavation, minor inflow	< 100	1
Medium inflow, occasional outwash of joint fill	100 – 250	0.66
Large flow with considerable outflow	250 – 1000	0.33
Exceptionally high flow, decaying with time	> 1000	0.2 – 0.1
Exceptionally high flow without noticeable decay	> 1000	0.1 – 0.05

Source: Barton et al, 1973

Table 17: Evaluation table for stress reduction factor (SRF) ratings.

Description	SRF
Multiple weakness zones with altered rock and very loose surrounding rock (any depth)	10
Single weakness zone with weak infill, shallower than 50 m	5
Multiple shear zones in competent rock and loose surrounding rock (any depth)	7.5
Single shear zone in competent rock and loose surrounding rock (any depth)	2.5
Single shear zone in competent rock, shallower than 50 m	5
Single shear zone in competent rock, deeper than 50 m	2.5
Loose open joints (any depth)	5

Source: Barton et al, 1973

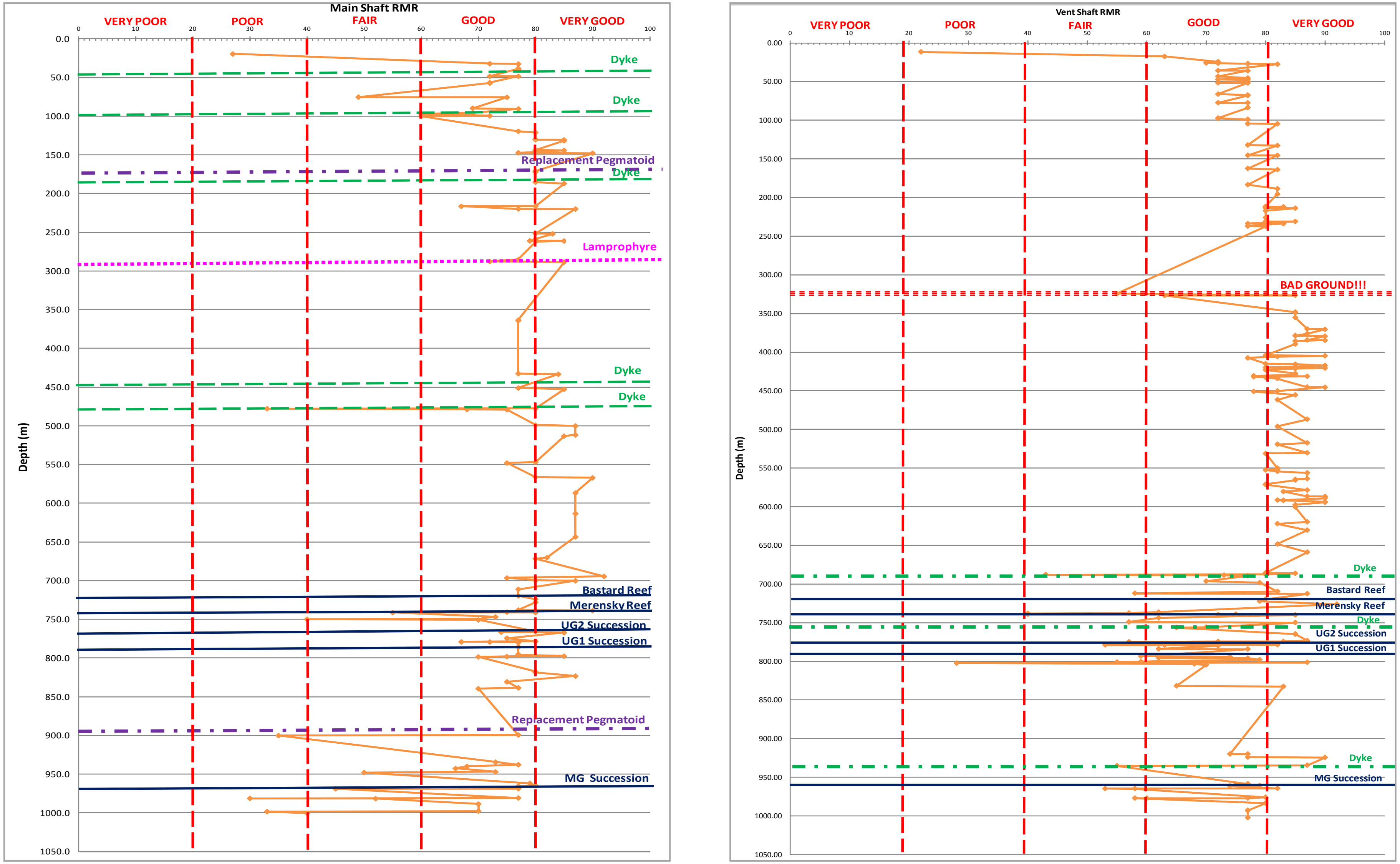
Taking into account the rock mass parameters and the ratings above, Q-values are presented for the different rock types in Table 18, and shown graphically with depth in Figure 18.

The Q values tend to be lower in the areas close to intrusions, the Merensky Reef, UG2 Reef, UG1 succession and MG succession. This is due to the lower RQD values, lower rock strength, the mode of fracturing and the stresses in these areas. Q values of the fresh rock are all greater than 10, and the rock mass is therefore classified as “Good Rock”.

Table 18: Q values for the rock types found in the Main and Ventilation Shaft.

Parameters		ANORTHOSITE		CHROMITITE		DOLERITE		IRUP		LAMPROPHYRE		NORITE		PEGMATOID		PYROXENITE		SAPROLITE	
		Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating
RQD	Main Shaft	0.94	94	0.78	78	0.83	83	0.94	94	0.86	86	0.87	87	0.93	93	0.84	84	0	0
	Vent Shaft	0.91	91	0.86	86	0.89	89	0.98	98			0.85	85	0.88	88	0.92	92	0	0
Jn	Main Shaft	Two	4	One	2	One	2	One	2	Three	9	Three	9	One	2	Two	4	Crushed, earthlike	20
	Vent Shaft	Two	4	One	2	One	2	Two	4			Three	9	One	2	Two	4	Crushed, earthlike	20
Jr	Main Shaft	Undulating, rough	3	Discontinuous, rough	1	Discontinuous, rough	1	Discontinuous, rough	1	Undulating, slickensided	1.5	Undulating, rough	3	Discontinuous, rough	1	Undulating, rough	3	Planar, no rockwall contact	1
	Vent Shaft	Planar, rough	1.5	Planar, rough	1.5	Planar, rough	1.5	Discontinuous, rough	1			Undulating, rough	3	Discontinuous, rough	1	Undulating, rough	3	Planar, no rockwall contact	1
Ja	Main Shaft	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	b) Unaltered, surface stain	1	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	b) Unaltered, surface stain	1	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	b) Unaltered, surface stain	1	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	t) Shattered or swelling clay +- crushed rock > 5 mm	18
	Vent Shaft	b) Unaltered, surface stain	1	b) Unaltered, surface stain	1	b) Unaltered, surface stain	1	b) Unaltered, surface stain	1			d) Slightly altered, non-cohesive fill 1 to 5 mm	4	b) Unaltered, surface stain	1	d) Slightly altered, non-cohesive fill 1 to 5 mm	4	t) Shattered or swelling clay +- crushed rock > 5 mm	18
Jw	Main Shaft	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Exceptionally high, decaying over time	0.1
	Vent Shaft	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Dry, minor inflow	1	Exceptionally high, decaying over time	0.1
SRF	Main Shaft	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Low stress, near surface (UCS / sigma 1 > 200)	2.5	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Low stress, near surface (UCS / sigma 1 > 200)	2.5
	Vent Shaft	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1			Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Medium stress (UCS / sigma 1 = 200 to 10)	1	Low stress, near surface (UCS / sigma 1 > 200)	2.5
Q	Main Shaft	**22**	**Good**	**31**	**Good**	**29**	**Good**	**44**	**Very Good**	**49**	**Very Good**	**10**	**Good**	**14**	**Good**	**14**	**Good**	**0**	**Exceptionally Poor**
	Vent Shaft	**27**	**Good**	**66**	**Very Good**	**46**	**Very Good**	**25**	**Good**			**22**	**Good**	**44**	**Very Good**	**27**	**Good**	**0**	**Exceptionally Poor**
Q'	Main Shaft	**22**		**28**		**32**		**65**		**37**		**11**		**15**		**13**		**0**	
	Vent Shaft	**31**		**55**		**57**		**33**				**21**		**44**		**25**		**0**	

Source: Clark-Mostert 2007



Source: Clark-Mostert, 2007

Figure 18: Line graph of the Main and Ventilation Shaft Q values in depth.

4.2.5 Laubscher's Mining Rock Mass Rating (MRMR), calculations and values

Laubscher's (1990) modified rock mass rating (MRMR) is based on Bieniawski's RMR, and is used to adjust in situ rock mass ratings (IRMR) for the mining environment (MRMR).

IRMR uses five parameters as shown in Table 19 and Equation 6. The MRMR is determined using 3 adjustments as shown in Table 22 and Equation 7.

Table 19: IRMR parameters and ratings.

Parameter	Abbreviation	Rating range
Intact Rock Strength (Table 18)	IRS	0 - 20
Rock Quality Designation*	RQD	0 - 15
Joint Spacing (Figure 19)	JS	0 - 25
Fracture Frequency**	FF	0 - 40
Joint Condition and Water (Table 21)	JCW	0 - 40

Source: Laubscher, 1990

** RQD Rating = RQD*15*

*** FF = total no. of discontinuities in geotechnical unit/length of geotechnical unit (m), Rating = 25*(0.121*LN (spacing) + 0.705)*

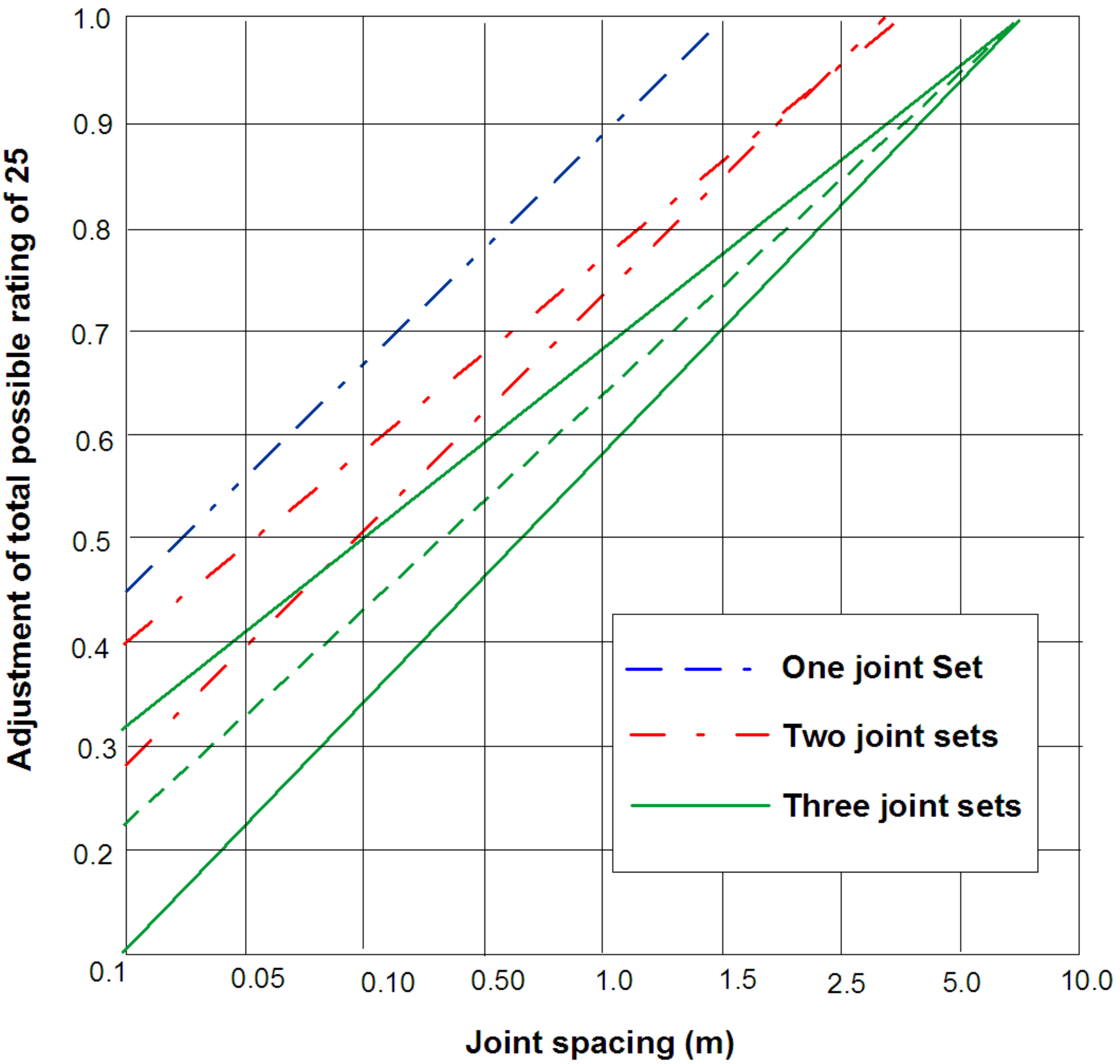
$$IRMR = IRS + RQD + JS + FF + JCW \qquad \text{(Equation 6)}$$

Table 20: Ratings for Intact Rock Strength.

Intact Rock Strength (MPa)	Rating
>185	20
165 to 185	18
145 to 164	16
125 to 144	14
105 to 124	12
85 to 104	10
65 to 84	8
45 to 64	6
25 to 44	4
5 to 24	0

Source: Laubscher, 1990

Figure 19 allows the values of the input parameters to be adjusted for the spacing measured of joints within the drill core.



Source: Laubscher, 1990

Figure 19: Ratings for joint spacing adjustment.

Table 21: Joint and Groundwater conditions for IRMR.

Parameter	Description		Dry Conditions	Water Pressure		
				Low	Moderate	High
A. Joint expression – large scale irregularities	Wavy	Multi-directional	10	10	10	10
		Uni-directional	9 to 9.5	9 to 9.5	9 to 8.5	8 to 7.5
	Curved		8.9 to 8.0	8.5 to 7.5	8 to 7	7 to 6
	Straight		7.9 to 7	7.4 to 6.5	6	4
B. Joint expression (small scale irregularities or roughness)	Very rough		10	10	9.5	9
	Striated or rough		9.9 to 8.5	9.9 to 8.5	8	7
	Smooth		8.4 to 6	8 to 5.5	6	5
	Polished		5.9 to 5	5 to 4	3	2
C. Joint water alteration zone	Stronger than rock		10	10	10	10
	No alteration		10	10	10	10
	Weaker than rock		7.5	7	6.5	6
D. Joint filling	No fill – surface staining only		10	10	10	10
	Non softening and sheared material (not clay or talc)	Coarse sheared	9.5	9	7	5
		Medium sheared	9	8.5	6.5	4.5
		Fine sheared	8.5	8	6	3
	Soft sheared material (e.g. talc)	Coarse sheared	7	6.5	4	2
		Medium sheared	6.5	6	3.5	1.5
		Fine sheared	6	5.5	3	1
	Gouge < amplitude of irregularity		40	30	10	0
	Gouge > amplitude of irregularity		20	10	5	

Source: Laubscher, 1990

The modified rock mass rating (MRMR) accounts for weathering, stress, joint orientation and blasting effects (Laubscher, 1990 and Laubscher and Jakubec, 2000).

Table 22: MRMR adjustments.

Parameter	Meaning	Rating Range
Aweath (Table 23)	Weathering	30 – 100 %
Ajo (Table 24)	Joint orientation	70 – 90 %
Ablast (Table 25)	Blasting	80 – 100 %

Source: Laubscher, 1990

MRMR = IRMR*Aweath*Ajo*Ablast* *(Equation 7)*

Table 23: Rate of weathering adjustment.

Weathering extent	6 months	1 year	2 years	3 years	> 4 years
Fresh	100	100	100	100	100
Slightly	88	90	92	94	96
Moderately	82	84	86	88	90
Highly	70	72	74	76	78
Completely	54	56	58	60	62
Residual soil	30	32	32	34	36

Source: Laubscher, 1990

Table 24: Joint orientation adjustment.

No. of joints defining block	Adjustment %				
	70	75	80	85	90
	Number of faces inclined away from vertical				
3	3	-	2	-	-
4	4	3	-	2	-
5	5	4	3	2	1
6	6	5	4	3	2 or 1

Source: Laubscher, 1990

Table 25: Blasting adjustment.

Excavation technique	Adjustment
Boring	1.00
Smooth wall blasting	0.97
Good conventional blasting	0.94
Poor conventional blasting	0.80

Source: Laubscher, 1990

Table 26 is a summary of the IRMR and MRMR as determined for the Main and Ventilation Shafts. When looking at the MRMR values in Table 26 all the rock types can be classified as “Good Rock”.

4.2.6 Summary and conclusions

Although there is a large number of rock types present at the planned shaft positions it is unrealistic to evaluate each separately. As such, the rock types were grouped using the intact strength and discontinuity characteristics. Saprolite ratings were calculated for all classification schemes for completeness, even though they only form the immediate weathered portion. This allows the sensible use of the information for rock engineering design. The rock types were grouped as anorthosite, chromitite, dolerite, IRUP, lamprophyre, norite, pegmatoid and pyroxenite. The rock mass characteristics for the groupings were determined per rock type per shaft area and per depth. The parameters calculated include RQD, Q, Q', and MRMR. All of these indicate the rock mass to be “Good Rock”. Table 26 summarises the rock mass parameters as calculated for the Main and Ventilation Shafts.

The RQD for the rock types ranges between 78% for chromitite, to 98% for the IRUP. The average for the boreholes was in the 86% to 88% range. The average discontinuity spacing is 0.39m, with the pegmatoid having the lowest spacing value of 0.15m and the highest being 0.53m for anorthosite. Even though the pegmatoid has the lowest spacing value, the rock type’s RQD is still high. The anorthosite as can be expected has longer lengths of intact core and therefore the greater discontinuity spacing.

The Q-system values of the unweathered rock were between 10 and 66, which are described as “Good” to “Very Good” rock. The overall rock mass ratings of both shafts are classified as “Good Rock”. Q' values range between 11 and 65; however these ratings are applicable to near surface excavations and not deeper shafts.

The RMR values were calculated for all the rock types, and all have been classified as Class II rock which is “Good Rock”. The values range between 70 and 80%, and the anorthosites in the main shaft had the highest rating of 84, ranking it as a Class I rock, which is “Very Good Rock”.

The MRMR for all the rock types varies between approximately 53 for chromitite and 65 for anorthosite, with an average at roughly 61. The lower value for the chromitite, pyroxenite and pegmatoid is due these rock types having lower uniaxial compressive strengths.

All the rating calculations show that the rock types encountered in both the Main and Ventilation shafts can be classified as “Good Rock”. The only problematic areas that can be expected are where the rockmass mechanical characteristics change at intrusive (see Figures 15 and 16, and Appendix A) and reef contacts (see Table 5). The differing response of various rocks can cause differential movement or weakening of pre-existing geological discontinuities at these positions.

The presence of IRUP’s in both the Main and Ventilation Shaft positions are emphasised as their effect on the shaft sinking process should not be underestimated. IRUP’s should be catered for appropriately and the following is again reiterated (Godden, 2000).

- IRUP’s and their associated alteration haloes accelerate corrosion of exposed steelwork and installed steel support.

- IRUP affected areas should be shotcreted, as this will lower salt levels to more manageable concentrations.

- To prevent, or reduce, the corrosion of shaft steelwork due to galvanic effects, the shaft column should be kept dry, drainage systems should be monitored, and the shaft buntens should be isolated from the surrounding rock mass, so that there is no electrical connection.

Table 26: Modified rock mass ratings (MRMR) values for the rock types in the Main and Ventilation shaft.

Parameters			ANORTHOSITE		CHROMITITE		DOLERITE		IRUP		LAMPROPHYRE		NORITE		PEGMATOID		PYROXENITE		SAPROLITE	
			Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating
RQD		Main Shaft	0.94	14.1	0.78	11.7	0.83	12.45	0.94	14.1	0.86	12.9	0.87	13.05	0.93	13.95	0.84	12.6	0	0
		Vent Shaft	0.91	13.7	0.86	12.9	0.89	13.35	0.98	14.7			0.85	12.75	0.88	13.2	0.88	13.2	0	0
UCS			165 to 185	18	65 to 84	8	165 to 185	18	105 to 124	12	45 to 64	6	165 to 185	18	85 to 104	10	105 to 124	12	5 to 24	4
Joint spacing		Main Shaft	0.53	15.70	0.30	13.98	0.36	14.53	0.35	14.45	0.34	14.36	0.37	14.62	0.32	14.18	0.41	14.93	3.79	21.66
		Vent Shaft	0.36	14.53	0.25	13.43	0.33	14.27	0.38	14.70			0.41	14.93	0.15	11.89	0.36	14.53	5.82	22.95
Joint conditions	Large scale joint expression	Main Shaft	Wavy multi-directional	10	multi-directiona	10	Wavy multi-directional	10	Wavy multi-directional	10	Wavy multi-directional	10	Wavy multi-directional	10	Wavy multi-directional	10	Wavy multi-directional	10	Straight	7
		Vent Shaft	Wavy multi-directional	10	Wavy multi-directiona l	10	Wavy multi-directional	10	Wavy multi-directional	10			Wavy multi-directional	10	Wavy multi-directional	10	Wavy multi-directional	10	Straight	7
	Small scale joint expression	Main Shaft	Striated or rough	9	Striated or rough	9	Striated or rough	9	Very rough	10	Smooth	7	Striated or rough	9	Striated or rough	9	Striated or rough	9	Polished	6
		Vent Shaft	Striated or rough	9	Striated or rough	9	Striated or rough	9	Very rough	10			Striated or rough	9	Striated or rough	9	Striated or rough	9	Polished	6
	Joint water alteration zone	Main Shaft	No alteration	10	No alteration	10	No alteration	10	No alteration	10	No alteration	10	No alteration	10	No alteration	10	Weaker than rock	7.5	Weaker than rock	7.5
		Vent Shaft	No alteration	10	No alteration	10	No alteration	10	No alteration	10			No alteration	10	No alteration	10	Weaker than rock	7.5	Weaker than rock	7.5
	Joint filling	Main Shaft	Non-softening and coarsely sheared	9.5	Non-softening and coarsely sheared	9.5	Non-softening and coarsely sheared	9.5	No fill - surface staining only	10	Non-softening and coarsely sheared	9.5	Non-softening and coarsely sheared	9.5	Non-softening and coarsely sheared	9.5	Non-softening and coarsely sheared	9.5	Gouge > amplitude of discontinuity	20
		Vent Shaft	No fill - surface staining only	10	No fill - surface staining only	10	No fill - surface staining only	10	No fill - surface staining only	10			Non-softening and coarsely sheared	9.5	No fill - surface staining only	10	Non-softening and sheared	9	Gouge > amplitude of discontinuity	20
	Groundwater	Main Shaft	Dry	39	Dry	39	Dry	39	Dry	40	Dry	37	Dry	39	Dry	39	Dry	36	High	21
		Vent Shaft	Dry	39	Dry	39	Dry	39	Dry	40			Dry	39	Dry	39	Dry	36	High	21
Intial MRMR		Main Shaft	**87**		**71**		**81**		**79**		**72**		**83**		**77**		**76**		**46**	
		Vent Shaft	**84**		**73**		**82**		**80**				**83**		**74**		**76**		**44**	
Weathering adjustment			a) Fresh	1	a) Fresh	1	a) Fresh	1	a) Fresh	1	a) Fresh	1	a) Fresh	1	a) Fresh	1	a) Fresh	1	l) Highly after six months	0.7
Joint orientation adjustment			3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 2 faces not vertical	0.8	3 joints, 3 faces not vertical	0.7
Blast adjustment			Good conventional blasting	0.94	conventio nal blasting	0.94	Good conventional blasting	0.94	Good conventional blasting	0.94	Good conventional blasting	0.94	Good convention al blasting	0.94	Good convention al blasting	0.94	Good conventional blasting	0.94	Poor conventional blasting	0.8
Final MRMR		Main Shaft	**65**		**53**		**60**		**58**		**54**		**62**		**58**		**57**		**18**	
		Vent Shaft	**63**		**55**		**61**		**59**				**62**		**56**		**57**		**17**	

Source: Clark-Mostert, 2007

4.3 Geotechnical characterisation of the fault position

Geotechnical logging was done on the diamond drill holes sunk at the positions indicated for the Wesizwe Main and Ventilation Shafts. The rock mass ratings indicated that these positions were favourable and that the rock mass of the shafts can be referred to as “Good Rock”.

A seismic survey was conducted on the area. This survey provided subsurface images of the rock mass in the lease area. These images however indicated a near vertical fault, with a roughly 30m throw, positioned approximately 50m from the Main Shaft position. This position was previously interpreted as being 100m to the North from the Main shaft position, based on geological logging information available and was not considered a risk. The decreased distance of the fault from the the Main shaft position was now considered as a potential hazard as it could possibly intersect underground infrastructure and jepoardise ground stability. It was feared that this would affect the rock mass conditions in the shafts even though it was not intersected by the Main and Ventilation shaft boreholes (see Figure 20).

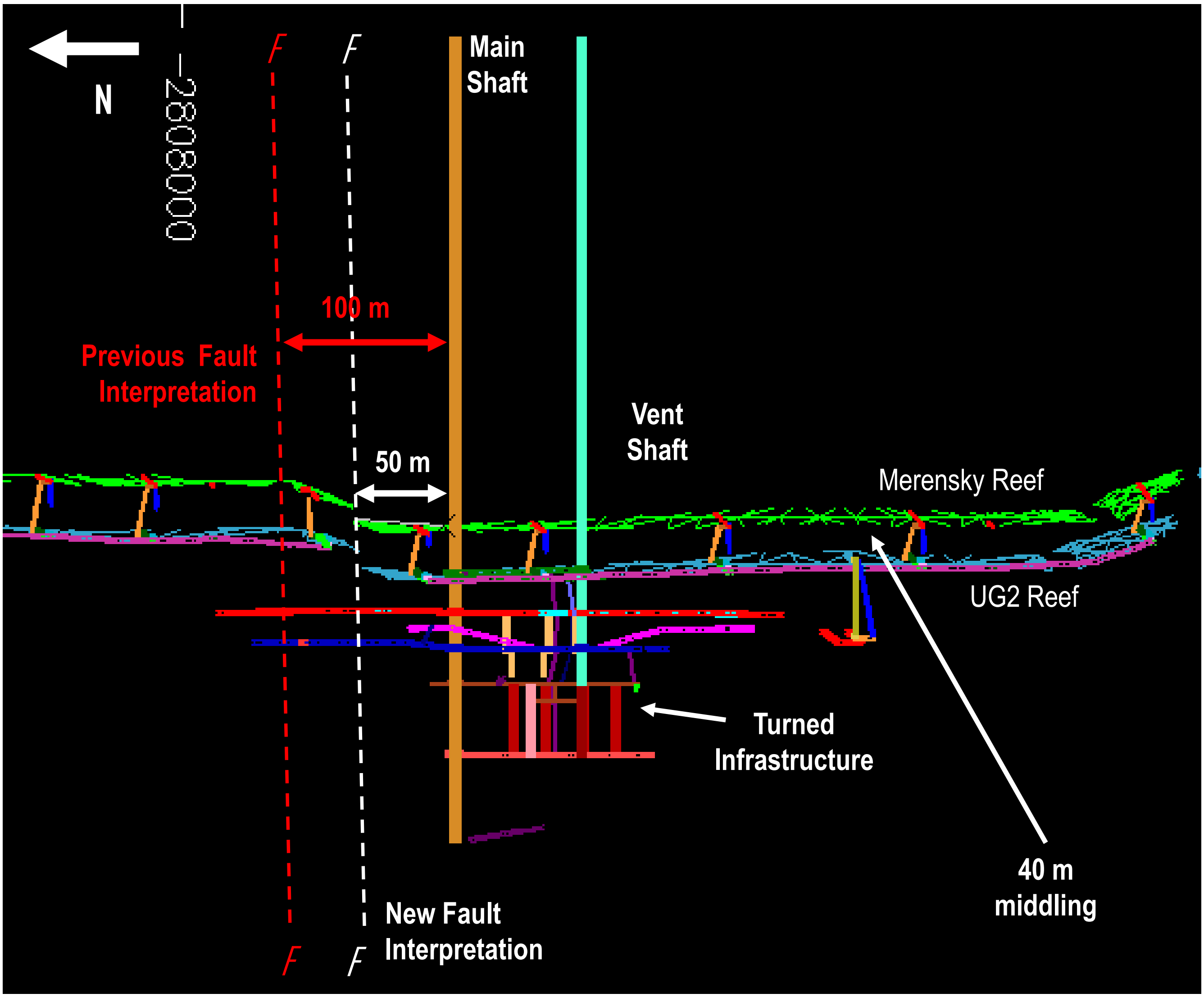


Figure 20: Section through the Main and Ven Shaft positions showing the old vs the new interpretation of the shaftpositions.

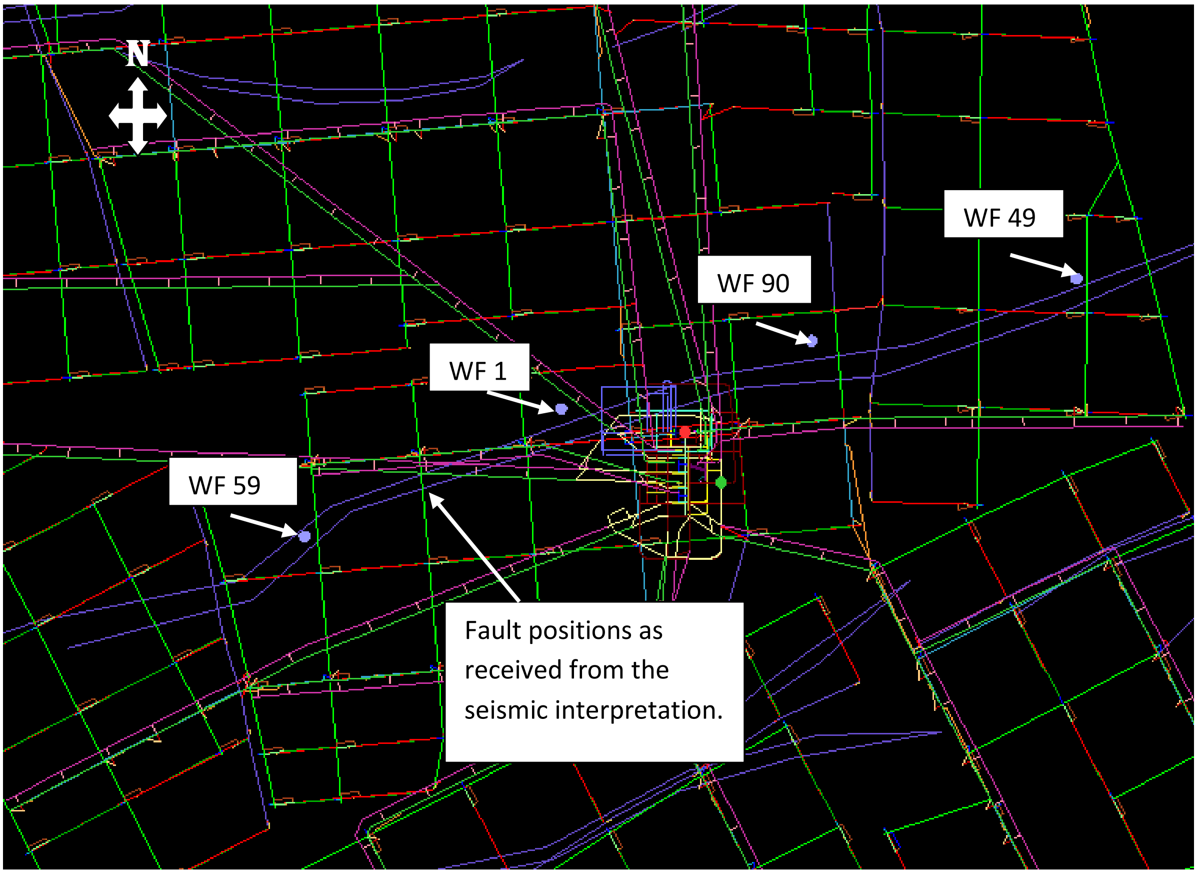
Geological boreholes are used to provide reference surfaces for the interpretation of the seismic images, and therefore all the geological borehole information that was already available was plotted together with the seismic information. With combining the information it became clear that the fault was not noted in the geological logs. It was suggested that the boreholes plotting closest to the interpreted fault position be re-examined to assess whether the intersection with the fault zone is visible in them, and if so that they be geotechnically logged in the fault area.

Four boreholes were identified that could possibly have intersected the fault; these holes were WF1, WF49, WF59 and WF90 (see Figure 2). With re-examination of the diamond drill core it was clear that a fault was indeed situated at the indicated position and these intersections were subsequently geotechnically logged in order to determine the rock mass classification and area of influence of this feature.

4.3.1 Seismic Survey information

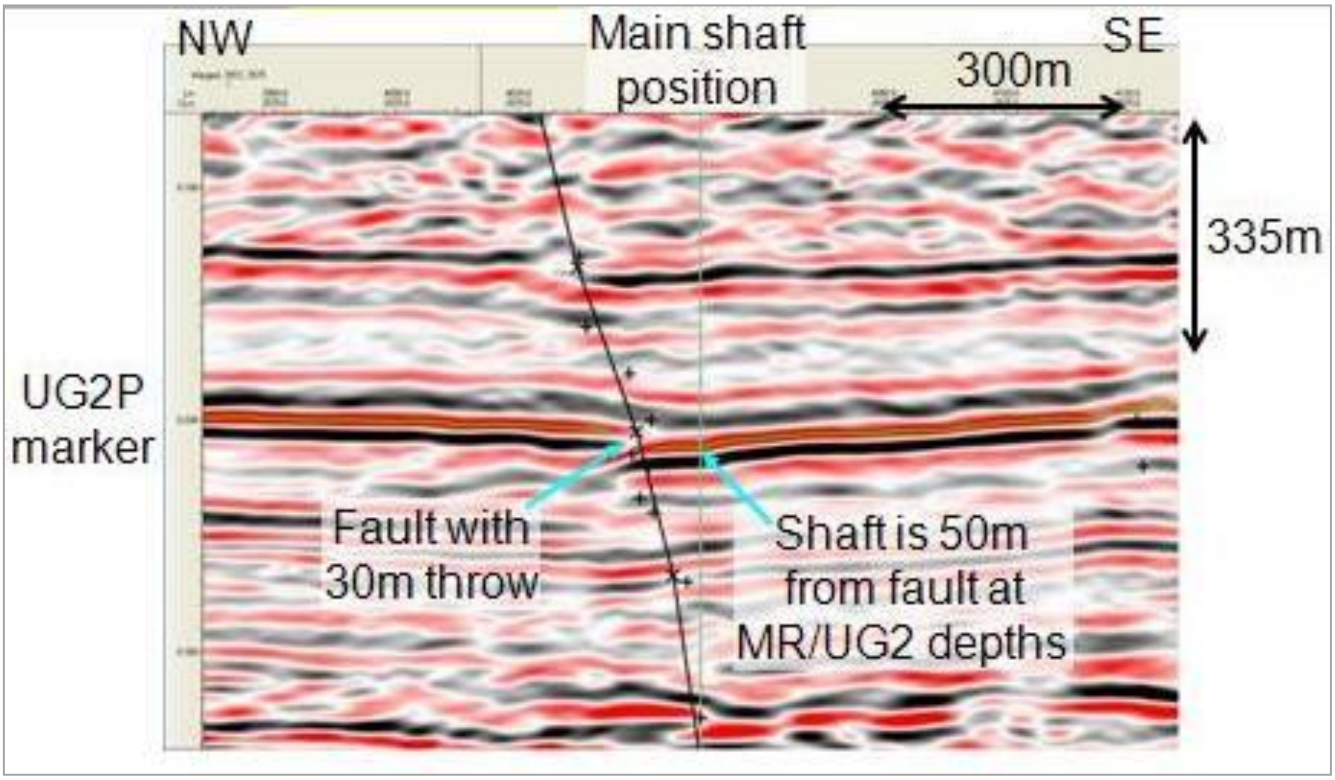
Figure 21 gives the projected fault position (as indicated from the seismic survey) relative to the Main and Ventilation shaft positions, and to the boreholes logged for additional information on the fault.

The near vertical fault is interpreted to be 50m away from the main shaft position, and is expected to have a throw of approximately 30m (Figure 22).



Source: Clark-Mostert, 2007

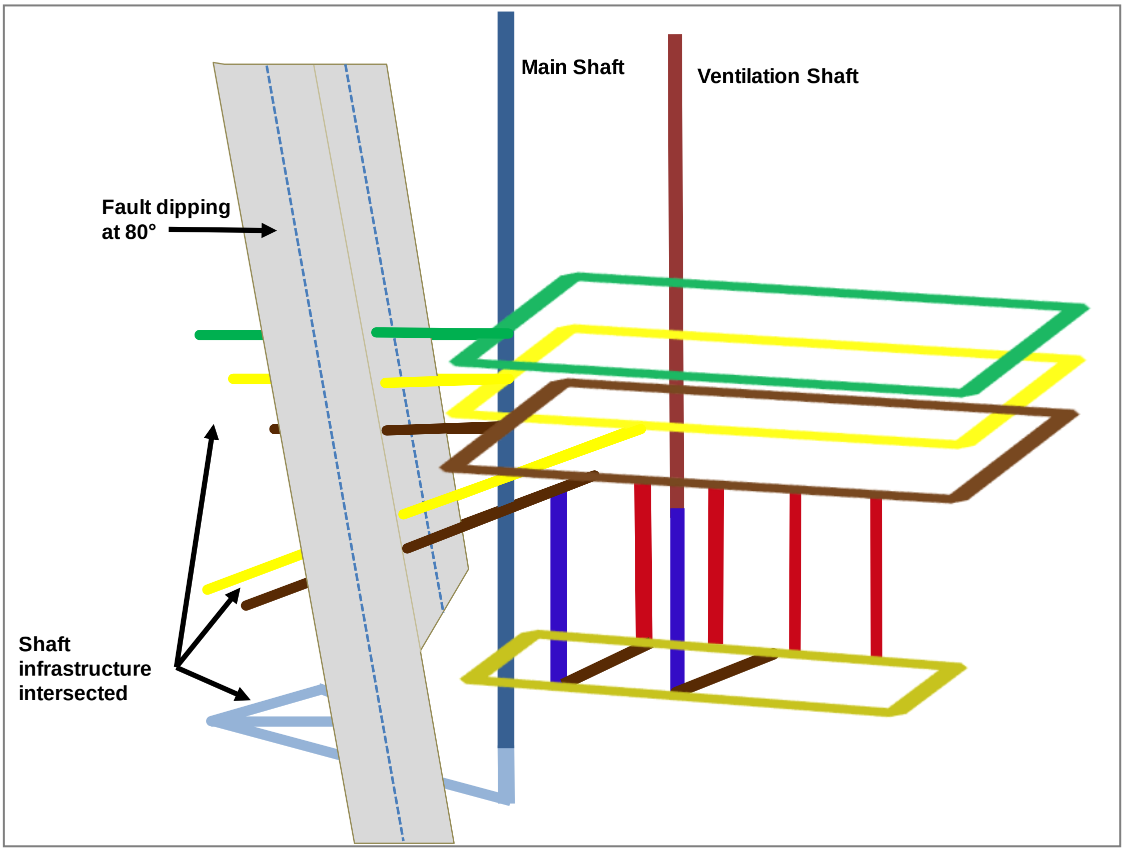
Figure 21: Main and Ventilation shaft infrastructure and logged boreholes relative to the fault trace as received from the seismic interpretation.



Source: Clark-Mostert, 2007

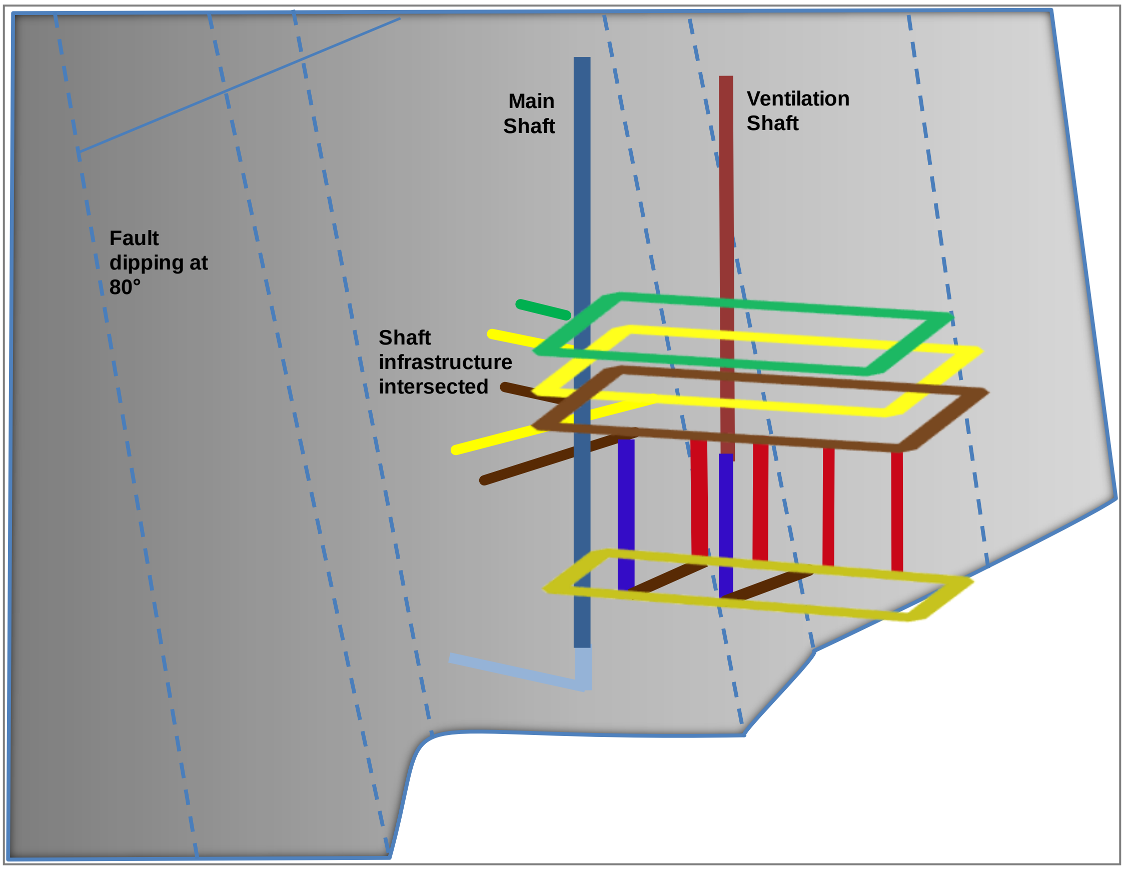
Figure 22: Predicted fault behaviour in depth according to the preliminary seismic survey results.

The Main Shaft borehole did not intersect the fault. Structures logged in other drill cores intersected the core at angles ranging between 70 to 90º as can be seen in Figure 26 and Figures 38 to 46 in Appendix F. Based on this and the interpretations made from the holes logged close to the fault intersection, the assumption is therefore made that the fault is dipping close to 80°, which is confirmed by the subsurface image given in Figure 22. Taking this scenario, the following sections (Figures 23 + 24) were drafted, indicating the shaft ramps being cut by the fault. The fault position closest to the main shaft position is estimated to be approximately 30m.



Source: Clark-Mostert, 2007

Figure 23: Fault as interpreted by current data.



Source: Clark-Mostert, 2007

Figure 24: Frontal view of fault intersection

4.3.2 Geotechnical characterisation

Processing of the data generated by geotechnical logging made it possible to examine the extent of the fault influence as intersected by the boreholes. The ratings are based on the characteristics of the intact rock and the discontinuities separating the fragments caused by faulting. The standard methods of rock mass characterisation were applied in trying to determine the extent of the predicted fault. The methods of calculating the various parameters can be referred to in Section 4.2.

The detailed rock mass ratings and photos of the intersections are attached in Appendix D, E and F.

Two related zones of weak rock mass were distinguished within the boreholes, and are correlated in the summary below.

Ratings of the rock mass affected by the fault in the various boreholes are given based on the depth of the intersections (Table 27). It should be noted that holes logged were not drilled to geotechnical standards (core less than 76mm in diameter) and have been exposed to the elements for a year or more, affecting rock mass ratings negatively.

The fault-affected area was noted to be associated with a highly destructive (associated with large amounts of jointing and movement as indicated by slickensides and serpentinite clay infilling) lamprophyre dyke accompanied by a dolerite stringer. The lamprophyre dyke disintegrates within months of exposure to water and oxygen, and will cause great support difficulties. At some places the boreholes intersected cavities filled with minerals such as talc and gypsum precipitated from mineral bearing solutions. This, together with the noted green discolouration indicates that this faulted area must be water bearing. From the areas where the core intersected the fault, the dip can be interpreted to be nearvertical to vertical, thus 70° or greater (Figure 26). In places the core investigated had an appearance of re-cemented shattered joints and the rock quality was not rated very high in these sections (Figure 25).

Figure 25: Shattered re-cemented core as was observed in WF90.

Figure 26: WF1 fault affected area.

4.3.3 Summary and conclusions

From the rock mass ratings and combining the two zones that were picked up, the affected area does not exceed a vertical influence of 58m, and has a minimum vertical influence of 25m as measured down hole. These distances need to be considered when interpreting the fault are intersections, as infrastructure might not fall within the direct line of intersection, but could still be influenced negatively in regard rockmass competence should it fall within this zone. The rock mass in these affected areas are rated overall as “poor rock” to “exceptionally poor”. The rock quality designation (RQD) ratings for the overall affected area fall between 36 to 52 %.

From the logs it also appears that there is a close association between the faulted area and the intrusion of a very destructive lamprophyre dyke (associated with extensive shearing movements as can be seen by the associated alteration features) accompanied by a dolerite stringer. These structures might be the reason for the more enhanced radius of influence. Green discolouration and cavity formation was also noted, and the assumption was made that the zone might be accompanied by water. It should be emphasised that these deductions are made from only 4 boreholes and is only an indication of the type of conditions that can be expected.

No intersection between the reef horizons and the fault was logged within the identified boreholes and the distance between intersection and the reef horizons are reflected in Table 28.

Table 27: Summary of rock mass ratings of interpreted area affected by the fault.

Borehole		Predicted depth of Intersection by Seismics (m)	Depth (m) From	Depth (m) To	Portion Influenced (m)	RQD	Q Value	Q Description	Q'	RMR Value	RMR Class	RMR Description	Intial MRMR Value	Final MRMR Value
WF01	Overall	+/- 580	555.04	579.89	24.85	40%	1.27	Poor	1.92	32.8	IV	Poor Rock	61.3	37.9
	Fault 1		555.04	567.00	11.96	2%	0.00	Exceptionally Poor	0.01	15	V	Very poor rock	52.7	29.5
	Fault 2		572.15	579.89	7.74	27%	0.07	Extremely Poor	0.10	20	V	Very poor rock	57.3	22.4
WF049	Overall	+/- 620	642.15	686.90	44.75	52%	2.67	Poor	3.06	44	III	Fair rock	65.6	40.3
	Fault 1		642.15	645.19	3.04	30%	0.07	Extremely Poor	0.11	35	IV	Poor rock	66.8	29.9
	Fault 2		670.28	686.90	16.62	22%	0.05	Extremely Poor	0.08	22	IV	Poor rock	56.8	22.3
WF059	Overall	+/-790	706.16	763.76	57.60	46%	3.46	Poor	3.46	43	III	Fair Rock	64.8	43.0
	Fault 1		706.16	709.36	3.20	27%	1.51	Poor	1.51	48	III	Fair rock	67.9	51.1
	Fault 2		751.22	763.76	12.54	20%	0.09	Extremely Poor	0.11	20	IV	Poor Rock	49.5	23.6
WF090	Overall	+/- 630	629.14	686.87	57.73	36%	1.49	Poor	1.55	38	IV	Poor Rock	60.1	29.2
	Fault 1		629.14	643.33	14.19	55%	0.30	Very Poor	0.46	44	III	Fair Rock	58.0	26.3
	Fault 2		659.98	686.87	26.89	12%	0.03	Extremely Poor	0.04	28	IV	Poor Rock	56.5	22.2

Table 28: Reef horizons in relation to fault intersection in logged boreholes.

Intersection	**WF01**	**WF049**	**WF059**	**WF090**
Bastard Reef	709.29	664.06	760.95	IRUP
Merensky Reef	725.83	679.66	787.65	697.71
UG2	767.22	718.55	**Hole aborted no UG2 intersection**	736.86
UG1	774.93	736.73	**Hole aborted no UG1 intersection**	753.79
Fault from	555.04	642.15	706.16	629.00
to	579.89	686.9	763.76	686.87
Distance between Merensky Reef and Fault	170.79	37.51	81.49	68.71

The following facts about the fault intersection are known and should be considered for the final decision on the shaft placements:

- The updated subsurface seismic imaging has indicated that the 30m down-throw fault is approximately 50m to the North from the proposed shaft positions at Merensky and UG2 level, with a near-vertical (70 to 90º) dip and is therefore unlikely to intersect the shaft.

- This is not a “new” fault, missed by interpretation – it has been part of the geological model, only its position and throw were not known. In fact, the seismic information indicates that the fault will have a positive impact as it terminates one of the dykes that occur near to the shaft.

- Detailed geotechnical logging of the shaft boreholes has shown that no significant fault zones are present within the proposed shafts.

- Other geological boreholes drilled through the fault were geotechnically logged and confirm the near-vertical (70 to 90º) dip of the feature. The position of the fault within these boreholes also indicates that the fault will not intersect the shafts.

- Although it is expected that there will be no impact on the shaft barrel itself, the ramps have been rotated through 90 degrees to ensure that they do not intersect the fault near to the shaft. The footwall drives will obviously pass through the anticipated fault position, but this can be negotiated following standard practices. Based on the available information and assumptions made, the fault near Wesizwe Main shaft does not intersect the Main Shaft (closest distance from shaft to fault is approximately 30m at the shaft bottom) or any other major infrastructure, shaft ramps and some footwall drives will be affected by the fault (Figures 23 & 24). The footwall drives will have to go through the fault, these drives can be supported adequately so that their operations can continue without a major problem (this is very common in South African mining practice).

- The presence of a lamprophyre dyke (with its associated alteration) within the fault position can be negotiated using standard support practices for weak ground, including shotcreting. This practice is in fact standard for long-term excavations such as the footwall drives.

- Many gold and platinum mines have significant faulting associated with severe shearing and throws exceeding 20m in depth at the shaft position (see Chapter 2 of this document for examples). These features have been successfully negotiated and managed during shaft-sinking and subsequent mining.

- Surface features (e.g. settlements, topography, and water intersection) have resulted in the shaft being positioned where it is. It will be difficult to re-site the shaft, considering these features.

5 RISK ANALYSIS

The following chapter sets out the procedures that were followed in determining the risk of the current shaft position and that of a possible new proposed site.

The aim of the risk analysis was to outline the foreseeable risks associated with the positioning of the shafts and to provide a set of actions to be taken to prevent the identified threats from occurring and to reduce the impact of the risk should it eventuate.

Participants in the risk assessment consisted of a geotechnical engineer, a geologist, a rock engineer, a mining engineer and a qualified risk facilitator. The participants were well briefed and all the information already mentioned in this document was made available to them. The following factors were highlighted beforehand:

- A platinum junior owns the Wesizwe Ledig Project and a limited amount of money was available for extended studies.

- Time was of the essence as orders were already placed for shaft sinking equipment and investors were already briefed as to the shaft sinking commencement date.

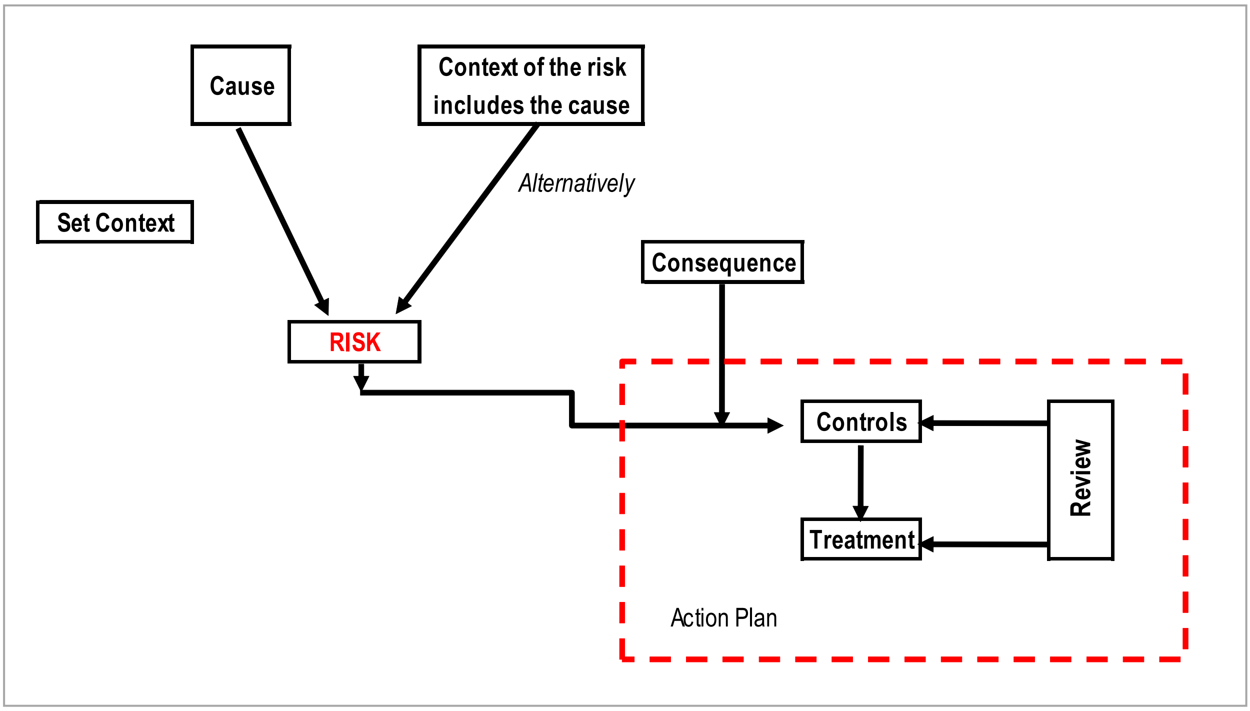
- The little town of Ledig was a large concern, as an 800m radius had to be kept between the shafts and the community. The community would have to be relocated at an enormous expense should a new position close to or inside town be established.

- All the mine planning, scheduling and geotechnical work was based on the current shaft positions, and would have to be repeated for a changed position, and this would delay the project by at least a year.

- Should the shaft be kept at the current position and the main shaft infrastructure be jeopardised due to the fault intersection, it could be a fatal blow to the project. In term of investors' confidence, the financial markets, employee safety and project success, it would far outweigh the additional costs and time spent to search for a more appropriate shaft position. It was therefore crucial that the elements posing a risk to this project be identified and addressed in the strictest of terms as the whole project success could be dependent on this exercise. The success of this project will also be used as a confidence measure for the future Wesizwe Platinum Mines Projects.

5.1 RISK IDENTIFICATION AND QUANTIFICATION

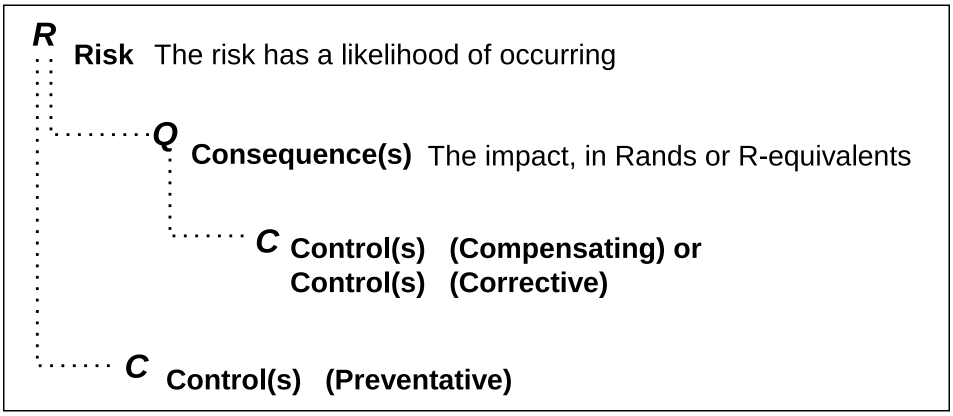
The risk analysis was rated in a program called “Know Risk”, which was set up in such as fashion as to apply the risk matrix, risk ratings and controls as are indicated within this chapter. It should be noted that the Risk Analysis was done using the Wesizwe Platinum Mines standards for risk analysis, and by using the “Know Risk” software an auditable procedure was ensured. A qualified risk manager assisted in the final interpretation and analysis of the risk quantification exercise. The Wesizwe risk management model is illustrated in Figure 27. This model formed the foundation for the assessment.



Source: Wesizwe Ledig Participants Guidelines, (Appendix H)

Figure 27: The Wesizwe risk management model.

This model is programmed into “Know Risk” as having the following structure.



Source: Wesizwe Ledig Participants Guidelines (Appendix H).

Figure 28: Wesizwe risk model structure as it occurs in the "Know Risk" program.

Some definitions of risk in a project environment have been described as "any element which is likely to adversely affect the ability of the project to achieve the defined objectives" (Basson, 2005). And more specifically technical risk was defined as: *"… those elements or issues associated with the scope definition, research and development (R&D), design, construction, and operation that could affect the actual level of performance vs. that specified in the project mission need and performance requirements documents*" (Kindinger and Darby, 2000).

For the purposes of this exercise risk was defined as any particular aspect of the shaft positioning which has the potential to cause harm, loss or danger during the lifecycle of the project and the operations.

The Wesizwe Ledig Project Participants Guideline (Appendix H) was followed for the whole process as is the requirement for all risk analysis conducted for the Wesizwe Ledig project. The process was started by identifying risks which could adversely affect the positioning of the shafts. This was followed by rating the likelihood (Table 29) of occurrence and possible degree of impact (Table 30) of each risk on the project and surrounding business. These ratings were then used to calculate the associated monetary value and were matched with the risk matrix. Figure 29 shows the calculation method used for calculating the monetary value of the risk.

Table 29: Scoring system for the likelihood of a risk occurring.

Value	**Description**	**Ranking**
Exceptionally Rare	Never known to have occurred or estimated to occur 1 in 100 years.	1
Rare	An event that has occurred in other similar service organizations around the world but also extremely low in probability, 1 in 75 years.	2
Unlikely	As per 2, with chance of occurrence 1 in 50 years.	3
Reasonably possible	Events that could infrequently occur in the whole of "*Company Name*", 1 in 25 years.	4
Possible	Events that are known to have occurred; and could occur 1 in 15 years.	5
Likely	An event that is likely to have been experienced at this service organization, or is known to have occurred in the past 3 years.	6
Highly Likely	Events that could occur or is known to have occurred in the past 2 years.	7
Almost Certain	Events that definitely have occurred at this service organization, which will occur once each year.	8
Certain	This event will occur more than once each year.	9

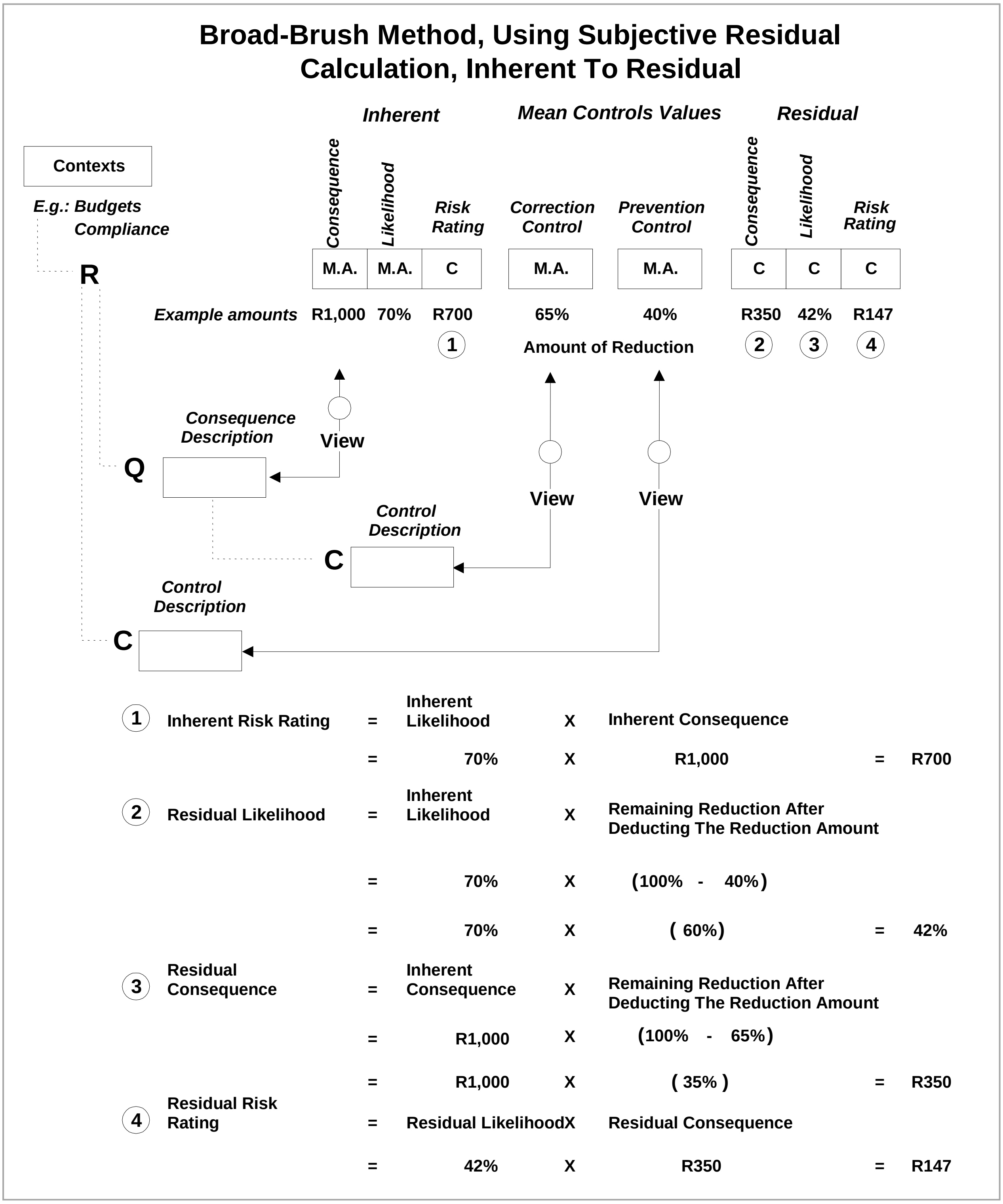
Source: Wesizwe Ledig Project Participants Guidelines (Appendix H)

Table 30: Scoring system for the degree of impact related to the occurrence of a risk.

Value	**Description**	**Ranking**
Negligible	The consequential cost or impact on reputation is hardly noticeable	1
Insignificant	The impact has a small material impact	2
Minor	The impact can be managed by the area of the business as part of normal operations	3
Modest	The impact will result in about 10% of profits being lost, or almost no media coverage or serious injuries / environmental damage.	4
Moderate	The impact will result in about 20% of profits being lost, or a small amount of media coverage, or levels of injuries / environmental damage that can be cured.	5
Serious	The impact will result in serious damage to objectives such as 30% profits lost, or some adverse media coverage, injuries that require hospitalization or a breach of the environment that attracts the regulators attention.	6
Major	The impact will compromise objectives such as 50% profits lost, with adverse media coverage over 1 day, injuries that require up to 6 months off work or a breach of the environment that attracts legal action from the regulator.	7
Severe	The impact will compromise objectives such as 75% profits lost, with adverse media coverage over 3 days, injuries that result in permanent disabilities or a breach of the environment that attracts significant cost to rectify.	8
Catastrophic	The impact threatens the viability of the business, for example where the losses compromise reserves the company has available, or significant adverse media coverage that results in losing customers, injuries that result in fatalities or a breach of the environment that can't be rectified.	9

Source: Wesizwe Ledig Project Participants Guidelines (Appendix H)

Figure 29 below illustrates the broad brush method which was followed to calculate the inherent and residual risk ratings. ‘M.A.’ indicates manual assessment and ‘C’ calculated values.



Source: Know Risk software program Help Files

Figure 29: Broad brush method applied in the Know Risk Software.

Table 31: Risk management matrix legend.

Level	**Risk management matrix – legend**
Very high risk	Requires the ***prompt*** attention of management. The Risk Committee would undertake detailed research, identify risk reduction options and prepare a detailed risk management plan.
High risk	Significant *inherent* risk requires the immediate attention of the relevant manager so that appropriate controls can be set in place. The Risk Committee would also need to monitor the implementation. Significant *residual* risk should be referred to stakeholders who are required to monitor that the associated controls are working. Risk Committee would undertake detailed research, identify additional risk reduction options and prepare a detailed risk management plan.
Tolerable	Responsibility would fall on the relevant manager and specific monitoring of response procedures would occur through the Risk Committee.
Low risk	Manage by routine procedures. The allocation of additional resources is unlikely to be required.
Very low risk	Would generally not require any attention.

Source: Wesizwe Ledig Project Participants Guidelines (Appendix H)

Table 32: Risk colour coding.

Priority Rating	**Colour**
Very low	Blue
Low	Green
Tolerable	Light Green
High	Orange
Very High	Red

Consequence

Likelihood	1. Exceptional	2. Rare	3. Unlikely	4. Reasonable	5. Possible	6. Likely	7. Highly Likely	8. Almost Certain	9. Certain
9. Catastrophic	High	High	High	High	Very High	Very High	Very High	Very High	Very High
8. Severe	High	High	High	High	Very High	Very High	Very High	Very High	Very High
7. Major	Tolerable	High	High	High	High	High	High	High	High
6. Serious	Tolerable	Tolerable	Tolerable	Tolerable	High	High	High	High	High
5. Moderate	Low	Low	Tolerable	Tolerable	Tolerable	High	High	High	High
4. Modest	Low	Low	Low	Low	Tolerable	Tolerable	Tolerable	Tolerable	Tolerable
3. Minor	Low	Low	Low	Low	Low	Low	Tolerable	Tolerable	Tolerable
2. Insignificant	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Low	Low	Low
1. Negligible	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Low

Source: Wesizwe Ledig Project Participants Guidelines (Appendix H)

Figure 30: Risk matrix derived for use in examining risk for the Wesizwe shaft positions.

Controls were then suggested and included for each identified risk and were applied to the inherent likelihood and consequence ratings. These controls were applied as illustrated in 2 and 3 in Figure 29 that resulted in residual likelihood and control ratings. The residual risk rating was then calculated as applied in 4 in Figure 29, using the residual likelihood and consequence ratings.

Table 33: The qualitative measure of the effectiveness of the controls to reduce the risk and / or mitigate the full consequence.

Level	**Description**	**Reduction Value**
Damaging	The control(s) in place actually increase the risk, not reduce it.	- 10 %
None	No controls are in place	+ 0%
Deficient	The controls that have been applied are not adequate for the job	+ 10 %
Marginal	The controls that have been applied go part of the way to reduce the risk or impact	+ 30 %
Qualified	The controls that have been applied go a reasonable way to reduce the risk or impact	+ 50%
Effective	The controls that have been applied are value for money to reduce the risk or impact	+ 70 %
Excessive	The controls that have been applied are more than necessary to reduce the risk or impact. There may be over control.	+ 90 %

Source: Wesizwe Ledig Project Participants Guidelines (Appendix H)

Once the residual risk ratings were allocated, a risk action plan to manage each risk was identified, and a risk owner tasked with the responsibility of monitoring and managing the risk.

5.2 Results

Risk categories were identified for both the current and proposed shaft positions. The same risks were rated for both areas in order to make a direct comparison and to ascertain the comparable risks.

By using the Delphi method, inputs on the perceived risk were obtained from professionals with differing mining and geological backgrounds.

Table 33 and Table 34 give the inherent risk ratings for the identified risks for both proposed areasTable 34: Inherent exposure from highest to lowest for the current area given no controls.

Risk Description	Inherent Likelihood		Inherent Consequence		Inherent Exposure (In Dollars)	Inherent Rating
More unknown geological structures	8	Almost Certain	8	Severe	$42,222,222	Very High
Insufficient geotechnical classification of shaft areas	3	Unlikely	8	Severe	$13,194,444	High
Inadequate modified design to avoid fault intersection	2	Rare	8	Severe	$7,916,667	High
Quality of work already performed not adequate	2	Rare	8	Severe	$7,916,6667	High
Insufficient time to complete the project	3	Unlikely	3	Minor	$3,472,222	Low
Not enough professional time available	3	Unlikely	3	Minor	$3,472,222	Low
Time delay of project in terms of capital payback period	3	Unlikely	3	Minor	$3,472,222	Low
Redesign and scheduling with limited time period	2	Rare	4	Modest	$2,916,667	Low
Encroaching community	8	Almost Certain	4	Modest	$15,555,556	Tolerable
Quality of additional work to be conducted within a tighter time framework of lower standard	8	Almost Certain	3	Minor	$11,111,111	Tolerable
Lack of investors interest	4	Reasonably Possible	6	Serious	$10,694,444	Tolerable
Reduce interest in project by potential investors	4	Reasonably Possible	6	Serious	$10,694,444	Tolerable
Inadequate support design for development navigation through known fault	3	Unlikely	6	Serious	$7,638,889	Tolerable
Inadequate support design for development navigation through unknown structures	3	Unlikely	6	Serious	$7,638,889	Tolerable
Inadequate design for unknown areas	2	Rare	6	Serious	$4,583,333	Tolerable
Inadequate mine design	2	Rare	6	Serious	$4,583,333	Tolerable
Relocation of locals	3	Unlikely	2	Insignificant	$2,083,333	Very Low
Total					**$159,166,667**	
Average	**4**	**Reasonably Possible**	**5**	**Moderate**	**$9,362,745**	**Tolerable**
Min	**2**	**Rare**	**2**	**Insignificant**	**$2,083,333**	**Very Low**
Max	**8**	**Almost certain**	**8**	**Severe**	**$42,222,222**	**Very High**

Table 35: Inherent exposure from highest to lowest for the new area given no controls.

Risk Description	**Inherent Likelihood**		**Inherent Consequence**		**Inherent Exposure (In Dollars)**	**Inherent Rating**
Encroaching community	9	Certain	9	Catastrophic	$49,845,679	Very High
Relocation of locals	9	Certain	9	Catastrophic	$49,845,679	Very High
Insufficient geotechnical classification of shaft areas	8	Almost Certain	8	Severe	$42,222,222	Very High
Not enough knowledge of geological structures	8	Almost Certain	8	Severe	$42,222,222	Very High
More unknown Geological structures	8	Almost Certain	8	Severe	$42,222,222	Very High
Inadequate support design for development navigation through un-known structures	6	Likely	8	Severe	$29,027,778	Very High
Reduce interest in project by potential investors	6	Likely	8	Severe	$29,027,778	Very High
Lack of investors interest	6	Likely	8	Severe	$29,027,778	Very High
Inadequate mine design	8	Almost Certain	7	Major	$28,888,889	High
Re-design and scheduling with limited time period	8	Almost Certain	6	Serious	$24,444,444	High
Quality of additional work to be conducted within a tighter time framework of lower standard	8	Almost Certain	6	Serious	$24,444,444	High
Insufficient time to complete the project	8	Almost Certain	6	Serious	$24,444,444	High
Inadequate design for unknown areas	6	Likely	6	Serious	$16,805,556	High
Time delay of project in terms of capital payback period	6	Likely	6	Serious	$16,805,556	High
Not enough professional time available	6	Likely	6	Serious	$16,805,556	High
Quality of work already performed not adequate	2	Rare	8	Severe	$7,916,667	High
Inadequate support design for development navigation through known fault	2	Rare	6	Serious	$4,583,333	Tolerable
Inadequate modified design to avoid fault intersection	2	Rare	2	Insignificant	$1,250,000	Very Low
Total					**$479,830,247**	
Average	**6**	**Likely**	**7**	**Major**	**$26,657,236**	**High**
Min	**2**	**Rare**	**2**	**Insignificant**	**$1,250,000**	**Very Low**
Max	**9**	**Certain**	**9**	**Catastrophic**	**$49,845,679**	**Very High**

In all instances, the new area rated higher except for the shaft infrastructure design, which is regarded as a high-risk category due to the vicinity of the identified fault. The community scored a very high priority rating for the new area.

The overall rating for the current area scored as Tolerable Risk at an estimated US$159M. The new area rated as High risk and had a considerably larger cost association of US$480M.

The next step is to identify where to apply preventative and corrective control actions in order to mitigate or relieve the identified risks. This resulted in residual risk ratings, which are given in Tables 36 and 37.

The applied controls lowered the risk ratings for both areas (residual risk rating), with the current area being reduced to a low risk rating with a financial consideration of US$63M, and the new area to a Tolerable risk rating of US$186M.

This was however, a good indication that the current area would still prove the least risky option and therefore the better option. It should be mentioned that the risk here is driven more by economic factors than social or health factors and will therefore relate to less risky in terms of the most financially viable approach and the most suitable timing for the products entering the commodity markets.

Table 38 and 39 gives the risk action plans devised for both areas.

The purpose of having such a plan is to assist management in monitoring and reviewing the status of the controls and ensuring its effectiveness. The control description is normally as per the team suggestion and can be elaborated upon by the responsible person once the action plan is put in place. The control type states the suggested management approach of the threat identified. In some instances preventative control is either not possible or is considered unpractical. Control status that are “New”, “To review” and “To Plan” should be given priority in terms of managing the risks as these measures therefore either still need to be planned for, or the current measures has proven to be less effective and needs to be reviewed, or new action plans need to be put in place.

It is important to note that for such a plan to be effective it requires that the risk register be updated if there are any changes to the risk and that the cost of controls be reviewed regularly as this may influence capital requirements.

Table 36: Residual exposure from highest to lowest for the current area given effectiveness of controls

Risk Description	Residual Exposure (In Dollars)	Prevention Control	Correction Control	Residual Likelihood		Residual Consequence		Residual Rating
More unknown Geological structures	$14,777,778	Marginal (30%)	Qualified (50%)	6	Likely	5	Moderate	High
Encroaching community	$10,888,889	Marginal (30%)	None (0%)	6	Likely	4	Modest	Tolerable
Lack of investors interest	$5,347,222	Qualified (50%)	None (0%)	2	Rare	6	Serious	Tolerable
Insufficient geotechnical classification of shaft areas	$4,618,056	Marginal (30%)	Qualified (50%)	2	Rare	5	Moderate	Low
Inadequate modified design to avoid fault intersection	$3,958,333	Qualified (50%)	None (0%)	1	Exceptionally Rare	8	Severe	High
Quality of additional work to be conducted within a tighter time framework of lower standard	$2,777,778	Qualified (50%)	Qualified (50%)	5	Possible	2	Insignificant	Very Low
Not enough knowledge of geological structures	$2,770,833	Effective (70%)	Qualified (50%)	2	Rare	5	Moderate	Low
Reduce interest in project by potential investors	$2,673,611	Qualified (50%)	Qualified (50%)	2	Rare	3	Minor	Low
Time delay of project in terms of capital payback period	$2,430,556	Marginal (30%)	None (0%)	2	Rare	3	Minor	Low
Not enough professional time available	$2,430,556	Marginal (30%)	None (0%)	2	Rare	3	Minor	Low
Quality of work already performed not adequate	$2,375,000	Effective (70%)	None (0%)	1	Exceptionally Rare	8	Severe	High
Inadequate support design for development navigation through known fault	$1,909,722	Qualified (50%)	Qualified (50%)	2	Rare	3	Minor	Low
Inadequate support design for development navigation through un-known structures	$1,909,722	Qualified (50%)	Qualified (50%)	2	Rare	3	Minor	Low
Inadequate mine design	$1,145,833	Qualified (50%)	Qualified (50%)	1	Exceptionally Rare	3	Minor	Low
Inadequate design for unknown areas	$1,145,833	Qualified (50%)	Qualified (50%)	1	Exceptionally Rare	3	Minor	Low
Relocation of locals	$1,041,667	Qualified (50%)	None (0%)	2	Rare	2	Insignificant	Very Low
Insufficient time to complete the project	$729,167	Effective (70%)	Marginal (30%)	1	Exceptionally Rare	2	Insignificant	Very Low
Re-design and scheduling with limited time period	$437,500	Effective (70%)	Qualified (50%)	1	Exceptionally Rare	2	Insignificant	Very Low
Total	**$63,368,056**							
Average	**$3,520,448**	**Qualified (50%)**	**Qualified (50%)**	**2**	**Rare**	**4**	**Modest**	**Low**
Min	**$437,500**	**Marginal (30%)**	**None (0%)**	**1**	**Exceptionally Rare**	**2**	**Insignificant**	**Very Low**
Max	**$14,777,7778**	**Effective (70%)**	**Qualified (50%)**	**6**	**Likely**	**8**	**Severe**	**Very High**

Table 37: Residual exposure from highest to lowest for the new area given effectiveness of controls.

Risk Description	Residual Exposure	Prevention Control	Correction Control	Residual Likelihood		Residual Consequence		Residual Rating
Encroaching community	$34,891,975	Marginal (30%)	None (0%)	6	Likely	9	Catastrophic	Very High
Relocation of locals	$24,922,839	Qualified (50%)	None (0%)	5	Possible	9	Catastrophic	Very High
More unknown Geological structures	$19,000,000	Deficient (10%)	Qualified (50%)	7	Highly Likely	5	Moderate	High
Insufficient geotechnical classification of shaft areas	$14,777,778	Marginal (30%)	Qualified (50%)	6	Likely	5	Moderate	High
Lack of investors interest	$14,513,889	Qualified (50%)	None (0%)	3	Unlikely	8	Severe	High
Time delay of project in terms of capital payback period	$11,763,889	Marginal (30%)	None (0%)	4	Reasonably Possible	6	Serious	Tolerable
Not enough professional time available	$11,763,889	Marginal (30%)	None (0%)	4	Reasonably Possible	6	Serious	Tolerable
Inadequate mine design	$10,111,111	Marginal (30%)	Qualified (50%)	6	Likely	4	Modest	Tolerable
Inadequate support design for development navigation through un-known structures	$7,256,944	Qualified (50%)	Qualified (50%)	3	Unlikely	5	Moderate	Tolerable
Reduce interest in project by potential investors	$7,256,944	Qualified (50%)	Qualified (50%)	3	Unlikely	5	Moderate	Tolerable
Not enough knowledge of geological structures	$6,333,333	Effective (70%)	Qualified (50%)	3	Unlikely	5	Moderate	Tolerable
Quality of additional work to be conducted within a tighter time framework of lower standard	$6,111,111	Qualified (50%)	Qualified (50%)	5	Possible	3	Minor	Low
Insufficient time to complete the project	$5,133,333	Effective (70%)	Marginal (30%)	3	Unlikely	4	Modest	Low
Inadequate design for unknown areas	$4,201,389	Qualified (50%)	Qualified (50%)	3	Unlikely	3	Minor	Low
Re-design and scheduling with limited time period	$3,666,667	Effective (70%)	Qualified (50%)	3	Unlikely	3	Minor	Low
Quality of work already performed not adequate	$2,375,000	Effective (70%)	None (0%)	1	Exceptionally Rare	8	Severe	High
Inadequate support design for development navigation through known fault	$1,145,833	Qualified (50%)	Qualified (50%)	1	Exceptionally Rare	3	Minor	Low
Inadequate modified design to avoid fault intersection	$625,000	Qualified (50%)	None (0%)	1	Exceptionally Rare	2	Insignificant	Very Low
Total	**$185,850,926**							
Average	**$10,325,051**	**Qualified (50%)**	**Qualified (50%)**	**4**	**Reasonably Possible**	**5**	**Moderate**	Tolerable
Min	**$625,000**	**Deficient (10%)**	**None (0%)**	**1**	**Exceptionally Rare**	**2**	**Insignificant**	**Very Low**
Max	**$34,891,975**	**Effective (70%)**	**Qualified (50%)**	**7**	**Highly Likely**	**9**	**Catastrophic**	**Very High**

Table 38: Wesizwe Shaft Positioning - current area risk control action plan.

Profile Risk										Profile Consequence (Impact)	Profile Control			
Profile Name	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/ Impact	Control Description	Type	Responsible	Status
Time	Time delay of project in terms of capital payback period	3 Unlikely	3 Minor	Low	Marginal (30%)	None (0%)	2 Rare	3 Minor	Low	Financial impact	No control	Corrective	N/A	N/A
											Use more consultants	Preventive	Mine Manager	To Plan
											Expediting of project	Preventive	Project Manager	To Plan
											Increase production at start -up	Corrective	Mine Manager	To Plan
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Investment	Lack of investors interest	4 Reasonably Possible	6 Serious	Tolerable	Qualified (50%)	None (0%)	2 Rare	6 Serious	Tolerable	Decrease in money availability from investors for additional work	No control	Corrective		
	Reduce interest in project bypotential investors	4 Reasonably Possible	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	2 Rare	3 Minor	Low	Financial impact	Communication strategy	Preventive	Project Manager	New
											Communication strategy	Corrective	Project Manager	New
											Investor relations strategy	Preventive	Public relations	To Plan
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Quality	Quality of work already performed not adequate	2 Rare	8 Severe	High	Effective (70%)	None (0%)	1 Exceptionally Rare	8 Severe	High	Financial impact	No control	Corrective		
	Quality of additional work to be conducted within a tighter time framework of lower standard	8 Almost Certain	3 Minor	Tolerable	Qualified (50%)	Qualified (50%)	5 Possible	2 Insignificant	Very Low	Safety impact	Stricter control of work outcomes	Preventive	Technical manager	Existing
											Third party consultants	Preventive	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Geological Structures	More unknown Geological structures	8 Almost Certain	8 Severe	Very High	Marginal (30%)	Qualified (50%)	6 Likely	5 Moderate	High	Safety impact	No control	Corrective		
	Not enough knowledge of geological structures	4 Reasonably Possib	8 Severe	High	Effective (70%)	Qualified (50%)	2 Rare	5 Moderate	Low	Financial impact	Employing more competent technical staff	Preventive	Mineral resources manager	Existing
										Time impact	More detailed geotechnical studies	Preventive	Engineering geologist	To Plan
											More resources	Corrective	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
Profile Name	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Shaft Infrastructure	Inadequate modified design to avoid fault intersection	2 Rare	8 Severe	High	Qualified (50%)	None (0%)	1 Exceptionally Rare	8 Severe	High	Financial impact	No control	Corrective		
	Inadequate design for unknown areas	2 Rare	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	1 Exceptionally Rare	3 Minor	Low	Safety impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
Profile Name	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Support design	Inadequate support design for development navigation through known fault	3 Unlikely	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	2 Rare	3 Minor	Low	Time impact	No control	Corrective		
	Inadequate support design for development navigation through un-known structures	3 Unlikely	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	2 Rare	3 Minor	Low	Safety impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
										Financial impact	More resources	Corrective	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Mine design	Inadequate mine design	2 Rare	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	1 Exceptionally Rare	3 Minor	Low	Safety impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
	Re-design and scheduling with limited time period	2 Rare	4 Modest	Low	Effective (70%)	Qualified (50%)	1 Exceptionally Rare	2 Insignificant	Very Low	Time impact	Additional third party consultants	Preventive	Planner	New
											More resources	Corrective	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Geotechnical ratings	Insufficient geotechnical classification of shaft areas	3 Unlikely	8 Severe	High	Marginal (30%)	Qualified (50%)	2 Rare	5 Moderate	Low	Financial impact	Geotechnical QAQC	Preventive	Chief rock engineer & Chief geologist	Existing
										Safety impact	SHE Plan	Corrective	SHE project manager	To Review
	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Community	Encroaching community	8 Almost Certain	4 Modest	Tolerable	Marginal (30%)	None (0%)	6 Likely	4 Modest	Tolerable	Financial impact	No control	Corrective		
	Relocation of locals	3 Unlikely	2 Insignificant	Very Low	Qualified (50%)	None (0%)	2 Rare	2 Insignificant	Very Low		Negotiations with local community	Preventive	Project Manager	Existing
											Communication with DME	Preventive	Environmental manager	Existing

Table 39: Wesizwe Shaft Positioning – proposed new area risk control action plan.

Profile Risk										Profile Consequence (Impact)	Profile Control			
Profile Name	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/ Impact	Control Description	Type	Responsible	Status
Time	Time delay of project in terms of capital payback period	6 Likely	6 Serious	High	Marginal (30%)	None (0%)	4 Reasonably Possible	6 Serious	Tolerable	Financial impact	Use more consultants	Preventive	Mine Manager	To Plan
	Not enough professional time available	6 Likely	6 Serious	High	Marginal (30%)	None (0%)	4 Reasonably Possible	6 Serious	Tolerable		Expediting of project	Preventive	Project Manager	To Plan
	Insufficent time to complete the project	8 Almost Certain	6 Serious	High	Effective (70%)	Marginal (30%)	3 Unlikely	4 Modest	Low		Increase production at start -up	Corrective	Mine Manager	To Plan
Investment	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Lack of investors interest	6 Likely	8 Severe	Very High	Qualified (50%)	None (0%)	3 Unlikely	8 Severe	High	Decrease in money availability from investors for additional work	Communication strategy	Corrective	Project Manager	New
	Reduce interest in project bypotential investors	6 Likely	8 Severe	Very High	Qualified (50%)	Qualified (50%)	3 Unlikely	5 Moderate	Tolerable	Financial impact	Investor relations strategy	Preventive	Public relations	To Plan
Quality	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Quality of work already performed not adequate	2 Rare	8 Severe	High	Effective (70%)	None (0%)	1 Exceptionally Rare	8 Severe	High	Financial impact	Stricter control of work outcomes	Preventive	Technical manager	Existing
	Quality of additional work to be conducted within a tighter time framework of lower standard	8 Almost Certain	6 Serious	High	Qualified (50%)	Qualified (50%)	5 Possible	3 Minor	Low	Safety impact	Third party consultants	Preventive	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
Geological Structures	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	More unknown Geological structures	8 Almost Certain	8 Severe	Very High	Deficient (10%)	Qualified (50%)	7 Highly Likely	5 Moderate	High	Safety impact	Employing more competent technical staff	Preventive	Mineral resources manager	Existing
	Not enough knowledge of geological structures	8 Almost Certain	8 Severe	Very High	Effective (70%)	Qualified (50%)	3 Unlikely	5 Moderate	Tolerable	Financial impact	More detailed geotechnical studies	Preventive	Engineering geologist	To Plan
										Time impact	More resources	Corrective	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
Shaft Infrastructure	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Inadequate design for unknown areas	6 Likely	6 Serious	High	Qualified (50%)	Qualified (50%)	3 Unlikely	3 Minor	Low	Financial impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
	Inadequate modified design to avoid fault intersection	2 Rare	2 Insignificant	Very Low	Qualified (50%)	None (0%)	1 Exceptionally Rare	2 Insignificant	Very Low	Safety impact	SHE Plan	Corrective	SHE project manager	To Review
Support design	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Inadequate support design for development navigation through un-known structures	6 Likely	8 Severe	Very High	Qualified (50%)	Qualified (50%)	3 Unlikely	5 Moderate	Tolerable	Safety impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
	Inadequate support design for development navigation through known fault	2 Rare	6 Serious	Tolerable	Qualified (50%)	Qualified (50%)	1 Exceptionally Rare	3 Minor	Low	Time impact	More resources	Corrective	HR	To Plan
										Financial impact	SHE Plan	Corrective	SHE project manager	To Review
Profile Name	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
Mine design	Inadequate mine design	8 Almost Certain	7 Major	High	Marginal (30%)	Qualified (50%)	6 Likely	4 Modest	Tolerable	Safety impact	Design policies and procedures	Preventive	Chief planner & Chief rock engineer	Existing
	Re-design and scheduling with limited time period	8 Almost Certain	6 Serious	High	Effective (70%)	Qualified (50%)	3 Unlikely	3 Minor	Low	Time impact	Additional third party consultants	Preventive	Planner	New
											More resources	Corrective	HR	To Plan
											SHE Plan	Corrective	SHE project manager	To Review
Geotechnical ratings	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Insufficient geotechnical classification of shaft areas	8 Almost Certain	8 Severe	Very High	Marginal (30%)	Qualified (50%)	6 Likely	5 Moderate	High	Financial impact	Geotechnical QAQC	Preventive	Chief rock engineer & Chief geologist	Existing
										Safety impact	SHE Plan	Corrective	SHE project manager	To Review
Community	Risk Description	Inherent Likelihood	Inherent Consequence	Inherent Rating	Prevention Control	Correction Control	Residual Likelihood	Residual Consequence	Residual Rating	Consequence/Impact	Control Description	Type	Responsible	Status
	Encroaching community	9 Certain	9 Catastrophic	Very High	Marginal (30%)	None (0%)	6 Likely	9 Catastrophic	Very High	Financial impact	No control	Corrective		
	Relocation of locals	9 Certain	9 Catastrophic	Very High	Qualified (50%)	None (0%)	5 Possible	9 Catastrophic	Very High		Negotiations with local community	Preventive	Project Manager	Existing
											Communication with DME	Preventive	Environmental manager	Existing

5.3 FINAL DECISION ON SHAFT POSITION

By using a very simple risk matrix, the risks for the current shaft positions and possible new positions were assessed.

For the area that has already been assessed the geological structures rated the highest and therefore contributes the most to the overall risk exposure after applying controls. The change from inherent and residual risk exposure can be seen in Figure 31 to 32. This was expected due to the close vicinity of the fault intersected at the northern boundary to the shaft area. Overall, the already assessed shaft position has a lower residual risk rating than the new postion.

For the proposed new area, the community rated highest, followed by geotechnical ratings and geological structures. The community is the main reason the shaft was sited at the current position, as it was the only suitable outside of the 800m radius. It was expected that as soon as this 800m was violated, that it would be one of the main priorities. Geological structures and geotechnical ratings rated high due to the vicinity of the project area to the Pilanesberg. The possibility of encountering a similar situation as present will be very high at any new location. The overall residual risk rating for the new proposed area is tolerable, but still has a far greater risk exposure than the current area.

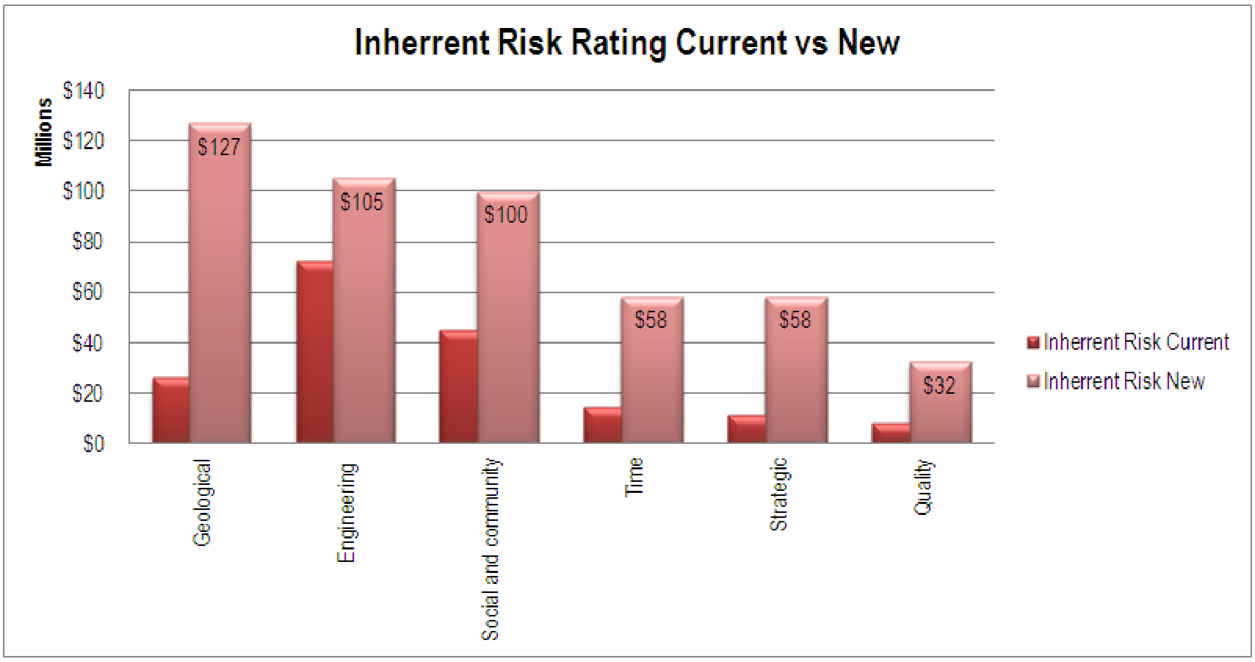


Figure 31: Inherrent risk ratings of the current vs new shaft positions.

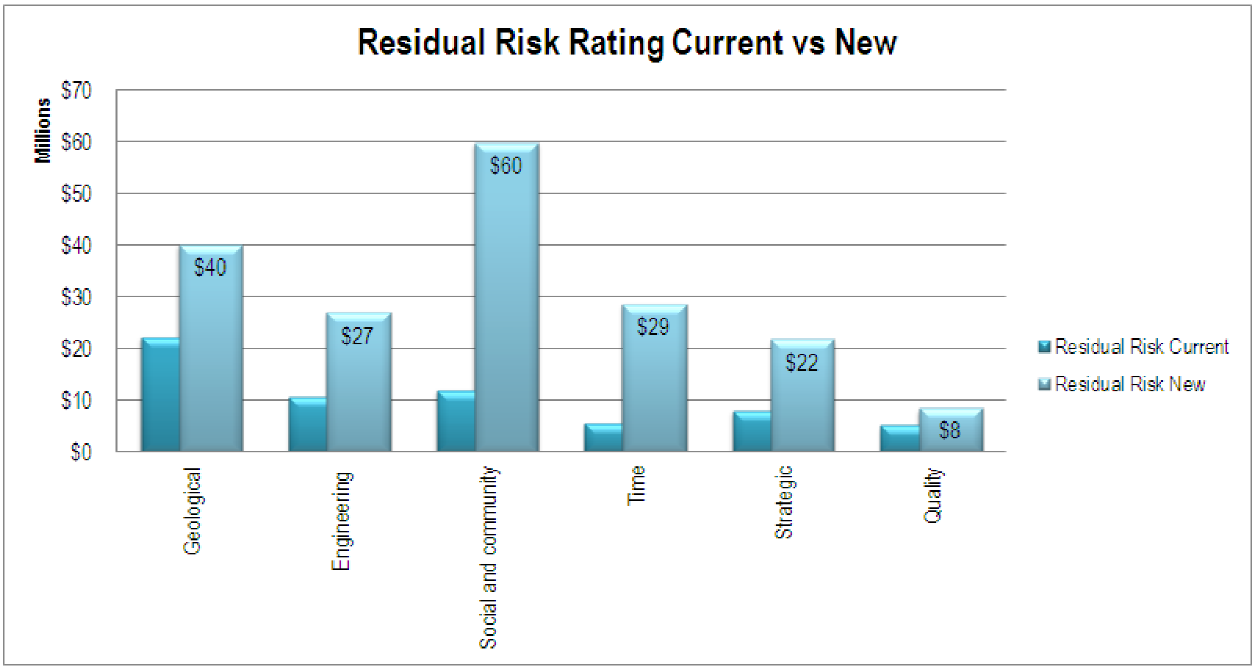


Figure 32: Inherrent risk ratings of the current vs new shaft positions.

Note that the risk rating was also somewhat skewed in favour of the current area, mainly due to the lack of information for the new area. It could very well have been that a new area would prove less of a risk once all the studies were completed. However, that said, the emphasis should then fall on the fact that all the studies that were already completed would have had to be repeated and would have a significant cost and timing implication for the project.

The total inherent and residual risk exposures for the curren and new positions are shown in Figures 33 and 31. By applying risk management controls to the new position the inherent risk of choosing a new area for placing the shaft the risk is lowered considerably from US$479,8 million to US$185,9 million, this is still significantly higher than the current positions residual risk of US$63,4 million.

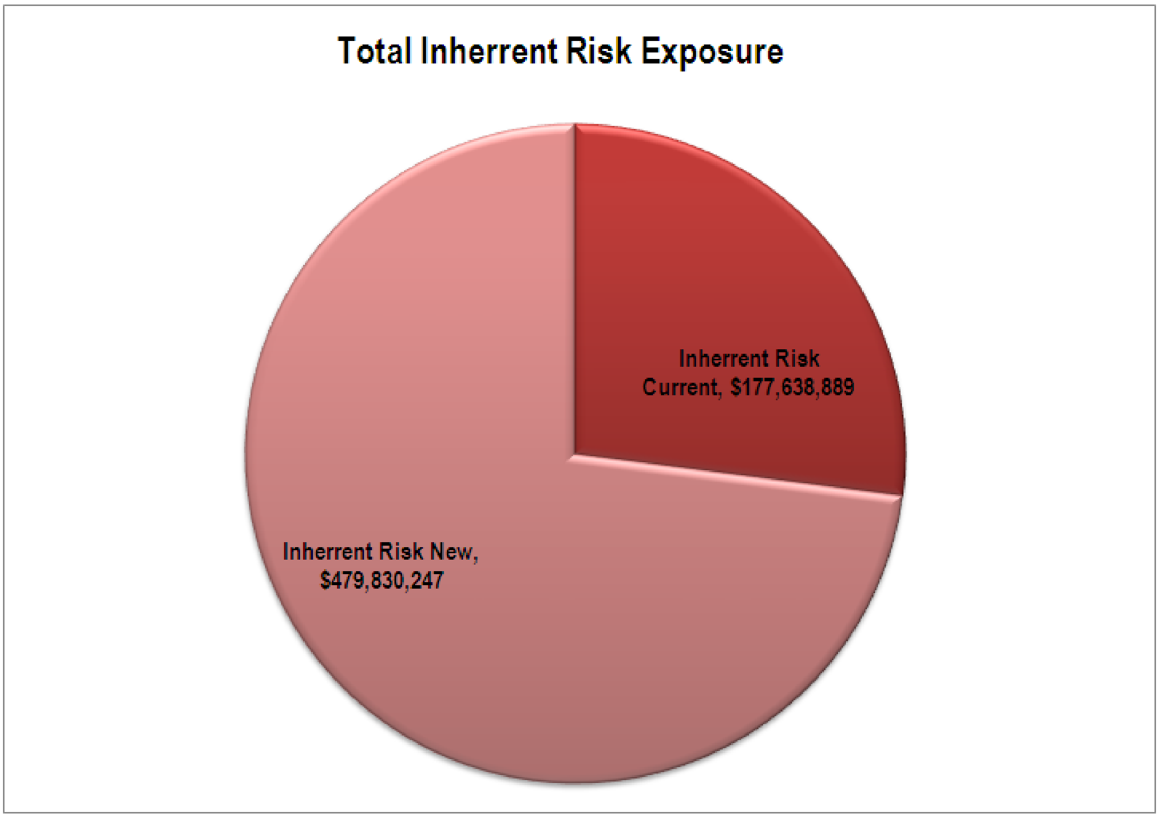


Figure 33: Total inherent risk rating of the current position vs. the new position.

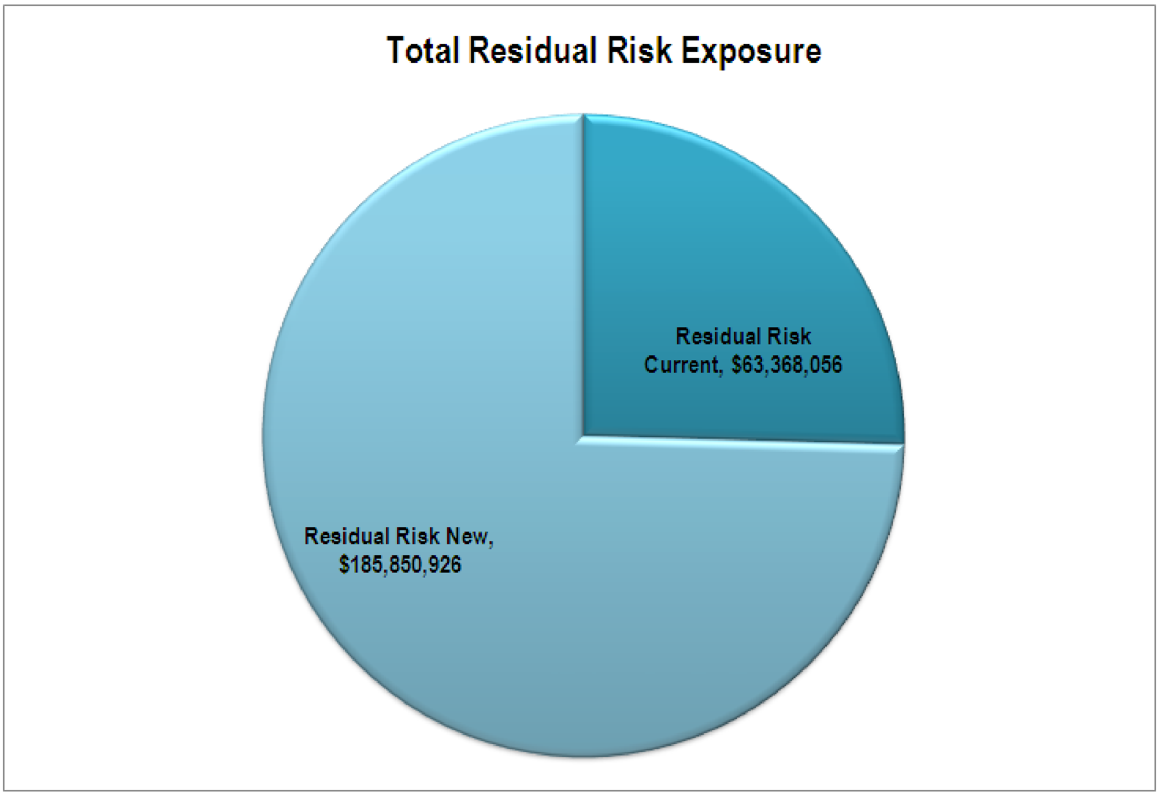


Figure 34: Total residual risk rating of the current position vs. the new position.

Due to the manageability of the risk posed by the current area it is clear that the current position is still considred the most favourable. Figure 35 and 36 also indicates some further aspects, which should be highlighted in terms of not only the risk, but also the time, cost, and quality factors associated with the placement.

Figure 35 was devised from the findings of this study and other similar projects by the author and indicates the typical knowledge levels aimed for during the concept to execution stages of a project such as the Wesizwe Ledig Platinum Project.

With increase in knowledge and movement down the mining value curve, it is assumed that the associated risk will decrease significantly. It can be seen that for various sections an already high level of knowledge is required regardless of the project stage. What is specifically of interest to this project is the seismic survey information under the “Geology and Mineral Resources” section that aims to achieve maximum knowledge at pre-feasibility level. For some this might seem extreme, but viewed in context it can be seen as one of the most crucial elements, since it forms the basis for the mine development and support design planning and consequently the operational and capital cost associated with the project.

Figure 36 was also derived by the author from this study and other similar projects. It focuses on the level at which the shaft positioning slots in, in terms of the stages indicated in Figure 35. Changing shaft positions at very late stages could be disastrous as the delays and reworking will amount to millions of dollars, not to mention the time and quality issues that will be associated with the repeated process which still runs the risk of not yielding significantly better results.

INCREASE IN KNOWLEDGE

Conceptual	Pre-Feasibility	Knowledge Area	Feasibility	Execution
		Project Scope Definition		
Low Level	Moderate Level	Strategic Intent	High Level	Very High Level
Very High Level	Very High Level	Scope Description	Very High Level	Very High Level
High Level	High Level	Multidisciplinery experienced team	High Level	Very High Level
Low Level	Moderate Level	Risk analysis	High Level	Very High Level
		Site Information		
Very High Level	Very High Level	Location	Very High Level	Very High Level
Low Level	Moderate Level	Infrastructure	Moderate Level	Very High Level
Very High Level	Very High Level	Geomorphology	Very High Level	Very High Level
Low Level	Moderate Level	Geotechnical Survey (structural foundation investigations and testwork)	Very High Level	Very High Level
Low Level	Very High Level	Land Survey	Very High Level	Very High Level
Very High Level	Very High Level	Tenure	Very High Level	Very High Level
Very High Level	Very High Level	Exploration Permit	Very High Level	Very High Level
Low Level	Low Level	Mining Licence	High Level	Very High Level
		Geology and Mineral Resources		
Very High Level	Very High Level	Regional Geology	Very High Level	Very High Level
Low Level	Low Level	Geochemical Survey	Moderate Level	Very High Level
Low Level	Very High Level	Geophysical Surveys	Very High Level	Very High Level
Low Level	Moderate Level	Drilling, logging, sampling, assay	High Level	Very High Level
Low Level	Moderate Level	Local Deposit Geology	Very High Level	Very High Level
Low Level	Moderate Level	Mineral Resource Model	High Level	Very High Level
Very High Level	Very High Level	Compliance SAMREC, JORC, NI 43-101	Very High Level	Very High Level
		Mining		
Low Level	Moderate Level	Mining Method	Moderate Level	Very High Level
Low Level	Moderate Level	Ore Reserves and Plant Feed	Moderate Level	Very High Level
Low Level	Moderate Level	Mine Plan, Layout, Infrastructure	Moderate Level	Very High Level
Low Level	Very High Level	Geotechnical/Rock Mechanics	Very High Level	Very High Level
Low Level	Moderate Level	Shaft Configuration	Moderate Level	Very High Level
Low Level	Moderate Level	Shaft Equipment	Moderate Level	Very High Level
Low Level	Moderate Level	Transportation System	Moderate Level	Very High Level
Low Level	Low Level	Trial Mining	Very High Level	Very High Level
		Process		
Low Level	Moderate Level	Plant Capacity	Moderate Level	Very High Level
Low Level	Moderate Level	Ore Characterisation	Moderate Level	Very High Level
Low Level	Moderate Level	Process Design	Moderate Level	Very High Level
Low Level	Moderate Level	Equipment Specification	Moderate Level	Very High Level
Low Level	Moderate Level	Bench and Pilot Tests	Very High Level	Very High Level
		Infrastructure		
Low Level	Moderate Level	Logistics	High Level	Very High Level
Low Level	Moderate Level	Utilities	High Level	Very High Level

Figure 35: Project execution flow.

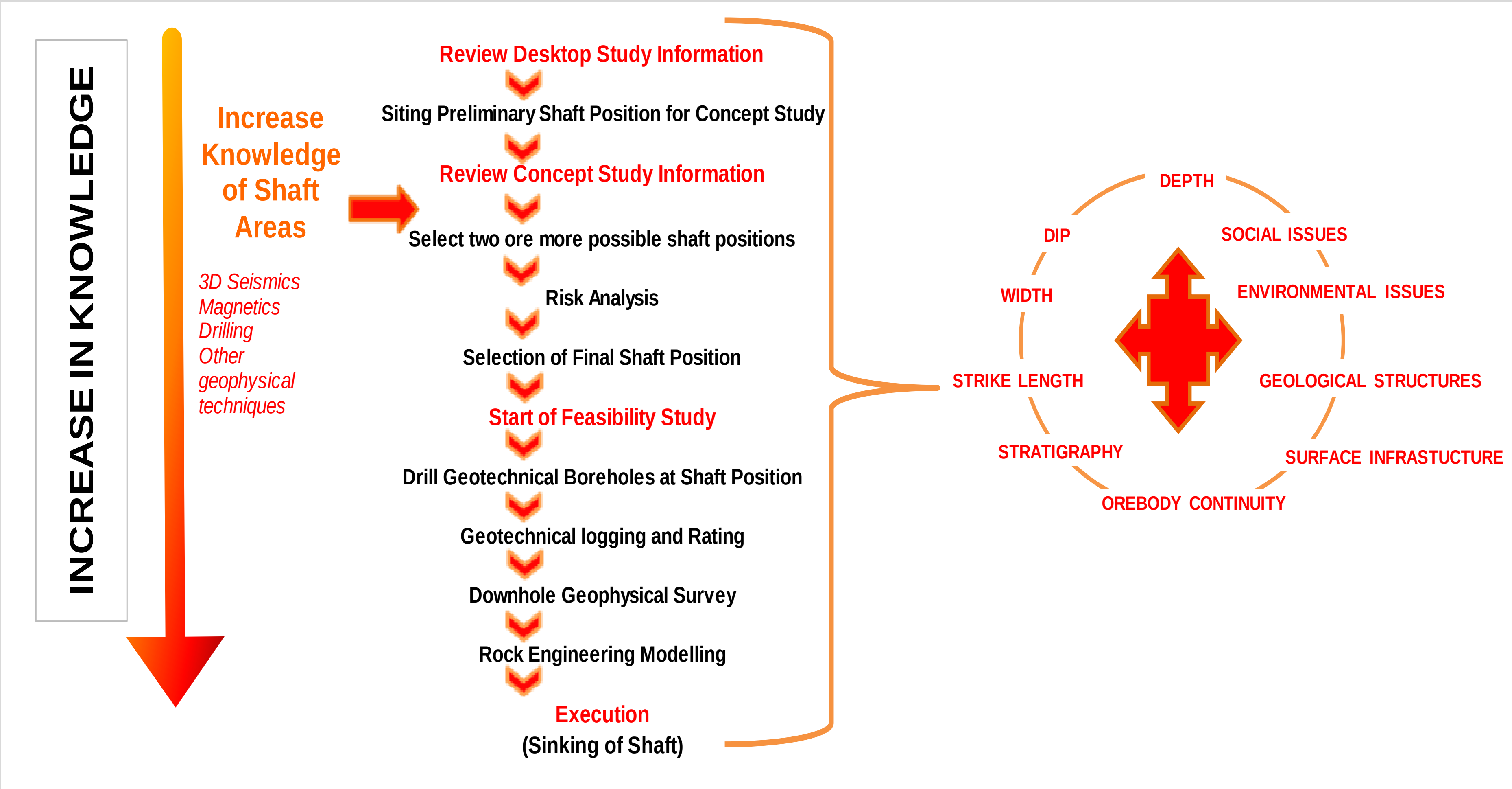


Figure 36: Shaft positioning methodology.

6 CONCLUSIONS AND RECOMMENDATIONS

A fault within 50m north of the sited position for the Main and Ventilation shafts of the Wesizwe Platinum Project was identified by a seismic survey on the lease area. Geotechnical logging and analysis of the boreholes drilled at the Main and Ventilation shaft positions was conducted to determine whether the fault affected the shaft postions. Logging determined that the fault did not intersect either of the positions, and that the rockmass charcteristics rated the overall rock conditions as good to very good. Dolerite and Lamprophyre dykes, sills and IRUP's are more of a concern. These are however, intersected by 90%+ of the geological boreholes drilled and are considered common to the lease area.

Seismic survey information was further utilised to determine the projected line of intersection in depth and boreholes were identified which possibly could have intersected the fault. These boreholes were re-logged geologically and geotechnically to establish the actual intersections in depth and to determine the radius of effect. The fault was found to be highly destructive, and commonly associated with doleritic and/or lamprhyric sills. It was determined that the vertical distance between this intersection and the Merensky reef horizon varied between 24m and 58m and that it could possibly intersect the major shaft infrastructure planned for the Main shaft. This was mitigated by mine design and infrastructure in the west was swinged around the shaft barrel to be situated in the east.

A team of technical experts was then asked to review the geotechnical analysis in conjunction with all the information available for the lease area. These experts formed part of a trade-off workshop to review the risk associated with the current shaft postion against the risk with choosing a new position and start the process from the beginning. It was found that mitigating the current situation was a better solution than moving the shaft position to a position most likely just as affected by structure, but also resulting in relocation of the community and a vast amount of re-engineering.

The Ledig Village is estimated to have a population of approximately 15 000 people (Ringhdahl, 2003). Costs associated with the relocation of just a third of the community were estimated to amount to approximately US$ 20 or more. The total risk exposure for this was estimated at US$60 million. Costs together with a delay in the project, and additional study costs would have been detrimental to the project success.

By using all the available information, a decision was reached that, the current shaft position was the most favourable and that the risks accompanying the sinking and development of the shafts in this area could be managed appropriately.

It has however also become very clear that the process of shaft siting is not conducted with the necessary background and care as one would expect for such a costly exercise. Various studies are reliant on the shaft positions and revolve around this very important issue. Studies affected would include the development and stoping planning and scheduling, geotechnical and rock engineering studies, shaft and building infrastructure, environmental impact studies and even the techno-economic modelling. These all account for the size of the capital footprint and subsequently the Nett Present Value (NPV) of an underground mining project such as the Wesizwe Ledig Platinum Project. The studies going from concept to feasibility stage typically take up to five years once the inferred mineral resource has been defined, and a delay at any stage could easily add one to two years to the life of a project. Not only will this affect the timing of the mine's first production reaches the market, but it also has an influence in initial capital expenditure, as consultants, contractors and staff have to be paid by investors' money.

To put a bit of perspective on the work upfront the focus should turn to the project financials. The Wesizwe Ledig Platinum Project was evaluated at the time of the study to generate a nominal NPV of US$1.2 billion at a discount rate of 5% (Wesizwe, 2008 a+b). This was a very conservative estimate with platinum estimated at a flat curve of US$1125/oz. This also included the exploration and feasibility study costs as part of the capital expenditure, which was budgeted at a total of US$681 million. Exploration costs (including seismics and drilling) contributed US$30 million toward this estimate, which is a mere 4.4% of the total Capital cost. This work not only defines your total mineble asset, but also the ground conditions to be encountered in terms of access to the orebody. Failure in safely accessing your mineral asset will result in failure of your entire project.

Being penny wise and pound foolish is therefore not an option and from the experience gained with this project, a flow diagram was derived (Figure 36) to assist with shaft siting for new platinum projects, assuming the project is executed as indicated in Figure 35. It should be noted that some of the areas indicated require a high level of knowledge, regardless of the stage of the project. It is crucial that updated information concerning the orebody geology, as well as social and environmental issues continue to play a part during all the phases of positioning the shaft. In platinum mines where the reefs are shallow dipping, the 3D seismic information is extremely valuable in accessing the final shaft location, and it is recommended that it be done no later than the period between the concept and feasibility studies thus, during the Pre-feasibility stages.

It is not suggested that 3D-seismics is the most reliable or only sure method of determining disturbances in the reef, but when these studies are appropriate and planned it should be at a suitable time in the study life cycle. Where terrain, reef properties or budget constraints do not allow for it, alternative methods should be considered. These methods include additional drilling at higher resolution in the capital footprint area, magnetic surveys, other geophysical techniques such as borehole radar, and additional geotechnical characterisation work. The emphasis is on increasing the geological knowledge for your shaft acces area, and the importance of shaft placement in the study phases.

One can argue that exploration work is a large investment for a project, for which no guarantee yet exists, but one should be aware that every step in exploration is value adding in terms of the mineral resource. In the case of platinum projects enough is known about the Merensky and UG2 ore bodies to know with certainty whether these reefs do exist at a selected location, and normally the main issue arising would be in terms of how to mine it. Not only will shaft positioning be conducted with better background, but also various unnecessary changes of scope could be avoided.

It is crucial that project managers for these types of projects have substantial experience and know which issues to be aware of. Shaft positioning seems to be pertinent and should be highlighted from the initial phases involving all the technical skill from the onset. Risk assessment exercises like the one in this study should be conducted and used as a decision making tool. The project teams should also be given ownership of the risks raised and be held accountable for the management thereof. With time, it will become standard procedure during project studies and could lead to better, more efficient initial shaft positioning practices.

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APPENDIX A (Geological Logs of Shafts)

Table 39 and 40 give the geological logs for the Main and Ventilation shafts as done by the Wesizwe exploration geologists.

Table 40: Geological Logs of the Main Shaft Borehole.

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL _MAJOR	COL _MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_ CBA	BOTTOM	BC _CBA	STRAT	REMARKS
MAIN#	D0	0.0	4.4	1	4.4	SOIL	B		M		COL		BRK			Black turf
MAIN#	D0	4.4	8.0	1	3.7	SAP	W	BR	FM		BRK		BRK			
MAIN#	D0	8.0	14.2	1	6.2	GN	GR	BR	MC		BRK		BRK			Highly oxidised
MAIN#	D0	14.2	14.8	1	0.6	MOTAN	W		C	MOT	BRK		GRAD			
MAIN#	D0	14.8	19.4	1	4.6	MGN	DGR	BR	FC		BRK		GRAD			
MAIN#	D0	19.4	46.1	1	26.7	GN	GR	W	FM		GRAD		GRAD			
MAIN#	D0	26.3	26.5	2	0.2	INT	B	GR	FM		INT	50	INT	55		
MAIN#	D0	28.3	28.3	2	0.1	INT	B	GR	FM		INT	75	INT	77		
MAIN#	D0	32.5	32.5	2	0.0	INT	B	GR	FM		INT	60	INT	60		
MAIN#	D0	38.6	39.1	2	0.5	IRUP	GRN	B	CVC	PG	GRAD		GRAD			
MAIN#	D0	46.1	67.6	1	21.6	LGN	W	GRN	FC	EQ	GRAD		GRAD			
MAIN#	D0	48.5	48.5	2	0.1	INT	B	GR	FM		INT	55	INT	55		
MAIN#	D0	56.7	57.4	2	0.7	INT	B	GR	FM		SI		INT	15		
MAIN#	D0	67.6	82.7	1	15.1	MGN	DGR	BR	FM		GRAD		GRAD			
MAIN#	D0	72.7	73.4	2	0.7	LGN	W	BR	FC	EQ	S	60	GRAD			
MAIN#	D0	75.6	75.7	2	0.1	INT	B	GR	FM		INT	50	INT	50		
MAIN#	D0	82.7	88.6	1	5.8	LGN	W	BRS	FC	EQ	GRAD		GRAD			
MAIN#	D0	88.6	132.4	1	43.9	GN	BR	W	FC		GRAD		GRAD			With bands of Anorthosites in places
MAIN#	D0	89.1	89.1	2	0.0	PYX	GR	BR	F		S	90	GRAD			
MAIN#	D0	90.1	90.8	2	0.7	IRUP	GRN	GR	MC	PGS	GRAD		GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_MAJOR	COL_MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_CBA	BOTTOM	BC_CBA	STRAT	REMARKS
MAIN#	D0	95.8	95.8	2	0.1	INT	B	GR	F		INT	65	INT	65		
MAIN#	D0	96.9	97.1	2	0.3	INT	B	GR	F		INT	70	INT	75		
MAIN#	D0	99.7	100.1	2	0.3	INT	B	GR	F		INT	80	INT	82		
MAIN#	D0	102.8	102.9	2	0.1	INT	B	GR	FM		INT	55	INT	50		
MAIN#	D0	107.1	107.2	2	0.1	INT	B	GR	FM		INT	40	INT	35		
MAIN#	D0	120.0	121.1	2	1.1	IRUP	W	BR	CVC	PG	GRAD		GRAD			
MAIN#	D0	130.0	130.5	2	0.4	INT	B	GR	F		INT	30	INT	70		
MAIN#	D0	130.7	131.7	2	1.1	IRUP	W	BR	CVC	PG	GRAD		GRAD			
MAIN#	D0	132.4	158.5	1	26.1	MGN	DGR	BR	FM		GRAD		GRAD			With bands of Anorthosites in places
MAIN#	D0	141.0	141.4	2	0.4	INT	B	GR	F		INT	70	INT	60		
MAIN#	D0	144.1	144.2	2	0.2	INT	B	GR	F		INT	90	INT	90		
MAIN#	D0	147.3	147.8	2	0.5	INT	B	GR	FM		INT	70	INT	75		
MAIN#	D0	158.5	210.8	1	52.3	GN	GR	BR	FC	PORPH	GRAD		GRAD		PCN	
MAIN#	D0	171.6	172.2	2	0.6	RPEG	W	BR	CVC	PG	GRAD		GRAD			
MAIN#	D0	185.4	187.3	2	1.9	INT	B	GR	FM		INT	85	INT	85		
MAIN#	D0	210.8	229.7	1	18.9	MGN	DGR	BR	VFM		GRAD		GRAD			
MAIN#	D0	216.4	216.8	2	0.5	INT	B	GR	FM		INT	65	INT	65		
MAIN#	D0	217.0	217.1	2	0.0	INT	B	GR	FM		INT	60	INT	65		
MAIN#	D0	219.7	220.2	2	0.5	INT	B	GR	FM		INT	75	INT	80		
MAIN#	D0	229.7	262.1	1	32.4	GN	GR	W	FM		GRAD		GRAD			
MAIN#	D0	251.6	251.9	2	0.3	INT	B	GR	FM		INT	80	INT	90		
MAIN#	D0	258.8	261.1	2	2.2	IRUP	W	GRN	CVC	PG	GRAD		GRAD			
MAIN#	D0	261.3	262.0	2	0.7	INT	B	GR	FM		INT	50	INT	45		
MAIN#	D0	262.1	270.7	1	8.6	LGN	W	GRN	FC	EQ	GRAD		GRAD			
MAIN#	D0	270.7	287.9	1	17.2	MGN	DGR	OW	FM		GRAD		GRAD			Blebs of M.GN in places
MAIN#	D0	286.1	287.7	2	1.6	LAMP	BR		M		INT	5	INT	5		
MAIN#	D0	287.9	288.5	1	0.6	MOTAN	GRNS	W	CVC	MOT	GRAD		GRAD		STM	
MAIN#	D0	288.5	295.3	1	6.8	LGN	P	GR	FC	EQ	GRAD		GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL _MAJOR	COL _MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_ CBA	BOTTOM	BC _CBA	STRAT	REMARKS
MAIN#	D0	295.3	314.5	1	19.2	GN	BR	W	FC		GRAD		GRAD			
MAIN#	D0	314.5	317.8	1	3.3	LGN	W	GRN	MC		GRAD		GRAD			
MAIN#	D0	317.8	342.6	1	24.8	MGN	DGR	GRN	FM		GRAD		GRAD			
MAIN#	D0	342.6	351.3	1	8.7	LGN	W	GRN	FC	EQ	GRAD		GRAD			
MAIN#	D0	351.3	441.1	1	89.8	GN	GR	W	FM		GRAD		GRAD			
MAIN#	D0	363.4	364.0	2	0.5	INT	B	GR	FM		INT	75	INT	70		
MAIN#	D0	429.4	430.4	2	0.9	INT	B	GR	FM		INT	90	INT	65		
MAIN#	D0	432.7	433.3	2	0.6	INT	B	GR	FM		INT	55	INT	60		
MAIN#	D0	441.1	457.0	1	15.9	LGN	W	BR	FC	EQ	GRAD		GRAD			
MAIN#	D0	445.7	445.7	2	0.1	PYX	GR	BR	FM		S	90	S	90		
MAIN#	D0	451.3	453.4	2	2.1	INT	B	GR	FM		INT	90	INT	90		
MAIN#	D0	457.0	476.7	1	19.7	MGN	DGR	BR	FM		GRAD		GRAD			
MAIN#	D0	459.5	460.8	2	1.2	INT	B	GR	FM		INT	65	INT	75		
MAIN#	D0	476.7	490.6	1	13.9	LGN	P	GR	MC	EQ	GRAD		GRAD			
MAIN#	D0	477.7	477.8	2	0.1	INT	B	GR	FM		INT	82	INT	78		
MAIN#	D0	478.9	479.1	2	0.2	INT	B	GR	FM		INT	55	BRK			
MAIN#	D0	490.6	534.5	1	43.9	MGN	DGR	BR	VFM		GRAD		GRAD			
MAIN#	D0	499.4	500.2	2	0.9	INT	B	GR	FM		INT	75	INT	80		
MAIN#	D0	512.2	512.3	2	0.1	INT	B		F		INT	80	INT	77		
MAIN#	D0	534.5	549.5	1	15.0	LGN	P	GR	FC	EQ	GRAD		GRAD			
MAIN#	D0	547.1	548.2	2	1.0	INT	B	GR	F		INT	65	INT	85		
MAIN#	D0	549.5	586.6	1	37.1	MGN	DGR	P	FM		GRAD		GRAD			
MAIN#	D0	566.7	567.1	2	0.4	INT	B	GR	FM		INT	90	INT	75		
MAIN#	D0	583.0	583.3	2	0.3	INT	B	GR	FM		SI		SI			
MAIN#	D0	586.6	613.4	1	26.8	SPMTAN	P	GR	MVC	SPOTMOT	GRAD		GRAD			
MAIN#	D0	588.9	588.9	2	0.1	INT	GR	B	FM		INT	70	INT	60		
MAIN#	D0	613.4	643.7	1	30.4	LGN	P	GR	MC	EQ	GRAD		GRAD			
MAIN#	D0	643.7	687.8	1	44.1	SPMTAN	P	GR	CVC	SPOTMOT	GRAD		GRAD		HW5	
MAIN#	D0	649.5	649.6	2	0.1	INT	B	GR	F		INT	70	INT	80		
MAIN#	D0	671.5	671.6	2	0.1	INT	B	GR	FM		INT	75	INT	75		
MAIN#	D0	687.8	700.3	1	12.5	SPOTAN	P	GR	CVC	SPOT	GRAD		GRAD		HW4	
MAIN#	D0	694.8	696.5	2	1.7	INT	B	GR	FM		INT	65	INT	85		

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL _MAJOR	COL _MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_ CBA	BOTTOM	BC _CBA	STRAT	REMARKS
MAIN#	D0	698.0	698.2	2	0.2	INT	GR	B	FM		INT	35	INT	40		
MAIN#	D0	699.8	700.1	2	0.3	INT	GR	B	FM		INT	30	INT	30		
MAIN#	D0	700.3	711.6	1	11.3	MOTAN	P	GR	CVC	MOT	GRAD		GRAD		HW3	
MAIN#	D0	711.6	716.9	1	5.3	LN	W	BR	FC	EQ	GRAD		GRAD		HW2	
MAIN#	D0	716.0	716.2	2	0.2	INT	GR	B	FM		INT	90	INT	85		
MAIN#	D0	716.9	719.8	1	2.9	N	DGR	BR	FM		GRAD		GRAD		HW1	
MAIN#	D0	719.8	724.5	1	4.7	FPYX	GR	BR	FM		GRAD		SI		BR	
MAIN#	D0	724.5	724.5	1	0.0	CR	B		F	STR	SI		SI		BR	
MAIN#	D0	724.5	728.1	1	3.6	MOTAN	P	GR	CVC	MOT	SI		GRAD		MID3	
MAIN#	D0	728.1	734.3	1	6.2	LN	P	GR	MC	EQ	GRAD		GRAD		MID2	
MAIN#	D0	734.3	738.0	1	3.7	N	DGR	W	FM		GRAD		GRAD		MID1	
MAIN#	D0	738.0	739.9	1	1.9	FPYX	GR	BR	FM		GRAD		SI		MP	
MAIN#	D0	739.9	739.9	1	0.0	CR	B		F	STR	SI		SI		MTC	
MAIN#	D0	739.9	740.6	1	0.6	PEGFPYX	BR	W	CVC	PG	SI		GRAD		MPEG	
MAIN#	D0	740.6	741.3	1	0.7	TROCT	GRN	GR	MVC	PGS	GRAD		S	50	MPEG	
MAIN#	D0	741.3	741.3	1	0.0	CR	B		M	STR	S	50	S	50	MBC	
MAIN#	D0	741.3	746.9	1	5.6	MOTAN	P	GR	CVC	MOT	S	50	GRAD		FW1	
MAIN#	D0	743.0	743.2	2	0.2	INT	B	GR	FM		INT	40	INT	30		
MAIN#	D0	746.9	750.0	1	3.1	LN	W	GR	MC	EQ	GRAD		GRAD		FW3	
MAIN#	D0	748.5	749.2	2	0.7	INT	GR		M	PORPH	INT	60	BRK			
MAIN#	D0	750.0	750.8	1	0.8	MOTAN	P	GR	CVC	MOT	GRAD		GRAD		FW4	
MAIN#	D0	750.8	754.3	1	3.5	LN	W	BR	FC	EQ	GRAD		SI		FW5	
MAIN#	D0	754.3	754.3	1	0.0	AN	W		F		SI		S	70	FW6	
MAIN#	D0	754.3	754.3	1	0.0	CR	B		F	STR	S	70	S	57	FW6	
MAIN#	D0	754.3	772.6	1	18.3	OLVN	GRN	W	FC	EQ	S	57	GRAD		FW7	
MAIN#	D0	765.6	766.5	2	0.9	INT	B	GR	FM	PORPH	INT	75	INT	80		
MAIN#	D0	767.6	772.6	2	5.0	RPEG	W	BR	CVC	PG	GRAD		GRAD			With some disseminated Cr
MAIN#	D0	772.6	773.0	1	0.4	HARZ	GRN	B	FC		GRAD		GRAD		FW10	
MAIN#	D0	773.0	774.3	1	1.3	RPEG	BR	GR	CVC	PG	GRAD		GRAD		PR	
MAIN#	D0	774.3	777.9	1	3.7	FPYX	GR	BR	FM		GRAD		S	90	UG2HWP	

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL _MAJOR	COL _MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_ CBA	BOTTOM	BC _CBA	STRAT	REMARKS
MAIN#	D0	777.9	777.9	1	0.0	CR	B		F	STR	S	90	S	90	UG2T3	
MAIN#	D0	777.9	778.5	1	0.6	FPYX	GR	BR	FM		S	90	S	80		
MAIN#	D0	778.5	778.6	1	0.1	CR	B		F	BND	S	80	S	85	UG2T2	
MAIN#	D0	778.6	778.7	1	0.1	FPYX	GR	BR	FM		S	85	S	90		
MAIN#	D0	778.7	778.8	1	0.2	CR	B		F	BND	S	90	S	90	UG2T1	
MAIN#	D0	778.8	778.9	1	0.0	FPYX	GR	BR	FM		S	90	S	80		
MAIN#	D0	778.9	778.9	1	0.1	CR	B		F	BND	S	80	S	85	UG2L	
MAIN#	D0	778.9	779.2	1	0.2	FPYX	GR	BR	FM		S	85	S	80		
MAIN#	D0	779.2	779.7	1	0.6	CR	B		F	MAS	S	80	SI		UG2	
MAIN#	D0	779.7	779.8	1	0.1	PEGFPYX	GR	BR	MVC	PG	SI		SI		UG2FWPEG	
MAIN#	D0	779.8	779.9	1	0.0	CR	B		F	STR	SI		SI			
MAIN#	D0	779.9	785.8	1	6.0	LN	W	BR	FC	EQ	SI		S	55	UG2FWN	Slightly mottled in places
MAIN#	D0	785.8	785.8	1	0.0	CR	B		F	STR	S	55	S	55		
MAIN#	D0	785.8	785.9	1	0.0	FPYX	GR	BR	FM		S	55	S	65		
MAIN#	D0	785.9	785.9	1	0.0	CR	B		F	STR	S	65	S	70		
MAIN#	D0	785.9	795.3	1	9.5	FPYX	GR	BR	VFM		S	70	S	85	UG1HWP	
MAIN#	D0	795.3	796.4	1	1.1	CR	B		FM	MAS	S	85	SI		UG1	With some Pyx waste
MAIN#	D0	796.4	797.6	1	1.2	FPYX	GR	BR	FC		SI		SI			
MAIN#	D0	797.6	797.9	1	0.3	CR	B		F	MAS	SI		SI		UG1	
MAIN#	D0	797.9	798.4	1	0.5	FPYX	GR	BR	FM		SI		S	65		
MAIN#	D0	798.4	798.5	1	0.1	CR	B		F	BND	S	65	SI			
MAIN#	D0	798.5	815.6	1	17.1	LN	W	BR	FVC	EQ	SI		S	65	UG1FWA	
MAIN#	D0	815.6	824.5	1	9.0	N	DGR	BR	FM		S	65	GRAD			
MAIN#	D0	818.3	821.4	2	3.1	RPEG	W	GR	CVC	PG	GRAD		GRAD			
MAIN#	D0	824.5	830.9	1	6.4	RPEG	W	GRN	CVC	PG	GRAD		GRAD			
MAIN#	D0	830.9	859.1	1	28.2	N	DGR	BR	FM		GRAD		GRAD			
MAIN#	D0	838.6	839.4	2	0.9	INT	B	GR	FM		INT	90	INT	85		
MAIN#	D0	859.1	877.7	1	18.7	LN	W	BR	FC		GRAD		GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL _MAJOR	COL _MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_ CBA	BOTTOM	BC _CBA	STRAT	REMARKS
MAIN#	D0	877.7	890.7	1	13.0	N	DGR	BR	VFM		GRAD		GRAD			
MAIN#	D0	890.7	919.3	1	28.6	LN	W	BR	FVC	EQ	GRAD		GRAD			M.Norite in places
MAIN#	D0	899.5	900.7	2	1.2	RPEG	W	GRN	CVC	PG	GRAD		GRAD			
MAIN#	D0	919.3	961.7	1	42.4	N	DGR	BR	VFF		GRAD		GRAD			
MAIN#	D0	934.3	937.7	2	3.3	LAMP	BR		M		INT	5	INT	15		
MAIN#	D0	942.4	942.6	2	0.3	INT	B	GR	FM		BRK		INT	72		
MAIN#	D0	947.1	947.4	2	0.3	INT	B	GR	FM		INT	75	INT	70		
MAIN#	D0	947.7	947.9	2	0.2	INT	B	GR	FM		INT	30	INT	60		
MAIN#	D0	961.7	962.5	1	0.8	FPYX	GR	BR	FM		S	85	S	80		
MAIN#	D0	962.5	963.4	1	0.8	CR	B		M	MAS	S	85	S	80		
MAIN#	D0	963.4	964.6	1	1.3	FPYX	GR	BR	FM		S	80	SI			
MAIN#	D0	964.6	965.7	1	1.1	CR	B		M	MAS	SI		SI			
MAIN#	D0	965.7	968.6	1	2.9	LN	W	BR	M	LAY	SI		GRAD			
MAIN#	D0	968.6	968.8	1	0.1	CR	B		F	BND	GRAD		S	90		
MAIN#	D0	968.8	968.8	1	0.0	AN	W		F	STR	S	90	S	90		
MAIN#	D0	968.8	968.9	1	0.1	LN	W	GRNS	FM	LAY	S	90	GRAD			
MAIN#	D0	968.9	980.6	1	11.7	N	DGR	BR	VFF		GRAD		S	75		
MAIN#	D0	980.6	981.4	1	0.8	CR	B		M	MAS	S	75	S	85		mm faulting at the base
MAIN#	D0	981.4	981.8	1	0.4	AN	OW	BR	CVC	SMOT	S	85	S	75		
MAIN#	D0	981.8	982.0	1	0.1	LN	W	BR	M	EQ	S	75	GRAD			
MAIN#	D0	982.0	982.1	1	0.1	TROCT	GRN	W	FC		GRAD		GRAD			
MAIN#	D0	982.1	988.9	1	6.8	N	DGR	BR	VFF		GRAD		GRAD			
MAIN#	D0	988.9	997.9	1	9.0	FPYX	GR	BR	VFM		GRAD		S	90		
MAIN#	D0	997.9	998.3	1	0.4	CR	B		F	BND	S	90	S	80		
MAIN#	D0	998.3	1000.4	1	2.2	FPYX	GR	BR	FM		S	80	EOH			

Table 41: Geological Logs of the Ventilation Shaft Borehole

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	0.0	0.1	1	0.1	SOIL	B		C				BRK			
VENT#	D0	0.1	33.8	1	33.7	GN	GR	R	MC	PORPH			GRAD			With IRUP patches.
VENT#	D0	18.0	23.5	2	5.5	IRUP	GR	GRN	VC	PG			GRAD			
VENT#	D0	24.1	25.3	2	1.1	IRUP	GR	GRN	VC	PG			GRAD			
VENT#	D0	25.8	25.9	2	0.1	INT	B		VF	PG	IR		IR			Dolerite dyke.
VENT#	D0	26.7	26.9	2	0.2	MOTAN	W	BR	VC	MOT			GRAD			
VENT#	D0	27.0	27.5	2	0.5	IRUP	GR	GRN	VC	PG			GRAD			
VENT#	D0	28.6	29.0	2	0.4	MOTAN	W	BR	VC	MOT			GRAD			
VENT#	D0	30.7	31.2	2	0.4	IRUP	GR	GRN	VC	PG			GRAD			
VENT#	D0	33.8	36.0	1	2.3	LGN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	36.0	36.2	1	0.2	IRUP	GR	BR	VC	PG			GRAD			
VENT#	D0	36.2	43.3	1	7.1	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	43.3	45.4	1	2.2	IRUP	BR	GR	VC	PG			GRAD			
VENT#	D0	45.4	49.5	1	4.1	LGN	GR	BR	C	SSPOT	S	55	S	55		
VENT#	D0	47.4	47.6	2	0.3	INT	B		VF	PORPH	S	55	S	55		Dolerite dyke.
VENT#	D0	49.5	52.0	1	2.5	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	51.1	51.5	2	0.5	IRUP	BR	GR	VC	PG			GRAD			
VENT#	D0	52.0	66.3	1	14.3	IRUP	BR	GR	VC	PG			GRAD			
VENT#	D0	66.3	77.8	1	11.5	LN	GR	B	C	PORPH			GRAD			With IRUP patches.
VENT#	D0	67.8	68.2	2	0.5	INT	B		VF	PORPH	S	60	S	60		Dolerite dyke.
VENT#	D0	77.4	77.6	2	0.1	INT	B		VF	PORPH	S	75	S	75		Dolerite dyke.
VENT#	D0	77.8	99.9	1	22.1	IRUP	BR	GR	VC	PG			GRAD			
VENT#	D0	83.8	84.0	2	0.2	INT	B		VF	PORPH	S	70	S	70		Dolerite dyke.
VENT#	D0	84.2	84.2	2	0.0	INT	B		VF	PORPH	IR		BRK			Dolerite

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
																dyke.
VENT#	D0	97.4	97.6	2	0.3	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	99.9	104.5	1	4.6	SPOTAN	W	BR	CVC	SPOT			GRAD			
VENT#	D0	104.5	183.8	1	79.3	IRUP	BR	GR	VC	PG			GRAD			
VENT#	D0	104.6	104.7	2	0.1	INT	B		VF	PORPH	S	65	S	65		Dolerite dyke.
VENT#	D0	115.1	115.3	2	0.2	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	115.3	115.5	2	0.1	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	117.8	117.9	2	0.1	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	120.6	120.8	2	0.2	INT	B		VF	PORPH	S	70	S	70		Dolerite dyke.
VENT#	D0	132.2	132.8	2	0.6	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	145.4	146.8	2	1.5	INT	B		VF	PORPH	S	15	S	15		Dolerite dyke.
VENT#	D0	161.0	161.2	2	0.2	INT	B		VF	PORPH	S	45	S	45		Dolerite dyke.
VENT#	D0	163.2	164.1	2	0.9	INT	B		VF	PORPH	S	65	S	65		Dolerite dyke.
VENT#	D0	176.9	177.1	2	0.1	INT	B		VF	PORPH	S	90	S	75		Dolerite dyke.
VENT#	D0	183.8	188.9	1	5.2	SPOTAN	W	BR	CVC	SPOT			GRAD			Partially disturbed.
VENT#	D0	184.8	184.9	2	0.0	INT	B		VF	PORPH	S	60	S	60		Dolerite dyke.
VENT#	D0	188.9	195.6	1	6.7	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	195.6	217.4	1	21.8	SPOTAN	W	BR	CVC	SPOT			GRAD			Partially disturbed.
VENT#	D0	211.7	211.8	2	0.1	INT	B		VF	PORPH	S	70	S	70		Dolerite dyke.

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	212.1	213.0	2	0.8	INT	B		VF	PORPH	S	55	S	65		Dolerite dyke.
VENT#	D0	213.7	213.8	2	0.1	INT	B		VF	PORPH	IR		IR			Dolerite dyke.
VENT#	D0	217.4	226.0	1	8.6	IRUP	GR	GRN	VC	PG			GRAD			
VENT#	D0	226.0	263.4	1	37.4	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	230.9	231.0	2	0.2	INT	GR		VF	PORPH	S	25	S	25		Dolerite dyke.
VENT#	D0	233.8	234.9	2	1.1	INT	GR		VF	PORPH	S	25	S	25		Dolerite dyke.
VENT#	D0	237.3	237.5	2	0.3	INT	GR		VF	PORPH	S	70	IR			Dolerite dyke.
VENT#	D0	263.4	275.4	1	12.1	LGN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	275.4	284.6	1	9.2	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	284.6	324.7	1	40.1	LGN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	288.9	289.5	2	0.6	INT	B		VF	PORPH	BRK		BRK			Dolerite dyke.
VENT#	D0	324.2	324.4	2	0.1	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	324.7	355.4	1	30.7	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	326.6	326.8	2	0.2	INT	B		VF	PORPH	S	90	S	90		Dolerite dyke.
VENT#	D0	348.5	349.1	2	0.6	INT	B		VF	PORPH			S			Dolerite dyke
VENT#	D0	355.4	370.0	1	14.6	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	370.0	370.9	1	0.9	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	370.9	376.7	1	5.8	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	376.7	378.8	1	2.1	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	378.8	379.2	1	0.4	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	379.2	379.7	1	0.6	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	379.7	384.4	1	4.6	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	384.4	385.0	1	0.7	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	385.0	386.0	1	0.9	GN	GR	BR	MC	PORPH			GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	386.0	390.3	1	4.4	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	390.3	404.2	1	13.9	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	398.3	398.4	2	0.0	INT	B		VF	PORPH			S	60		Dolerite dyke.
VENT#	D0	399.6	399.9	2	0.4	INT	B		VF	PORPH			S	65		Dolerite dyke.
VENT#	D0	404.2	404.9	1	0.7	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	404.4	404.7	2	0.2	INT	B		VF	PORPH			S	45		Dolerite dyke.
VENT#	D0	404.9	406.0	1	1.1	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	406.0	407.8	1	1.8	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	407.8	415.2	1	7.5	GN	GR	BR	MC	PORPH			GRAD			Disturbed.
VENT#	D0	415.2	415.9	1	0.7	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	415.9	416.1	1	0.1	LGN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	416.1	416.2	1	0.1	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	416.2	417.8	1	1.6	MGN	BR	GR	F	EQ			GRAD			
VENT#	D0	416.7	417.6	2	0.9	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	417.8	419.4	1	1.6	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	419.4	470.9	1	51.5	LGN	GR	BR	C	SSPOT			GRAD			Partially disturbed, with IRUP patches.
VENT#	D0	419.7	419.8	2	0.1	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	420.3	420.8	2	0.5	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	421.6	423.1	2	1.5	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	427.9	429.3	2	1.4	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	430.8	431.5	2	0.7	INT	B		VF	PORPH			GRAD			Dolerite dyke.
VENT#	D0	431.5	432.0	2	0.6	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	433.0	434.3	2	1.3	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	443.0	444.5	2	1.5	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	444.6	444.8	2	0.2	INT	B		VF	PORPH	IR		S	70		Dolerite dyke, with norite intrusions
VENT#	D0	445.6	445.8	2	0.2	IRUP	B	BR	VC	PG	S	70	S	70		
VENT#	D0	445.8	445.9	2	0.1	INT	GR		VF	PORPH			GRAD			Dolerite dyke.
VENT#	D0	450.5	451.0	2	0.4	INT	B		VF	PORPH	BRK		S	85		Dolerite dyke.
VENT#	D0	454.1	454.1	2	0.0	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	455.1	455.2	2	0.1	INT	B		VF	PORPH	BRK		S	75		Dolerite dyke.
VENT#	D0	455.4	461.7	2	6.2	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	470.9	479.0	1	8.1	GN	GR	BR	MC	PORPH			GRAD			
VENT#	D0	479.0	550.3	1	71.3	LGN	GR	BR	C	SSPOT			GRAD			With IRUP patches, disturbed.
VENT#	D0	487.0	496.3	2	9.3	IRUP	B	GR	VC	PG			GRAD			Grinded.
VENT#	D0	497.9	497.9	2	0.1	INT	B		VF	PORPH	S	75	S	75		Dolerite dyke.
VENT#	D0	498.3	499.1	2	0.8	INT	B		VF	PORPH	S	65	S	65		Dolerite dyke.
VENT#	D0	517.8	519.5	2	1.7	IRUP	GR	B	VC	PG			GRAD			
VENT#	D0	529.9	529.9	2	0.1	INT	B		VF	PORPH	S	70	S	70		Dolerite dyke.
VENT#	D0	530.5	531.2	2	0.7	INT	B		VF	PORPH	IR		IR			Dolerite dyke.
VENT#	D0	550.3	554.3	1	4.0	IRUP	GR	B	VC	PG			GRAD			
VENT#	D0	550.7	550.8	2	0.1	INT	B		VF	PORPH	S	90	S	90		Dolerite dyke.
VENT#	D0	552.0	552.0	2	0.0	INT	B		VF	PORPH	S	70	S	70		Dolerite dyke.
VENT#	D0	552.2	552.6	2	0.4	INT	B		VF	PORPH	S	85	IR			Dolerite

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
																dyke.
VENT#	D0	554.3	556.6	1	2.3	MOTAN	GR	B	VC	MOT			GRAD			
VENT#	D0	556.6	563.9	1	7.3	LN	GR	BR	C	SSPOT			GRAD			With IRUP patches.
VENT#	D0	563.9	564.5	1	0.6	MOTAN	P	GR	VC	MOT			GRAD			
VENT#	D0	564.5	565.1	1	0.6	LN	GR	BR	C	SPOT			GRAD			With IRUP patches.
VENT#	D0	565.1	565.6	1	0.5	MOTAN	P	GR	VC	MOT			GRAD			
VENT#	D0	565.6	578.6	1	13.0	LN	GR	BR	C	SPOT			GRAD			Disturbed, with IRUP patches.
VENT#	D0	570.7	570.8	2	0.2	INT	B		VF	PORPH	S	75	S	75		Dolerite dyke.
VENT#	D0	571.4	571.4	2	0.0	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	578.6	580.6	1	2.0	SPMTAN	W	GR	CVC	SPOT			GRAD			
VENT#	D0	580.6	586.8	1	6.2	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	586.8	587.4	1	0.6	SPMTAN	W	GR	CVC	SPOT			GRAD			
VENT#	D0	587.4	591.8	1	4.4	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	589.2	591.5	2	2.3	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	591.8	592.2	1	0.4	MOTAN	P	GR	VC	MOT			GRAD		SDM	
VENT#	D0	592.2	658.9	1	66.7	LN	GR	BR	C	SSPOT			GRAD		MZGN1	With IRUP patches, partially disturbed.
VENT#	D0	592.8	593.1	2	0.3	INT	B		VF	PORPH	S	90	S	90		Dolerite dyke.
VENT#	D0	594.3	594.4	2	0.1	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	597.7	600.5	2	2.8	IRUP	B	GR	VC	PG			GRAD			
VENT#	D0	607.0	607.1	2	0.1	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	611.1	611.8	2	0.7	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	619.9	622.3	2	2.4	IRUP	B	BR	VC	PG			GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	630.7	648.5	2	17.8	IRUP	B	BR	VC	PG			GRAD			
VENT#	D0	648.5	648.6	2	0.1	INT	B		VF	PORPH	S	80	S	80		Dolerite dyke.
VENT#	D0	658.9	696.7	1	37.8	SPOTAN	W	BR	CVC	SPOT			GRAD		HW5	
VENT#	D0	686.1	686.3	2	0.2	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	687.7	687.9	2	0.2	INT	B		VF	PORPH	S	25	S	25		Dolerite dyke, with norite bands.
VENT#	D0	688.7	689.4	2	0.6	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke, with norite bands.
VENT#	D0	693.0	693.2	2	0.2	INT	B		VF	PORPH	S	90	S	90		Dolerite dyke.
VENT#	D0	696.4	696.6	2	0.1	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	696.7	698.5	1	1.8	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	698.5	699.0	1	0.5	SPOTAN	W	BR	C	SPOT			GRAD		HW4	
VENT#	D0	698.8	698.9	2	0.1	INT	B		VF	PORPH	S	85	S	85		Dolerite dyke.
VENT#	D0	699.0	710.0	1	11.0	MOTAN	P	GR	VC	MOT			GRAD		HW3	
VENT#	D0	710.0	713.2	1	3.2	LN	BR	GR	C	SSPOT			GRAD		HW2	
VENT#	D0	712.2	712.6	2	0.4	IRUP	GR	BR	VC	PG			GRAD			
VENT#	D0	713.2	719.9	1	6.7	MN	BR	GR	F	EQ			GRAD		HW1	
VENT#	D0	719.9	722.8	1	2.9	FPYX	BR	GR	F	EQ			GRAD		BR	Cr stringer at bottom contact, with sulphides.
VENT#	D0	722.8	726.2	1	3.4	MOTAN	W	BR	VC	MOT			GRAD		MID3	
VENT#	D0	726.2	735.5	1	9.4	LN	GR	BR	C	SSPOT			GRAD		MID2	

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	735.5	736.5	1	1.0	MN	GR	BR	F	EQ			GRAD		MID1	Sulphide disseminati ons
VENT#	D0	736.5	739.2	1	2.7	FPYX	BR	GR	F	EQ			IR		MP	Core loss of 10cm.
VENT#	D0	739.2	739.2	1	0.0	CR	B		F	EQ			IR		MTC	
VENT#	D0	739.2	739.9	1	0.7	PEGPYX	BR	GR	VC	PG			GRAD		MPEG	Sulphide blebs.
VENT#	D0	739.9	740.0	1	0.1	TROCT	GRN	GR	CVC	PG			IR		MPEG	
VENT#	D0	740.0	740.0	1	0.0	CR	B		F	EQ			IR		MBC	
VENT#	D0	740.0	743.9	1	3.9	MOTAN	P	GR	VC	MOT			GRAD		FW1	Core loss of 10cm.
VENT#	D0	743.9	749.3	1	5.4	LN	GR	BR	C	SSPOT			GRAD		FW3	
VENT#	D0	749.3	750.1	1	0.8	MOTAN	P	GR	VC	MOT			GRAD		FW4	
VENT#	D0	750.1	752.4	1	2.3	LN	GR	BR	C	SSPOT			GRAD		FW5	
VENT#	D0	752.4	754.0	1	1.6	N	GR	BR	MC	PORPH			GRAD		FW5	
VENT#	D0	754.0	754.0	1	0.1	TROCT	GRN	GR	CVC	PG			IR		FW6	
VENT#	D0	754.0	754.0	1	0.0	CR	B		F	EQ			IR		FW6	
VENT#	D0	754.0	754.1	1	0.0	TROCT	GRN	GR	CVC	PG			GRAD		FW7	
VENT#	D0	754.1	755.3	1	1.2	LN	GR	BR	MC	PORPH			GRAD		FW7	Olivine rich.
VENT#	D0	755.3	756.0	1	0.7	N	GR	BR	MC	PORPH			S	70	FW7	Olivine rich, platy layering.
VENT#	D0	756.0	757.0	1	1.0	INT	B		VF	PORPH			S	75		Dolerite dyke.
VENT#	D0	757.0	764.7	1	7.7	N	GR	BR	MC	PORPH			S	40	FW7	Olivine rich.
VENT#	D0	764.7	765.2	1	0.5	INT	B		VF	PORPH			S	40		Dolerite dyke.
VENT#	D0	765.2	773.7	1	8.5	LN	GR	BR	C	SSPOT			GRAD		FW7	Olivine rich.
VENT#	D0	773.7	774.4	1	0.8	FPYX	BR	GR	F	EQ			GRAD		UG2HW P	With cr stringers.
VENT#	D0	774.4	774.8	1	0.4	PEGPYX	BR	B	VC	PG			IR		UG2HW P	

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	774.8	774.9	1	0.0	CR	B		F	EQ			IR		UG2HWP	
VENT#	D0	774.9	778.6	1	3.8	FPYX	BR	GR	F	EQ			S	70	UG2HWP	
VENT#	D0	778.6	778.7	1	0.1	CR	B		F	EQ			S	70	UG2T3	
VENT#	D0	778.7	778.8	1	0.1	FPYX	BR	GR	F	EQ			S	70		With cr disseminations.
VENT#	D0	778.8	778.9	1	0.1	CR	B		F	EQ			S	70	UG2T2	
VENT#	D0	778.9	779.0	1	0.1	FPYX	BR	GR	F	EQ			S	75		With cr disseminations.
VENT#	D0	779.0	779.1	1	0.1	CR	B		F	EQ			S	55	UG2T1	
VENT#	D0	779.1	779.3	1	0.2	FPYX	BR	GR	F	EQ			S	65		With cr disseminations.
VENT#	D0	779.3	780.0	1	0.7	CR	B		F	EQ			S	30	UG2	
VENT#	D0	780.0	780.0	1	0.1	AN	W	B	VF	BND			GRAD		UG2FWN	
VENT#	D0	780.0	784.1	1	4.1	LN	GR	BR	C	SSPOT			GRAD		UG2FWN	
VENT#	D0	784.1	784.2	1	0.1	AN	W	B	VF	BND			IR		UG2FWN	
VENT#	D0	784.2	784.2	1	0.0	CR	B		F	EQ			IR		UG1HWP	
VENT#	D0	784.2	784.2	1	0.1	FPYX	BR	GR	F	EQ			IR		UG1HWP	With cr disseminations.
VENT#	D0	784.2	784.3	1	0.0	CR	B		F	EQ			S	90	UG1HWP	
VENT#	D0	784.3	793.4	1	9.1	FPYX	BR	GR	F	EQ			S	90	UG1HWP	
VENT#	D0	793.4	793.6	1	0.2	CR	B		F	EQ			IR		UG1	
VENT#	D0	793.6	793.6	1	0.0	FPYX	BR	GR	F	EQ			IR			With cr bands.

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	793.6	794.3	1	0.6	CR	B		F	EQ			S	75	UG1	
VENT#	D0	794.3	794.3	1	0.1	FPYX	BR	GR	F	EQ			S	85		
VENT#	D0	794.3	794.4	1	0.1	CR	B		F	EQ			S	85	UG1	
VENT#	D0	794.4	795.9	1	1.5	FPYX	BR	GR	F	EQ			S	90		With cr disseminati ons and bands.
VENT#	D0	795.9	795.9	1	0.1	CR	B		F	EQ			S	90	UG1	
VENT#	D0	795.9	796.0	1	0.0	FPYX	BR	GR	F	EQ			S	85		
VENT#	D0	796.0	796.1	1	0.2	CR	B		F	EQ			S	85	UG1	
VENT#	D0	796.1	796.2	1	0.0	FPYX	BR	GR	F	EQ			S	85		
VENT#	D0	796.2	796.2	1	0.0	CR	B		F	EQ			GRAD		UG1	
VENT#	D0	796.2	796.4	1	0.2	INT	B		VF	PORPH			S	85		
VENT#	D0	796.4	798.0	1	1.6	MOTAN	P	GR	VC	MOT			GRAD		UG1FW A	With cr stringers and disseminati ons.
VENT#	D0	798.0	800.7	1	2.7	LN	GR	BR	C	SSPOT			GRAD			Grinded.
VENT#	D0	800.7	801.1	1	0.4	MOTAN	P	GR	VC	MOT			GRAD			
VENT#	D0	801.1	801.4	1	0.3	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	801.4	802.5	1	1.1	MOTAN	P	GR	VC	MOT			GRAD			
VENT#	D0	802.5	803.6	1	1.1	LN	GR	BR	C	SSPOT			BRK			
VENT#	D0	803.6	804.7	1	1.1	INT	GR	GRN	VF	PORPH			BRK			Dolerite dyke.
VENT#	D0	804.7	807.2	1	2.5	MOTAN	P	GR	VC	MOT			GRAD			
VENT#	D0	807.2	812.7	1	5.5	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	812.7	818.3	1	5.6	N	GR	BR	MC	PORPH			GRAD			
VENT#	D0	818.3	826.1	1	7.8	MN	BR	GR	F	EQ			GRAD			
VENT#	D0	826.1	826.3	1	0.2	N	GR	BR	MC	PORPH			GRAD			
VENT#	D0	826.3	828.4	1	2.1	MN	BR	GR	F	EQ			GRAD			
VENT#	D0	828.4	831.9	1	3.5	N	GR	BR	MC	PORPH			S	80		
VENT#	D0	831.9	832.7	1	0.9	INT	B		VF	PORPH			S	80		Dolerite

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
																dyke.
VENT#	D0	832.7	835.3	1	2.6	N	GR	BR	MC	PORPH			S	60		
VENT#	D0	835.3	835.4	1	0.1	INT	B		VF	PORPH			S	60		Dolerite dyke.
VENT#	D0	835.4	859.2	1	23.9	N	GR	BR	MC	PORPH			GRAD			
VENT#	D0	859.2	874.0	1	14.8	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	874.0	920.0	1	46.0	N	GR	BR	MC	PORPH			S	60		
VENT#	D0	920.0	920.1	1	0.1	INT	B		VF	PORPH			S	60		Dolerite dyke.
VENT#	D0	920.1	924.3	1	4.3	N	GR	BR	MC	PORPH			S	80		
VENT#	D0	924.3	924.6	1	0.3	INT	B		VF	PORPH			S	80		Dolerite dyke.
VENT#	D0	924.6	934.8	1	10.2	N	GR	BR	MC	PORPH			S	60		
VENT#	D0	934.8	935.1	1	0.4	INT	B		VF	PORPH			S	70		Dolerite dyke.
VENT#	D0	935.1	958.6	1	23.5	N	GR	BR	MC	PORPH			IR			
VENT#	D0	958.6	959.5	1	0.9	CR	B		F	EQ			IR			
VENT#	D0	959.5	960.8	1	1.4	FPYX	BR	GR	C	EQ			S	90		
VENT#	D0	960.8	961.9	1	1.1	CR	B		F	EQ			IR			
VENT#	D0	961.9	964.6	1	2.7	N	GR	B	MC	PORPH			S	85		Platy layering with cr disseminati ons.
VENT#	D0	964.6	964.8	1	0.2	CR	B		F	EQ			S	90		
VENT#	D0	964.8	964.9	1	0.1	AN	GR	GRN	VF	BND			GRAD			
VENT#	D0	964.9	976.2	1	11.3	N	GR	BR	MC	PORPH			S	75		
VENT#	D0	976.2	977.0	1	0.8	CR	B		F	EQ			S	60		
VENT#	D0	977.0	977.1	1	0.1	N	GR	BR	MC	PORPH			IR			
VENT#	D0	977.1	977.2	1	0.1	CR	B		F	EQ			IR			
VENT#	D0	977.2	977.2	1	0.1	N	GR	BR	MC	PORPH			GRAD			
VENT#	D0	977.2	977.7	1	0.5	LN	GR	BR	C	SSPOT			GRAD			
VENT#	D0	977.7	983.6	1	6.0	N	GR	BR	MC	PORPH			GRAD			

Sm_Unit_ID	Sm_Profile_ID	From	To	Type	WIDTH	ROCK	COL_ MAJOR	COL_ MINOR	GRAIN SIZE	TEXTURE	TOP_	TC_C BA	BOTTOM	BC_ CBA	STRAT	REMARKS
VENT#	D0	983.6	992.9	1	9.2	FPYX	BR	GR	F	EQ			S	80		
VENT#	D0	992.9	992.9	1	0.0	CR	B		F	EQ			S	80		
VENT#	D0	992.9	992.9	1	0.0	FPYX	BR	GR	F	EQ			S	80		
VENT#	D0	992.9	993.2	1	0.3	CR	B		F	EQ			S	80		With pyroxenite disseminati ons and bands.
VENT#	D0	993.2	1002.4	1	9.1	FPYX	BR	GR	F	EQ			EOH			

Stratigraphic columns for the Main and Ventilation Shafts were generated from these logs for the main reef areas and can be seen in Figure 37.

	Main Shaft Stratigraphy		From - To (m)	Thickness (m)
	HW5 (Anorthosite)		643.7-687.78	44.08
	HW4 (Anorthosite)		687.78-700.28	12.5
	HW3 (Anorthosite)		700.28- 711.6	11.32
	HW2 (Norite)		711.6-716.89	5.29
	HW1 (Norite)		716.89-719.75	2.86
	Bastard Reef (Pyroxenite)	4.7 m	719.75-724.471	4.72
	MID3 (Anorthosite)		724.471-728.07	3.599
15.4 m	MID2 (Norite)		728.07-734.31	6.24
	MID1 (Norite)		734.31-737.97	3.66
	Pyroxenite		739.97-739.88	1.91
	Merensky Reef (Pegmatoidal Feldspathic Pyroxenite)	1.4 m	739.88-741.28	1.4
	FW1 (Anorthosite)		741.28-746.91	5.63
	FW3 (Norite)		746.91-750	3.09
	Dyke		*748.46-749.17*	*0.71*
	FW3 (Norite)			
	FW4 (Anorthosite)		750-750.79	0.79
	FW5 (Norite)		750.79-754.31	3.52
36.6 m	FW6 (Anorthosite)		754.31-754.34	0.03
	FW7 (Pyroxenite)		754.34-772.59	18.25
	Dyke		*765.61-766.48*	*0.87*
	FW7 (Pyroxenite)			
	Replacement Pegmatoid		*767.59-772.58*	*4.99*
	FW7 (Pyroxenite)			
	FW10 (Pyroxenite)		772.59-773.01	0.42
	Replacement Pegmatoid		773.01-774.26	1.25
	UG2HW (Pyroxenite)		774.26-777.925	3.665
	UG2T3 (Chromitite)		777.925-777.93	0.005
	Pyroxenite		777.93-778.54	0.61
	UG2T2 (Chromitite)		778.54-778.605	0.065
	Pyroxenite		778.605-778.655	0.05
	UG2T1 (Chromitite)	1.8 m	778.655-778.81	0.155
	Pyroxenite		778.81-778.85	0.04
	UG2L (Chromitite)		778.85-778.93	0.08
	Pyroxenite		778.93-779.17	0.24
	UG2 (Chromitite)		779.17-779.73	0.56
	UG2FWPEG		779.73-779.835	0.105
	Chromitite		779.835-779.85	0.015
	UG2FWN (Norite)		779.85-785.83	5.98
15.6 m	Chromitite		785.83-785.845	0.015
	Pyroxenite		785.845-785.87	0.025
	Chromitite		785.87-785.88	0.01
	UG1HW (Pyroxenite)		785.88-795.34	9.46
	UG1 (Chromitite)		795.34-796.39	1.05
	Pyroxenite		796.39-797.61	1.22
	UG1 (Chromitite)		797.61-797.94	0.33
	Pyroxenite		797.94-798.39	0.45
	Chromitite		798.39-798.47	0.08
	UG1FW (Norite)		798.47-824.51	26.04
	Norite			
	Replacement Pegmatoid		*818.31-821.38*	*3.07*
	Norite			
	Replacement Pagmatoid		*824.51-830.86*	*6.35*
	Norite		830.86-859.05	28.19
	Dyke		*838.56-839.43*	*0.87*
	Norite		859.05-919.31	60.26
	Replacement Pegmatoid		*899.5-900.71*	*1.21*
	Norite		919.31-961.71	42.4
	Lamprophyre		*934.34-937.68*	3.34
	Norite			
	Pyroxenite		961.71-962.51	0.8
	Chromitite		962.51-963.35	0.84
	Pyroxenite		963.35-964.6	1.25
	Chromitite		964.6-965.73	1.13
	Norite		965.73-968.64	2.91
	Chromitite		968.64-968.77	0.13
	Anorthosite		968.77-968.79	0.02
	Norite		968.79-980.62	11.83
	Chromitite		980.62-981.39	0.77
	Anorthosite		981.39-981.83	0.44
	Norite		981.83-981.97	0.14
	Troctolite		981.97-982.05	0.08
	Norite		982.05-988.87	6.82
	Pyroxenite		988.87-997.86	8.99
	Chromitite		997.86-998.25	0.39
	Pyroxenite		998.25-1000.41	2.16

	Vent Shaft Stratigraphy		From - To (m)	Thickness (m)
	HW5 (Anorthosite)		658.92-696.67	37.75
	Dyke		*688.71-689.35*	*0.64*
	Norite		69667-698.49	1.82
	HW4 (Anorthosite)		698.49-699	0.51
	HW3 (Anorthosite)		699-709.96	10.96
	HW2 (Norite)		709.96-713.15	3.19
	IRUP		*712.24-712.61*	*0.37*
	HW1 (Norite)		713.15-719.87	6.72
	Bastard Reef (Pyroxenite)	2.92 m	719.87-722.79	2.92
	MID3 (Anorthosite)		722.79-726.17	3.38
16.41 m	MID2 (Norite)		726.17-735.53	9.36
	MID1 (Norite)		735.53-736.54	1.01
	Pyroxenite		736.54-739.2	2.66
	Merensky Reef (Pegmatoidal Feldspathic Pyroxenite)	0.83 m	739.2-740.02	0.825
	FW1 (Anorthosite)		740.025-743.89	3.865
	FW3 (Norite)		743.89-749.3	5.41
	FW4 (Anorthosite)		749.3-750.1	0.8
	FW5(Norite)		750.1-753.98	3.88
	FW6 (Pyroxenite)		753.98-754.04	0.06
	FW6 (Chromitite)			
38.62 m	FW7 (Pyroxenite)		754.04-754.06	0.02
	FW7 (Norite)		754.06-756	1.94
	Dyke		756-756.97	0.97
	FW7 (Norite)		756.97-764.68	7.71
	Dyke		764.68-765.19	0.51
	FW7 (Norite)		765.19-773.66	8.47
	UG2HW (Pyroxenite)		773.66-774.43	0.77
	UG2HW		774.43-774.84	0.41
	UG2HW (Chromitite)		774.84-774.86	0.02
	UG2HWP (Pyroxenite)		774.86-778.64	3.78
	UG2T3		778.64-778.7	0.06
	Pyroxenite		778.7-778.76	0.06
	UG2T2		778.76-778.9	0.14
	Pyroxenite		778.9-778.96	0.06
	UG2T1	1.34 m	778.96-779.05	0.09
	Pyroxenite		779.05-779.25	0.2
	UG2		779.25-779.98	0.73
	UG2FW (Anorthosite)		779.98-780.03	0.05
	UG2FW (Norite)		780.03-784.1	4.07
	UG2FW (Anorthosite)		784.1-784.18	0.08
13.41 m	UG1HW (Chromitite)		784.18-784.19	0.01
	UG1HW (Pyroxenite)		784.19-784.24	0.05
	UG1HW (Chromitite)		784.24-784.25	0.01
	UG1HW (Pyroxenite)		784.25-793.39	9.14
	UG1		793.39-793.58	0.19
	Pyroxenite		793.58-793.62	0.04
	UG1		793.62-794.25	0.63
	Pyroxenite		794.25-794.32	0.07
	UG1		794.32-794.42	0.1
	Pyroxenite		794.42-795.87	1.45
	UG1		795.87-795.94	0.07
			795.94-795.96	0.02
	UG1		795.96-796.12	0.16
	Pyroxenite		796.12-796.16	0.04
	UG1		796.16-796.2	0.04
	Dyke		796.2-796.38	0.18
	UG1FW (Anorthosite)		796.38-798.02	1.64
	Norite		798.02-800.71	2.69
	Anorthosite		800.71-801.06	0.35
	Norite		801.06-801.39	0.33
	Anorthosite		801.39-802.49	1.1
	Norite		802.49-803.63	1.14
	Dyke		803.63-804.69	1.06
	Anorthosite		804.69-807.22	2.53
	Norite		807.22-831.88	24.66
	Dyke		831.88-832.74	0.86
	Norite		832.74-835.31	2.57
	Dyke		835.31-835.36	0.05
	Norite		835.36-920	84.64
	Dyke		920-920.05	0.05
	Norite		920.05-924.3	4.25
	Dyke		924.3-924.58	0.28
	Norite		924.58-934.75	10.17
	Dyke		934.75-935.12	0.37
	Norite		935.12-958.59	23.47
	Chromitite		958.59-959.48	0.89
	Pyroxenite		959.48-960.84	1.36
	Chromitite		960.84-961.93	1.09
	Norite		961.93-964.59	2.66
	Chromitite		964.59-964.8	0.21
	Anorthosite		964.8-964.89	0.09
	Norite		964.89-976.16	11.27
	Chromitite		976.16-977	0.84
	Norite		977-977.1	0.1
	Chromitite		977.1-977.15	0.05
	Norite		977.15-983.64	6.49
	Pyroxenite		983.64-992.88	9.24
	Chromitite		992.88-992.89	0.01
	Pyroxenite		992.89-992.9	0.01
	Chromitite		992.9-993.24	0.34
	Pyroxenite		993.24-1002.37	9.13

Figure 37: Stratigraphy for the Main and Ventilation Shafts modified from raw data supplied by the Wesizwe geologists (not to scale).

APPENDIX B (Geotechnical data for shafts)

Table 42: Geotechnical data in depth for the Main Shaft borehole.

Rock Type	Depth	Spacing	RQD	Thickness	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
					Q Value	Description		Value	Class	Description		Value	Value
SAPROLITE	19.6	3.79	0%	19.62	0	Exceptionally Poor	0	27	IV	Poor rock,"Very poor rock	22	46	18
NORITE	32.2	0.40	93%	12.53	2	Poor	6	72	II	Good rock	67	75	51
DOLERITE	32.5	0.38	100%	0.36	10	Fair	25	77	II	Good rock	72	79	53
NORITE	38.3	0.54	92%	5.75	14	Good	34	77	II	Good rock	72	78	53
IRUP	39.0	0.40	100%	0.75	60	Very Good	150	77	II	Good rock	72	80	54
NORITE	48.5	0.37	93%	9.44	5	Fair	12	72	II	Good rock	67	77	52
DOLERITE	48.5	0.35	100%	0.01	20	Good	50	77	II	Good rock	72	78	53
NORITE	56.5	0.22	91%	8.08	3	Poor	8	72	II	Good rock	67	75	51
DOLERITE	57.3	0.34	100%	0.77	3	Poor	6	72	II	Good rock	67	78	53
NORITE	75.3	0.36	79%	17.96	0	Very Poor	1	49	III	Fair rock	44	63	42
DOLERITE	75.6	0.14	100%	0.36	20	Good	50	75	II	Good rock	70	77	52
NORITE	89.7	0.34	78%	14.03	3	Poor	7	69	II	Good rock	64	72	49
IRUP	90.5	0.35	100%	0.86	20	Good	50	77	II	Good rock	72	79	54
NORITE	95.9	0.36	83%	5.38	6	Fair	16	69	II	Good rock	64	75	51
DOLERITE	97.1	0.32	38%	1.22	3	Poor	7	60	III	Fair rock	55	65	44
NORITE	99.5	0.37	98%	2.38	7	Good	18	72	II	Good rock	67	78	53
DOLERITE	100.1	0.28	38%	0.58	6	Fair	14	60	III	Fair rock	55	68	46
NORITE	119.4	0.37	85%	19.36	4	Fair	11	77	II	Good rock	72	84	63
IRUP	121.0	0.32	100%	1.51	5	Fair	13	80	II	Good rock	75	81	61
NORITE	130.0	0.51	99%	9.00	10	Fair	25	80	II	Good rock	75	88	66
DOLERITE	130.3	0.15	90%	0.39	18	Good	45	80	II	Good rock	75	79	60
NORITE	130.6	0.23	100%	0.27	20	Good	50	85	I	Very good rock	80	86	65
IRUP	131.7	0.31	100%	1.06	20	Good	50	85	I	Very good rock	80	81	61
NORITE	143.9	0.36	94%	12.24	14	Good	35	80	II	Good rock	75	85	64
DOLERITE	144.2	0.30	100%	0.29	27	Good	67	85	I	Very good rock	80	87	65
NORITE	147.2	0.33	90%	3.00	7	Fair	17	77	II	Good rock	72	84	63
DOLERITE	147.8	1.11	100%	0.58	20	Good	50	90	I	Very good rock	85	91	68
NORITE	171.0	0.46	92%	23.17	2	Poor	5	80	II	Good rock	75	86	64
PEGMATIOD	172.1	0.23	100%	1.18	20	Good	50	80	II	Good rock	75	78	59
NORITE	185.3	0.37	98%	13.12	3	Poor	8	80	II	Good rock	75	86	64
DOLERITE	187.0	0.45	100%	1.73	20	Good	50	85	I	Very good rock	80	87	66
NORITE	216.2	0.48	98%	29.17	37	Good	37	80	II	Good rock	75	87	65
DOLERITE	216.4	0.71	100%	0.22	9	Fair	9	67	II	Good rock	62	80	60
NORITE	219.7	0.21	100%	3.31	19	Good	19	77	II	Good rock	72	78	59
DOLERITE	219.9	0.37	100%	0.18	50	Very Good	50	87	I	Very good rock	82	88	66
NORITE	251.6	0.35	92%	31.72	8	Fair	8	80	II	Good rock	75	85	64
DOLERITE	251.9	0.14	100%	0.33	50	Very Good	50	83	I	Very good rock	78	84	63
NORITE	258.7	0.45	98%	6.78	6	Fair	6	80	II	Good rock	75	86	65
IRUP	261.0	0.37	84%	2.34	84	Very Good	84	79	II	Good rock	74	78	59
NORITE	261.2	0.15	100%	0.16	50	Very Good	50	85	I	Very good rock	80	85	64
DOLERITE	262.0	0.40	100%	0.81	25	Good	25	80	II	Good rock	75	86	57
NORITE	285.2	0.22	80%	23.23	7	Fair	7	77	II	Good rock	72	81	61
LAMP	287.7	0.25	91%	2.43	4	Poor	4	72	II	Good rock	67	69	52
NORITE	287.8	0.38	100%	0.17	13	Good	13	80	II	Good rock	75	78	58
ANORTHOSITE	288.5	0.21	100%	0.66	38	Good	38	85	I	Very good rock	80	85	64
NORITE	363.3	0.31	85%	74.84	5	Fair	5	77	II	Good rock	72	83	63
DOLERITE	364.0	0.20	86%	0.65	43	Very Good	43	77	II	Good rock	72	84	63
NORITE	432.5	0.31	83%	68.49	7	Fair	7	77	II	Good rock	72	83	62
DOLERITE	433.3	0.24	84%	0.79	42	Very Good	42	84	I	Very good rock	79	84	63
NORITE	451.1	0.32	84%	17.84	2	Poor	2	77	II	Good rock	72	82	62
DOLERITE	452.7	0.47	100%	1.55	50	Very Good	50	85	I	Very good rock	80	86	65
NORITE	477.6	0.26	91%	24.96	8	Fair	8	80	II	Good rock	75	84	63
DOLERITE	477.8	0.09	0%	0.19	0	Exceptionally Poor	0	33	IV	Poor rock,"Very poor rock	28	59	44
NORITE	478.8	0.16	71%	0.98	3	Poor	3	68	II	Good rock	63	71	53
DOLERITE	479.0	0.11	90%	0.25	4	Poor	4	75	II	Good rock	70	72	54
NORITE	499.1	0.48	97%	20.02	8	Fair	8	80	II	Good rock	75	86	65
DOLERITE	500.1	0.43	100%	1.07	50	Very Good	50	87	I	Very good rock	82	88	66
NORITE	511.7	0.40	98%	11.58	12	Good	12	87	I	Very good rock	82	86	65
DOLERITE	513.3	0.70	98%	1.56	12	Good	12	85	I	Very good rock	80	87	65
NORITE	547.0	0.37	94%	33.73	8	Fair	8	80	II	Good rock	75	85	64
DOLERITE	548.0	0.16	77%	0.97	39	Good	39	75	II	Good rock	70	80	60
NORITE	566.2	0.42	94%	18.22	18	Good	18	80	II	Good rock	75	86	64
DOLERITE	567.1	0.66	94%	0.93	94	Very Good	94	90	I	Very good rock	85	87	66
NORITE	586.6	0.43	98%	19.51	11	Good	11	87	I	Very good rock	82	87	65
ANORTHOSITE	613.3	0.51	97%	26.72	36	Good	36	87	I	Very good rock	82	87	66
NORITE	643.4	0.76	98%	30.04	37	Good	37	87	I	Very good rock	82	88	67
ANORTHOSITE	670.2	0.55	97%	26.82	18	Good	18	82	I	Very good rock	77	87	65
DOLERITE	671.5	0.58	94%	1.34	23	Good	23	80	II	Good rock	75	87	65
ANORTHOSITE	694.5	0.68	99%	22.94	25	Good	25	92	I	Very good rock	87	88	66
DOLERITE	696.5	0.17	84%	1.98	16	Good	16	75	II	Good rock	70	81	61
ANORTHOSITE	699.6	0.28	91%	3.13	6	Fair	6	80	II	Good rock	75	84	63
DOLERITE	700.0	0.42	100%	0.45	75	Very Good	75	87	I	Very good rock	82	87	65
ANORTHOSITE	711.1	0.43	88%	11.05	7	Fair	7	77	II	Good rock	72	85	64
NORITE	719.5	0.55	82%	8.40	7	Fair	7	77	II	Good rock	72	85	64
PYROXENITE	723.9	0.39	97%	4.37	18	Good	18	80	II	Good rock	75	81	61
ANORTHOSITE	728.0	0.36	93%	4.12	9	Fair	9	80	II	Good rock	75	85	64
NORITE	737.9	0.47	85%	9.88	7	Fair	7	77	II	Good rock	72	85	64
PYROXENITE	738.7	1.26	100%	0.84	75	Very Good	75	90	I	Very good rock	85	85	64
PEGMATOID	740.6	0.18	88%	1.87	44	Very Good	44	75	II	Good rock	70	76	57
NORITE	741.2	0.15	90%	0.65	45	Very Good	45	80	II	Good rock	75	82	62
CHROMITITE	741.3	0.20	0%	0.06	0	Exceptionally Poor	0	55	III	Fair rock	50	58	44
ANORTHOSITE	746.8	0.51	71%	5.54	13	Good	13	73	II	Good rock	68	83	62
NORITE	748.3	0.19	72%	1.45	12	Good	12	71	II	Good rock	66	80	60
DOLERITE	749.2	0.14	73%	0.89	18	Good	18	71	II	Good rock	66	79	60
NORITE	749.8	0.28	62%	0.64	0	Very Poor	0	40	IV	Poor rock,"Very poor rock	35	86	48
ANORTHOSITE	750.7	0.30	55%	0.88	2	Poor	2	70	II	Good rock	65	79	59
NORITE	765.5	0.37	95%	14.86	3	Poor	3	80	II	Good rock	75	85	64
DOLERITE	766.5	0.43	85%	0.96	7	Fair	7	74	II	Good rock	69	76	57
NORITE	767.2	0.44	100%	0.66	75	Very Good	75	85	I	Very good rock	80	86	65
PEGMATOID	774.3	0.36	96%	7.09	6	Fair	6	75	II	Good rock	70	78	59
PYROXENITE	778.4	0.30	92%	4.11	6	Fair	6	80	II	Good rock	75	78	59
CHROMITITE	779.0	0.18	78%	0.63	7	Fair	7	67	II	Good rock	62	71	53
PYROXENITE	779.1	0.12	75%	0.14	7	Fair	7	72	II	Good rock	67	73	55
CHROMITITE	779.8	0.36	100%	0.68	25	Good	25	77	II	Good rock	72	77	58
NORITE	785.3	0.32	77%	5.52	10	Fair	10	77	II	Good rock	72	73	55
CHROMITITE	785.9	0.28	100%	0.52	50	Very Good	50	77	II	Good rock	72	75	56
PYROXENITE	795.1	0.56	94%	9.26	12	Good	12	77	II	Good rock	72	77	58
CHROMITITE	796.2	0.40	100%	1.05	50	Very Good	50	77	II	Good rock	72	77	58
PYROXENITE	797.5	0.51	100%	1.32	50	Very Good	50	85	I	Very good rock	80	82	61
CHROMITITE	798.0	0.15	100%	0.47	50	Very Good	50	75	II	Good rock	70	74	56
PYROXENITE	798.4	0.39	67%	0.45	4	Fair	4	70	II	Good rock	65	66	50
NORITE	817.6	0.39	94%	19.23	10	Good	8	80	II	Good rock	75	85	64
PEGMATOID	818.4	0.41	100%	0.73	67	Very Good	50	80	II	Good rock	75	79	59
NORITE	823.2	0.52	100%	4.88	67	Very Good	50	87	I	Very good rock	82	89	67
PEGMATOID	830.6	0.32	96%	7.36	8	Fair	8	75	II	Good rock	70	77	58
NORITE	838.4	0.27	82%	7.75	20	Good	15	77	II	Good rock	72	80	60
DOLERITE	839.5	0.41	68%	1.11	68	Very Good	51	70	II	Good rock	65	82	61
NORITE	899.3	0.33	80%	59.83	9	Fair	7	77	II	Good rock	72	83	62
PEGMATOID	900.0	0.44	35%	0.74	3	Poor	2	35	IV	Poor rock,"Very poor rock	30	66	50
NORITE	934.3	0.32	74%	34.29	8	Fair	6	73	II	Good rock	68	82	61
LAMRPOPHYRE	937.6	0.42	82%	3.30	82	Very Good	61	77	II	Good rock	72	73	55
NORITE	939.8	0.54	26%	2.20	4	Fair	3	68	II	Good rock	63	73	55
DOLERITE	942.6	0.15	48%	2.75	11	Good	8	66	II	Good rock	61	69	52
NORITE	947.0	0.24	74%	4.43	19	Good	14	73	II	Good rock	68	81	61
DOLERITE	947.8	0.20	86%	0.83	76	Very Good	57	50	III	Fair rock	45	82	61
NORITE	961.7	0.22	80%	13.85	9	Fair	7	79	II	Good rock	74	82	61
PYROXENITE	964.5	0.48	96%	2.84	11	Good	8	80	II	Good rock	75	80	60
CHROMITITE	965.4	0.39	91%	0.88	40	Very Good	30	77	II	Good rock	72	68	51
NORITE	968.6	0.39	100%	3.19	11	Good	8	77	II	Good rock	72	83	63
CHROMITITE	968.8	0.13	100%	0.18	89	Very Good	67	45	III	Fair rock	40	68	51
NORITE	980.6	0.38	80%	11.83	9	Fair	7	77	II	Good rock	72	81	61
CHROMITITE	981.1	0.38	0%	0.54	0	Exceptionally Poor	0	30	IV	Poor rock,"Very poor rock	25	55	41
ANORTHOSITE	981.5	0.44	100%	0.38	1	Very Poor	1	52	III	Fair rock	47	80	60
NORITE	988.4	0.24	57%	6.88	6	Fair	5	70	II	Good rock	65	76	57
PYROXENITE	997.6	0.25	65%	9.19	11	Good	8	70	II	Good rock	65	68	51
CHROMITITE	998.3	0.17	38%	0.69	0	Very Poor	0	33	IV	Poor rock,"Very poor rock	28	72	46
PYROXENITE	1000.4	0.32	48%	2.13	5	Fair	4	40	IV	Poor rock,"Very poor rock	35	80	51
Weighted Average for Main Shaft		0.39	86%		12	Good	13	77	II	Good rock	72	82	61
MIN		0.09	0%	0.01	0	Exceptionally Poor	0	30	V	Very Poor Rock	25	55	41
Max		1.26	100%	74.84	94	Very Good	150	92	I	Very good rock	87	91	68
Median		0.36	93%	2.13	11	Good	13	77.00	II	Good rock	72	81	61

Table 43: Geotechnical data in depth for the Ventilation Shaft borehole.

Rock Type	Depth	Spacing	RQD	Thickness	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
					Value	Description		Value	Class	Description		Value	Value
SAPROLITE	11.50	5.82	0%	11.50	0	Exceptionally Poor	0	22	IV	Poor rock,"Very poor rock	17	44	17
NORITE	17.56	0.16	71%	6.06	5	Fair	12	63	II	Good rock	58	69	47
IRUP	24.19	0.54	100%	6.63	15	Good	38	72	II	Good rock	67	77	52
NORITE	25.70	0.19	100%	1.51	15	Good	38	70	II	Good rock	65	74	50
DOLERITE	25.91	0.13	90%	0.21	9	Fair	23	70	II	Good rock	65	72	48
NORITE	26.27	0.40	100%	0.36	10	Good	25	72	II	Good rock	67	78	53
ANORTHOSITE	26.67	0.29	100%	0.40	20	Good	50	77	II	Good rock	72	78	53
NORITE	26.96	0.53	100%	0.29	30	Good	75	77	II	Good rock	72	81	55
IRUP	27.49	0.69	100%	0.53	20	Good	50	82	I	Very good rock	77	82	55
NORITE	35.75	0.39	100%	8.26	7	Fair	19	72	II	Good rock	67	78	53
IRUP	36.06	0.31	100%	0.31	5	Fair	13	77	II	Good rock	72	78	53
NORITE	43.16	0.41	99%	7.10	3	Poor	8	72	II	Good rock	67	76	51
IRUP	45.30	0.44	100%	2.14	10	Fair	25	77	II	Good rock	72	80	54
NORITE	47.22	0.27	100%	1.92	15	Good	38	72	II	Good rock	67	77	52
DOLERITE	47.57	1.28	100%	0.35	30	Good	75	77	II	Good rock	72	80	54
NORITE	49.66	0.75	100%	2.09	15	Good	38	77	II	Good rock	72	78	53
IRUP	51.55	0.35	100%	1.89	15	Good	38	72	II	Good rock	67	78	53
NORITE	51.80	0.27	100%	0.25	20	Good	50	77	II	Good rock	72	79	53
IRUP	66.22	0.42	99%	14.42	7	Fair	19	72	II	Good rock	67	76	52
NORITE	67.42	0.46	100%	1.20	20	Good	50	77	II	Good rock	72	79	54
DOLERITE	68.07	0.77	100%	0.65	15	Good	38	77	II	Good rock	72	80	54
NORITE	77.33	0.32	91%	9.26	14	Good	34	72	II	Good rock	67	76	52
DOLERITE	77.53	0.29	100%	0.20	60	Very Good	150	77	II	Good rock	72	78	53
IRUP	83.48	0.43	100%	5.95	10	Good	25	77	II	Good rock	72	79	53
DOLERITE	83.77	0.22	100%	0.29	30	Good	75	77	II	Good rock	72	78	53
IRUP	97.24	0.43	99%	13.47	15	Good	37	72	II	Good rock	67	78	53
DOLERITE	97.44	0.56	100%	0.20	30	Good	75	72	II	Good rock	67	79	54
IRUP	98.87	0.40	100%	1.43	20	Good	50	77	II	Good rock	72	80	54
ANORTHOSITE	104.53	0.27	95%	5.66	14	Good	36	77	II	Good rock	72	82	62
DOLERITE	104.61	0.25	100%	0.08	60	Very Good	150	82	I	Very good rock	77	85	64
IRUP	132.01	0.37	98%	27.40	7	Fair	16	77	II	Good rock	72	80	60
DOLERITE	132.73	0.23	100%	0.72	60	Very Good	150	82	I	Very good rock	77	85	64
IRUP	145.33	0.31	97%	12.60	6	Fair	16	77	II	Good rock	72	79	60
DOLERITE	145.51	0.38	100%	0.18	60	Very Good	150	82	I	Very good rock	77	87	65
IRUP	162.35	0.54	100%	16.84	7	Fair	17	77	II	Good rock	72	82	62
DOLERITE	163.91	0.25	100%	1.56	30	Good	75	82	I	Very good rock	77	85	64
IRUP	183.38	0.37	99%	19.47	7	Fair	17	77	II	Good rock	72	80	60
ANORTHOSITE	188.58	0.41	97%	5.20	29	Good	73	82	I	Very good rock	77	84	63
IRUP	195.63	0.40	100%	7.05	30	Good	75	82	I	Very good rock	77	82	62
ANORTHOSITE	211.57	0.31	97%	15.94	8	Fair	8	80	II	Good rock	75	85	64
DOLERITE	211.77	0.21	100%	0.20	150	Extremely Good	150	80	II	Good rock	75	84	63
ANORTHOSITE	211.98	0.15	100%	0.21	150	Extremely Good	150	83	I	Very good rock	78	84	63
DOLERITE	212.62	0.24	100%	0.64	38	Good	38	80	II	Good rock	75	85	64
ANORTHOSITE	213.50	0.23	93%	0.88	69	Very Good	69	80	II	Good rock	75	84	63
DOLERITE	213.77	0.29	100%	0.27	150	Extremely Good	150	85	I	Very good rock	80	86	65
ANORTHOSITE	217.27	0.20	93%	3.50	70	Very Good	70	80	II	Good rock	75	83	63
IRUP	225.91	0.31	94%	8.64	16	Good	16	80	II	Good rock	75	79	59
NORITE	230.87	0.30	96%	4.96	16	Good	16	80	II	Good rock	75	85	64
DOLERITE	230.96	0.57	100%	0.09	50	Very Good	50	85	I	Very good rock	80	88	66
NORITE	233.75	0.23	90%	2.79	15	Good	15	77	II	Good rock	72	83	63
DOLERITE	233.82	0.15	100%	0.07	150	Extremely Good	150	83	I	Very good rock	78	84	63
NORITE	237.04	0.27	82%	3.22	14	Good	14	77	II	Good rock	72	83	62
DOLERITE	237.26	0.41	100%	0.22	50	Very Good	50	80	II	Good rock	75	84	63
NORITE	324.51	0.78	34%	87.25	2	Poor	2	55	III	Fair rock	50	78	59
IRUP	326.52	0.34	100%	2.01	50	Very Good	50	85	I	Very good rock	80	80	60
DOLERITE	326.79	0.10	0%	0.27	0	Exceptionally Poor	0	63	II	Good rock	58	68	51
IRUP	348.16	0.34	97%	21.37	73	Very Good	73	85	I	Very good rock	80	81	61
DOLERITE	349.07	0.44	100%	0.91	50	Very Good	50	85	I	Very good rock	80	87	66
IRUP	355.26	0.25	98%	6.19	24	Good	24	85	I	Very good rock	80	80	60
NORITE	370.03	0.35	97%	14.77	24	Good	24	87	I	Very good rock	82	86	65
IRUP	370.64	0.93	100%	0.61	50	Very Good	50	90	I	Very good rock	85	83	63
NORITE	376.17	0.41	100%	5.53	75	Very Good	75	87	I	Very good rock	82	87	65
IRUP	378.57	0.33	100%	2.40	25	Good	25	85	I	Very good rock	80	81	61
NORITE	378.91	0.55	100%	0.34	50	Very Good	50	85	I	Very good rock	80	88	66
IRUP	379.46	0.63	100%	0.55	50	Very Good	50	90	I	Very good rock	85	83	63
NORITE	384.37	0.36	100%	4.91	25	Good	25	87	I	Very good rock	82	87	65
IRUP	384.74	0.88	100%	0.37	50	Very Good	50	90	I	Very good rock	85	83	63
NORITE	385.62	0.59	100%	0.88	50	Very Good	50	85	I	Very good rock	80	88	66
IRUP	389.56	0.23	98%	3.94	49	Very Good	49	85	I	Very good rock	80	80	60
NORITE	404.19	0.27	98%	14.63	16	Good	16	80	II	Good rock	75	85	64
IRUP	404.87	0.68	100%	0.68	50	Very Good	50	90	I	Very good rock	85	83	63
NORITE	405.89	0.41	100%	1.02	50	Very Good	50	82	I	Very good rock	77	87	65
IRUP	407.54	0.44	100%	1.65	38	Good	38	77	II	Good rock	72	84	63
NORITE	415.15	0.34	99%	7.61	12	Good	12	80	II	Good rock	75	86	64
IRUP	415.73	0.46	100%	0.58	50	Very Good	50	85	I	Very good rock	80	82	62
NORITE	417.33	0.88	100%	1.60	50	Very Good	50	90	I	Very good rock	85	89	67
IRUP	418.94	0.35	97%	1.61	49	Very Good	49	85	I	Very good rock	80	80	60
NORITE	419.97	0.26	95%	1.03	35	Good	35	80	II	Good rock	75	84	63
IRUP	420.76	0.66	100%	0.79	150	Extremely Good	150	90	I	Very good rock	85	82	62
NORITE	421.42	0.37	100%	0.66	50	Very Good	50	85	I	Very good rock	80	87	65
IRUP	423.02	0.32	100%	1.60	75	Very Good	75	80	II	Good rock	75	80	60
NORITE	427.84	0.24	96%	4.82	24	Good	24	85	I	Very good rock	80	85	64
IRUP	429.23	0.20	98%	1.39	24	Good	24	85	I	Very good rock	80	79	60
NORITE	430.72	0.16	92%	1.49	15	Good	15	78	II	Good rock	73	82	62
DOLERITE	431.37	0.22	100%	0.65	75	Very Good	75	87	I	Very good rock	82	85	64
IRUP	432.00	0.15	93%	0.63	70	Very Good	70	78	II	Good rock	73	76	57
NORITE	432.72	0.31	100%	0.72	38	Good	38	80	II	Good rock	75	86	64
IRUP	434.23	0.21	100%	1.51	75	Very Good	75	82	I	Very good rock	77	79	59
NORITE	445.31	0.49	98%	11.08	74	Very Good	74	87	I	Very good rock	82	87	66
IRUP	445.60	0.61	100%	0.29	150	Extremely Good	150	90	I	Very good rock	85	82	62
NORITE	450.36	0.23	98%	4.76	73	Very Good	73	82	I	Very good rock	77	84	63
DOLERITE	450.93	0.17	91%	0.57	17	Good	17	78	II	Good rock	73	82	62
NORITE	455.39	0.21	97%	4.46	24	Good	24	85	I	Very good rock	80	84	63
IRUP	461.56	0.29	97%	6.17	48	Very Good	48	82	I	Very good rock	77	78	59
NORITE	486.84	0.32	99%	25.28	25	Good	25	87	I	Very good rock	82	86	65
IRUP	496.20	0.22	93%	9.36	23	Good	23	82	I	Very good rock	77	79	59
NORITE	517.50	0.48	99%	21.30	37	Good	37	87	I	Very good rock	82	87	66
IRUP	519.20	0.27	96%	1.70	24	Good	24	82	I	Very good rock	77	79	59
NORITE	530.30	0.34	98%	11.10	25	Good	25	87	I	Very good rock	82	86	65
DOLERITE	531.18	0.20	100%	0.88	19	Good	19	80	II	Good rock	75	84	63
NORITE	550.21	0.38	99%	19.03	16	Good	16	82	I	Very good rock	77	86	65
IRUP	551.44	0.36	95%	1.23	24	Good	24	82	I	Very good rock	77	80	60
DOLERITE	552.50	0.29	100%	1.06	19	Good	19	80	II	Good rock	75	85	64
IRUP	554.30	0.49	100%	1.80	50	Very Good	50	82	I	Very good rock	77	81	61
ANORTHOSITE	556.20	0.24	92%	1.90	35	Good	35	87	I	Very good rock	82	84	63
NORITE	563.85	0.37	100%	7.65	50	Very Good	50	87	I	Very good rock	82	87	65
ANORTHOSITE	564.74	0.23	100%	0.89	75	Very Good	75	85	I	Very good rock	80	85	64
NORITE	565.09	0.26	100%	0.35	50	Very Good	50	85	I	Very good rock	80	86	64
ANORTHOSITE	565.58	0.39	100%	0.49	75	Very Good	75	85	I	Very good rock	80	87	65
NORITE	571.07	0.33	98%	5.49	74	Very Good	74	80	II	Good rock	75	85	64
DOLERITE	571.42	0.47	100%	0.35	75	Very Good	75	80	II	Good rock	75	87	66
NORITE	578.57	0.39	100%	7.15	50	Very Good	50	87	I	Very good rock	82	87	65
ANORTHOSITE	580.48	0.19	91%	1.91	68	Very Good	68	83	I	Very good rock	78	83	63
NORITE	586.50	0.32	99%	6.02	50	Very Good	50	87	I	Very good rock	82	86	65
ANORTHOSITE	586.88	0.61	100%	0.38	75	Very Good	75	90	I	Very good rock	85	88	66
NORITE	588.90	0.67	100%	2.02	75	Very Good	75	90	I	Very good rock	85	88	66
IRUP	591.48	0.24	100%	2.58	25	Good	25	82	I	Very good rock	77	80	60
NORITE	591.69	0.16	100%	0.21	50	Very Good	50	83	I	Very good rock	78	84	63
ANORTHOSITE	591.96	0.19	100%	0.27	75	Very Good	75	83	I	Very good rock	78	85	64
NORITE	593.80	0.72	100%	1.84	50	Very Good	50	90	I	Very good rock	85	89	67
DOLERITE	594.39	0.61	100%	0.59	75	Very Good	75	90	I	Very good rock	85	88	66
NORITE	597.48	0.33	100%	3.09	50	Very Good	50	85	I	Very good rock	80	86	65
IRUP	600.36	0.48	97%	2.88	49	Very Good	49	85	I	Very good rock	80	82	62
NORITE	619.66	0.44	100%	19.30	17	Good	17	87	I	Very good rock	82	87	66
IRUP	622.00	0.31	100%	2.34	50	Very Good	50	82	I	Very good rock	77	81	61
NORITE	630.39	0.40	100%	8.39	38	Good	38	87	I	Very good rock	82	87	65
IRUP	648.41	0.35	99%	18.02	33	Good	33	82	I	Very good rock	77	81	61
NORITE	658.81	0.49	100%	10.40	38	Good	38	87	I	Very good rock	82	87	66
ANORTHOSITE	685.72	0.44	99%	26.91	8	Fair	8	80	II	Good rock	75	87	65
DOLERITE	686.31	0.22	100%	0.59	75	Very Good	75	85	I	Very good rock	80	85	64
ANORTHOSITE	687.60	0.17	90%	1.29	67	Very Good	67	80	II	Good rock	75	83	62
DOLERITE	687.80	0.14	0%	0.20	0	Exceptionally Poor	0	43	III	Fair rock	38	59	45
ANORTHOSITE	688.64	0.14	59%	0.84	44	Very Good	44	73	II	Good rock	68	76	58
DOLERITE	689.28	0.18	89%	0.64	44	Very Good	44	77	II	Good rock	72	78	58
ANORTHOSITE	696.40	0.32	70%	7.12	13	Good	13	70	II	Good rock	65	79	59
NORITE	698.40	0.24	88%	2.00	66	Very Good	66	79	II	Good rock	74	82	61
ANORTHOSITE	709.70	0.31	86%	11.30	65	Very Good	65	82	I	Very good rock	77	84	63
NORITE	712.04	0.23	63%	2.34	12	Good	12	58	III	Fair rock	53	76	57
IRUP	712.56	0.60	100%	0.52	50	Very Good	50	87	I	Very good rock	82	83	62
NORITE	719.83	0.37	91%	7.27	34	Good	34	80	II	Good rock	75	85	64

PYROXENITE	722.15	0.32	88%	2.32	132	Extremely Good	132	79	II	Good rock	74	78	59
ANORTHOSITE	726.14	0.86	100%	3.99	50	Very Good	50	92	I	Very good rock	87	89	67
NORITE	736.53	0.27	83%	10.39	7	Fair	7	62	II	Good rock	57	80	60
PYROXENITE	737.75	0.16	76%	1.22	7	Fair	7	57	III	Fair rock	52	69	52
NORITE	738.05	0.98	0%	0.30	0	Exceptionally Poor	0	40	IV	Poor rock,"Very poor rock	35	65	49
PYROXENITE	739.17	0.05	0%	1.12	0	Exceptionally Poor	0	40	IV	Poor rock,"Very poor rock	35	52	39
CHROMITITE	739.22	0.18	100%	0.05	75	Very Good	75	75	II	Good rock	70	74	56
PEGMATOID	739.71	0.15	88%	0.49	44	Very Good	44	72	II	Good rock	67	74	56
NORITE	739.98	0.43	100%	0.27	50	Very Good	50	85	I	Very good rock	80	87	65
ANORTHOSITE	743.84	0.23	79%	3.86	4	Fair	4	62	II	Good rock	57	76	57
NORITE	749.16	0.17	75%	5.32	4	Fair	4	57	III	Fair rock	52	74	56
ANORTHOSITE	749.94	0.46	100%	0.77	75	Very Good	75	85	I	Very good rock	80	87	66
NORITE	756.00	0.20	64%	6.07	8	Fair	8	70	II	Good rock	65	76	57
DOLERITE	756.44	0.37	0%	0.44	0	Exceptionally Poor	0	65	II	Good rock	60	72	54
NORITE	764.61	0.26	92%	8.17	23	Good	23	85	I	Very good rock	80	84	63
DOLERITE	765.11	0.26	100%	0.50	75	Very Good	75	85	I	Very good rock	80	86	64
NORITE	773.34	0.29	99%	8.23	50	Very Good	50	87	I	Very good rock	82	86	64
PYROXENITE	774.44	0.15	91%	1.10	68	Very Good	68	83	I	Very good rock	78	76	57
PEGMATOID	774.52	0.19	89%	0.08	45	Very Good	45	72	II	Good rock	67	76	57
CHROMITITE	774.86	0.28	100%	0.34	38	Good	38	57	III	Fair rock	52	73	55
PYROXENITE	778.63	0.34	98%	3.77	73	Very Good	73	82	I	Very good rock	77	80	60
CHROMITITE	778.87	0.07	0%	0.24	0	Exceptionally Poor	0	53	III	Fair rock	48	56	42
PYROXENITE	778.94	0.08	0%	0.07	0	Exceptionally Poor	0	63	II	Good rock	58	61	46
CHROMITITE	779.96	0.22	92%	1.02	23	Good	23	72	II	Good rock	67	73	55
NORITE	784.04	0.26	93%	4.08	9	Fair	9	62	II	Good rock	57	82	61
CHROMITITE	784.28	0.34	100%	0.24	75	Very Good	75	77	II	Good rock	72	76	57
PYROXENITE	793.38	0.26	90%	9.10	7	Fair	7	59	III	Fair rock	54	75	56
CHROMITITE	794.07	0.28	84%	0.69	63	Very Good	63	74	II	Good rock	69	73	55
PYROXENITE	795.64	0.27	100%	1.57	13	Good	13	62	II	Good rock	57	74	56
CHROMITITE	796.10	0.31	100%	0.46	75	Very Good	75	77	II	Good rock	72	76	57
ANORTHOSITE	798.00	0.35	85%	1.90	64	Very Good	64	79	II	Good rock	74	84	63
NORITE	800.54	0.20	86%	2.54	6	Fair	5	59	III	Fair rock	54	80	60
ANORTHOSITE	801.08	0.23	74%	0.54	37	Good	28	55	III	Fair rock	50	78	59
NORITE	801.40	0.63	100%	0.32	100	Very Good	75	87	I	Very good rock	82	88	66
ANORTHOSITE	802.47	0.13	0%	1.07	0	Exceptionally Poor	0	28	IV	Poor rock,"Very poor rock	23	73	55
NORITE	803.45	0.19	73%	0.98	36	Good	27	68	II	Good rock	63	80	60
DOLERITE	804.71	0.36	75%	1.26	37	Good	28	70	II	Good rock	65	82	62
NORITE	831.86	0.41	94%	27.15	10	Good	8	65	II	Good rock	60	86	64
DOLERITE	832.65	0.18	99%	0.79	99	Extremely Good	74	83	I	Very good rock	78	84	63
NORITE	920.00	0.29	88%	87.35	10	Fair	7	74	II	Good rock	69	84	63
DOLERITE	920.07	0.23	100%	0.07	25	Good	19	77	II	Good rock	72	82	61
NORITE	924.05	0.22	91%	3.98	5	Fair	4	77	II	Good rock	72	83	62
DOLERITE	924.52	0.75	100%	0.47	100	Extremely Good	75	90	I	Very good rock	85	89	67
NORITE	934.59	0.49	100%	10.07	100	Extremely Good	75	87	I	Very good rock	82	87	66
DOLERITE	935.12	0.02	0%	0.53	0	Exceptionally Poor	0	55	III	Fair rock	50	62	47
NORITE	958.57	0.37	88%	23.45	10	Fair	7	77	II	Good rock	72	84	63
CHROMITITE	959.45	0.20	100%	0.88	100	Very Good	75	75	II	Good rock	70	75	56
PYROXENITE	960.84	0.26	88%	1.39	88	Very Good	66	79	II	Good rock	74	78	58
CHROMITITE	961.50	0.26	85%	0.66	85	Very Good	63	74	II	Good rock	69	73	55
NORITE	964.48	0.50	100%	2.98	100	Very Good	75	82	I	Very good rock	77	88	66
CHROMITITE	964.81	0.07	0%	0.33	0	Exceptionally Poor	0	53	III	Fair rock	48	56	42
ANORTHOSITE	964.89	0.07	0%	0.08	0	Exceptionally Poor	0	58	III	Fair rock	53	66	50
NORITE	975.97	0.34	93%	11.08	10	Good	8	80	II	Good rock	75	85	64
CHROMITITE	977.00	0.29	100%	1.03	100	Very Good	75	77	II	Good rock	72	76	57
NORITE	977.10	0.02	0%	0.10	0	Exceptionally Poor	0	60	III	Fair rock	55	63	47
CHROMITITE	977.12	0.08	0%	0.02	0	Exceptionally Poor	0	58	III	Fair rock	53	57	43
NORITE	983.62	0.44	98%	6.50	49	Very Good	37	80	II	Good rock	75	86	65
PYROXENITE	992.90	0.40	96%	9.28	11	Good	8	77	II	Good rock	72	77	58
CHROMITITE	993.24	0.46	93%	0.34	93	Very Good	70	77	II	Good rock	72	76	57
PYROXENITE	1002.37	0.57	100%	9.13	13	Good	9	77	II	Good rock	72	78	59
Weighted Average for Vent Shaft		0.39	88%		24	Good	26	76	II	Good rock	71	82	61
MIN		0.02	0%	0.02	0	Exceptionally Poor	0	28	V	Very Poor Rock	23	52	39
Max		1.28	100%	87.35	150	Extremely Good	150	92	I	Very good rock	87	89	67
Median		0.31	99%	1.54	35	Good	41	80.00	II	Good rock	75	82	62

APPENDIX C (Geotechnical test results)

Table 44: First batch of UCS test results.

TABLE 1 RESULTS OF UNIAXIAL COMPRESSIVE STRENGTH TEST

ROCKLAB
DIVISION OF SOILLAB (PTY) LTD
Tel: 012 481 3894
Fax: 012 481 3812
E-mail: Chenj@rocklab.co.za

Client: Wesizwe Platinum Limited Sampling Site:

18-Aug-07

SPECIMEN PARTICULARS			SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS			
Rocklab Specimen No 3082-	Sample No.	Rock Type	Diameter mm	Height mm	Ratio of Height to Diameter	Mass g	Density g/cm³	Failure Load kN	Strength (UCS) MPa	Failure Code	Note
UCS-01a	1	Anorthosite	47.49	128.8	2.7	647.0	2.84	378.2	213.5	XA	
UCS-01b			47.46	118.3	2.5	582.5	2.78	414.3	234.2	XA	
UCS-01c			47.48	125.4	2.6	617.7	2.78	309.2	174.6	XA	
UCS-02a	2	Leuco Norite	47.46	130.4	2.7	667.0	2.89	274.2	155.0	XA	
UCS-02b			47.45	126.0	2.7	633.9	2.85	267.6	151.4	XB	
UCS-02c			47.45	129.6	2.7	654.4	2.86	275.4	155.7	XB	
UCS-03a	3	Norite	47.33	130.6	2.8	719.4	3.13	413.8	235.2	YB	
UCS-03b			47.30	129.4	2.7	710.0	3.12	453.7	258.2	YA	
UCS-03c			47.33	130.9	2.8	724.3	3.15	484.7	275.5	YB	
UCS-04a	4	Lamprophyre	46.63	125.4	2.7	604.5	2.82	91.3	53.5	XA	
UCS-04b			47.02	128.7	2.7	640.4	2.86	91.8	52.9	XB	
UCS-04c			47.43	104.3	2.2	529.8	2.88	121.5	68.8	XB	
UCS-05a	5	IRUP	47.41	128.5	2.7	706.3	3.11	178.7	101.2	XB	
UCS-05b			47.45	134.3	2.8	710.2	2.99	264.5	149.6	XA	
UCS-05c			47.43	108.1	2.3	579.3	3.03	168.0	95.1	2B	
UCS-06a	6	Merensky Reef	47.36	129.9	2.7	713.4	3.12	199.2	113.1	XA	
UCS-06b			47.49	126.9	2.7	712.0	3.17	148.1	83.6	XA	
UCS-06c			47.45	129.5	2.7	707.5	3.09	140.6	79.5	XA	
UCS-07a	7	UG2 Chromitite	47.30	129.1	2.7	951.8	4.19	100.0	56.9	4B	
UCS-07b			47.59	132.1	2.8	989.8	4.21	121.2	68.1	2B	
UCS-07c			47.32	127.0	2.7	938.3	4.20	108.2	61.5	3B	

Note: All tests were conducted according to the ISRM specification.

Table 45: Second batch of UCS test results.

TABLE 1 RESULTS OF UNIAXIAL COMPRESSIVE STRENGTH TESTS

ROCKLAB
DIVISION OF SOILLAB (PTY) LTD
Tel: 012 481 3894
Fax: 012 481 3812
E-mail: Chenj@rocklab.co.za

Client: Wesizwe Platinum Limited Samping Site:

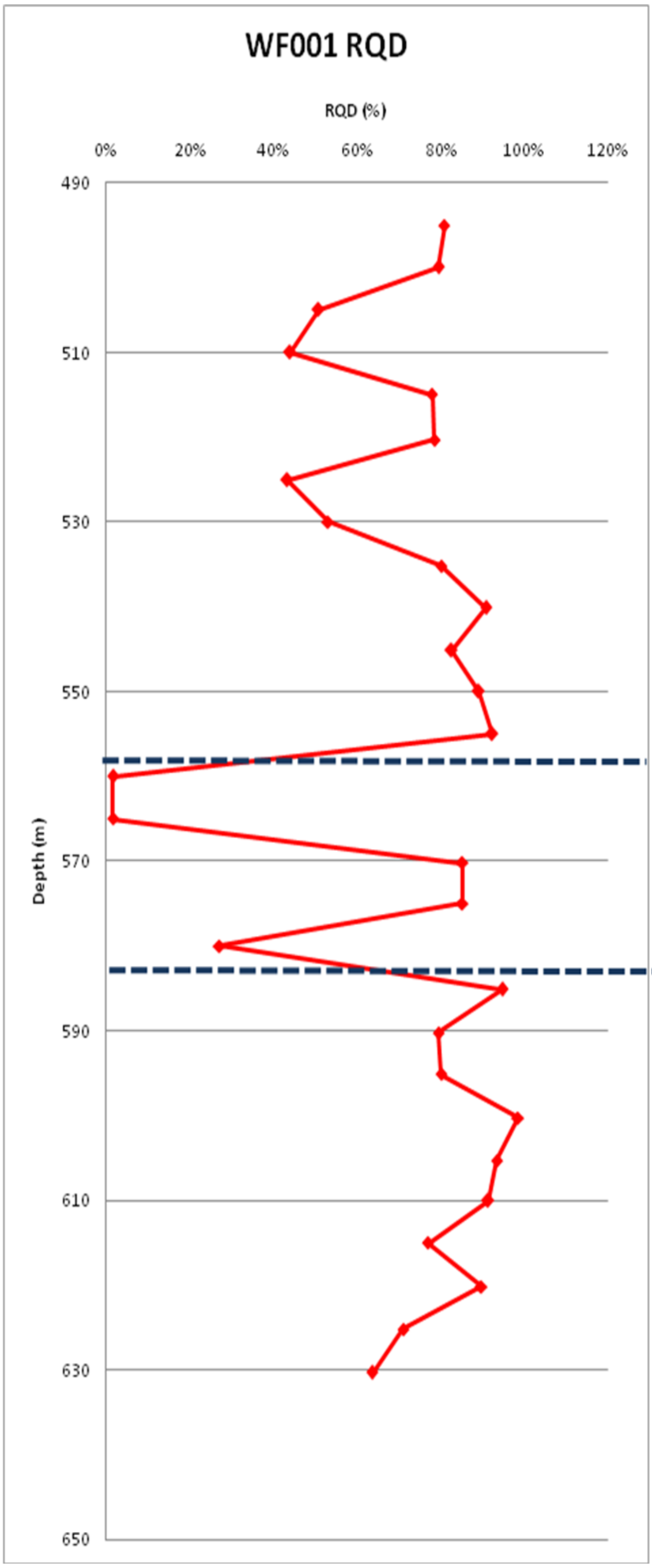
29-Aug-07

SPECIMEN PARTICULARS				SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS			
Rocklab Specimen No 3089-	Sample No.	Sample Depth m	Rock Type	Diameter mm	Height mm	Ratio of Height to Diameter	Mass g	Density g/cm³	Failure Load kN	Strength (UCS) MPa	Failure Code	Note
UCS-01	1	722.55 - 722.82	BAS Pyroxenite	47.43	126.7	2.7	721.5	3.22	244.8	138.6	2B	
UCS-02	2	738.70 - 738.97	MR HW Pyroxenite	47.48	144.1	3.0	821.6	3.22	301.6	170.4	XA	
UCS-03	3	778.07 - 778.36	UG2 HW Pyroxenite	47.50	136.9	2.9	784.9	3.23	298.0	168.2	XB	

Note: All tests were conducted according to the ISRM specification.

APPENDIX D (Faulted core rating graphs)

The blue dashed lines indicate the fault affected area.



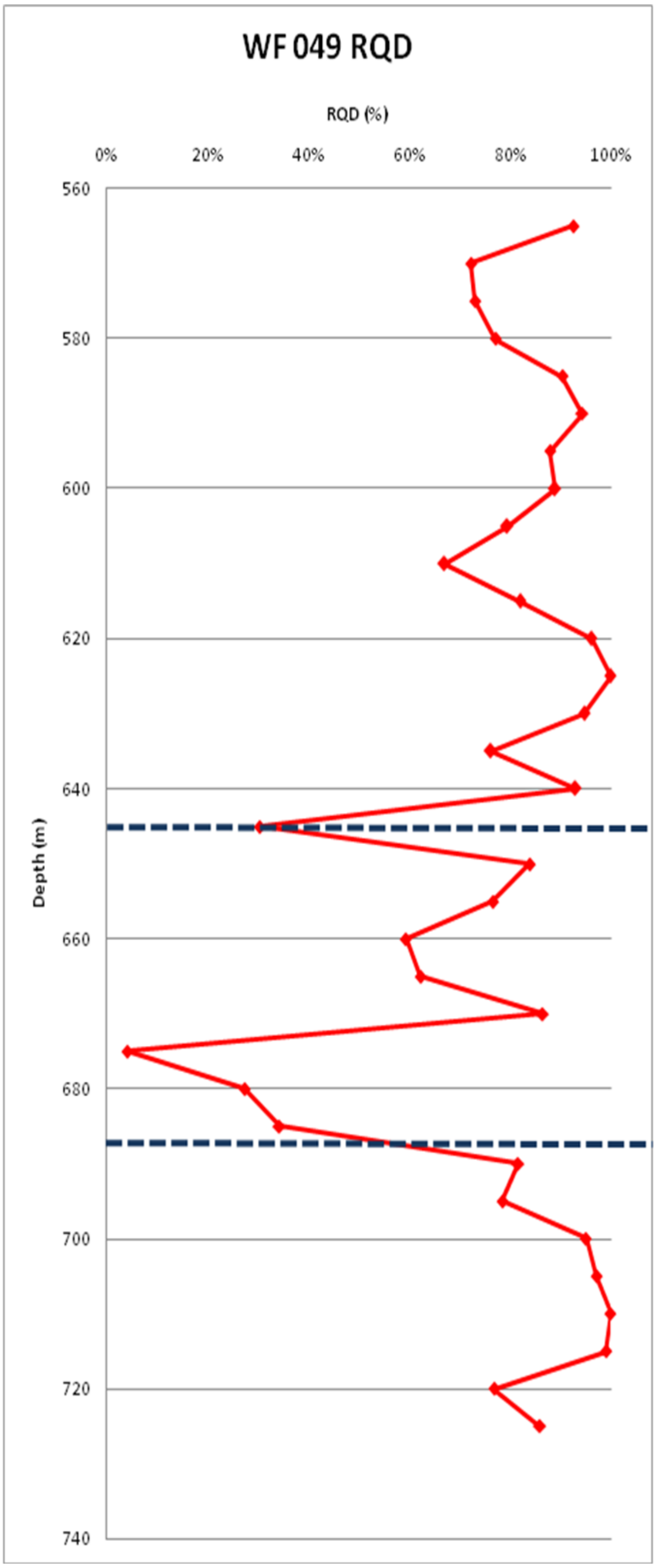


Figure 38: RQD for WF01 and WF049 at the interpreted fault intersection.

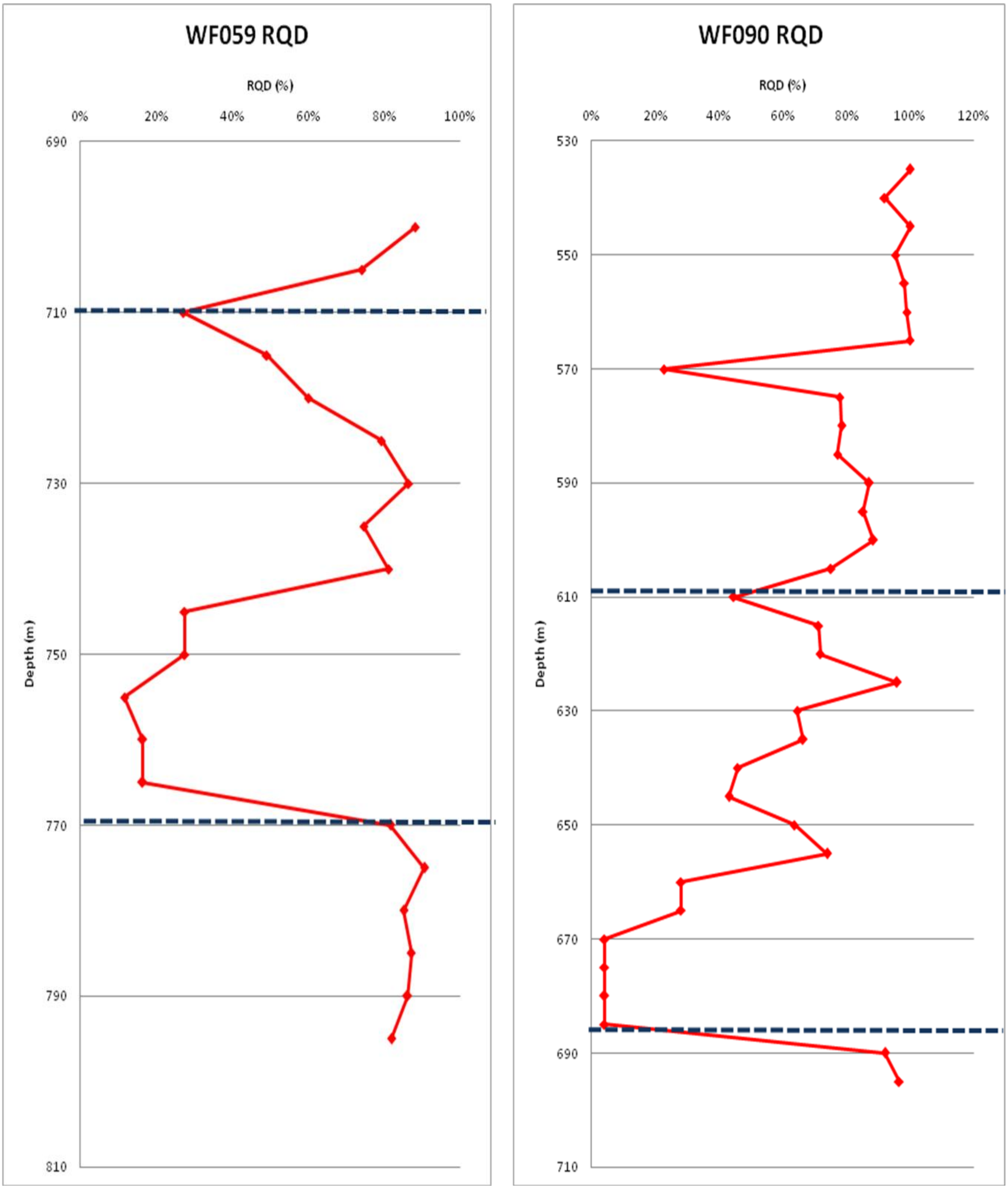


Figure 39: RQD for WF059 and WF090 at the interpreted fault intersection.

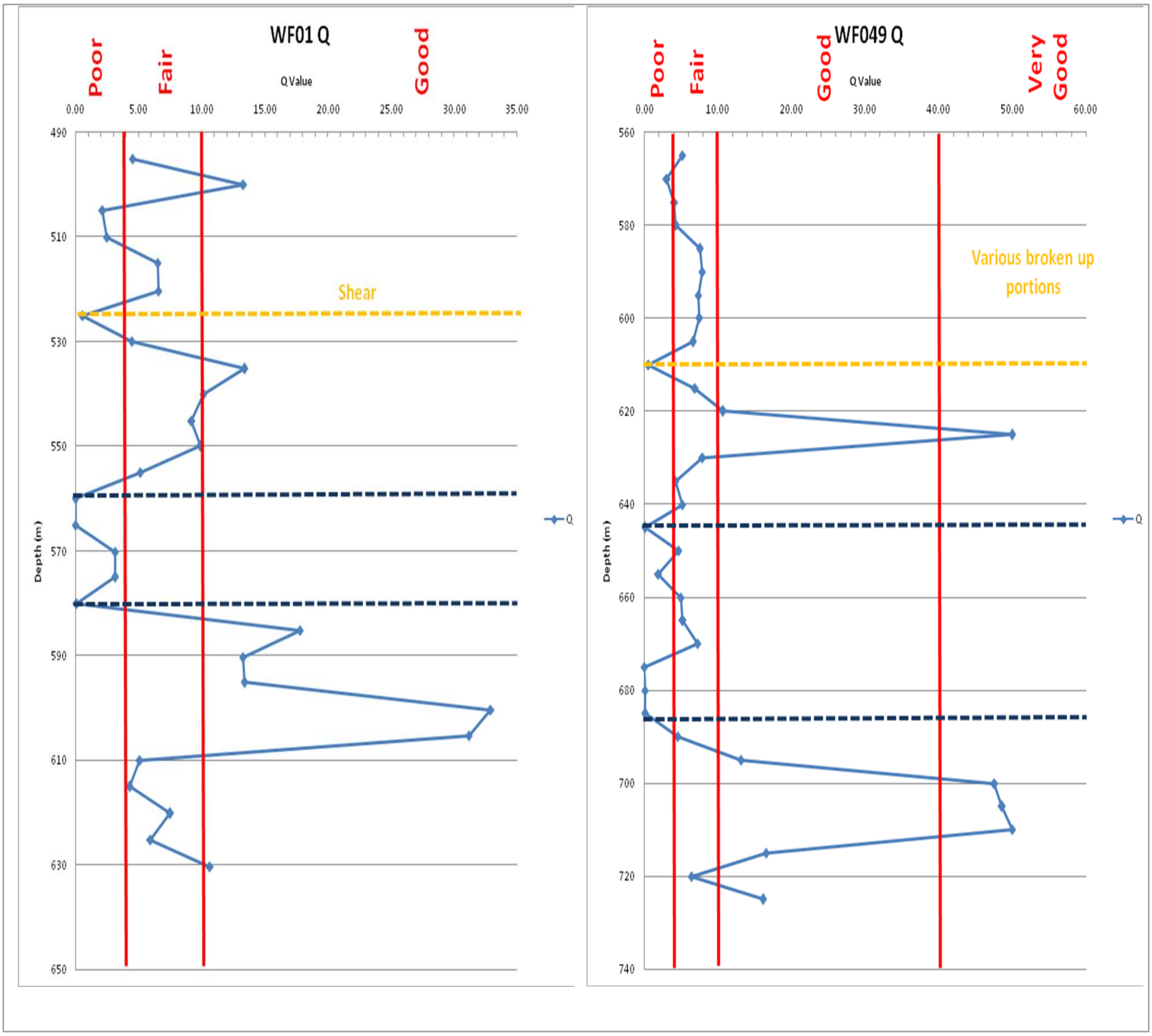


Figure 40: Q values for WF01 and WF049 at the interpreted fault intersection.

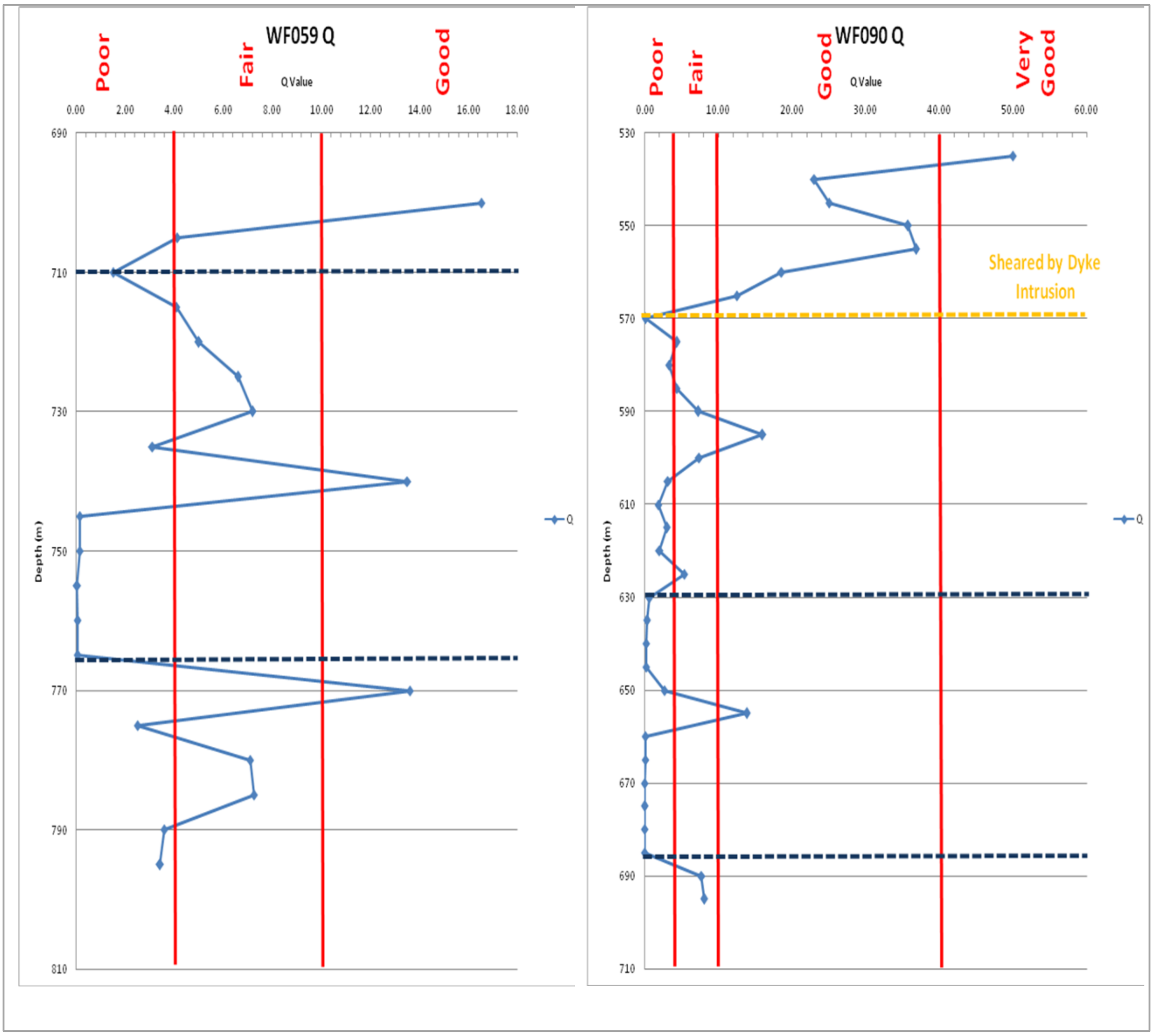


Figure 41: Q values for WF059 and WF090 at the interpreted fault intersection.

APPENDIX E (Faulted core detailed ratings)

Table 46: Rock mass ratings for WF01.

WF01	Expected fault intersection at 580 m										
Depth	Spacing	RQD	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
			Value	Description		Value	Class	Description		Value	Value
495	0.20	81%	4.50	Fair	4.50	72	II	Good rock	67	77.2	58.1
500	0.20	80%	13.28	Good	13.28	70	II	Good rock	65	76.4	57.5
505	0.13	51%	2.12	Poor	2.12	56	III	Fair rock	51	68.0	51.2
510	0.12	44%	2.45	Poor	2.45	51	III	Fair rock	46	64.0	48.1
515	0.16	78%	6.51	Fair	6.51	60	III	Fair rock	55	73.3	55.1
520	0.28	79%	6.56	Fair	6.56	62	II	Good rock	57	82.1	61.7
525	0.42	43%	0.56	Very Poor	0.56	50	III	Fair rock	45	67.5	50.8
530	0.18	53%	4.43	Fair	4.43	56	III	Fair rock	51	76.9	57.8
535	0.22	80%	13.37	Good	13.37	77	II	Good rock	72	81.5	61.3
540	0.24	91%	10.11	Good	10.11	85	I	Very good rock	80	83.9	63.1
545	0.32	83%	9.19	Fair	9.19	82	I	Very good rock	77	83.6	62.9
550	0.30	89%	9.91	Fair	9.91	82	I	Very good rock	77	84.3	63.4
555	0.20	92%	5.13	Fair	5.13	63	II	Good rock	58	75.6	56.8
560	0.21	2%	0.00	Exceptionally Poor	0.01	15	V	Very poor rock	10	52.7	29.5
565	0.21	2%	0.00	Exceptionally Poor	0.01	15	V	Very poor rock	10	52.7	29.5
570	0.25	85%	3.13	Poor	4.74	57	III	Fair rock	52	71.9	54.1
575	0.25	85%	3.13	Poor	4.74	57	III	Fair rock	52	71.9	54.1
580	0.27	27%	0.07	Extremely Poor	0.10	20	V	Very poor rock	15	57.3	22.4
585	0.53	95%	17.78	Good	17.78	80	II	Good rock	75	86.4	65.0
590	0.36	80%	13.27	Good	13.27	77	II	Good rock	72	83.0	62.4
595	0.36	80%	13.39	Good	13.39	77	II	Good rock	72	83.1	62.5
600	0.29	99%	32.89	Good	32.89	85	I	Very good rock	80	85.7	64.4
605	0.31	94%	31.17	Good	31.17	85	I	Very good rock	80	85.1	64.0
610	0.26	92%	5.08	Fair	5.08	65	II	Good rock	60	81.3	61.1
615	0.20	77%	4.29	Fair	4.29	50	III	Fair rock	45	73.8	55.5
620	0.28	90%	7.49	Fair	7.49	62	II	Good rock	57	81.2	61.1
625	0.25	71%	5.93	Fair	5.93	58	III	Fair rock	53	78.1	58.8
630	0.17	64%	10.63	Good	10.63	71	II	Good rock	66	75.8	57.0
Average	**0.26**	**71%**	**8.44**	**Fair**	**8.56**	**62**	**II**	**Good rock**	**57**	**75.5**	**55.3**

Table 47: Rock mass ratings WF049

WF049	Expected Fault intersection at 620 m										
Depth	Spacing	RQD	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
			Value	Description		Value	Class	Description		Value	Value
565	0.18	93%	5.14	Fair	5.14	63	II	Good rock	58	77.3	58.1
570	0.18	72%	3.01	Poor	3.01	56	III	Fair rock	51	74.3	55.9
575	0.18	73%	4.06	Fair	4.06	56	III	Fair rock	51	77.4	58.2
580	0.18	77%	4.29	Fair	4.29	60	III	Fair rock	55	80.5	60.6
585	0.23	90%	7.54	Fair	7.54	65	II	Good rock	60	83.3	62.6
590	0.25	94%	7.86	Fair	7.86	65	II	Good rock	60	84.1	63.2
595	0.26	88%	7.34	Fair	7.34	62	II	Good rock	57	83.2	62.6
600	0.25	89%	7.41	Fair	7.41	62	II	Good rock	57	83.2	62.6
605	0.18	79%	6.62	Fair	6.62	60	III	Fair rock	55	80.8	60.8
610	0.38	67%	0.56	Very Poor	5.58	58	III	Fair rock	53	77.8	58.5
615	0.21	82%	6.84	Fair	6.84	62	II	Good rock	57	81.8	61.5
620	0.47	96%	10.69	Good	10.69	85	I	Very good rock	80	86.7	65.2
625	0.34	100%	50.00	Very Good	50.00	85	I	Very good rock	80	86.3	64.9
630	0.27	95%	7.90	Fair	7.90	65	II	Good rock	60	84.4	63.4
635	0.20	76%	4.19	Fair	6.36	55	III	Fair rock	50	73.8	55.5
640	0.30	93%	5.12	Fair	7.76	60	III	Fair rock	55	71.5	53.8
645	0.37	30%	0.07	Extremely Poor	0.11	35	IV	Poor rock	30	66.8	29.9
650	0.18	84%	4.62	Fair	6.99	55	III	Fair rock	50	74.6	56.1
655	0.16	77%	1.87	Poor	2.84	47	III	Fair rock	42	54.9	41.3
660	0.16	59%	4.95	Fair	4.95	56	III	Fair rock	51	74.9	56.4
665	0.17	62%	5.19	Fair	5.19	56	III	Fair rock	51	72.1	54.2
670	0.24	87%	7.21	Fair	7.21	77	II	Good rock	72	76.7	57.7
675	0.09	4%	0.01	Extremely Poor	0.01	18	V	Very poor rock	13	52.6	20.6
680	0.16	27%	0.07	Extremely Poor	0.10	23	IV	Poor rock	18	57.8	22.7
685	0.23	34%	0.08	Extremely Poor	0.13	25	IV	Poor rock	20	59.9	23.5
690	0.27	82%	4.54	Fair	4.54	62	II	Good rock	57	78.9	51.9
695	0.18	79%	13.10	Good	13.10	75	II	Good rock	70	73.7	55.4
700	0.20	95%	47.56	Very Good	47.56	83	I	Very good rock	78	84.0	63.2
705	0.41	97%	48.59	Very Good	48.59	85	I	Very good rock	80	86.5	65.1
710	0.42	100%	50.00	Very Good	50.00	85	I	Very good rock	80	87.0	65.4
715	0.32	99%	16.51	Good	16.51	80	II	Good rock	75	79.5	59.8
720	0.17	77%	6.41	Fair	6.41	75	II	Good rock	70	73.2	55.1
725	0.20	86%	16.12	Good	16.12	75	II	Good rock	70	82.1	61.8
Average	**0.24**	**77%**	**11.08**	**Good**	**11.48**	**62**	**II**	**Good rock**	**57**	**76.4**	**54.8**

Table 48: Rock mass ratings WF059.

WF059	Expected fault intersection at bottom of hole										
Depth	Spacing	RQD	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
			Value	Description		Value	Class	Description		Value	Value
700	0.35	88%	16.54	Good	16.54	62	II	Good rock	57	81.6	61.4
705	0.22	74%	4.11	Fair	4.11	58	III	Fair rock	53	78.1	58.7
710	0.08	27%	1.51	Poor	1.51	48	III	Fair rock	43	67.9	51.1
715	0.08	49%	4.09	Fair	4.09	51	III	Fair rock	46	71.2	53.5
720	0.15	60%	5.01	Fair	5.01	56	III	Fair rock	51	74.8	56.3
725	0.21	79%	6.61	Fair	6.61	62	II	Good rock	57	78.7	59.2
730	0.31	86%	7.19	Fair	7.19	62	II	Good rock	57	81.0	60.9
735	0.19	75%	3.11	Poor	3.11	56	III	Fair rock	51	75.3	56.6
740	0.20	81%	13.51	Good	13.51	75	II	Good rock	70	81.4	61.2
745	0.18	27%	0.15	Very Poor	0.15	23	IV	Poor rock	18	58.1	27.7
750	0.18	27%	0.15	Very Poor	0.15	23	IV	Poor rock	18	58.1	27.7
755	0.08	12%	0.04	Extremely Poor	0.06	18	V	Very poor rock	13	41.4	19.7
760	0.20	16%	0.06	Extremely Poor	0.09	18	V	Very poor rock	13	44.8	21.3
765	0.20	16%	0.06	Extremely Poor	0.09	18	V	Very poor rock	13	44.8	21.3
770	0.18	82%	13.61	Good	13.61	70	II	Good rock	65	76.9	57.8
775	0.19	90%	2.51	Poor	2.51	63	II	Good rock	58	82.6	62.1
780	0.17	85%	7.10	Fair	7.10	60	III	Fair rock	55	79.1	59.4
785	0.18	87%	7.26	Fair	7.26	60	III	Fair rock	55	82.0	61.6
790	0.17	86%	3.59	Poor	3.59	60	III	Fair rock	55	62.2	46.8
795	0.28	82%	3.42	Poor	3.42	62	II	Good rock	57	63.0	47.4
Average	**0.19**	**62%**	**4.98**	**Fair**	**4.98**	**50**	**III**	**Fair rock**	**45**	**69.2**	**48.6**

Table 49: Rock mass ratings for WF090.

WF090	Expected fault intersection at 630 m										
Depth	Spacing	RQD	Q		Q'	RMR			GSI	Intial MRMR	Final MRMR
			Value	Description		Value	Class	Description		Value	Value
535	0.45	100%	50.00	Very Good	50.00	85	I	Very good rock	80	87.2	65.6
540	0.34	92%	23.00	Good	23.00	85	I	Very good rock	80	85.2	64.0
545	0.68	100%	25.00	Good	25.00	90	I	Very good rock	85	88.5	66.5
550	0.41	95%	35.74	Good	35.74	80	II	Good rock	75	85.8	64.5
555	0.58	98%	36.82	Good	36.82	80	II	Good rock	75	87.2	65.6
560	0.64	99%	18.54	Good	18.54	70	II	Good rock	65	87.6	65.9
565	0.53	100%	12.50	Good	12.50	80	II	Good rock	75	87.2	65.6
570	0.24	23%	0.08	Extremely Poor	0.08	20	V	Very poor rock	15	61.2	27.4
575	0.22	78%	4.33	Fair	4.33	62	II	Good rock	57	73.2	55.1
580	0.34	78%	3.27	Poor	3.27	62	II	Good rock	57	76.1	57.3
585	0.21	77%	4.29	Fair	4.29	62	II	Good rock	57	75.5	56.8
590	0.43	87%	7.26	Fair	7.26	77	II	Good rock	72	82.1	61.7
595	0.24	85%	15.98	Good	15.98	62	II	Good rock	57	82.6	62.1
600	0.24	88%	7.36	Fair	7.36	62	II	Good rock	57	80.5	60.6
605	0.15	75%	3.13	Poor	3.13	60	III	Fair rock	55	73.2	55.0
610	0.18	45%	1.86	Poor	1.86	51	III	Fair rock	46	69.1	52.0
615	0.23	71%	2.97	Poor	2.97	58	III	Fair rock	53	73.8	55.5
620	0.21	72%	2.00	Poor	2.00	58	III	Fair rock	53	70.2	52.8
625	0.36	96%	5.33	Fair	5.33	60	III	Fair rock	55	71.9	54.1
630	0.20	64%	0.59	Very Poor	0.90	50	III	Fair rock	45	64.6	41.4
635	0.20	66%	0.29	Very Poor	0.44	50	III	Fair rock	45	58.5	22.3
640	0.15	46%	0.17	Very Poor	0.25	38	IV	Poor rock	33	54.4	20.7
645	0.18	43%	0.16	Very Poor	0.24	38	IV	Poor rock	33	54.5	20.8
650	0.16	64%	2.65	Poor	2.65	56	III	Fair rock	51	72.7	54.6
655	0.22	74%	13.87	Good	13.87	58	III	Fair rock	53	77.1	58.0
660	0.21	28%	0.07	Extremely Poor	0.10	25	IV	Poor rock	20	58.6	23.0
665	0.21	28%	0.07	Extremely Poor	0.10	25	IV	Poor rock	20	58.6	23.0
670	0.24	4%	0.01	Extremely Poor	0.01	30	IV	Poor rock	25	55.5	21.8
675	0.24	4%	0.01	Extremely Poor	0.01	30	IV	Poor rock	25	55.5	21.8
680	0.24	4%	0.01	Extremely Poor	0.01	30	IV	Poor rock	25	55.5	21.8
685	0.24	4%	0.01	Extremely Poor	0.01	30	IV	Poor rock	25	55.5	21.8
690	0.24	92%	7.67	Fair	7.67	65	II	Good rock	60	80.1	60.2
695	0.41	97%	8.04	Fair	8.04	65	II	Good rock	60	83.4	62.7
Average	**0.30**	**66%**	**8.88**	**Fair**	**8.90**	**56**	**III**	**Fair rock**	**51**	**72.2**	**47.9**

APPENDIX F (Photos of fault affected core)

Figure 42: WF1 fault affected area.

Figure 43: WF1 fault affected area.

Figure 44: WF49 fault affected area.

Figure 45: WF49 fault affected area.

Figure 46: WF59 fault affected area.

Figure 47: WF59 fault affected area.

Figure 48: WF59 fault affected area.

Figure 49: WF90 fault affected area.

Figure 50: WF90 fault affected area.

APPENDIX G (TWP Geotech Logging Procedure)

Field Guide for
Geotechnical Core Lo

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Appendix H (Wesizwe Ledig Participants Guidelines)

PARTICPANTS
GUIDELINE WESIZWE

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