APPENDIX 1

Description of major rock types

Hanging wall

i. Nortite

This is the dominant rock in the Main Zone. It consists of 35-65% cumulus plagioclase and 35-65% orthopyroxene. Norites typically contain more plagioclase than orthopyroxene. Clinopyroxene can make up to 10% of the rock. Both plagioclase and pyroxene minerals occur as cumulus grains with a medium grain size.

ii. Leuco-norite

A leuco-norite contains 65-90% plagioclase and is identified by the generally lighter colour. Orthopyroxene content drops to 10-35%.

iii. Mela-norite

A mela-norite is darker coloured containing 65-90% orthopyroxene and 10-35% plagioclase.

iv. Gabbronorite

Gabbronorites are identified by containing both a orthopyroxene and clinopyroxene content of >10% and up to 65%. Plagioclase varies between 35-65%. Both plagioclase and pyroxene minerals occur as cumulus grains with a medium grain size.

v. ***Leuco-gabbronorite***

A leuco-gabbronorite contains 65-90% plagioclase and is identified by the generally lighter colour. Orthopyroxene and clinopyroxene content drops to 10-35%.

vi. ***Mela-gabbronorite***

A mela-gabbronorite is darker coloured containing 65-90% pyroxene and 10-35% plagioclase minerals.

vii. ***Hybrid Norite***

Hybrid norite is a term used in the production geology department to describe norite which exhibits a recrystalised texture in addition to chloritisation - resulting in a green stain noticeable on the plagioclase. Plagioclase also looks more opaque with slightly fine crystals. Hybrid norite is found commonly in the immediate hangingwall, pervasive at South Pit. Hybrid norite can be mineralised.

The exploration department uses the term Hybrid Norite to describe metamorphically altered norite or gabbronorite found throughout the stratigraphic succession.

Reef

i. ***Pyroxenite***

Pyroxenite contains >90% cumulus pyroxene minerals. Intercumulus plagioclase content is <10%. The plagioclase may not be visible in core by is always present in thin sections (Nex et al., 2006).

Grain size varies between fine to pegmatiodal. Fine grained pyroxenites are found near the hangingwall contact in the C-Reef and in the footwall and are of Lower Zone affinity (covered under *Granofels*) (Nex et al., 2006).

Figure 1: Coarse grained pyroxenite with evidence of alteration.

ii. Serpentinised Pyroxenite

Pyroxenites which have undergone hydrothermal alteration display a darker black-green colour. The alteration occurs due to the hydration of ferromagnesian minerals (olivines and pyroxenes). Serpentine minerals include antigorite, chrysotile and lizardite (Nex et al., 2006). Minor amounts of chlorite and talc are also present. The rock is termed a Serpentinite if alteration has completely overprinted the original texture and minerals beyond visual recognition (see *Serpentinite*).

iii. Feldspathic Pyroxenite

Feldspathic pyroxenite is not an IUGS term but a locally derived term to separate the HW mela-norties from the reef mela-norites due to the textural difference. The textural difference lies in the relationship between pyroxene and plagioclase. The plagioclase in Feldspathic Pyroxenite (withing the reef) is 10-20% intercumulus.

No precise upper limit exists for the amount of plagioclase present (Nex et al., 2006) which is most apparent in pegmatoidal variants.

The following variants exist in the exploration database:

iv. Serpentinised Feldspathic Pyroxenite

This term is used for visual hydrous alteration of Feldspathic Pyroxenite. Intercumulus plagioclase is still visually identifiable.

v. Pegmatoidal Feldspathic Pyroxenite

The composition is more accurately termed noritic but the term feldspathic Pyroxenite is used to distinguish between Platreef and MZ rocks (Nex et al., 2006). Visually these rocks contain >20% plagioclase.

vi. Serpentinite

Serpentine minerals include antigorite, chrysotile and lizardite (Nex et al., 2006). Minor amounts of chlorite and talc are also present

The original texture is overprinted and grain sizes are often reduced. The origin of the rock is then difficult to identify without geochemical analyses (Nex et al., 2006).

vii. Calc-silicate

A calc-silicate is a metamorphic derivation of dolomite containing calcium rich silicates. The rock occurs within the reef package as xenoliths and can also be found on the footwall contact. The mineral content is extremely varied and therefore colour variation is wide. Minerals include (but not limited to) tremolite, metamorphic forsterite, diopside, wollastonite and Ca-rich garnet (Nex et al., 2006). Grain size varies between fine and medium depending on mineral assemblage. The database describes the texture as recrystalised and cumulus. The two textural descriptions may be diagnostic of differing mineral proportions.

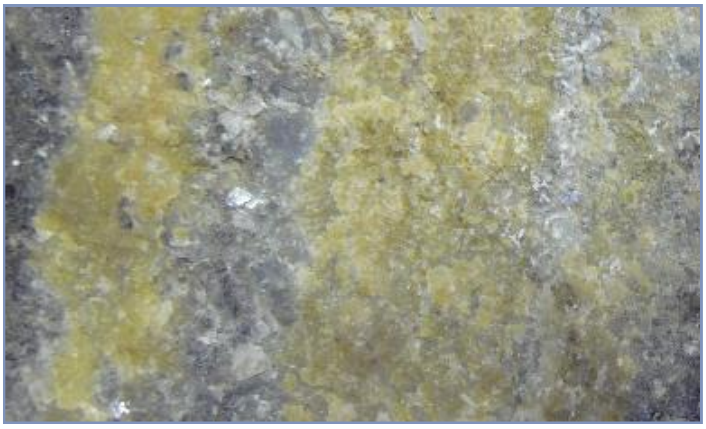

Figure 2: Calc-silicate with medium grained diopside (yellow mineral).

viii. Parapyroxenite

The term Parapyroxenite is not internationally recognised but refers to rocks containing metamorphically derived clinopyroxene (Nex et al., 2006). There is significant variation in appearance which is dependent on degree of metamorphism. Grains are usually fine and interlocking due to metamorphic recrystallization. Rocks have a green hue due to the high content of diopside (Nex et al., 2006). The term is used in exploration database to describe igneous reef rocks in close proximity to calc-silicate which exhibit a metamorphosed texture.

The term Parapyroxenite should be applied carefully (Nex et al., 2006). Visual identification of Parapyroxenite variants in core is therefore extremely difficult.
The following variants of parapyroxenite exist in the exploration database:

ix. Feldspathic Parapyroxenite

A Parapyroxenite is termed a Feldspathic Parapyroxenite when the intercumulus plagioclase content is 10-20%.

x. Serpentinised Parapyroxenite

A Parapyroxenite is termed a Serpentinised Parapyroxenite if it displays visible hydrous alteration which darkens the colour. Pressumably this is in combiniation to a finer grain size.

xi. Serpentinised Feldspathic Parapyroxenite

A Parapyroxenite is described as a Serpentinsed Feldspathic Parapyroxenite when the intercumulus plagioclase content is 10-20% and the original green hue is darkened by hydrous alteration.

Foot wall

i. Granofels

Granofels is a term used for footwall agmatites, breccia and agmatitic breccia containing two igneous components developed at the footwall contact. Fine grained Pyroxenite fragments occur within a granitic matrix (Nex et al., 2006). Pyroxenite fragments are identified as irregular and angular blocks of varying size between the cross cutting leucocratic veins. The leucocratic and granitic matrix contains plagioclase and quartz from an unknown origin – presumably assimilated Archean granite (Cawthorn et al., 1985).

APPENDIX 2

Abbr	Description
A	Anorthosite
C	Calc Silicate
CRFPYX	Chromite bearing Feldspathic pyroxenite
D	Dyke
F	Granofels
FPEG	Feldspathic Pegmatoid pyroxenite
FPYX	Feldspathic pyroxenite
G	Granite
GF	Granofels
GN	Gabbronorites
GRAN	Granite
H	Hybrid Norite
I	Intrusive Norite
K	Chromitite
LGN	Leuco-Gabbronorites
LGRAN	Leuco-Granite
MGN	Mela-Gabbronorites
N	Norite
O	Oxidised Ore
ON	Oxidised norites
OP	Oxidised pyroxenite
P	Pyroxenite
PYXCR	Pyroxenite bearing chromitite
Q	QZFS
QZFS	Quartz-feldspar
QZFSSZ	Quartz-feldspathic Shear zone
QZV	Quartz Vein
R	ParaPyroxenite
S	Serpentinite
SFHARZ	Serpentinised Feldspathic Harzburgite
SFPYX	Serpentinised Feldspathic Pyroxenite
SHARZ	Serpentinised Harzburgite
SLg	Sample Loss (Geological features i.e faults, joints and fracturing)
Slu	Sample Loss (UG Workings)
SPARA	Serpentinised Parapyroxenites
SPYX	Serpentinised pyroxenite
STD	Standard
V	Vein
X	Serpentinised Parapy

TEXTURE	Description
BND	Banding
BREC	Brecciated
CONT	Continuous
COR	Coronas
CUMU	Cumulate
DISS	Disseminated
EUHEDRAL	Euhedral
FBND	Flow banding
G	
GNESSIC	Gneissic
GRAN	Granular
GRAPH	Graphitic (Pegmatite Veins - Qz-Kfs exsolution)
GRAPHIC	Graphic
HOM	Homogeneous
LENSE	Lense
MASSIVE	Massive
MOT	Mottled
OIKS	Oikocrysts
P	
PEG	Pegmatoidal
POIK	Poikiltic
POR	Porphyroblastic
PORPH	Porphyritic
POSTCUM	Postcumulate
Recrt	Recrt
RECRY	Recrystallised
SBHEDRAL	Subhedral
Spck	Spck
SPOT	Spotted
SPOT MOT	Spotted Mottled
SPOTMOT	Spotted and Mottled
STR	Stringers
VARI	Varitextured
VTAN	VTAN

GRAIN SIZE	Description
VF	Very fine
F	Fine
F-M	Fine to medium
F-C	Fine to coarse
F-PEG	Fine to pegmatoidal
M-F	Medium to fine
M	Medium
M-C	Medium to coarse
M-VC	Medium to very coarse
M-PEG	Medium to pegmatoidal
C-M	Coarse to medium
C	Coarse
C-VC	Coarse to very coarse
C-PEG	Coarse to pegmatoidal
VC	Very coarse
VC-PEG	Very coarse to pegmatoidal
PEG	Pegmatoidal

APPENDIX 3

Test Types

4 tests are discussed below. Data for all 4 tests are available in different quantities in the exploration database:

UCS

A widely used method of testing the strength of a rock is using the Uniaxial Compressive Strength (UCS) test. The UCS (σ_c) of the intact rock is used in rock mass classification schemes (section 3.7), and as a basic parameter in the rock mass strength criterion. These tests are usually done on cylindrical samples (Jager and Ryder, 1999). It is used to determine the unconfined compressive strength (σ_c), elastic constants, Young's modulus, *E*, and Poisson's ratio of the rock material (refer to Jager and Ryder, 1999 for more information regarding rock engineering variables).

Despite its apparent simplicity, great care must be exercised in interpreting results obtained in the test. observed response will depend on the nature and composition of the rock and on the condition of the test specimens. the uniaxial compressive strengths of samples of rock having the same geological name, can vary widely but do indicate a qualitative mechanical behaviour. Despite the fact that such features are typical of some rock types, it is dangerous to attempt to assign mechanical properties to rock from a particular location on the basis of its geological description alone (Brady & Brown, 2006).

The strength of the rocks may vary due to mineralogical, physical and chemical composition (Heinz, 2009). For similar mineralogy, decreases in unconfined compressive strength (σ_c) occur with increases in (Jager & Ryder, 1999) (Palmstrom, 1995):

- Porosity
- Weathering
- Microfissuring
- Water content

A positive correlation between UCS and Blast Efficiency (a measure of block size distribution after a blast) exists showing that a decrease in UCS increases the blasting efficiency (Saliu et al., 2013), increase in crushing efficiency (Adeyemo & Olaleye, 2012) and increase in drilling efficiency (Bourgoyne et al., 1986).

PLI

The Point Load Index is a representative rock strength index calculated by investigating the amount of stress applied to a rock at failure. The test is done using a point load tester which consists of a loading frame with a mounted hydraulic ram. The rock sample is set between two conical platens. Stress is applied by pumping the ram until the rock fails. A pressure gauge records the greatest stress applied. The diameter of the rock sample must also be recorded. The test is simple and cost effective.

The PLI results can be converted to UCS (Hayes & Piper, 2003) (Ozturk et al., 2014). UCS is calculated from the PLI using conversion factors, either site specific or universal. Failure mode from point load test is primarily by tensile fracturing and therefore a stronger correlation between PLI and tensile strength exists (Dhungana, 2013). The estimation of compressive strength is conducted by making a linear approximation (Zacoeb and Ishibashi, 2009). Broch and Franklin (1972) reported that for 50 mm diameter cores the uniaxial compressive strength is approximately equal to 24 times the point load index (Broch & Franklin, 1972).

Conversion factors have been found to be rock dependant (Akram & Bakar, 2007). Pells (1975) showed that the index-to-strength conversion factor of 24 can lead to 20 % error in the prediction of compressive strength for rocks such as dolerite, norite and pyroxenite. The onsite factors for UCS conversion for rock types are:

Table 1: Site conversion factors for UCS calculation from PLI test (Source: Little, 2006)

Rock Type	UCS Conversion Factor
Norite	23
Feldspathic Pyroxenite	22
Pyroxenite	16
Parapyroxenite	28
Serpentinite	28
Granofels	26
Calc-silicate	25

These are site specific conversion factors calculated from the lab UCS tests for the major rock types (Hayes & Piper, 2003). These factors fall within the ISRM (1985) recommendations (Little, 2006).

The index is calculated to a standard point load index $I_{s(50).}$ This is calculated with the following variables (Dhungana, 2013):

- Load at failure
- Core size

The test gives a Load (kN) amount read off an dial. This result is used as the input to convert the test to MPa taking into account the size of the core. The test method follows international best practice (ISRM, 1985)

First the uncorrected point load strength (I_s) in MPa is calculated:

$$\boldsymbol{I_s = P/D_e{}^2}$$

Where:

P is the load in kN

$\boldsymbol{D_e}$ is the equivalent core diameter (D = D_e for diametral testing on core)

Secondly, the uncorrected point load strength (I_s) is changed to a standardised reference diameter of 50mm ($I_s(50)$):

$$\boldsymbol{I_s(50) = F \times I_s}$$

Where:

$F = (D_e/50)^{0.45}$

Lastly, the $I_s(50)$ is converted to UCS by using a conversion factor
A large database of results exists at Mogalakwena to the low costs and ease of use. A large database is required to calculate UCS from PLI (Dhungana, 2013).

BWI

The Bond Work Index is calculated from conducting Bond Ball Mill Grindability test to correlate the testwork directly to a full size mill. The test makes use of smaller ball mills to proxy larger equipment. The test is a measure of the resistance of the material to crushing and grinding defined as the energy per unit mass to reduce a particle from infinite size to 80% passing 100 microns. It is used to predict grinding efficiency in ball mills (Napier-Munn et al., 1999) and throughput.

DWT

The Drop Weight Test simulates breakage characterisation of material during ore handling (Napier-Munn et al., 1999). A measured weight is dropped from a known height onto a sample and the size distribution of the broken chips is measured. The relationship between surface area (A) and input energy (b) is calculated. The results simulate breakage of ores in crushers, primarily, and mills.

UCS vs DWT

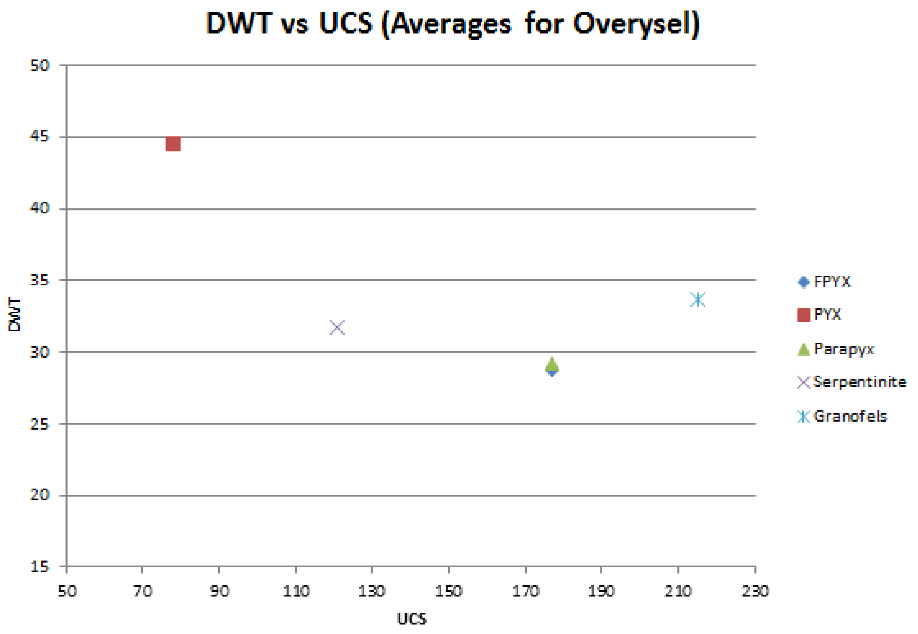

Figure 3: DWT vs UCS means for OY.

BWI vs DWT

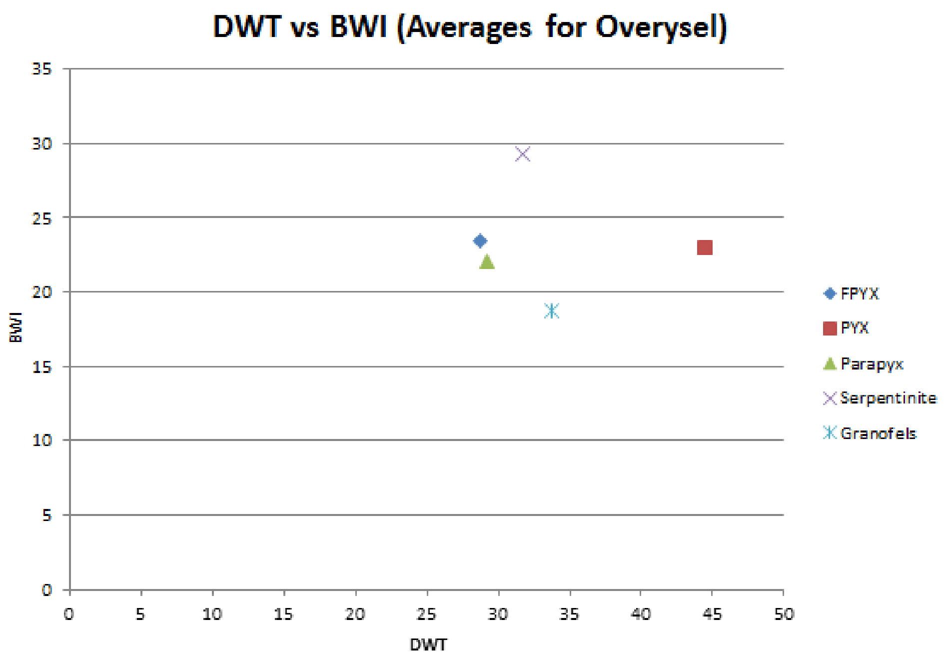

Figure 4: DWT vs BWI mean for OY.

APPENDIX 4

AngloAmerican

PLATINUM

CHIP LOGGING SHEET

Geologist ____________________
Pattern ____________________
Date logged ____________________

Hole	Sample	Lithology	Stratigraphy	Alteration Type	Alteration Intensity	Texture	Grain size	Mineralisation	Comments
	A								
	B								
	C								
	D								
	E								
	F								
	A								
	B								
	C								
	D								
	E								
	F								
	A								
	B								
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	A								
	B								
	C								
	D								
	E								
	F								

Figure 5: Proposed logging sheet for RC drill chips

APPENDIX 5

Overview of different rig performance:

Drill rig	Hole count	Meters	Time	Penetration Rate
PV141	214	3541.3	184.58	19.19
PV143	292	4768	226.05	21.09
PV144	387	5320.3	186.65	28.50
PV145	249	4033.5	203.17	19.85
PV146	148	1922.1	79.58	24.15
PV147	8	141.6	11.03	12.83
PV148	94	1451.7	93.47	15.53
PV149	1017	14136.6	458.22	30.85
Total	2409	35315.1	1443	24.48

Performance results in different patterns. Note that PV143 has a sweeper installed which increases ROP.

329-043 Reef and HW

Rig	Penetration	Holes
PV145	21.08378	37
PV141	21.17654	25
PV144	14.23271	5
PV143	**24.46378**	85

326-050 Reef and FW

Rig	Penetration	Holes
PV143	**27.94784917**	55
PV144	18.96761005	19
PV145	22.06948642	49

326-085 FW

Rig	Penetration	Holes
PV149	14.06358689	16
PV141	13.46098593	27
PV143	**22.63386666**	4
PV144	20.59564064	20