PRO FORMA CODE OF PRACTICE TO

COMBAT ROCKFALL ACCIDENTS IN

NARROW TABULAR MINES

INTRODUCTION

This document has been prepared as part of a Safety in Mines Research Advisory Committee (SIMRAC) research project OTH 602 entitled “Best practice rock engineering handbook for other mines including underground and open pit mines and quarries”.

The objective of this document is to assist employers at narrow tabular mines (other than gold, platinum and coal mines) in preparing a code of practice to combat rockfall and rockburst accidents (COP) in accordance with the requirements of the Mine Health and Safety Act (MHSA), 1996 (Act No. 29 of 1996), and in accordance with the Department of Minerals and Energy (DME) Guideline Reference No. 7/4/118-AB1 (Tabular Metalliferous Mines) issued by the Chief Inspector of Mines on 16 October 1996. At the time of compiling this pro forma COP, the revised Guideline for tabular metalliferous mines had not been completed yet. It is recommended that the new Guideline be consulted when it becomes available.

DEFINITION OF NARROW TABULAR MINING

For the purpose of this COP, narrow tabular mining is defined as underground mining operations in which tabular type orebodies are extracted which dip at less than 30 degrees and do not exceed 7m in width. Orebodies, which may typically fall into this category, are chromitite and manganese seams.

STRUCTURE OF DOCUMENT

This document presents the requirements of a COP as defined in the Guideline as boxed text.

REQUIREMENTS AS BOXED TEXT

The requirements are followed by an example of how the actual COP document may be written to satisfy the requirements. Additional notes on particular issues that require attention are presented in *italics.*

FORMAT AND CONTENT OF COP

TITLE PAGE	
• *Name of mine*	*Y*
• *Heading: Mandatory COP to Combat Rockfall Accidents in Tabular Metalliferous Mines.*	*Y*
• *Statement: The COP was drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996.*	*Y*
• *Mine's reference number*	
• *Effective date*	*Y*
• *Revision date*	*Y*
	Y

SHALLOW TABULAR MINE (PTY) LTD

MANDATORY CODE OF PRACTICE TO COMBAT ROCKFALL AND ROCKBURST ACCIDENTS IN TABULAR METALLIFEROUS MINES

This code of practice (COP) was drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996.

REF. No. : TAB COP1/2001
EFFECTIVE DATE : FEBRUARY 2001
REVISION DATE : FEBRUARY 2002

CONTENTS OF CODE OF PRACTICE	
Table of contents	*Y*

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

STATUS OF MANDATORY COP	
State that:	
• *The COP has been drawn up in accordance with the relevant guideline issued by the Chief Inspector of Mines.*	***Y***
• *This is a mandatory COP in terms of Section 9(2) of the Mine Health and Safety Act, 1996 (Act 29 of 1996).*	***Y***
• *This COP may be used in accident investigation/inquiry to ascertain compliance and also to establish whether the COP is effective and fit for purpose.*	***Y***
• *This COP supersedes all previous COP's in this regard.*	***Y***
• *All managerial instructions or recommended procedures and standards on the relevant topics must comply with the COP and must be reviewed to ensure compliance.*	***Y***

1 STATUS OF MANDATORY CODE OF PRACTICE (COP)

- The COP has been drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996.
- This is a mandatory COP in terms of Section 9(2) of the Mine Health and Safety Act, 1996 (Act 29 of 1996).
- This COP may be used in accident investigation/inquiry to ascertain compliance and also to establish whether the COP is effective and fit for purpose.
- This COP supersedes all previous COP's in this regard.
- All managerial instructions or recommended procedures and standards on the relevant topics must comply with the COP and must be reviewed to ensure compliance.

MEMBERS OF DRAFTING COMMITTEE	
• *Full names*	*Y*
• *Designation*	*Y*
• *Professional qualifications, experience and affiliation*	*Y*
• *Must include a competent RE practitioner*	*Y*

2 MEMBERS OF DRAFTING COMMITTEE

The Manager of Shallow Tabular Mine, after consultation with the Health and Safety Committee (H&SC), appointed a committee for the drafting of this COP to combat rockfall accidents. Combating rockbursts does not form part of this COP, since the likelihood of rockbursts occurring at Shallow Tabular Mine is minimal.

The full names, designation, professional qualifications and/or experience and affiliation of the COP Drafting Committee members are:

Mr BLA Stall ***(Production Manager)***

- National Higher Diploma - Metalliferous Mining (Technikon Witwatersrand)
- National Diploma - Metalliferous Mining (Technikon Witwatersrand)
- Mine Managers Certificate of Competency
- Mine Overseers Certificate of Competency
- Associate Member of Mine Managers Association.
- Thirteen years mining experience in various positions in the production environment.

Mr CLE Wirr ***(Rock Engineering Practitioner)***

- National Diploma - Metalliferous Mining (Technikon Witwatersrand)
- COM Certificate in Rock Mechanics
- Member of SANGORM
- Fifteen years mining rock engineering experience on a tabular mine.

<u>Mr STOF Engate</u> ***(Mine Overseer)***

- Mine Overseers Certificate of Competency
- Experience in tabular mining:

-	5 Years	Shift Boss	Mine A
-	4 Years	Shift Boss	Mine B
-	3 Years	Mine Overseer	Mine C

<u>Mr PA Soppa</u> ***(Safety Officer)***

- N.O.S.A S.A.M.T.R.E.C.
- Experience in tabular mining:

-	5 Years	Stoper	Mine A
-	3 Years	Shift Boss	Mine B
-	2 Years	Safety Officer	Mine C

<u>Mr SHI Bas</u> ***(Shift Supervisor)***

- Experience in tabular mining:

-	2 Years	Onsetter	
-	20 Years	Developer	Mine A
-	5 Years	Shift Boss	Mine B
-	2 Years	Safety Officer	Mine C
-	2 Years	Shift Boss	Mine D

<u>Mr Wilnet Boor</u> ***(Rockdrill Operator)***

- Experience in tabular mining:

-	2 Years	Stope Timber Man	Mine A
-	6 Years	Rockdrill Operator	Mine B

GENERAL INFORMATION	
Include locality map, indicating: • *location relative to towns* • *existing infrastructure* • *other relevant features, e.g. common boundaries, dams, rivers and other topographical features which could influence the strategies adopted.*	 *Y* *Y* *Y*
Describe geological structures, such as: • *faults* • *dykes* • *stratigraphy (around individual orebodies or seams)*	 *Y* *Y* *Y*
Highlight any dangerous or difficult strata.	*Y*
Include typical section.	*Y*
Include map showing major geological features in relation to mining outlines and shafts.	*Y*
Give general description of orebodies or seams being mined, including relevant information such as: • *average mining depth* • *range of mining depths* • *orebody width* • *dip* • *strike*	 *Y* *Y* *Y* *Y* *Y*
Describe regional hydrology such as the occurrence of any significant groundwater and/or any relevant information.	*Y*
Describe ground control districts based on: • *known geological hazards* • *structures* • *jointing* • *changes in rock type* • *changes in rock strength* • *any other factors which may impact on mining.*	 *Y* *Y* *Y* *Y* *Y* *Y*

(Include nature of virgin stress field, occurrence of significant pore water and any other local geological features)	
Depict location and extent of above information on a plan.	*Y*
Tabulate 5 year history of rock-related: • *casualties* • *non-casualty incidents (where available).* *(Categorise according to rockfalls per 1000 employees at work for both surface and underground operations.)*	 *Y* *Y*
Present above information graphically, depict annual statistics and highlight trends.	*Y*
State who is responsible for: • *completion of accident report forms* • *maintenance and interpretation of mine accident statistics.*	 *Y* *Y*
Use accident report form 13 and ID root causes of fatal and reportable accidents	*Y*
Store above information in mine's data bank	*Y*

3 GENERAL INFORMATION

3.1 Location

Shallow Tabular Mine is situated on the farms Mooihoek and Maandagshoek in the Lydenburg district of the Northern Province (see locality map, Figure 1). The area is bounded by the farm Driekop in the north, the Maandagshoek/Mooihoek boundary in the east, Hendriksplaats in the south and a line east of the UG2 outcrop as the western boundary.

The position of Tabular Mine in relation to the eastern compartment of the Bushveld Complex (BC) can be seen on Figure 2. There are no rivers or dams in close proximity to the mine and the slimes dam is situated 300m east and down slope of the shaft.

The Steelpoort (LG 6) and Leader (LG 6a) chrome seams outcrop some 40 to 50m above the general valley floor along the eastern edge of a major North-South trending ridge. The ridge forms part of a system of nearly parallel ridges which are generally about 500m above the alluvial valley.

The neighbouring mines are not being mined at the moment. The Groothoek Mine to the north of Tabular was mined down to a maximum depth of 300m. Mooihoek mine was mined down to a depth of 100m by means of adits. These mining operations are remote from Tabular's boundaries and well outside the zone of influence. Mining on neighbouring mines is therefore not a factor to be considered in this COP. However, this situation shall be reconsidered at least with every review of this COP.

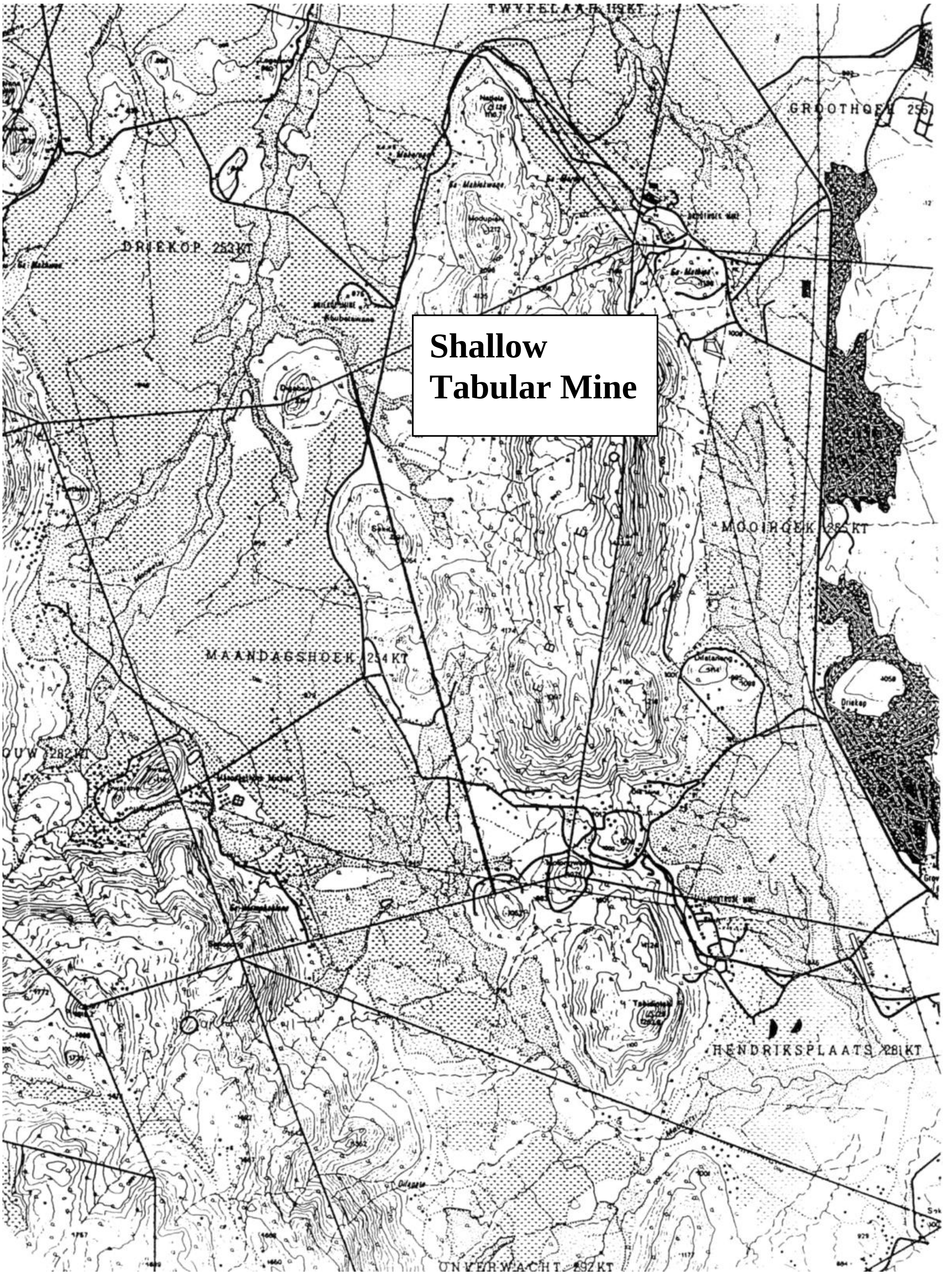


Figure 1 Locality map

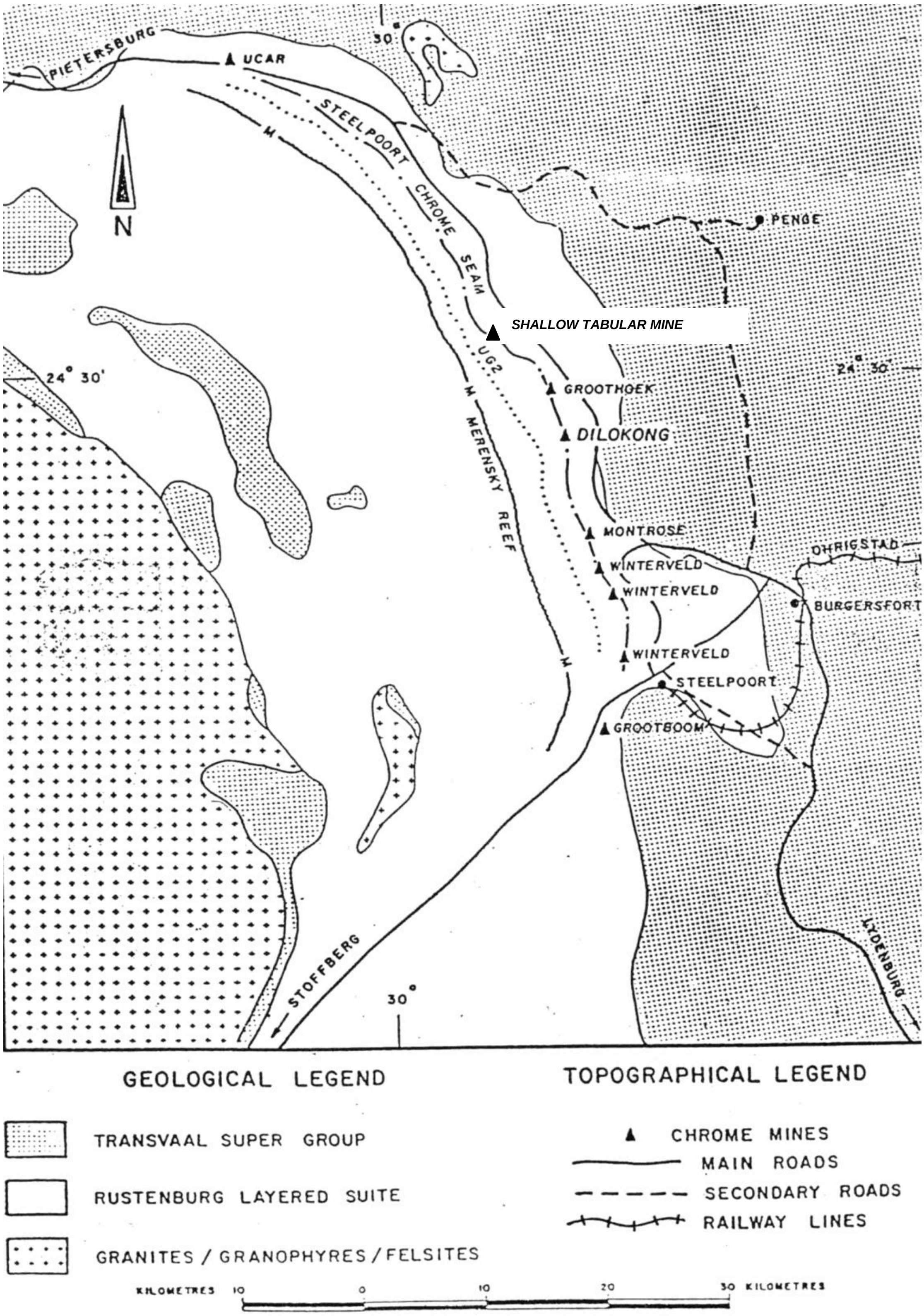


Figure 2 Position of Shallow Tabular Mine relative to the Eastern Compartment of the Bushveld Complex

3.2 Geological Setting

3.2.1 Stratigraphy

A generalised stratigraphic column (Figure 3) and East-West geological section (Figure 4) together illustrate the geological succession at the mine.

The farm Maandagshoek lies almost wholly in the Critical Zone of the BC. The Critical Zone is up to a kilometre and a half thick in which norites alternate with bands of pyroxenite and chromitite.

The Critical Zone comprises two distinct series namely, the pyroxenites and the anorthosites. In the vicinity of the mine, the Steelpoort and Leader chromite seams occur centrally within the Pyroxenite Series. These seams are the two major chromitite bands.

In the vicinity of the Tabular Mine, the Pyroxenite Series is characterised by the remarkable persistence of the major units and the continuity of the Steelpoort seam has, apart from local interruptions by dykes and faults, been clearly established.

The Steelpoort seam at the bottom varies in thickness from 1,0 to 1,4m. It has disseminated chromite hangingwall and footwall contact zones and is parted from the Leader seam by chromitiferous pyroxenites of between 0,9 and 1,2m thick. The parting between the hangingwall pyroxenite and the Steelpoort chromitite, is conspicuous. This type of parting is useful as the chromitite layer usually parts cleanly from the hangingwall. The Leader seam has a sharp footwall contact, a gradational hangingwall contact and has an average width of 0,38m. Above these layers, and parted by between 25 to 30m of coarse grained porphyritic pyroxenite, is the Upper Marker Chromitite. It is approximately 0,4m thick and generally shows sharp contacts. The average depth of the Lower Marker Chromitite below the Steelpoort Chromitite is 10,4m. It is approximately 0,17m in width, has sharp contacts, and a 1 cm wide footwall serpentinite layer.

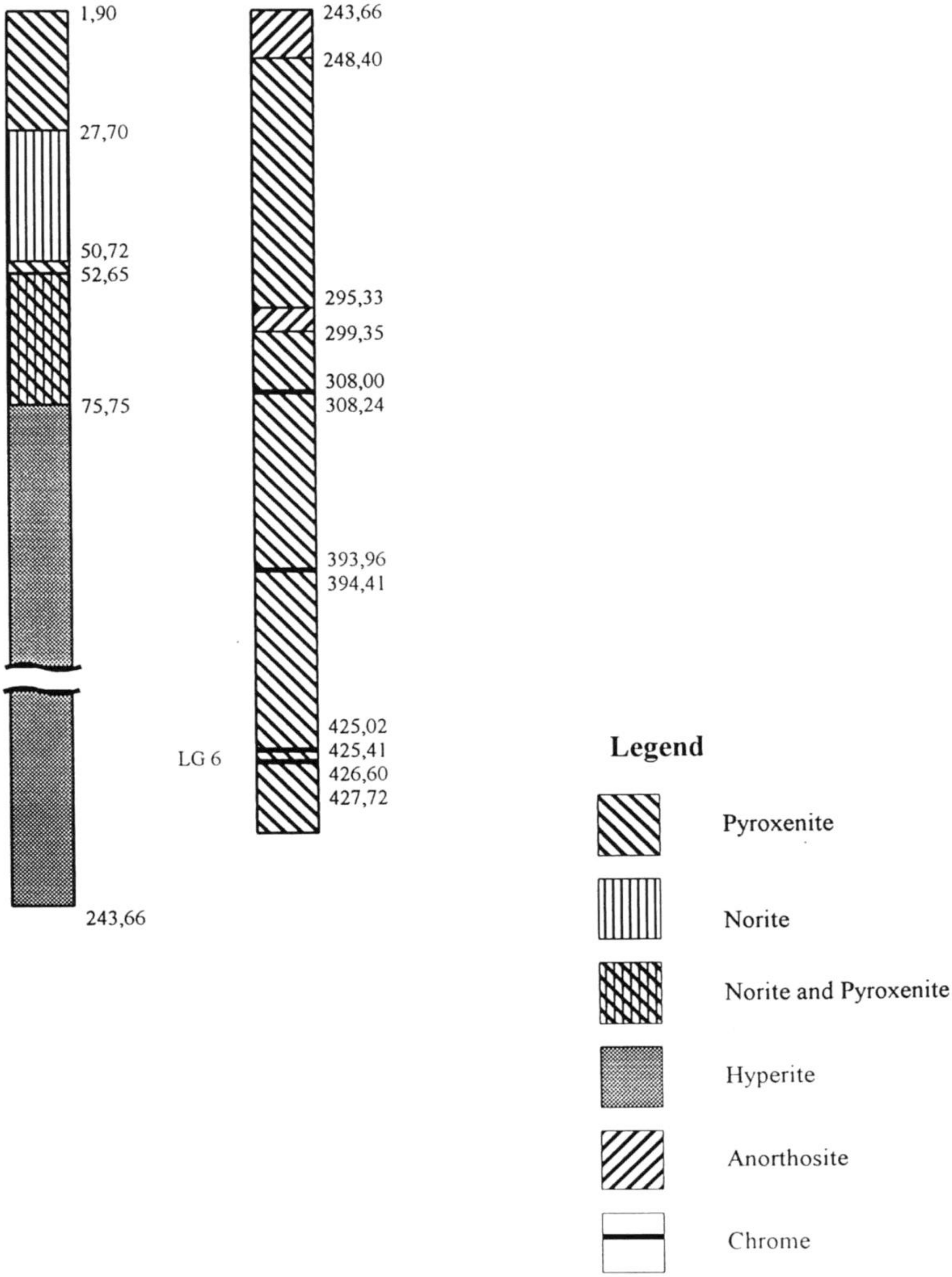


Figure 3 Generalised stratigraphic column

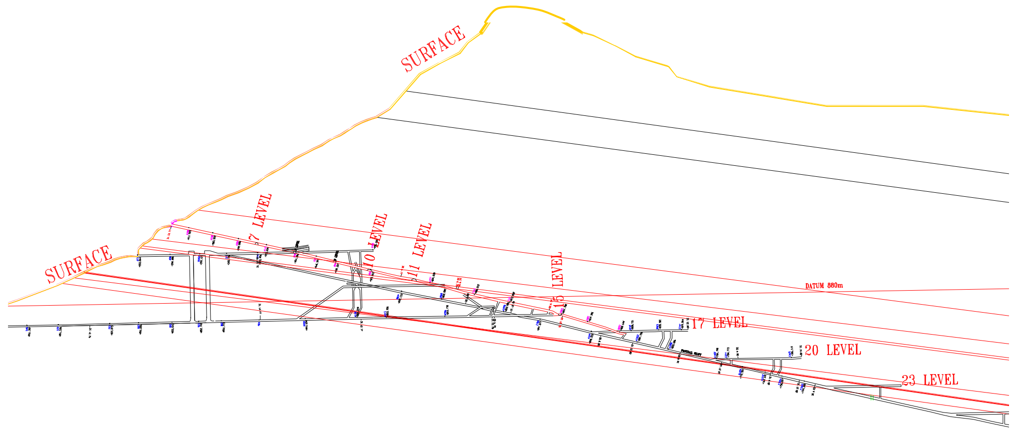


Figure 4 Generalised EW geological section

3.2.2 Structure

On Shallow Tabular Mine, four major geological structures are known. Three of these features are situated in the upper section of the mine where no mining is being done and do not require further consideration at this stage. The main feature to be considered in this COP is the 21m wide dolerite dyke which has been intersected on 5 level North.

These features are shown in

Figure 5 and can be described as follows:

- a 4,0m down throw fault situated between surface and 1 level;
- a 11,0m down throw fault situated between 1 and 2 levels;
- a 40m thick dolerite dyke situated above 3 level with no throw on it;
- the dolerite dyke intersected on 5 level North which dips at approximately 80 degrees and with no throw on it. The mine planning for this dyke area will be discussed under Special Areas.

Minor faulting which strikes approximately E-W, is fairly common at Tabular. This can give rise to an increase in the apparent dip of the seam of 2 to 3 degrees.

A study of the fracture pattern at Tabular Mine, both on surface and underground, revealed three prominent joint directions with average strikes of N 33^0 W, N 28^0 E, and N 88^0 E. The dip of these joints is sub-vertical. Small scale jointing patterns are sympathetic in orientation to these major systems. The spacings of these joints within each of the three sets vary between 0,1 and 1,5m on average. The lengths of the joints range from a few centimetres to several tens of metres. The joints do not posses significant waviness.

A fourth joint set of shallow inclination, exaggerated waviness and random orientation can be found in most stopes, especially in the southern section of the mine. This joint set can also become parallel to the hangingwall within a few centimetres up to several metres of the chrome seam. The strength of these joints is reduced by the presence of a thin veneer of magnesite or talc/serpentinite. ***The presence of these joints can lead to unstable hangingwall conditions, especially when intersected by more than one of the major sub-vertical joint sets mentioned above and requires special attention.***

These joints were initially recognised as domes but detailed observations in stopes showed that the Steelpoort and Leader seams continue without disruption of the layering. In plan these joints form elongated low-angled ellipsoid domes which strike in a NW-SE direction. Due to the large areas which these joints cover, their ability to penetrate through the layering, and en echelon nature upwards, ***these joints could produce dangerous conditions if not correctly supported, barred or blasted down.*** Figure 6 illustrates these joints.

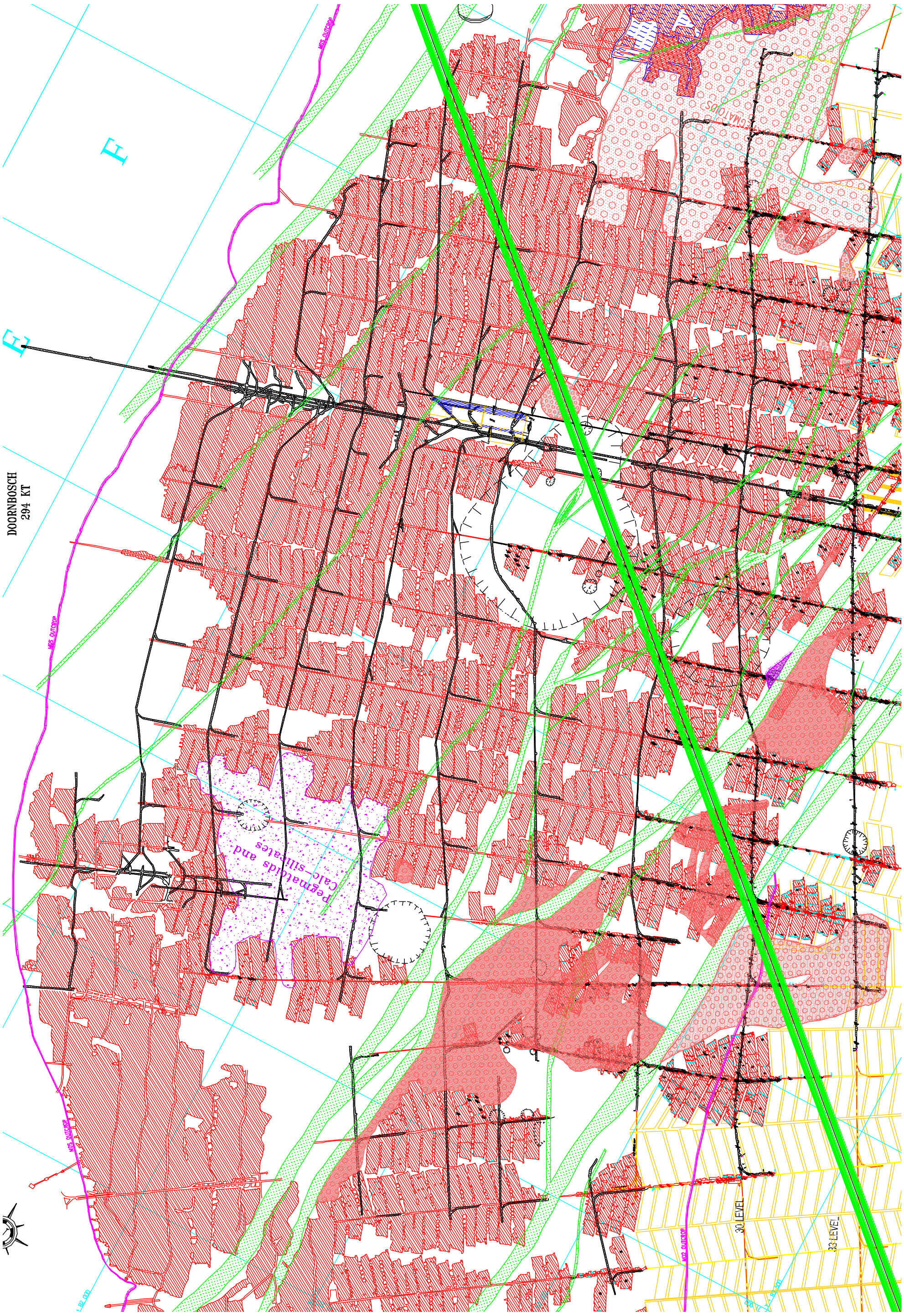


Figure 5 **Plan of underground workings and major geological structures**

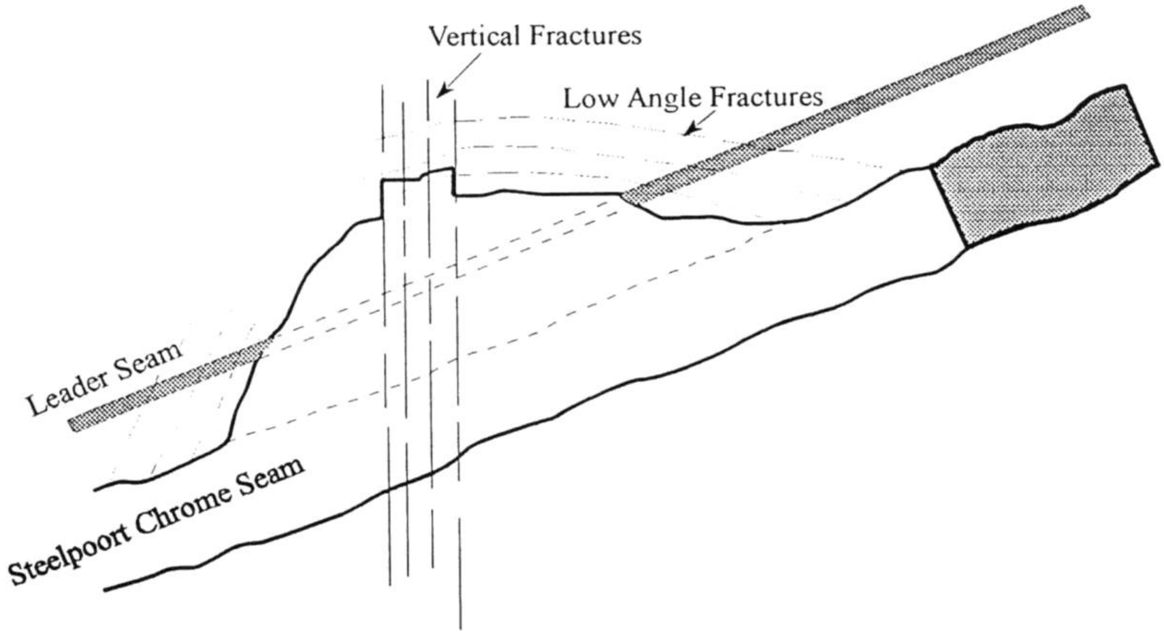


Figure 6 **Section through stope showing the features typical of the flat dipping joints found at Shallow Tabular Mine**

3.3 Orebodies Mined

The Steelpoort Chrome Seam is the only orebody being exploited by Shallow Tabular Mine. It is not planned to mine any other chrome seam in the foreseeable future. This chrome seam strikes approximately north-south and dips at about 26 degrees at the outcrop. This dip decreases towards the west to about 18 degrees along the Mooihoek/Maandagshoek boundary and about 12 degrees in the Maandagshoek area.

At Tabular Mine, the depth of this seam ranges from zero where it outcrops in the east to a maximum of about 550m to the south-west. Tabular is currently mining at an average depth of approximately 480m below surface. The increase in depth as mining proceeds towards the west is not affected by the dip of the seam only, but also by the varying surface topography (Figure 7).

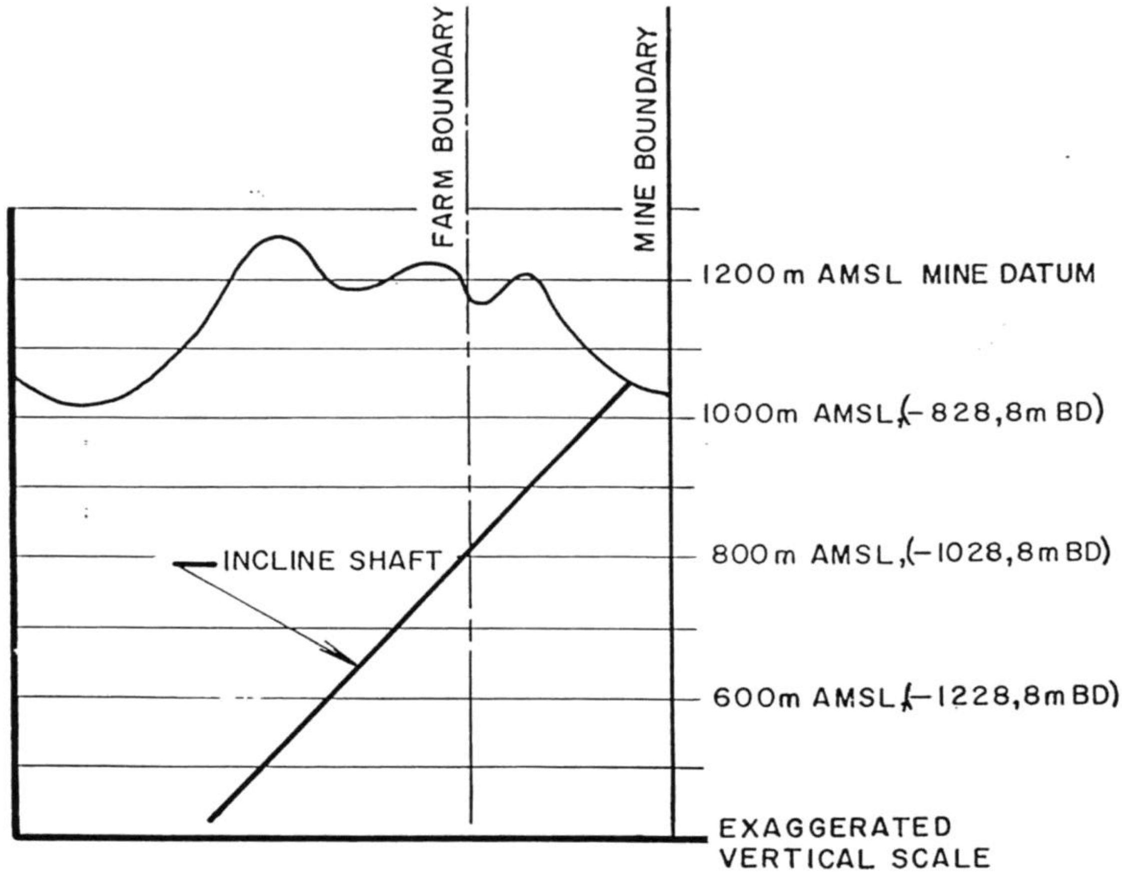


Figure 7 Surface topography at Shallow Tabular Mine

3.4 Regional Hydrology

Shallow Tabular Mine is situated on the watershed between the Olifants river to the north and the Steelpoort river to the south. In the current mining area conditions are dry and no fissures have been intersected below 2 level.

As mentioned above, the chromite seams outcrop some 40 to 50m above the general valley floor along the eastern edge of a major north-south trending ridge. Drainage in this area is in a general south-easterly direction along tributaries of the Moopetsi river.

3.5 Underground State of Stress

3.5.1 Virgin State of Stress

The virgin or pre-mining stress state of stress is the stress acting in the ground prior to any mining taking place. This stress acts in all directions but is not equal in all directions and as such, the stress state is fully defined by the orientation and magnitudes of the three principal stresses. These are mutually orthogonal (act in directions that are 90 degrees apart) and are termed the major, intermediate and minor principal stresses in descending order of magnitude. These stresses are denoted as $\sigma_{1,}$ σ_2 and σ_3 respectively. In shallow dipping and bedded strata one of the principal stresses is usually approximately perpendicular to the dip of the strata with the other two acting in the plane of the dip, approximately parallel to the dip and strike directions.

In the absence of actual data from in situ stress measurements, the following assumptions will be made in order to define the virgin stress field:

- $\sigma_{1,}$ is approximately equal to the vertical virgin stress (σ_v);
- $\sigma_2 = \sigma_{3,}$ and are approximately equal to the horizontal stresses (σ_h);
- σ_v is equal to the load per unit area caused by the mass of the overburden rock.
- $\sigma_h = 0{,}8 \times \sigma_v$ (The k-ratio ($\sigma_h : \sigma_v$) is therefore 0,8)

It can be calculated that:

$$\sigma_v = \rho.g.h. \; [\mathrm{MPa}] \qquad \textbf{(1)}$$

where: ρ = density of the overburden rock (3 200 kg/m^3 for pyroxenite)
g = gravitational acceleration (9,81 m/s^2)
h = depth below surface

Care must be taken when calculating σ_v for Tabular Mine because of the varying topography. When calculating the depth below surface, the following facts should be considered:

- The average elevation above mean sea level of the surface is 1 200m.
- The datum elevation is 1828,8m above mean sea level.
- ***The depth below surface varies along strike and is approximately 100m deeper in the south than in the north.***

The depth below surface to the different operating levels of the incline shaft is shown in Table 1.

Table 1 Depth below surface of mining levels at shaft position

Level	Elevation Below Datum (m)	Average Depth Below Surface (m)
1	-906	277,2
2	-960	331,2
3	-1066	437,2
4	-1110	481,2
5	-1150	521,2

3.5.2 Mining Induced Stresses

The stress in the ground exists in a state of equilibrium. Any excavation made in the ground, disrupts that state of equilibrium and causes a redistribution of the stresses to what is then termed the field or resultant stress state. The difference between the field stresses and virgin stress is termed mining induced stress.

Calculation of the resultant stress state is important in terms of pillar stability analysis at Tabular Mine. This can be done by means of computer analyses, or by means of the tributary area theory which is described in detail under Section 6.4.4.

3.6 Ground control districts

Tabular Mine can be divided geologically into two main structural zones to the east and west of the 40m dyke mentioned above. To the east of the dyke, the structure is characterised by dips of the seam of approximately 18E to the east and several minor faults striking NNW. These faults have caused several localised losses in mineable ground. During mining of the tribute area close to surface, more support had to be used due to the water filled joints and the formation of serpentine and talc along fractures and joints.

To the west of the dyke, the dips are shallower (approximately 15^{E}) and flatten to between 6E and 10E at 5 level. The strike of the seam is also variable, curving from approximately NW to NE along the current development. No faulting is evident however and extraction has been high in this area.

Mining is currently only taking place west of the dyke, and therefore, for the purposes of this COP, Tabular Mine can be considered as one ground control district. Should mining east of the dyke be continued in future, that area will be considered as a different ground control district and mining strategies will be developed to cater for those conditions.

The mechanical properties of chromitite, pyroxenite and anorthosite can be described as follows:

- Pyroxenites and Anorthosites

  In their unweathered state these rocks classify as very hard with small scale strengths typically as given in Table 2.
- Chromitite

  The chromitite is quite friable and disintegrates rapidly to a coarse sand when exposed to weathering or during mining and handling. It is not a very competent material in relatively small pillars, but provides a good support in the form of wider barrier pillars. The mechanical properties of chromitite are listed in Table 2 below. A point to note is the chromitite varies from area to area and can be more or less competent depending on the percentage lumpy chrome.

Table 2 Mechanical properties of rocks

Rock Type	Density (kg/m^2)	Young's Modulus (GPa)	Poisson's Ratio	Uniaxial Compressive Strength (MPa)
Pyroxenite	3210 - 3260	124 - 143	0,26 - 0,27	131 - 155
Anorthosite	2820 - 2870			168 - 210
Chromitite	4060 - 4370	15 - 51	0,08 - 0,43	36 - 173

It is important to note that the above-mentioned rock properties are typical for rocks found elsewhere in the BC and are not specific to Tabular Mine.

3.7 Mine rockfall accident analysis

3.7.1 Rock-related accident statistics

The mine's rockfall accident records since 1988 are summarised in Table 3 below and presented graphically in Figure 8. Detailed accident records for the period prior to March 1995 are not available due to the mine's closure between 1992 and 1995.

Table 3 Rock-related accidents (1988 – 1997)

Date	Working Place	Accident Type	Excavation Type	Location	Origin	Cause
21/06/88	122 Strike Gully	Fatal	Gully	Face	Hanging	Lack of (or inadequate) standards / procedures
11/10/90	102 Boxhole / Orepass	Reportable	Development	Face	Hanging	Inadequate examination / inspection
12/12/91	102 Boxhole / Orepass	Reportable	Development	Face	Hanging	Inadequate examination / inspection
13/12/91	119 Stope	Reportable	Stope	Face	Face	Inadequate examination / inspection
30/08/95	119 Stope	Reportable	Stope	Face	Face	Failure to comply with good practice / standards
23/11/95	119 Stope, 5 Level South	Reportable	Stope	Face	Hanging	Inadequate examination / inspection
16/09/96	106 Reef Drive, 4 Level Footwall	Reportable	Development	Face	Face	Inadequate examination / inspection

The immediate cause of most fall of ground accidents is the so-called "false hanging" or flat dipping and almost cohesionless joint planes described above which are found in most stopes on the mine. The typical thickness of the unstable part of this layer varies between 50 and 200 mm. This "false hanging" tends to fall out between the permanent support in blocks when intersected by one or more of the sub-vertical joint sets.

However, after the last fall of ground disabling injury in September 1996, a special instruction was issued that ***all false hanging should be blasted down with the advancing stope face***. Since the implementation of this instruction, there has been no rockfall accident at Shallow Tabular Mine.

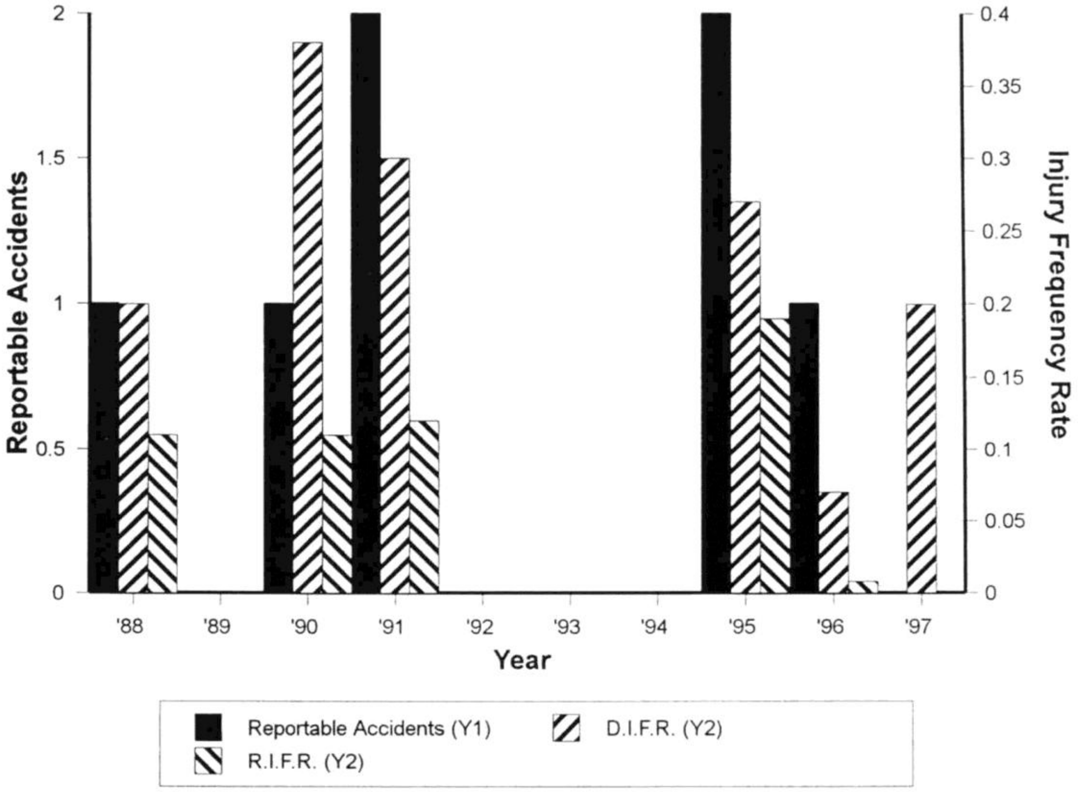


Figure 8 Fall of ground accident records (1988 – 1997)

Based on the above fall of ground accident statistics, drawing any conclusions is difficult and it was therefore decided to obtain information on typical fall of ground incidents. Unfortunately, these incidents are not normally reported and information on this matter could only be obtained by consultation with the workers of Tabular Mine. ***According to their observations, rockfalls normally vary in thickness between 0,2 and 1,2m, with 95% of all rock falls less than 1,0m thick.*** This corresponds with the thickness of the pyroxenite parting up to the base of the Leader seam. It will be assumed that the fallout thickness in stopes and development ends are the same.

3.7.2 Fall of Ground Accident Records

As required by the Mine Health and Safety Regulation 34.1, ***accident report Form 13 must be completed for all incidents that result in the loss of 14 or more shifts***. This form is formulated in a manner which facilitate identification of the root causes of fatal and reportable accidents.

As mentioned above, information on fall of ground accidents at Tabular Mine is limited and drawing any meaningful conclusions is therefore difficult. In order to build up a more useful rock-related database, the following data will be recorded for all fall of ground disabling accidents:

- Date;
- Working Place;
- Type of accident (e.g. fatal / reportable / disabling injury)
- Excavation Type (e.g. Stope / Footwall Development / Gully / Shaft / Other);
- Location in Excavation (e.g. Face Area / Back Area);
- Origin of F.O.G. (e.g. Face / Hangingwall / Sidewall);
- F.O.G. Dimensions (Thickness, Width and Length);
- Characteristics of geological features at the scene of the accident (joint/fault strike and dip orientation, frequency, etc.);
- Activity being performed at time of accident;
- Support type and density being used at time of accident;

- Distance of accident from support;
- Root causes.

This information will be stored in the mine's data bank to facilitate analyses and identification of root causes.

The responsibilities of safety representatives, supervisors, shift bosses and other officials with regards to accident investigations, completion of accident report forms, maintenance and interpretation of mine accident statistics are as follows:

- **Safety Representative responsible for area where accident occurred:**
  - He must assist with all F.O.G. accident investigations.
  - He must assist the injured person's immediate supervisor with the completion of the accident report form.

- **The injured person's immediate supervisor:**
  - He must assist with all F.O.G. accident investigations.
  - He must complete the accident report form.

- **The shift boss in charge of the area where the accident occurred:**
  - He must arrange for an in loco investigation of all F.O.G. accidents.
  - He must inform the responsible safety representative, supervisor and safety officer and other officials (if necessary) of the time and place of the accident investigation.
  - He must attend all in loco F.O.G. accident investigations.
  - He must ensure that the accident report form is completed by the injured person's immediate supervisor.
  - He must complete his section of the accident report form.
  - On completion of the accident report form by the responsible mine overseer, the shift boss must forward the accident report form to the safety officer.

- **The mine overseer in charge of the area where the accident occurred:**
  - He must attend all in loco investigations for F.O.G. reportable accidents.
  - He must complete his section of the accident report form.

- **The safety officer:**
  - He must attend all in loco investigations for F.O.G. reportable accidents and all other F.O.G. accidents as far as possible.
  - He must receive all F.O.G. accident report forms and ensure that they have been completed properly.
  - He must analyse the accident and report his findings to the Health and Safety Committee at the monthly meeting.
  - He must keep copies of the accident report forms on file.
  - He must update the F.O.G. accident data base on a monthly basis.
  - He must ensure that Accident Form 13 is completed after each F.O.G. accident.

GLOSSARY OF TERMS AND DEFINITIONS	
Incorporate a glossary of terms and definitions	*Y*

4 GLOSSARY OF TERMS AND DEFINITIONS

A glossary of terms and definitions is included in Appendix B This appendix forms part of the COP.

ROCK-RELATED RISK MANAGEMENT	
• *Identify and describe rock-related hazards which are likely to arise from the mining of each geotechnical area identified.*	*Y*
• *Assess and prioritise the health and safety risks to which workers will be exposed and record findings.*	*Y*
• *Develop and implement reasonably practicable strategies to reduce and manage the significant risks, based on above risk assessment and accident analysis.*	*Y*
• *Use Tripartite Risk Assessment Guidelines when dealing with the aspects of hazard ID and risk assessment.*	*Y*

5 ROCK-RELATED RISK MANAGEMENT

5.1 Introduction

The Mine Health and Safety Act requires the manager to identify the hazards, to assess the health and safety risks to which workers may be exposed while they are at work, record these findings and implement reasonably practicable measures to control the risk.

The management of Tabular Mine will use the following basic risk assessment strategy, based on the Tripartite Risk Assessment Guidelines on this subject:

1) Identify all rock-related hazards which are likely to arise from mining.
2) Describe all rock-related hazards which are likely to arise from mining.
3) Develop strategies to reduce and manage rock-related risks. (These strategies are described in Section 6.)

The following general principles will be followed when conducting rock-related risk assessments at Tabular Mine:

1) Rock-related risk assessment should be carried out systematically to cover all work activities and to ensure that all relevant risks or hazards are addressed. This will be done by:

- identifying the major rock-related risks;
- considering those aspects of the work which have the potential to cause harm;
- considering existing safety measures and controls and their effectiveness.

2) The risk assessment should address what actually happens in the workplace during the work activity.

3) Employees, maintenance staff, visitors and contractors must be considered.

4) The risk assessment should highlight those groups and individuals who may be particularly at risk, such as machine operators or inexperienced workers.

5.2 Forms of Risk Assessment

The following forms of risk assessment will form part of Tabular Mine's rock-related risk management system:

1) **Baseline Risk Assessments**

This involves the following aspects:

- identifying the major rock-related risks;
- establishing their priorities;
- establishing a programme for future risk control;
- regular review to ensure that it is still relevant and accurate.

Critical Task Inventories (CTI's) will form the basis of the next baseline risk assessment scheduled for February 2002 and must be reviewed before this risk assessment commences. Each task must then be evaluated to determine the criticality of each task using the Workplace Risk Assessment and Control (WRAC) technique. According to this technique, hazards are identified by considering each step in the completion of a task and ranking the risk according to the probability of an incident happening and the likely consequence, as indicated by the risk ranking matrix illustrated in Table 4 and discussed in Section 5.4.

2) **Issue Based Risk Assessments**

This is a separate risk assessment which will be carried out when:

- a new support type is considered for the mine;
- a new support or mining layout is considered;
- an accident or a "near-miss" has occurred;
- new knowledge becomes available and information is received which may influence the level of rock-related risks to employees at the mine.

3) **Continuous Risk Assessments**

This is the most important part of the rock-related risk assessment process and will take place continually and will form an integral part of the day to day management. It will be conducted by all front-line supervisors. In this type of risk assessment, the emphasis will be on hazard awareness through hazard identification and will include:

- regular audits (e.g. inspections by the shift boss, mine overseer or manager);
- general hazard identification by all workers on an ongoing basis;
- pre-work assessments by the ganger and his team using checklists (e.g. early morning examination);
- Critical Task Analysis and Planned Task Observations by the shiftboss on an ongoing basis.

5.3 Hazard Identification

This is the first and most important stage of the risk assessment process at Tabular Mine. The following techniques and tools will be used to ensure that all rock-related hazards are identified systematically:

1) The manager will ensure that the safety officer is trained as a risk assessment facilitator and to advise management on the gathering of data, the selection of the risk assessment team and in the development of the risk assessment process.

2) The safety officer should define the scope of each risk assessment exercise by considering one of the following ways:

- **geographically based** such as looking at stopes, shafts, footwall development, etc.;
- **functional based** such as barring, drilling, cleaning, etc.;
- **hazard based** such as the hangingwall, sidewall, face, etc.

3) The safety officer should select a risk assessment team from the workplace being reviewed by taking a vertical slice through the management structure, to the lowest levels in the organisation. . Where necessary, specialist expertise should be brought in. It is important that all members should receive formal training in order to do risk assessments. Front line supervisors should also be trained in Critical Task Analysis, Planned Task Observations and workplace inspections. This training should be carried out by the safety officer.

4) The safety officer should gather all relevant background information by assessing:

- the database on the mine;
- the types of accidents and incidents and their major underlying causes;
- past accidents and incidents;
- log books and audit reports.

All these data need to be assimilated, analysed and converted into a useful format so as to prepare the team which undertakes the risk assessment.

5) The safety officer should present the analysed data, describe the scope of work and discuss the potential hazards with the risk assessment team.

6) The risk assessment team and safety officer should visit the relevant working

place and identify the hazards. The following techniques will be considered:

- **Top Down Technique**

  This technique involves working from a top event downwards to arrive at the underlying causes and also potential other events. Examples of this approach involve checklists, accident analysis, Fault Tree Analysis, task analysis and brain storming.

- **Bottom Up Technique**

  This approach is one of breaking down the system or problem into small components and then seeing how they or others may fail, building up to a major event. Examples of this type of technique include Hazard and Operability Studies (HAZOP), Workplace Risk Assessment and Control (WRAC), etc.

5.4 Risk Measurement

Several approaches can be used for the measurement of risk. The Risk Matrix Approach is most widely used in the mining industry and will be followed by Tabular Mine. With this approach, the consequences of the hazard and its likelihood/frequency are first categorised separately and then combined in a matrix to produce a priority. Thus, the system consists of the following basic components:

- **Consequence Assessment**

  Here, the degree of harm from the identified hazard is assessed in terms of the potential severity of the injuries or ill health and/or the number of people potentially affected.

- **Frequency or Likelihood**

  This is normally a compound of two separate factors. Firstly, **exposure** which is an analysis of how often and for how long the employees involved are exposed to the hazard. Secondly, it includes an analysis of **probability**, that is the chance that a person or persons will be harmed during the exposure period.

Using this technique, the assessment is done by a group or "vertical slice" of people from the workplace ranging from the person undertaking a given task to a higher level supervisor and is facilitated by a safety professional. Hazards are identified by considering each step in the completion of a task and ranking the risk according to the probability of an incident happening and the likely consequence, as indicated by the risk ranking matrix illustrated in Table 4. A risk ranking of 1 is the most serious and 25 is the least serious. Thus all rankings from 1 to 7 are critical and require urgent consideration, rankings 8 to 15 are serious and 16 to 25 are of lesser severity and should be addressed only when the more serious risks have been eliminated or controlled.

Table 4 Risk ranking matrix

CONSEQUENCE	PROBABILITY				
	Common (Daily) A	**Likely (Weekly) B**	**Happens (Monthly) C**	**Unlikely (Yearly) D**	**Rarely (1 - 5 years) E**
Fatality R500 000+ 1	1	2	4	7	11
Reportable Injury R250 000 - R500 000 2	3	5	8	12	16
Disabling Injury R100 000 - R250 000 3	6	9	13	17	20
First Aid Case R50 000 - R100 000 4	10	14	18	21	23
No Injury Nil - R50 000 5	15	19	22	24	25

The risk associated with critical and serious hazards should then be evaluated in more detail using the guidelines and classification in Tables 5 and 6 respectively, and equation (2) below:

$$\text{Risk} = \text{Probability} \times \text{Exposure} \times \text{Consequences} \qquad \textbf{(2)}$$

Table 5 Risk evaluation guidelines

Probability (The chance of harm or loss during the exposure period)		**Value**
Might well be expected	(Happens often)	10
Quite possible		6
Unusual but possible		3
Only remotely possible	(Has happened somewhere)	1
Conceivable, but very unlikely	(Has not happened yet)	0,5
Practically impossible	(One in a million)	0,2
Virtually impossible	(Approaches the impossible)	0,1
Exposure (How often or how long a hazardous event occurs or is present)		**Value**
Continuous		10
Frequently	(Daily)	6
Often	(Weekly)	3
Unusual	(Monthly)	2
Unusual	(A few per year)	1
Rare	(Yearly)	0,5
No exposure		0,1
Consequence		**Value**
Catastrophic	(Many fatalities or damage over R10 000 000,00)	100
Disaster	(A few fatalities, or damage over R1 000 000,00)	40
Very serious	(One fatality, or damage over R100 000,00)	15
Serious	(Reportable injury or damage over R10 000,00)	7
Important	(Disabling injury or damage over R1 000,00)	3
Of concern	(Minor injury or damage over R100,00	1

Table 6 Risk classification

Over 400	Very high risk, correct with urgent action and high priority
200 - 400	High risk, immediate correction required
70 - 200	Substantial risk, correction needed
20 - 70	Possible risk, attention indicated
Under 20	Risk perhaps tolerable as it is

5.5 Risk Control Measures

The risk assessment team should consider the following strategies and make recommendations to the manager:

1) **Elimination**

This can be done by either removing the hazard from the working environment, or by working in a different area.

2) **Control the Risk at Source**

This strategy may involve limiting access to the hazardous area, or by guarding against the hazard, or by operating from a remote distance.

3) **Minimise the Risk**

This strategy involves aspects such as hazard awareness training programmes to ensure that workers keep away from the hazardous areas and the use of safety devices such as hydraulic props under rock burst conditions.

4) **Personal Protective Equipment and Monitoring of the Risks**
This approach should be the last resort to risk control.

High frequency and high consequence hazards are the highest priority. Those with a low frequency and low consequence are low priority and those with either high frequency and low consequence, or high consequence and low frequency are considered as medium priority.

5.6 Reporting and Recording of significant risks

All risk assessment exercises should be recorded by the safety officer and must be easily accessible to employees, their representatives and to inspectors. However, the documentation system should not detract from the major purpose of risk assessment and that is to improve the management of risks, thereby ensuring the health and safety of employees. The following aspects should be reported on:

- The major hazards identified.
- A review of the existing safety measures and the extent to which they work in controlling risks.
- Those who may be affected by the major hazards.

5.7 Preventative and Protective Measures

If possible, risks should be eliminated. If this is not possible, then they should either be mitigated/controlled or minimised or, if none of these is possible, then personal protection should be provided. In deciding upon the types of preventative and protective measures that need to be provided, the following principles should be considered by the manager:

- It is always best, if possible, to avoid a risk altogether. This can be done by using a different approach, substance or method of work.
- Combat risks at source rather than by adopting secondary measures.
- Wherever possible, work should be adapted to the individual rather than the individual adapted to the work.
- Make use of technological and technical progress when treating risks.

- Collective protection measures should be given priority.
- Protection provided should be backed up with adequate training and supervision.
- Measures to avoid, prevent and reduce risks need to be an accepted part of the approach and attitudes at all levels of the organisation.

5.8 Review and Revision

Risk assessment is a continuous process and as work changes, the hazards and risks may change and therefore the risk assessment process must also change. Risk assessments should be reviewed or modified when an accident occurs, or if more is learnt about certain hazards in the workplace. Thus, after an accident, the safety officer should select a risk assessment team and revisit the previous risk assessment to see:

- whether the accident which has occurred was predicted;
- whether it was decided to prevent that accident;
- if so, why the preventative measures did not work;
- if the accident was not predicted, whether it is necessary to revise the risk assessment process or not;
- if the accident was predicted but it was decided to tolerate the risk, whether the decision was valid;
- why the accident occurred, and what should be done to prevent similar accidents occurring, so far as is reasonably practicable.

5.9 Practical Rock-Related Risk Assessment at Tabular Mine

The management of Tabular Mine is committed to the risk assessment approach as outlined above and has completed a baseline rock-related risk assessment as discussed in paragraph 4.9.1 below. This has determined the priority of risk assessment work to be done in more detail. A safety professional from N.O.S.A. was appointed as a facilitator and to advise management on the gathering of data, the selection of the risk assessment team and in the development of the risk assessment process.

It is planned to do a more detailed baseline risk assessment in March 2001. In the mean time, relevant mine employees will be trained further in the practical application of risk assessment, Critical Task Analysis (CTA), Planned Task Observations (PTO), and other techniques. Critical Task Inventories (CTI) will then be revised by the Safety Officer and the Risk Assessment Team. Once the inventories are completed, each task will be analysed using the Workplace Risk Assessment and Control technique. This will form the basis of future baseline risk assessments.

5.9.1 Baseline Rock-Related Risk Assessment

A baseline rock-related risk assessment has been carried out by the risk assessment team consisting of the following employees:

Name	**Occupation**
STOF Engate	Mine Overseer
PA Soppa	Safety Officer
HS Member	Health and Safety Committee member
SHI Bas	Shift Supervisor
TR Officer	Training Officer
MI Stof	Miner
TM Leader	Team Leader

Gravity driven falls of ground at Tabular Mine are the major rock-related hazards which need to be addressed. Tables 7 to 9 below systematically describe the different fall of ground hazards likely to arise from mining.

Table 7 Baseline rock-related risk assessment – geographically based

F.O.G. Hazard Description			Freq.	Cons.	Risk Rank
Stope	Face Area	Hanging	C	1	4
		Face	C	2	8
		Sidewall	D	2	12
	Back Area	Hanging	D	1	7
		Face	N/A	N/A	N/A
		Sidewall	E	2	16
Off-Reef Development (Horizontal)	Face Area	Hanging	D	1	7
		Face	D	2	12
		Sidewall	E	1	11
	Back Area	Hanging	E	1	11
		Face	N/A	N/A	N/A
		Sidewall	E	1	11
Off-Reef Development (Inclined)	Face Area	Hanging	D	1	7
		Face	D	2	12
		Sidewall	E	2	16
	Back Area	Hanging	E	1	11
		Face	N/A	N/A	N/A
		Sidewall	E	2	16

(Stope Sidewall - From the sidewall of in-stope pillars and gully headings)

Table 8 Baseline rock-related risk assessment – task based

F.O.G. Hazard Description		Freq.	Cons.	Risk Rank
Stope	Barring	D	1	7
	Drilling Face	E	1	11
	Drilling Hangingwall	D	1	7
	Cleaning	E	1	11
	Support Installation	D	1	7
	Charging-up	E	1	11
	Inspection	E	1	11
Off-Reef Development (Horizontal)	Barring	D	1	7
	Drilling Face	E	1	11
	Drilling Hangingwall	D	1	7
	Cleaning	E	1	11
	Support Installation	D	1	7
	Charging-up	E	1	11
	Inspection	E	1	11
Off-Reef Development (Inclined)	Barring	D	1	7
	Drilling Face	E	1	11
	Drilling Hangingwall	D	1	7
	Cleaning	E	1	11
	Support Installation	D	1	7
	Charging-up	E	1	11
	Inspection	E	1	11

Table 9 Baseline rock-related risk assessment – hazard based

F.O.G. Hazard Description		Freq.	Cons.	Risk Rank
Geologically Disturbed Area	Unfavourable Jointing	B	1	2
	Fault Intersection	C	1	4
	Dyke Intersection	D	1	7
Panel Collapse	Pillar Under-designed	D	1	7
	Pillars Spacing	D	1	7

The highlighted risk rankings above indicate "high risks" and will be addressed in more detail in the following section.

Strategies to Reduce and Manage Rock-Related Risks
• *State department or persons responsible for the execution of the particular strategies or portions thereof.* • *Provide time table for preparation and implementation of strategies.* • *Derive mine standards from strategies.*
Mining Method, Sequence and Overall Mine Stability: • *Include measures to avoid failures that may injure employees or damage mine excavations or equipment.* • *Take into account:* - *the geotechnical environment* - *potential major rock related hazards identified in risk assessment* • *Describe:* - *mining method* - *mining sequence to be followed.* • *Describe strategy adopted to manage risk where mining of one orebody can be expected to have an adverse effect on the other.* • *Describe in detail the use of ongoing RE input in mine layout design and performance monitoring.*
Describe the design methodology to avoid uncontrolled collapses.
Describe the effects on: • *surface structures* • *topography.*
Describe: • *methodology* • *criteria used for the design of in-panel and barrier pillars.*
Give reasons for selecting a specific type of pillar.

6 STRATEGIES TO REDUCE AND MANAGE ROCK-RELATED RISKS

6.1 Mining Method

The mining method being used by Tabular Mine can be described as a room and pillar mining method and is widely used by mines to extract orebodies of similar nature. Stope panels are normally mined in both strike directions and in a “breast” fashion, leaving strike orientated pillars for regional stability purposes. A typical mining layout is shown in Figure 9.

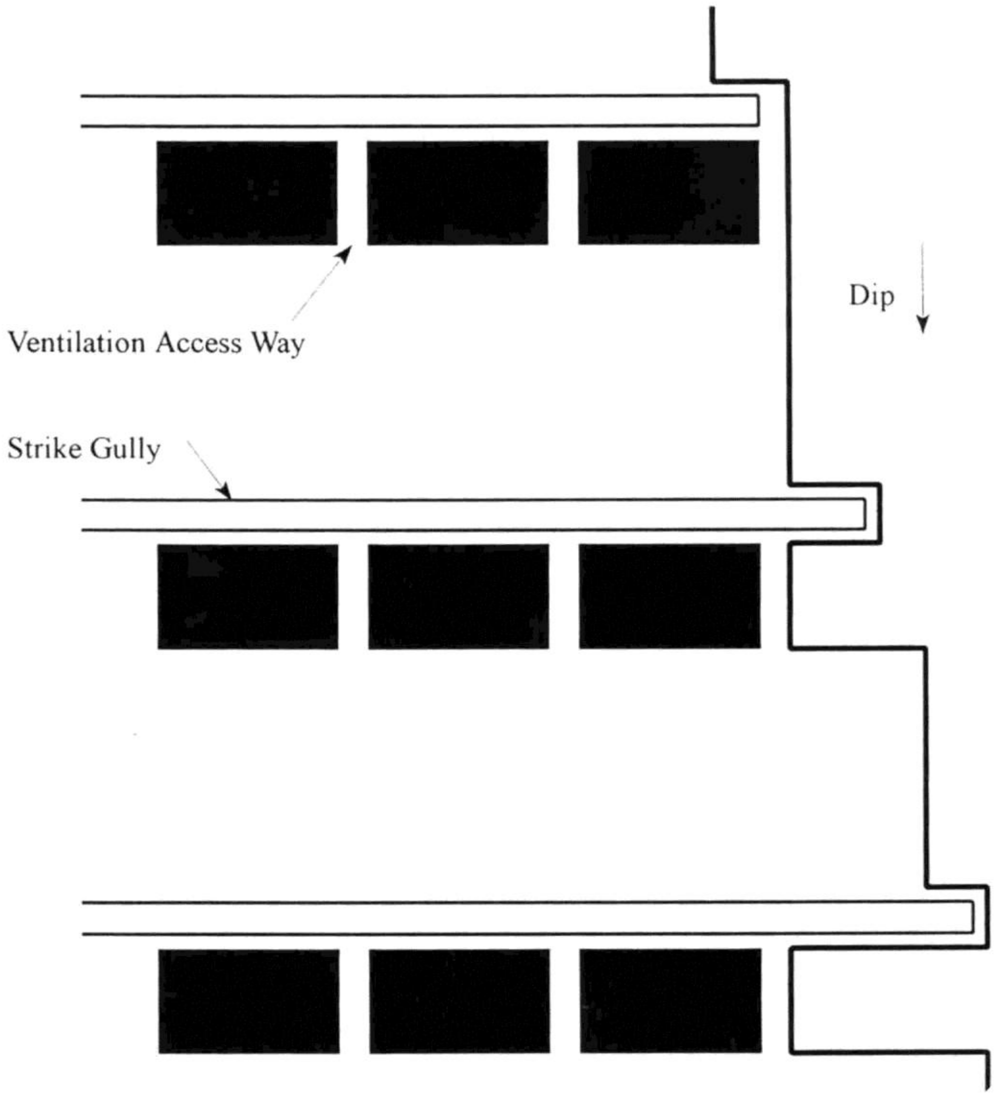


Figure 9 Typical mining layout for Shallow tabular Mine

The pillars should ideally be orientated on strike in order to intercept the major joint sets as far as possible. In Tabular's case, the two major joint sets strike approximately N 33^0 W and N 28^0 E respectively. The third joint set, which strikes approximately N 88^0 E, will be intercepted by the face.

6.2 Mining Sequence

6.2.1 Development

Main access to the underground workings is along the Hanekom Shaft. This is a decline shaft of approximately 1 250m long with dimensions of 5,7m wide x 2,8m high. It has been developed approximately 18m below the Steelpoort seam at an inclination of approximately 18E above 1 level and approximately 12E below 1 level. Shaft stations are approximately 220m apart along the decline.

From the shaft stations, footwall drives (2,7m x 2,7m) are developed approximately 18,0m below the Steelpoort seam along the footwall marker band. From this footwall drive, crosscuts are developed towards the reef. These crosscuts are approximately 120m apart along strike and are developed either up to the reef horizon or are stopped short of the reef intersection. In the latter case, a travelling way is used to connect the crosscut with the reef horizon.

From the cross cut/reef or travelling way/reef intersections, raises (2,0 x 2,0m) are developed on reef and along dip, from one level to the next level. During this development stage, two boxholes are developed from each cross cut to the raise above at an inclination of approximately 60E.

6.2.2 Ledging

From the centre raises, strike gullies (2,0 x 2,0m) are developed to divide the length of face between levels into panels of not more than 35m long. Between the strike gullies and on either side of the centre gully, crush pillars (2,0 x 2,0m) are left to ensure long term stability of the centre gully. The optimum panel length is normally determined by regional stability requirements and available mining equipment.

6.2.3 Stoping

Gullies are normally advanced not more than 5,0 metres ahead of the advancing face to provide additional structural geological information and also to provide a second free face for effective blasting. Breast panels are mined using conventional drilling and blasting techniques. Normally, approximately 1,2 metre face advance is achieved per blast.

Contrary to mining at depths ranging from intermediate to deep, the overall extraction sequence is not important from a rock engineering point of view, provided that pillars of adequate size and spacing are left in situ to provide regional stability. However, from a local support and face area support point of view, ***the installation of face area support must be properly integrated into the blasting and cleaning cycle*** so that the exposure of workers to under supported conditions is minimised. The key concerns here are that:

1) The distance from the face to the first line of permanent support does not exceed 4,0m at any time during the mining cycle.

2) Maximum face advance per blast should not exceed 1,2m per blast.

3) Support spacings do not exceed the recommended standard to ensure that the installed support meets the support resistance criterion.

4) Temporary support used in the face area or other areas should be installed from a safe position and not more than 1,0m away from previously installed support.

The above points apply to gully headings as well. (Also see Section 6.7.3)

6.3 Overall Mine Stability

Roof support pillars are usually found in shallow mines and mines at intermediate depths. These mines normally suffer from large tensile zones in the hangingwall. Robust and stiff support is thus required to resist large FOG's or panel collapses ("back breaks") and large surface movements. Only stiff backfill or pillars can deliver this.

The following roof support pillars will be used at Tabular Mine:

- non-yield pillars for systematic and regional support;
- crush pillars for additional support along faults and dykes, to support potentially unstable hangingwall due to flat dipping joints and for protection of centre gullies.

6.3.1 Non-Yield Pillars

These pillars are usually found at depths < 500 m. These pillars must support the full cover load and will remain unfailed if the pillar stresses are kept within the elastic range. At Tabular Mine, non-yield strike stabilising pillars will be left on the down dip side of strike gullies. The design methodology of these pillars is discussed in section 5.4.

6.3.2 Crush Pillars

These pillars are usually found at shallow and intermediate depths > 300 m. Their W:H ratio varies between 1 and 2,5. They can be considered as an alternative to non-yield and yield pillars at deeper depths. They are slender pillars which crush rapidly and stably. However, their residual strength can still supply the required support resistance up to the critical weak parting in hangingwall.

They are easier to design, but larger strata movements are permitted. The potential danger of a pillar run exists if pillars are not pre-fractured by the time they are cut from the face.

At Tabular Mine, these pillars are not used for the purposes as described above, but rather for additional support where bad ground conditions are encountered between non-yield pillars. In such cases the crush pillars should be at least 2,0m wide with a W : H ratio of approximately 1,6.

6.3.3 Room Widths

Room width design is normally done on an empirical basis and depends on the hangingwall jointing and blockyness, as well as on local support resistance and areal spacings. Based on experience of ground conditions at Tabular Mine, stope spans should not exceed 35m (centre to centre spacing between strike stabilising pillars).

6.4 Pillar Design

The following aspects should be considered during the design of pillars:

- pillar strength;
- foundation strength;
- pillar stress;
- factor of safety.

6.4.1 Pillar Strength

Stacey and Page recommended that the following design approach be followed to ascertain the strength of pillars with W : H ratio less than 4,5:

$$\text{Pillar Strength } (p_S) = k \frac{W_{eff}^{0,5}}{H^{0,7}} \quad [\text{MPa}] \qquad \textbf{(3)}$$

Where k	=	The strength of a cube of chromitite
W_{eff}	=	4 x (pillar area / pillar perimeter)
H	=	Pillar height

The above relationship indicates a decreasing rate of strength increase for greater W : H ratios and does not take into account the strengthening effect of increased confinement with increased W : H ratio. Thus, for W : H ratios greater than 4,5, the following relationship should be used:

$$\text{Pillar Strength } (p_S) = k\,\frac{2{,}5}{V^{0{,}07}}\{0{,}13[(\frac{R}{4{,}5})^{4{,}5}-1]+1\}\ [\mathrm{MPa}] \qquad \textbf{(4)}$$

where: $R = W_{eff} / H$

$V = W^2_{eff}\,.\,H$

From the above relationships, pillar strength clearly depends on the following factors:

- rock mass strength of the pillar rock type;
- shape and size of the pillar defined by its width and height.

Pillar strength can also be significantly influenced by gross structural features such as clay bands, unfavourably orientated faults and joints.

- **Rock Mass Strength**

  The strength of a cube of chromitite (k) is well below the intact strength of chromitite and can be related to the design rock mass strength (DRMS), which is the adjusted strength of intact rock to allow for factors such as geological weaknesses, excavation technique, orientation of pillar or excavation relative to major geological features, and other.

  The procedure as described by Laubscher should be followed to ascertain the DRMS value required in pillar design work. This procedure can be summarised as follows:

  1) Determine the uniaxial compressive strength (σ_c) of rock. This could be done by means of laboratory, point load or Schmidt hammer tests. Care should however be taken to ensure that point load and Schmidt hammer test results are calibrated against laboratory determined test results.

     The σ_c forms the basis of all the following calculations and should be ascertained for a number of rock samples from the immediate hanging, footwall and chrome seam. Test samples should also be obtained from different areas of the mine.

2) Obtain the Mining Rock Mass Rating (*MRMR*) value for the rock mass using Laubscher's rock mass classification system. This value is obtained by summing the four individual parameter ratings for:

- drill core quality (*RQD*);
- uniaxial compressive strength;
- spacing of joints;
- condition of joints including groundwater.

3) Determine the Rock Mass Strength (*RMS*) by using the following relationship:

$$RMS = \sigma_c \text{ x } \left(\frac{MRMR - \sigma_c \text{ rating}}{80}\right) \text{ x } 0{,}8 \text{ [MPa]} \qquad \textbf{(5)}$$

- where: σ_c rating = the adjusted σ_c to take account of the ratio of weak to strong zones in the rock mass.

4) Determine the *DRMS* by applying a series of cumulative adjustments to the *RMS* to allow for:

- weathering;
- joint orientation;
- fault orientation;
- pillar orientation relative to plunge of joint intersection;
- effects of excavation method.

6.4.2 Foundation Strength

Once the strength of the pillars has been determined, considering the strength of the roof and floor is necessary as these form the pillar foundations. If the pillar and the foundation consist of the same material then, once a pillar reaches a W : H ratio of approximately 7 : 1, foundation failure rather than pillar failure can be expected.

At Tabular Mine, the immediate hangingwall and footwall consist of very competent pyroxenites with an average strength of at least 1,5 times that of the chromitite seam. Also, clay bands or other weaknesses which could have an influence on pillar foundation stability have not been encountered in close proximity of the hanging or footwalls, and this mode of failure will not be considered further. However, this situation must be reviewed immediately if such weaknesses are found or if any sign of foundation failure such as footwall heave is observed.

6.4.3 Pillar Stress

The design of the pillars must ensure that the expected pillar stress never exceeds the pillar strength as pillar failure can release energy violently. As a result the required pillar size must increase with increasing mining depth.

As discussed in before, resultant or pillar stresses can be calculated by means of computer analysis. The use of computer analysis is especially important when analysing complex mining geometries. However, analysing simple layouts such as the room and pillar mining layout found at Tabular Mine, can be done adequately by using the tributary area theory. This theory ignores the effects of abutments and thus pillar loads obtained by using this method will be higher than the actual pillar loads, resulting in a conservative approach.

According to the tributary area theory, the average vertical pre-mining stress, σ_v, will increase linearly with the increase in ratio between the area tributary to a specific pillar and the area of the pillar. This relationship can be described by the following formulae:

For horizontal seams:

$$\text{Pillar Stress} = \frac{\sigma_v}{1-e}\ [\text{MPa}] \qquad \textbf{(6)}$$

For inclined pillars the above relationship becomes:

$$\text{Pillar Stress} = \frac{\sigma_v \cos^2\alpha + \sigma_h \sin^2\alpha}{1-e}\ [\text{MPa}] \qquad \textbf{(7)}$$

where: σ_v = vertical field stress

σ_h = horizontal field stress

e = extraction ratio

α = the dip angle in degrees

The extraction ratio(e) can be calculated as follows:

$$e = 1 - \frac{\text{pillar area}}{\text{tributary area}}$$

$$= 1 - \frac{(A \times B)}{(A + C) \times (B + D)} \quad \text{(See Fig. 10)} \qquad \textbf{(8)}$$

Where: A and B are the length and width of the pillar

C and D are the strike and dip spacings between pillars

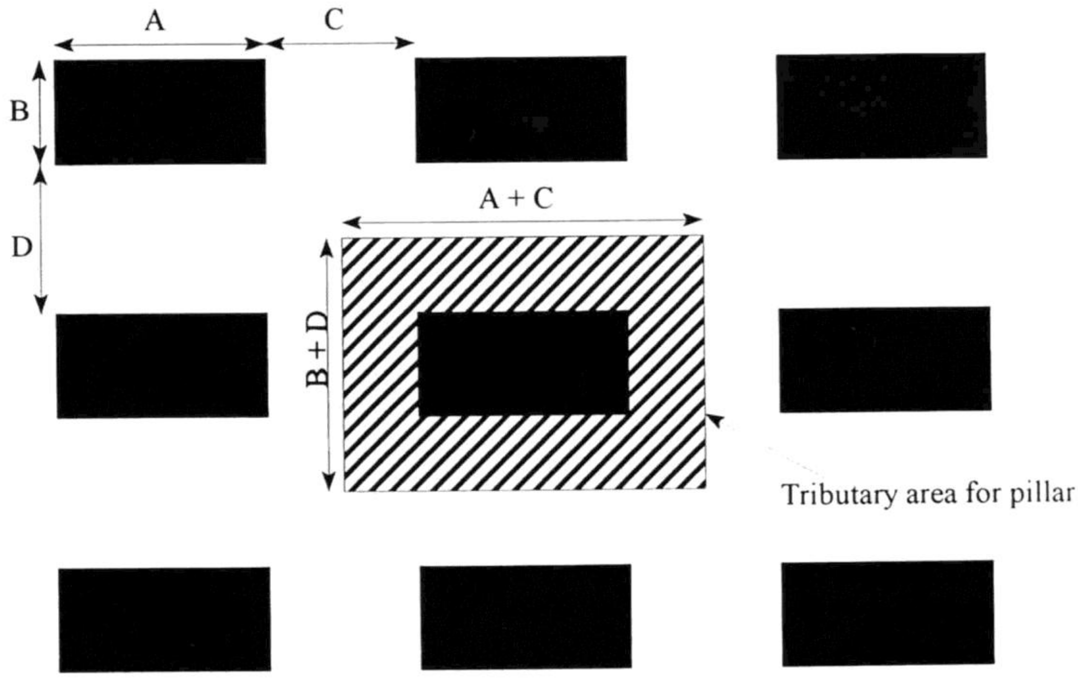
For example, for a typical room and pillar layout where pillars of 10 x 5m are used, spaced 2,0m apart on strike and 27,0m apart on dip, the extraction ratio will be:

$$e = 1 - \frac{(10 \times 5)}{(10 + 2) \times (5 + 27)}$$

$$= 1 - \frac{50}{12 \times 32}$$

$$= 1 - 0{,}13$$

$$= 0{,}87$$



Extraction ratio = pillar area / tributary area

= (A x B) / {(A + C) x (B + D)}

Figure 10 Typical geometry for tributary area analysis of pillars in uniaxial loading

6.4.4 Pillar Design Factor of Safety

As identified in the baseline risk assessment, pillar runs and regional collapses are one of the major risks and pillars should therefore be designed at a factor of safety (FOS) of at least 1,5. This FOS relates to the stability of the pillar layout only and additional support is therefore still required to supplement the pillars for immediate hangingwall support.

Factor of safety can be calculated as indicated in equation (9) below:

$$\text{Factor of Safety (FOS)} = \frac{\text{Pillar Strength}}{\text{Pillar Stress}}$$

(9)

The above design methodology should be used to design a variety of pillar layouts for varying depths below surface.

As an alternative to the standard room and pillar layout being used by Tabular Mine, a layout using strike barrier pillars with smaller crush pillars in between should also be considered. These barrier pillars should be approximately 20 m wide and spaced at distances which will prevent the hangingwall from turning "soft", even when discontinuities are encountered. As a rule of thumb, barrier pillars should be spaced a distance apart equal to approximately one third of the depth beneath surface. This spacing is required to prevent the development of excessive shearing stresses on joints which may occur in the hangingwall over the barrier abutments. The design of such a system should follow the same basic procedure as outlined above. Stability of such a layout should however be confirmed by doing detailed numerical analysis, rather than relying on the tributary area theory.

The Influence of Mining Activities on Neighbouring Mines	
• Describe method to ensure that, where the possibility exists of one mine's activity influencing the activities of another mine, the mines concerned exchange data concerning:	
- *mining methods*	*Y*
- *regional support*	*Y*
- *mining sequence*	*Y*
- *common geological features*	*Y*
- *% extraction*	*Y*
- *the location, magnitude and nature of seismic events.*	*Y*
• Include timing and overall sequencing for the removal of the boundary pillar where applicable.	*NA*

6.5 The Influence of Mining Activities on Neighbouring Mines

As mentioned in Section 2.1 above, mining activities on neighbouring mines are remote from Tabular's boundaries and well outside the zone of influence. Mining on neighbouring mines is therefore not a factor to be considered in this COP. However, this situation shall be reconsidered at least with every review of this COP.

6.6 The Effect of Mining Activities on Surface Structures

Mining at Tabular Mine is being done at depths of more than 400 m below surface and will not affect surface structures. It is also not planned to do mining at shallow depths (less than 240 m below surface) in the foreseeable future. However, should this change for one or other reason, this situation should be reviewed immediately.

6.7 Stope Support Strategy and Design Methodology

6.7.1 Introduction

Support strategies are required to ensure the safety of personnel working in, or travelling through stopes. When designing stope support systems for Tabular Mine, overall mine stability and local or room stability should be considered. Overall mine stability has been discussed in detail in Sections 6.3 and 6.4 above.

Stable room spans for Tabular Mine will be determined on an empirical basis, taking cognisance of the following factors:

- *The general composition of the hanging and footwall rocks.*

  As discussed before, the Steelpoort seam has disseminated chromitite hangingwall and footwall contact zones and is parted from the Leader seam by chromitiferous pyroxenites of between 0,9 and 1,2 m thick. The parting between the hangingwall pyroxenite and the Steelpoort chromitite is conspicuous and the chromitite usually parts cleanly from the hangingwall. There is a sharp contact between the hangingwall pyroxenites and the footwall of the Leader seam. The immediate footwall rock also consists of competent pyroxenites.

  The conclusion can thus be made that, the stope hangingwall and footwall consist of competent pyroxenites and, the stope hangingwall beam is between 0,9 and 1,2 m thick. ***Any changes in the general composition of the hanging or footwall rock or a decrease in the thickness of the hangingwall beam, could have a negative effect on room stability.*** The following strategies should be considered under these conditions:

  1) Reduce stope span by cutting additional pillars.
  2) Install extra support.
  3) Use headboards on existing supports.
  4) Redesign stope layout if changes appear to be on regional basis.

- *The geological structure of the hangingwall.*

The four major joint sets found at Tabular Mine are summarised in Table 10 below.

Table 10 Average joint orientation

Joint Set	Strike	Dip
J1	N 33^{E} W	sub-vertical
J2	N 28^{E} E	sub-vertical
J3	N 88^{E} E	sub-vertical
J4	random	sub-horizontal

Ideally, panels should be orientated such that the strike of the major joint sets are sub-parallel to the stope faces and sub-perpendicular to the long axis of the stabilising pillars being used. This is currently the case at Tabular Mine, but will be reviewed on a regular basis.

Cognisance should also be taken of the orientation of other geological structures such as faults and dykes. These discontinuities should be demarcated with paint and additional support should be installed on both sides of the contact plane. If necessary, additional pillars should be left along these features to prevent instability on a regional basis.

6.7.2 Stope Support Design Process

The support design process for stopes at Tabular Mine will be as follows:

1) Determine or assess the rock mass environment for which the support is to be designed.

As mentioned above, ***stability/instability of excavations at Tabular Mine is mostly controlled by the geological structure such as joints and faults***. The stability of such a rock mass can be maintained by using support of an appropriate length and strength, properly installed at the optimum density. However, ***friable ground conditions being experienced in some areas would require support to be installed at a higher density and/or with good areal coverage***.

2) Determine or assess the probable volume of rock to be supported in the hangingwall.

The volume of rock to be supported is determined by the following factors:

- Orientation and frequency of geological discontinuities.
  This will determine the shape and size of potentially unstable blocks and will affect the strength and density of support units required to stabilise the hangingwall.

  As mentioned in Section 3.1, ***the immediate cause of most fall of ground accidents is the so-called false hangingwall or flat dipping and almost cohesionless J4 joint set found in the hangingwall of most stopes*** at Tabular Mine. The typical thickness of the unstable part of this layer varies between 50 and 200 mm and tends to fall out between permanent support units when intersected by one ore more of the sub-vertical joint sets. ***It is important that special attention be paid to the identification of these joints by all underground workers.*** The location of these joints must then be reported to the ganger responsible for the working place who will be responsible for making the area safe by barring off any loose hangingwall and supporting any potentially unstable blocks. Should this not be possible, the area must be barricaded off.

- Position of sharp contact planes parallel to the hangingwall
  This will determine the thickness and stability of the immediate hangingwall beam, the potential fallout thickness, the strength of support units required and where applicable, the length of support tendons.
  A base line risk assessment has shown that some falls of ground could be up to 1,2m thick. However, 95% of all falls of ground are less than 1,0m thick. This corresponds with the thickness of the pyroxenite parting up to the base of the Leader seam. Should the fallout thickness of falls of ground increase in a particular area, the manager should be informed immediately. The following steps should then be taken:

1) Review the stope support design and standard for that area based on the new fallout thickness.

2) Increase the support density of existing support units or use support units with better load-deformation characteristics.

3) Consult a competent rock engineering practitioner.

3) *Establish criteria for the selection of all the support elements that constitute the support system, so as to cope with the anticipated rock mass structure.*

The following criteria should be considered when selecting support elements and support systems:

- **Support resistance**

The support resistance (SR) of a support system is defined as the force applied by the support system per square metre of hangingwall. The SR required by the support system depends on the volume of potentially unstable rock that needs to be supported and can be calculated as:

$$SR = \rho . g . h \ \ [kN/m^2]$$

where: ρ = rock density (3 200 kg/m^3 for pyroxenite)
g = gravitational acceleration (9,81 m/s^2)
h = rockfall thickness (m)

Based on a fallout thickness of 1,0 m, it can be calculated that the stope support resistance required per unit area should be 31,4 kN/m^2 for Tabular Mine.

The SR of a support system depends on the force-deformation behaviour of individual support units, their spacing and the amount of stope closure that has acted on the support system. When calculating the SR capability of a support system, the SR available for each line of support should be calculated individually and on a tributary area basis. For example, for the first line of support, the area from the face to midway to the second line of support along strike and from midway between two support units to midway between the next unit along dip. The face is not considered to provide any support. The available support resistance of the supports installed per unit area from the face, back to the sweeping line, should then be totalled and divided by the area.

- **Strength of support units.**

The strength of support units is commonly expressed in terms of tons or kN, and refers to the tensile strength of support tendons or compressive strength of mine poles and mechanical props as determined in a laboratory. ***However, the strength of timber support units, when determined in a laboratory, should be down-rated sufficiently*** to allow for factors such as creep, hanging and footwall irregularities, etc.**.**

The down-rated peak strengths of some support units are summarised in Table 11.

Table 11 Down-rated strengths of some support units

Support Type	Function	Maximum Strength (De-rated) (kN)
H2 Camlock prop	temporary support of key blocks (active)	203
120 mm x 1,2m mine pole	permanent support of keyblocks (passive)	80
5 pole cluster pack	permanent support - breaker line, etc.	850
150 mm x 1,5m mine poles	permanent support of key blocks (passive)	145
200 mm x 2,0m mine poles	permanent support of key blocks (passive)	290
12 mm x 1,8m shepherds crooks	permanent support (passive) of key blocks	74

- **Spacing of support units.**

Support density is a function of the strength of the support units being used on the one hand, and the size of potentially unstable blocks as determined by the sub-vertical jointing on the other hand. ***The smaller the size of potentially unstable blocks, the closer support units should be spaced (or improved areal coverage should be provided)*** but, the strength required from individual support units could be reduced accordingly.

Thus, the spacing of support units has a large influence on the SR of a support system. For example, if a mine pole has a strength of 200 kN, then a support line or system comprising of mine poles will have a SR of 200 kN/m^2 if they are installed at a density of 1 mine pole/m^2. If the mine pole density is decreased to 1 mine pole per 4m^2, then the SR of the support system will be reduced to 50 kN/m^2.

The support spacing is always more critical for the first row of support closest to the face, as the area of the hangingwall supported by each unit in that row increases as the face advances and so the SR of that support line decreases.

- **The force deformation characteristics of support units that constitute the support system**.

The main function of support units should be to minimise inelastic closure, to keep key blocks in position and to maintain a continuous beam. Elastic stope convergence at Tabular Mine could be regarded as negligible and therefore, ***support resistance would be generated only by installing active support or when inelastic closure takes place.*** However, the cost of active, permanent support units is approximately ten times more than for conventional mine poles and should only be considered in extreme cases.

It is thus important that units considered for permanent support be as stiff as possible in order to allow minimum closure and to generate support resistance early in the life of the excavation. A mine pole can be regarded as very stiff support and reaches its maximum load at approximately 2% deformation. Unfortunately, the load generated is shed very rapidly with further deformation. This characteristic could be undesirable if the in-stope closure exceeds the critical limit.

Stope closure at Tabular Mine is estimated at approximately 0,5 mm per day. However, stope closure does not continue indefinitely, but reaches a maximum at a distance (d/2) from the face and approximately halfway between strike stabilising pillars, where d is the distance between strike stabilising pillars. It is therefore unlikely that mine pole support will exceed its maximum load capacity, provided that stope spans are kept within reasonable limits.

Where high stiffness and strength are required to obviate strata separation, cluster packs should be considered. These characteristics are normally required along gullies, faults, dykes and in stoping widths more than 1,5m.

The load-deformation curves of some typical support units are depicted in Figure 11. Although these graphs are based on laboratory test work, the load-deformation curves of the timber units have been down-rated to allow for creep effects under slow loading conditions similar to that found at Tabular Mine.

Passive support units start with a zero support resistance at installation. As closure (deformation) takes place, load is generated in the support unit. This load normally increases with increase in deformation, up to a point where the support unit reaches its maximum strength. Beyond this point, and with further deformation, load generated in the support unit tends to decrease.

Theoretically, unmachined timber poles fail after yielding 2 to 3% of their length. The behaviour of mine poles is generally very erratic and peak loads of between 150 and 410 kN can be generated at maximum closures of between 15 and 40 mm. Some mine poles display a limited yieldability of between 50 and 150 mm after the peak load is attained. In all cases, however, the forces decrease with increasing deformation once the yield point of the mine pole has been exceeded.

The behaviour of mine poles is affected by factors such as pole diameter, pole length, closure rate, moisture content, hanging and footwall contact surfaces, quality of installation, etc. At Tabular Mine, these potential negative effects will be controlled by:

- using mine poles with a minimum diameter of 120 mm;
- adjusting the support spacing according to the pole diameter;
- using mine poles with a length to diameter ratio of less than 10:1;
- reducing stope spans between pillars where closure rates are high enough to cause failure of mine poles;
- using timber with a moisture content of more than 10%, i.e. timber which has been in the timber yard for less than 4 months;
- providing the necessary tools, equipment and training to install mine poles correctly.

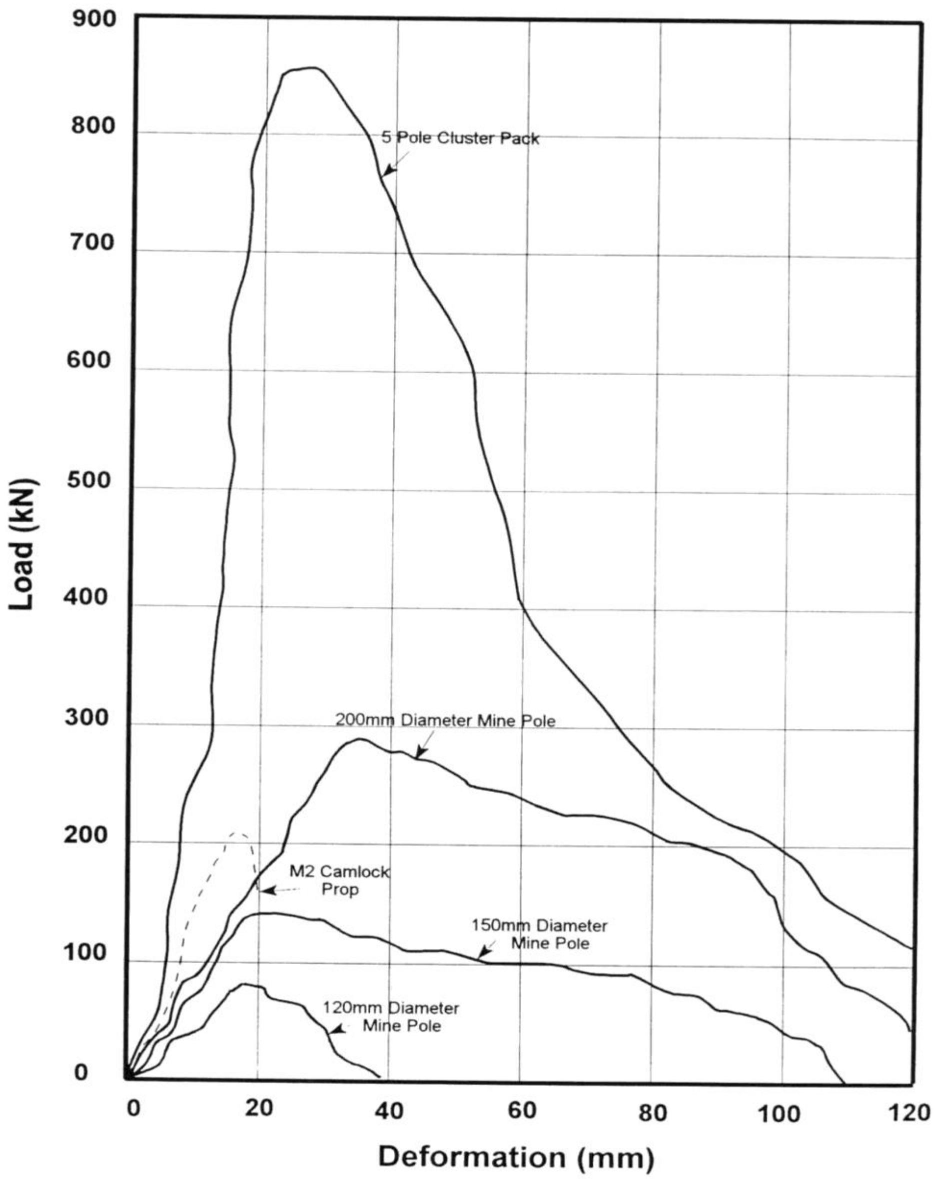


Figure 11 Down-rated load deformation curves for stope support

Conclusions can thus be drawn that:

- ***Should hangingwall failure occur because of the passive nature of mine poles, pre-stressing devices should be considered*** to increase the support resistance required early in the excavation's life.

- The support resistance capacity of a support unit decreases with time after its installation and as it is subjected to stope closure. ***Failure of support units is normally due to excessive loads exerted by unstable rock blocks bigger than anticipated or after excessive deformation. This is a dangerous sign and could be a symptom of a back break waiting to occur.***

  Under such conditions, workers should be withdrawn from the panel and from neighbouring panels. A competent rock engineering practitioner should investigate this matter and make the necessary changes to the support design. ***Special attention must also be given to signs of pillar failure.***

- **Length of the support units.**

The length of a mine pole, mechanical prop, cluster pack or other support units considered for Tabular Mine should be compatible with the stoping width. Mechanical props should preferably be of a flexible length in order to cater for a range of stoping widths.

It is important to note that, with an increase in the length of support units:

- the bucking potential also increases;
- the strength of the support units decreases.

It is therefore important that the height to width ratio of mine poles does not exceed 10:1. Table 13 should be used as a guideline when compiling support standards for Tabular Mine.

Table 12 Maximum stoping width for the available support sizes

Mine Pole Diameter	Maximum Stope Width
120 mm	1,2 m
150 mm	1,5 m
180 mm	1,8 m
5 x 150 mm cluster pack	3,0 m

- **Areal coverage**

The ideal support system should provide adequate area cover to prevent potential key blocks in the immediate hangingwall from dislodging between support units. The potential for this to occur depends on the orientation, spacing, surface geometry and persistence of any potential planes of weakness in the hangingwall which may be joints, faults, etc. The design of a support system that will prevent all possible key block failures demand advanced knowledge of all possible discontinuities and their characteristics. This is impossible to predict with certainty. Therefore, the ***design of support spacings should be based on the average conditions encountered, with the effective support of potential instabilities that require additional support relying on the recognition of such instabilities and the judicious installation of support over and above the normal standard, as and when required.***

Experience has shown that support spacings dictated by the support resistance criteria are adequate for area support purposes. However, management will endeavour to gather good quality discontinuity data from different stoping areas at Tabular Mine which will help to optimise support design.

Where abnormally friable ground conditions are experienced due to high frequency of jointing, proximity to major geological structures or other reasons, the following strategies will be considered:

- install support units at a higher density and closer to the face and/or;
- use support with good areal coverage, e.g. headboards on mechanical and timber props.

- **Safe support installation procedures**

The following principles should be adhered to when installing support units. These principles should also be used to compile detailed installation procedures for each support type and should be included in the mine's support standards:

- ***where practically possible, persons should not work more than 1,0 m away from support (i.e. support spacings should not exceed 2,0 m in any direction)***;
- ***the maximum distance from the face to the first line of permanent support should not exceed 4,0 m after the blast***.

The above stope support design process for Tabular Mine can be summarised as follows:

1) From the mine's FOG statistics, determine the maximum fallout thickness for 95% of the FOG's, say 1,0 m.

2) Calculate the SR required by using equation (10), say 31,4 kN/m^2 and plot as a horizontal line as in Figure 12.

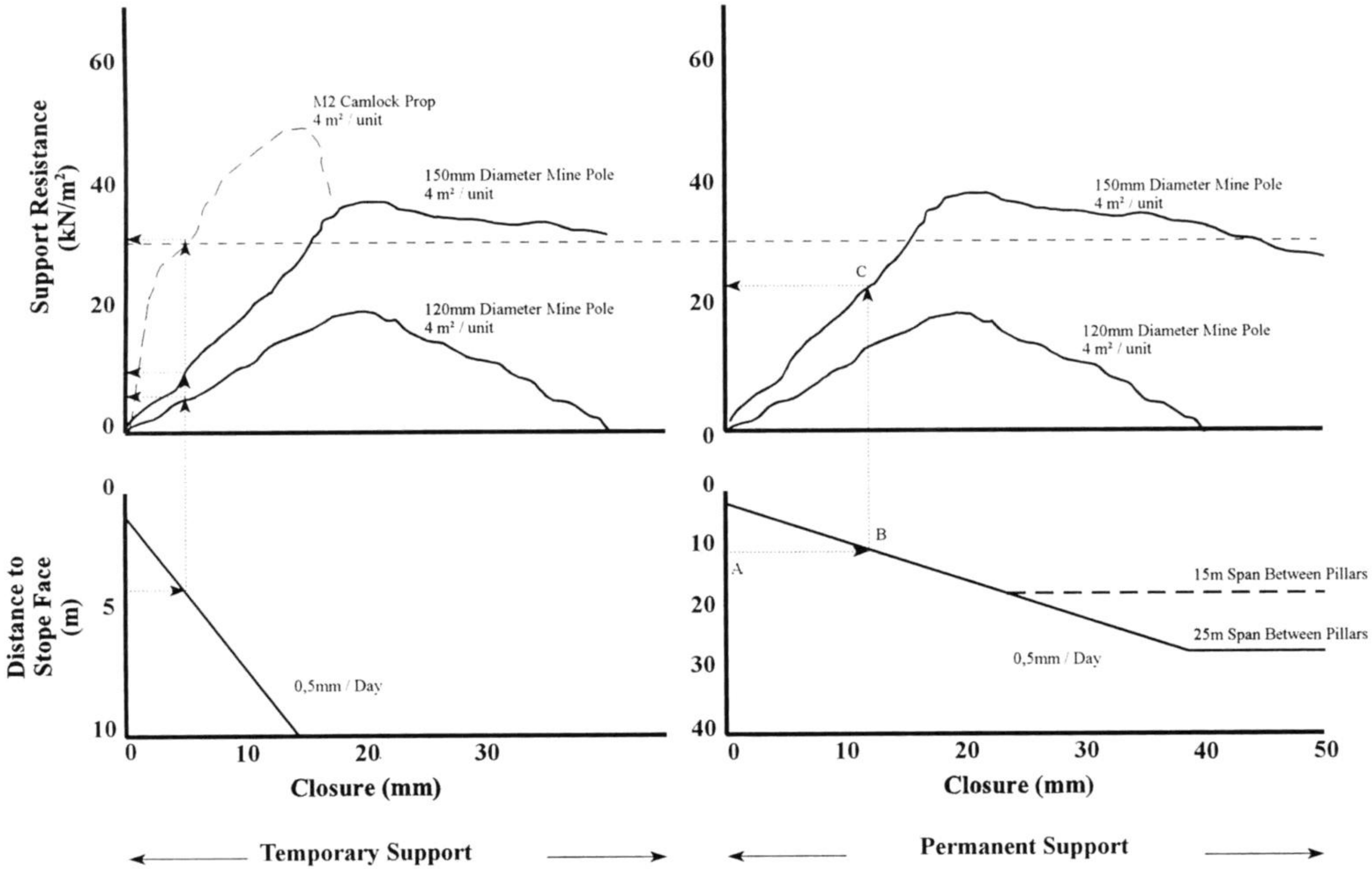


Figure 12 Support resistance – deformation curves of various stope support elements as a function of stope closure and the distance behind the stope face for temporary and permanent support areas

3) Based on the general composition of the hangingwall, decide on an appropriate support pattern, say 2,0 m apart on dip and strike, i.e. 4,0 m^2 per support unit.

4) Calculate the force required to support a block of ground 2 x 2m wide and 1,0m thick by multiplying the results of steps (2) and (3) above, e.g. 31,4 x 4,0 = 125,6 kN.

5) Obtain load-deformation curves for appropriate support elements, e.g. Figure 11. (If necessary, down-rate laboratory test results for timber units to allow for creep, surface irregularities, etc.)

6) Eliminate all load-deformation curves with peak strengths less than the value calculated in step (4) above, (e.g. the 120 mm diameter mine pole).

7) Based on the support density decided on in step (3) and the load-deformation curves in step (5), plot SR-deformation curves as in. Figure 12. (This is done by dividing the load values on the load-deformation curves by the support density and plotting the corresponding SR-deformation curve for each mm of deformation.)

8) Below the SR-deformation curves, draw a "closure-distance from face" curve based on the anticipated mining cycle, closure rate and the support to face distance at the time of installation for the planned mining area. (The "closure-distance from face" curve in Figure 12 is based on the assumption that the mine works on a 3-day cycle, the closure rate is 0,5 mm per day, average face advance is 1,2m per blast and the temporary and permanent support are installed 1,0 and 2,0 m from the face respectively).

9) From this combined graph, the SR of the support system some distance behind the face can be ascertained. As indicated in Figure 12, e.g. at a distance 10 m from the face, the SR = 24 kN/m^2 (From point A on the "distance from face" axis, draw a horizontal line to intersect the "closure - distance from face" curve at point B. From point B, draw a vertical line to intersect the "SR-deformation" curve at point

C. From point C, draw a horizontal line to read off the corresponding SR value).

10) ***A SR-value less than the SR criterion calculated in step (2), indicates potential failure of the support system which could lead to local collapses or back breaks***. In such a case the SR of the support system should be improved by considering one of the following steps:

- use active support, especially close to the face;
- install support closer to the face;
- increase the support density;
- use support units with better load-deformation characteristics;
- complement the support system by installing support such as cluster packs and/or,

The stope closure rate can be reduced by:

- reducing the dip span between strike stability pillars or,
- cutting additional pillars between strike stability pillars.

Subsequent to any modification in the design process, repeat steps (4) to (9) until a satisfactory SR is achieved.

6.7.3 General Strategies

The following strategies represent the best safe practice to minimise exposure of workers to hazardous conditions such as experienced directly after the blast and when intersecting major geological discontinuities such as faults and dykes:

1) Precautions in unsupported stope face area after the blast:
The period after the blast and until the face has been cleaned and re-supported is the most critical time in the mining cycle and the following strategies represent the best safe practice to minimise exposure of workers to hazardous conditions at this time:

- ***Nobody is allowed to enter a stope panel prior to the installation of***

temporary support, except for persons responsible for making safe and installing temporary support. Other workers are allowed to work in supported areas of the panel only and may move in other areas only after the installation of the necessary temporary or permanent support.

- ***Any area which is not supported according to mine standard must be barricaded off***. This barricade may only be removed once the area has been made safe and the necessary temporary and/or permanent support has been installed.
- Drill all face scraping rig holes required prior to blasting.
- A person moving scraper ropes in the face area should keep as close to the installed lines of support as practically possible.
- ***When making safe, work from a safe area*** and from the top of the panel down.

2) Precautions for geological discontinuities:

The recognition of geological discontinuities that traverse the stope area is an essential prerequisite for pro-active strata control. Where significant and hazardous structures are identified, these are to be marked with paint and suitably supported with additional support on both sides of the contact plane or by cutting additional pillars.

3) Precautions where the unsupported stope span exceeds the maximum allowed standard due to the removal of mine poles or other support by blasting, scraper cleaning or other means:

The risk of an unstable hangingwall collapse increases rapidly where the unsupported stope span exceeds the maximum allowed standard. Such instability could also affect the stability of well-supported areas adjacent to the unsupported area. The use of cluster packs to compartmentalise potentially unstable hangingwall collapses is therefore essential.

A row of cluster packs should thus be installed on the face after every 12m of face advance. The installation of additional cluster packs on the perimeter of unsupported areas should also be considered. Also, consider the same precautions as mentioned in (1) above.

6.7.4 Stope Access and Cleaning Ways

Access to and cleaning from the stope faces are via strike and dip gullies with access to the stoping horizon itself usually via travelling ways from the crosscuts or from the crosscut directly. The second outlet for each panel is along the down dip side of the strike stability pillars. As such, it is necessary for access and cleaning ways to remain open and be effectively supported for a minimum of one to two years.

At Tabular Mine, a row of double mine poles is used to support the updip shoulder of strike gullies and the breast shoulders of dip gullies if not supported by crush pillars. Strike gullies are also supported by strike stability pillars directly below. Additional support in the form of 1,8 m long grouted support tendons are used in all dip gullies and, where required, in strike gullies.

The span across gullies, gully intersections, winch chambers and other in-stope service excavations, between mine pole support units or pillar support, should never exceed 2,0m. Should this not be possible due to unforeseen reasons or, where the hangingwall conditions are friable, a special instruction should be issued and additional grouted support tendons must be used to give the necessary support resistance (SR) of at least 31,4 kN/m^2. These units should be installed a maximum of 1,5 m apart.

6.7.5 Ledging

(Also see Section 6.7.4 above.)

At Tabular Mine, very high SR is provided during the ledging phase by leaving a row of crush pillars (2,0 x 2,0 m) on either side of the centre gully. In addition, 1,8 m x 12 mm shepherds crooks are installed between these crush pillars.

6.7.6 Travelling Ways

The spans should be kept to the practical minimum where travelling ways intersect the stope. If the crosscut has been carried right up to the reef plane, then the wedge of footwall forming the hangingwall at the end of the crosscut should be blasted down to form a solid brow of at least 1,0m thick. Soft support such as skeleton packs should be installed on the updip side of this brow and immediately above the crosscut itself to prevent punching failure. Grouted support tendons and/or timber sets should also be used to stabilise the brow formed at the stope entrance. The ledges of the reef/crosscut intersection should be supported by cluster packs on either side of the holing to minimise the span across the holing and between the two rows of cluster packs to a maximum of 5,0 m. The hangingwall between these two rows of cluster packs should be supported by grouted support tendons to provide a SR of at least 31,4 kN/m^2.

For ease of support, to minimise unsupported spans and to obviate the time-consuming installation of additional support, it is preferred to stop the crosscut short of the reef horizon so that a travelling way of not less than 4,0 m long may be mined up at approximately 65^0 to make the travelling way holing into the stope.

In either case, such travelling ways are critical areas and must be inspected daily on re-entry, barred, made safe and re-supported when necessary.

Tunnel and service excavation stability	
• Describe strategy to ensure that the safety of personnel working and/or travelling in tunnels.	*Y*
• Include	
- opening-up;	*Y*
- re-supporting procedures.	*Y*

6.8 Tunnel and service excavation support strategy and design methodology

6.8.1 Introduction

Strategies are required to ensure the safety of personnel working and/or travelling in tunnels and for the long term stability of service excavations. When designing tunnels or service excavations at Tabular Mine, the following questions should be asked:

1) What is the purpose of the excavation?

The purpose of the excavation will determine the shape, size and position requirements. At Tabular Mine, the following standard type and size of excavations are used:

Figure 13 Standard type and size tunnels

Type Excavation	Dimensions	Position
Footwall Drives/ Reef Drives	2,7 x 2,7 m	Developed from the shaft stations and along the lower footwall seam, which is situated 18,0m vertically below the stoping plane. This seam is kept 40 cm above the grade line. Approximately 50 cm above this seam is a sharp contact which is used as the hangingwall of this tunnel.
Crosscuts	2,7 x 2,7 m	Developed from the footwall drives (60m apart on strike), to the reef plane on the west side of the footwall drive.
Boxholes	1,5 x 1,5 m	Developed from each crosscut to the raise above at approximately 60 degrees.
Travelling ways	3,0 x 2,0 m	Developed from crosscut to reef horizon at less than 35 degrees.
Raises	2,0 x 2,0 m	Developed from the crosscut/reef intersection, on reef from one level to the next level above.
Winzes	2,0 x 2,0 m	Same as above, but in a down dip direction, from one level to the level below.

2) *Will the opening be stable?*

The above dimensions can be considered as ideal. The practicality of this ideal opening must then be considered in relation to the properties of the rockmass in which it will be located.

3) *What is the mode of any identified instability?*

Evaluation of the mode of instability is a pre-requisite to the design of a support system. At Tabular Mine, ***instability can result from movement and collapse of rock blocks as a result of the geological structure. Faults, dykes, and major joint planes may combine to form unstable blocks which should be identified***.

4) *Can the instability be overcome by changing the size, shape, orientation or location of the excavation?*

The stability of an underground excavation can often be improved by rearranging of its geometry. Should any geometrical optimisation be made, it will be necessary to return to (2) and (3) above to reassess stability of the new geometry. The following geometry changes should be considered:

- Location
  Ideally, the excavation should be located in the most competent rock.

- Orientation
  Reorientation of the excavation in plan can result in considerable optimisation in terms of geological structure. The aim should be to:
  - minimise the number and/or volume of potentially unstable roof wedges;
  - not to have excavation sidewalls parallel to major joint directions;
  - develop across joint planes rather than parallel to strike of the joint planes.

- Shape

  As much use as possible should be made of the natural stable shape of the excavation.

- Size

  The larger an excavation, the greater the number of structural weakness planes that will be exposed in the surfaces of the excavation and hence the less stable the excavation.

5) Design an appropriate support system to prevent instability from occurring.

To design an appropriate support system, it is first necessary to define the functions required of it. At Tabular Mine, the function of support is merely to pin individual potentially loose blocks, generally defined by geological discontinuities, to the competent rock mass. However, in cases of weak, friable rock or rock which is likely to deteriorate by weathering, the support must hold in place all the friable material by supplying maximum area support as early as possible.

6.8.2 Support Design Process

The support design process for tunnels and service excavations at Tabular Mine will be as follows:

1) Determine or assess the rock mass environment for which the support is to be designed.

As mentioned above, ***stability/instability of excavations at Tabular Mine is mostly controlled by the geological structure such as joints and faults.*** The stability of such a rock mass can be maintained by using support of an appropriate length and strength and installed at the optimum density and orientation. However, ***friable ground conditions being experienced in some areas require support to be installed at a higher density and/or with good areal coverage.***

2) *Determine or assess the probable volume of rock to be supported or reinforced in the hanging and sidewalls.*

The volume of rock to be supported is determined by the following factors:

- Orientation and frequency of geological discontinuities.
  This will determine the shape and size of potentially unstable blocks and will affect the optimum orientation and density of support units required to stabilise the excavation.

- Position of sharp contact planes parallel to the hangingwall
  This will determine the thickness and stability of the immediate hangingwall beam, the potential fallout thickness, the strength of support units required and, where applicable, the length of support tendons.

In the absence of any fall of ground accident records for tunnels at Tabular Mine, it will be assumed that 95% of all rock falls is less than 1,0 m thick. There are no records of any sidewall instabilities at Tabular Mine and support will therefore be considered for the hangingwall only.

3) *Establish criteria for the selection of all the support elements that constitute the support system, so as to cope with the anticipated rock mass structure.*

The following criteria should be considered when selecting support elements and support systems:

- **Support resistance**

  The support resistance (SR) required per unit area of hangingwall can be calculated as before:

$$SR = \rho.g.h \ \ [kN/m^2]$$

where: ρ = rock density (3 200 kg/m^3 for pyroxenite)

g = gravitational acceleration (9,81 m/s^s)

h = rockfall thickness (m)

It can thus be calculated that the support resistance required per unit area should be 31,4 kN/m^2 for Tabular Mine.

- **Strength and density of support units**

The strength of support units is commonly expressed in terms of tons or kN, and refers to the tensile strength of support tendons or compressive strength of mine poles and mechanical props as determined in a laboratory. The typical tensile/compressive strengths of various support types which could be considered for Tabular Mine are listed below. It is however important that the support density being used be compatible with the size of potentially unstable blocks as determined by the sub-vertical jointing.

Table 13 Typical tensile/compressive strengths of development support types

Support Type	Function	Maximum Strength (kN)
16 mm diameter shepherds crook (smooth bar)	permanent support (passive) of key blocks	120
16 mm diameter shepherds crook (ripple bar)	permanent support (passive) of key blocks	112
bullhorn sets	permanent support (passive) of friable ground	*50 (per m^2)
pipe sets	permanent support (passive) of friable ground	*80 (per m^2)
mechanical props (M2)	temporary support (active) of key blocks	203
wiremesh and lacing	permanent support (passive) of friable ground	*120 (per m^2)
gunite (no fibre – 50 mm)	permanent support (passive) of friable ground	60 (per m^2)
12 mm x 1,8m shepherds crooks	permanent support (passive) of key blocks	74

* Estimated

- **Length of the support units.**

  For the standard size tunnels being used by Tabular Mine, the following rule of thumb could be used to estimate the required tendon length:

  - The support tendon length should exceed half the tunnel width.

  In the case of mechanical or timber props, the length of these units should be compatible with the height of the tunnel. Mechanical props should preferably be of a flexible length in order to cater for a range of tunnel heights.

- **Areal coverage**

  As mentioned above, friable ground conditions being experienced in some areas require support to be installed at a higher density and/or with good areal coverage. The following strategies should be considered under such conditions:

  - Install support units at a higher density and/or,
  - support units with bearing plates (in the case of support tendons) or headboards (in the case of mechanical or timber props) and/or,
  - support tendons plus steel straps between tendons or
  - shepherds crook type support tendons with wiremesh and lacing or
  - support tendons and gunite or
  - timber or steel sets.

- **Compatibility with other support elements and geometrical requirements**.

  This selection criterion can be explained best by using the following examples:

  - If areal support in the form of wiremesh and lacing is to be used, support tendons with an eye at the protruding end should be used.
  - Steel strap support is more compatible with support tendons using bearing plates.
  - Steel or timber sets might use too much space and may restrict movement of transport.

6.8.3 Working Face Area and Support Installation Procedures

The following aspects should be considered when mine standards are compiled:

- **Examination procedures**
  Described in Section 6.12

- **Making safe procedures**
  Described in Section 6.12

- **Maximum Unsupported Spans**
  Before blasting, permanent support should be installed not further than 2,0 m from the face. On re-entry after blasting, the work face should be examined, barred and made safe for cleaning by a competent person. At this stage, ***the unsupported span should not exceed 4,0 m.***

- **Marking of support holes**
  The miner, after undertaking his follow-up examination, marks off support holes for permanent support installation. At this stage any faults, slips or dykes must be demarcated with paint and additional support holes for these marked off. Any additional support requirements must be assessed at this stage.

- **Installation of temporary support and drilling of support holes**
  After the end has been cleaned and re-examined, temporary support must be installed prior to the drilling of any support or shot holes. However, if the face area is not safe for cleaning after initial barring, then mechanical props should be installed on top of the muck pile and permanent support installed to render the end safe prior to cleaning. Only when the permanent support tendons of the prescribed pattern and spacing have been installed, as well as any additional support deemed necessary, may drilling of the face commence.

  All holes drilled according to the standard support pattern should be drilled as near as possible at 90 degrees to the plane of the hangingwall. The only exception to this is if the holes would then be parallel to or at an angle of less than 30 degrees to prominent planes of weakness such as joints and faults. If this is the case, then the hole should be drilled at not less than 60E to the plane of the hangingwall and in the most favourable direction and inclination with respect to planes of weakness.

- **Grouting of support holes**

  Unless specified differently, all support tendons should be full column grouted. Temporary support installed for the drilling of support holes may only be removed after the grout has set to the required hardness, and blasting should not take place before the grout has hardened sufficiently. The management of Tabular Mine will ensure that grouting of support holes is done effectively at all times by ensuring that:

  - the correct procedure is described in the mine standard;
  - support crews are proficient in the grouting of support holes by regular on the job training;
  - grouting procedures and discipline are effectively enforced;
  - follow-up inspections are done on a regular basis;
  - supervisors do not condone poor practices;
  - the correct material and equipment are made available at all times.

6.8.4 Corrosion of Support Elements

Corrosive groundwater problems have not been encountered at Tabular Mine. However, over a period of years, corrosion due to rusting of exposed steel support could occur, especially where exposed to humid airflow. Where such conditions are anticipated, one of the following strategies should be considered:

- shotcrete or other similar protection will be applied over the existing support as soon as possible after the installation of that support;
- relevant areas will be rehabilitated as described above;
- relevant areas will be abandoned.

Grout material used to secure support tendons are to be of a non-corrosive nature. In this regard, the supplier of such grout material is to validate this.

6.8.5 Support for Poor Ground Conditions

Poor ground may be caused by weak, friable rock types or fractured ground associated with geological structures. If increased density of temporary and permanent support does not improve conditions, then one or more of the following strategies should be considered:

- smoothwall blasting;
- shotcreting;
- wiremesh and lacing;
- timber, steel, pipe or bullhorn sets;
- changing the tunnel shape;
- changing the position of the tunnel.

6.8.6 Strategies for wide tunnels

In cases of developing excavations larger than standard tunnel sizes, the risk of rockfall accidents due to unfavourable geological structures will increase. In this case, the same procedure as for the developing of service excavations will be followed. In addition, the following strategies will be considered:

- advance the end as two equal sized split ends, one end leading by not less than 5,0m;
- reduce the blast advance to minimise the unsupported span;
- smoothwall blasting;
- longer support tendons.

6.8.7 Strategies for Widening of Tunnels

Where a standard tunnel is to be widened over a distance of greater than the width of that tunnel, then the sequence of mining and support installation should be as follows:

1) Establish the support requirements for the final width of the tunnel;
2) Install those support tendons as determined in (1) above, that fall within the existing tunnel, before blasting;
3) As tunnel is widened with successive blasts, install remaining support as determined in (1) above;
4) Widening of tunnel and re-supporting of newly exposed hangingwall should be done in short sections of not more than 3,0m at a time;
5) The maximum unsupported span should not exceed 4,0m at any point in time;
6) Issue the outcome of this strategy as a written special instruction.

6.8.8 Assessment of Development Conditions

The condition of development ends and other off-reef excavations will be assessed during routine underground inspections by the shift boss, mine overseer and mine manager. External audits will be undertaken as and when considered necessary by management. Their findings will be recorded in writing and must be available for review at any time. Any special instructions will be issued in writing and regular follow-up inspections will be done to monitor conditions.

Records of development conditions must include the following information:

- tunnel or excavation name, location and size;
- current and anticipated rock conditions;
- description of jointing, faulting or other geological structures in terms of their orientation, frequency and extent;
- description of the current support installed (quality and density);
- reference to any previous special instructions or recommendations pertaining to the tunnel or excavation.

A separate file will be kept for large service excavations which are essential for the maintenance of the mine's service infrastructure. The support performance of these must be inspected and appraised at least annually by a suitably qualified rock engineering practitioner. The appraisal must be recorded in the database file. If deterioration is noted, more frequent inspections should be made with timeous recommendations for remedial measures as required.

6.8.9 Rehabilitation

The manager should consider the following aspects when compiling a written instruction for the rehabilitation of existing tunnels at Tabular Mine:

1) The excavation that needs to be rehabilitated must be inspected by a team consisting of at least the mine manager, mine overseer and shift boss. A suitably trained rock engineering practitioner and a geologist should also be considered if necessary.
2) An Issue Based Risk Assessment must be done and potential failure modes should be identified.
3) Decide on the temporary support type and density required to be used during the rehabilitation to ensure the safety of everybody working and people travelling through this area.
4) Design the new permanent support system required to ensure long term stability of the excavation.
5) Compile a working procedure to address all the potential risks identified in (2) above.
6) The rehabilitation of the tunnel should commence by making safe from a point of stability and should be done in short sections of not more than 5,0m at a time.

6.8.10 Service Excavations

Compared to standard sized excavations, increased static rockfall hazards are associated with the rockwalls exposed in large excavations. Since these are generally long term excavations in which support deterioration cannot be tolerated, the excavation location, orientation, mining sequence and support design should ideally be individually assessed for each case. Examples of such excavations include pump chambers, workshops, settlers, silos, shafts, etc. It is therefore important that the stability assessment be done in more detail than for normal tunnels. The following procedure should be used to evaluate the stability of such excavations:

1) Test for instability of large blocks and hangingwall beams by using stereonet or similar techniques for an approximate analysis;
2) Classify the rock mass and test for rock mass instability;
3) Optimise the opening with respect to location, orientation, shape and size;
4) Loop back to the beginning of the stability evaluation procedure if any geometrical adjustments are made;
5) Prevent potentially unstable blocks/beams from becoming unstable by designing an appropriate mining sequence and support system.

The stability assessment and support design mentioned above is not a simple task and should therefore be carried out by a competent rock engineering practitioner.

Mine access protection	
• Describe strategies for the protection of shafts and/or the main entrances.	*Y*
• Include a summary of the RE appraisal of the existing access ways' current stability	*N*
• Include procedures employed to monitor ground movement in shafts and access ways where danger of instability exists	*Y*
• Include steps taken to minimise the risk associated with such movement.	*Y*

6.9 Mine Access Protection

Main access to the underground workings at Tabular Mine is through the Hanekom incline shaft. This shaft is 5,7 m wide x 2,8 m high and is situated in competent pyroxenite rock, approximately 18 m in the footwall of the Steelpoort chrome seam. Support in this shaft consists of:

- steel reinforced concrete lining and 20m of steel arches and timber cribbing at the entrance of the shaft;
- timber sets where friable ground had been exposed;
- steel arches and timber cribbing of the fault intersection at 1 level;
- spot bolting in the form of split sets and other rock studs.

Visual inspection of the shaft is done on a weekly basis and no changes in rock conditions have been observed over the last few years. No future damage is anticipated since the shaft had been overstoped many years ago and the field stresses should remain constant since pillar extraction is not planned for the mine. If conditions deteriorate for some or other reason, strategies listed in Section 6.8.9 should be considered.

The mine's second outlet is along the B-Winze. This excavation is approximately 3,0 x 3,0 m in size and had been developed along the Steelpoort seam elevation. Support in this excavation consists of:

- steel reinforced concrete and sets at the entrance;
- spot bolting where required;
- two rows of mine poles, approximately 2,5 m apart.

The stability of this access way is also monitored on a weekly basis and, although no deterioration is anticipated in the near future, strategies listed in Section 6.8.9 should be considered if deterioration takes place.

Stability of the ventilation shaft is monitored on a monthly basis.

The responsible Shift Boss will report any deterioration in the stability of the above excavations to the Manager who will take immediate rectifying action.

Special Areas	
• *Describe strategy to ID and deal with an increased risk of rockfalls which may develop during the course of routine mining operations.*	*Y*
• *Describe responsibility of RE in:*	
- *designing the layout*	*Y*
- *mining sequence*	*Y*
- *support*	*Y*
- *monitoring of special areas*	*Y*
• *Indicate:*	
- *where approved procedure, and any subsequent modifications for individual/specific areas are to be located*	*Y*
- *to whom copies of these instructions are to be distributed.*	*Y*

6.10 Strategies for Special Areas

6.10.1 Introduction

During the course of routine mining at Shallow Tabular Mine, an increased risk of rockfalls may develop. Such areas will require additional attention and the assistance of a suitably qualified rock engineering practitioner must be considered to advise management on additional support measures, alternative layouts or other rock engineering related issues.

6.10.2 Appointment of Special Area Officer

To ensure the smooth operation of the entire procedure, the mine manager will appoint, in writing, a Special Area Officer. His duties must be specified in the letter of appointment and will include aspects such as:

- convening Special Areas Meetings on a regular basis (at least every three months);

- recording of all proceedings associated with special areas;
- informing all relevant personnel in writing of areas declared as “special” and of any changes to the support, mining layout or other aspects;
- ensuring receipt of written acknowledgment from the above personnel;
- keeping records of all relevant documentation on file.

6.10.3 Special Areas Committee

The Mine Manager will appoint a Special Areas Committee comprising of the Special Area Officer, Mine Manager, Mine Overseer, Shift Boss, Safety Officer and a representative from the Health and Safety Committee. The inclusion of a competent rock engineering practitioner in this committee will be at the discretion of the Mine Manager.

The function of this committee will be to:

- scrutinize all existing mine layouts and mine planning for the following three months and to identify all potential special areas;
- consider all relevant risks and to declare these areas as Aspecial≅ if necessary;
- review progress with the extraction of previously declared special areas and to reconsider the future classification of these areas;
- coordinate general mine policy regarding the extraction of special areas.

This committee must meet at least once every three months.

6.10.4 Special Areas Declaration Procedure

1) *Identification of Special Areas*

Mining in the following areas should be considered for declaration as special areas:

- areas in the vicinity of major geological discontinuities such as faults and dykes;
- areas abnormally disturbed by joints or faults with unfavourable density,

orientation or quality;

- mining at depths less than 240m below surface and below any surface structures;
- areas previously mined sub-standard (too small pillars, excessive stope spans between pillars, inadequate support, etc.);
- any other areas as decided by the mine manager.

These areas should be visited by the Special Areas Committee before being declared as a special area.

2) *Notification to Relevant Personnel*

All relevant personnel must be informed in writing of the decision to declare an area as "special". They must also be informed of all the necessary safety instructions and changes to existing mine standards.

3) *Acknowledgment of Receipt*

All the above personnel must acknowledge receipt of Special Area notifications and relevant instructions in writing.

4) *Work place entry procedure*

A copy of the Special Area notification and instructions must be displayed at the applicable waiting places. Workers must be reminded of the relevant safety instructions and standards on a daily basis.

5) *Support Considerations*

Alternative pillar spacings, pillar sizes, support types and support spacings must be considered and must reduce the risk of rock fall accidents occurring to a reasonable level.

6) *Documentation*

All relevant information regarding the classification, declaration procedure, and monitoring of special areas must be well documented and kept on file by the Special Area Officer.

Blast Design and Practice	
• *Describe strategy adopted to minimise blast induced damage. This must include:*	*Y*
- *methods to ensure drilling accuracy*	*Y*
- *types of explosives*	*Y*
- *method of initiation*	

6.11 Blast Design and Practice

The following aspects should be considered when compiling standards for blasting at Tabular Mine:

- *Marking of shotholes*
  This includes hole spacing, number of rows, direction of holes, and making provision for a second free face.

- *Making safe before charging-up*
  Barring should be done before charging-up to ensure that rock scaling from the face or hangingwall does not damage the igniter cord and cause misfires.

- *Drilling of Shotholes*
  This includes aspects such as using the correct length and diameter of drillsteel, proper training and discipline, making allowance for restrictions caused by narrow stoping widths and support elements, sufficient air pressure and water supply, drilling according to the marked positions and orientations.

- *Charging up*
  This includes aspects such as de-sludging of holes, optimum explosive charges, correct detonation, use of tamping.

- *Timing*

  The correct sequence of firing is required to ensure that the force of each blast is directed towards the free face. For the stope face itself, the free face is the toe of the panel. In the case of gully headings or development ends, the initial blast holes must create a free face. This is normally done by using a burn cut in which a central uncharged hole acts as the free face. The length of igniter cord between shot holes should also be considered.

- *Face shape*

  This includes aspects such as the influence of poor face shapes on unsupported spans, burdens, cleaning, gully headings relative to the stope faces, etc.

- *Smoothwall blasting*

  Smoothwall blasting techniques should be considered when developing through friable or weak ground conditions. This includes the reduction of burdens and the use of light explosive charges.

Monitoring and Control	
• Describe monitoring strategies which will ensure that: - the orebody is safely exploited - early warning of changing conditions is communicated to responsible persons. (Monitoring can be done either visually or with the use of instruments) • Describe procedures and persons responsible (all relevant categories) for: - the examination - reporting - control of the safety of the working area • Specify appropriate procedures taken: - for rendering an area safe - to reduce risk. • For each ID hazard outline the: - controls to be followed - procedures to be followed - the responsible person	 *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y*
• Table content must be site specific.	*Y*
• *Table must be expanded to include all relevant rock-related:* - hazards - controls - procedures	 *Y* *Y* *Y*
• Describe monitoring programmes and procedures to ensure that the COP is being properly: - implemented - maintained	 *Y* *Y*
• Describe procedures for defining responsibility and authority for: - assuring conformance with the COP - taking action to mitigate any impact caused by non-conformance - implementing corrective actions to ensure conformance.	 *Y* *Y* *Y*

• Describe method to ensure that the general conditions of the rockwalls in **all** working places are reported on a **regular** basis. For example: - record in shift boss's logbook - communicate to those specified in COP	 *Y* *Y*
• Specify and describe procedures for analysing the data to ID deteriorating conditions	*Y*
• Describe: - role of RE department/consultant - the routine input by RE personnel in the monitoring process.	 *Y* *Y*
• Specify frequency of review of **every** separate working places with different risk classifications by a competent RE practitioner**.**	*Y*
• Specify frequency of visits to working places with different risk classifications by suitably trained personnel.	*Y*
• *Describe influence of mining on adjacent properties.*	*Y*

6.12 Monitoring and Control Strategies

Hazard monitoring strategies are required to ensure safe orebody exploitation and particularly to identify when changes in underground conditions increase the hazard levels. These strategies must ensure that the early warning of changing conditions is communicated to responsible persons and is acted on appropriately.

The following additional monitoring and control strategies will be used by Tabular:

1) *Quality Control of Support Products*

Quality assurance certificates from an approved testing facility stating shelf life, working time, setting time and corrosive nature of grout in use should be provided by the supplier. Thereafter the supplier is to provide batch certificates. Suppliers of grout should comply with ISO 9002.

Certificates from an approved testing facility shall be obtained for all steel tendons currently in use. All these certificates are to be kept on file by the store keeper.

2) *Early Examination by Ganger and Team Leader*

The team leader and his gang should only pass the waiting place when a definite instruction to do so has been given by the ganger in charge.

The instruction to examine and make safe working places which have been blasted or remained idle for more than 48 hours, must be recorded in the team leaders instruction book by the night shift cleaner. The team leader will then enter the working place with his team of three people and make safe. They should check the hangingwall and sidewalls from the waiting place to the centre gully nearest to his working place and bar down any loose rocks.

They should then enter the stope panel along the gully to the last line of permanent support nearest the face, physically checking the hangingwall with a pinch bar and four pound hammer and also the hanging and sidewall along the top of the stope up to the face. Then they must bar the hangingwall and face, moving down the panel to the bottom gully and back along the gully. When making safe, they should always work from a safe and well supported position.

If the team leader is satisfied that the work place is safe, he should then commence with his task indicated in his instruction book. He should also inform the ganger in charge of the working place of any source of danger found or observed, and the steps taken to safeguard the safety and health of persons under his charge. Such places must be visited immediately by the ganger to ensure that the necessary precautions had been taken.

The ganger must also re-examine and, if necessary make safe each working place within 90 minutes after resumption of work. He must be accompanied by the Team Leader and must communicate with the workers to find out if they have any problems with the safety in their working place. He must then sign the Team Leader's instruction book.

3) *Mid-Shift Examination by Ganger and Team Leader*

The ganger, accompanied by the responsible team leader, should also do a mid shift examination of all his working places. If it is found that the work place or part of it has become unsafe, the necessary steps should be taken to make such work place safe.

4) *Examination Before Charging Up*

Before any charging up, the team leader in charge shall bar down the hangingwall, sidewalls and face for a distance of 4 metres in all directions of the face to be charged up.

5) *Regular Examination of Rock wall Conditions and Support Standards in Stopes, Development Ends, Shafts, etc.*

Strata control checklists will be compiled for the use by shiftbosses, gangers, safety representatives and team leaders to provide a tool for the rating of ground conditions. The objective of using these checklists is to ensure that persons working underground consider all the pertinent factors on a regular basis and not to allow familiarity with sub-standard acts/conditions to be condoned.

The frequencies with which these checklists are to be completed are listed below.

Table 14 Frequency with which checklists are to be completed

Inspection Area	Frequency
All stope faces	1 / week
All development faces	1 / week
Main shaft	1 / week
Ventilation shaft	1 / month
Haulages	1 / month
Refuge bays	1 / month
Service excavations, e.g. pump chambers	1 / month
Waiting places and crosscuts	1 / month
Travelling ways and escape routes	1 / week
Stope tips and winch cubbies	1 / week

These checklists must be submitted to the responsible mine overseer who will inform the manager of any hazardous conditions. Where necessary, the mine overseer should visit problem area as soon as possible to familiarize himself of the extent of the problem and take the necessary action to reduce the risk.

In addition, the shift boss and other senior officials will record all relevant observations, action plans, planned completion dates and people responsible for the execution of the action plans during all their underground visits.

Other strategies or part thereof, the responsible persons and target dates for implementation, are summarized in Appendix A.

6.13 Deviation from the support design methodology

The following strategies should be considered when deviating from the support design methodology as described in this COP:

- **Non-standard conditions**

  If a support system designed according to the above methodology cannot be followed because of unexpected conditions underground or for some other valid reason, this should be brought to the attention of the Mine Overseer and Mine Manager. As a first remedial measure, extra support should be installed in the problem area as appropriate to the circumstances. Any changes to the support system thus made should be recorded as a Special Instruction and signed off by everybody concerned.

- **Trials with new support systems**

  From time to time new support units or standards will be put on trial. The following procedure should be followed before implementing such trials:

  1) Do an Issue Based Risk Assessment to ensure that all risks are adequately addressed. A competent rock engineering practitioner should form part of the risk assessment team.
  2) Compile a new mine standard and issue as a special instruction.
  3) Test a new support unit or standard in a limited area.
  4) Monitor performance of a new support unit/standard on a daily basis and record in writing. (This could be done in the shift boss's logbook).
  5) Review the new support unit/standard after three months. If acceptable for widespread use on the mine, make the necessary amendments to the Mine Standards and Training Manuals. After approval by a competent rock mechanics practitioner and the mine manager, issue the new standard for implementation.

6.14 The Function of A Rock Engineering Service

According to Tabular's risk profile, a full time rock engineering service is not required on the mine. The services of a competent rock engineering practitioner or consultant will be used on an ad hoc basis and at management's discretion. These services will be considered under the following conditions:

- during the design and mine planning for the extraction of new areas;
- when new support systems are considered;
- when abnormally bad ground conditions are experienced;
- when considering any deviations from this COP;
- to review the mine's COP and mine standards on an annual basis;
- to review strategic planning for the mine;
- to review special areas and to advise management on special support requirements;
- to implement monitoring, recording and reporting systems and procedures;
- when designing the layout and support of special service excavations;
- to assist mine management with the training of mine personnel in rock engineering aspects;
- to audit existing mine layouts, planning, support systems and strata control practices in the underground excavations;
- to assist mine management with the investigation of serious fall of ground incidents and accidents;
- to do geotechnical mapping and classification of new mining areas;
- to give input on risk assessment matters pertaining to rock related issues;
- when the risk of fall of ground accidents increases.

6.15 Implementation of the Code of Practice

A training and communication programme is required to familiarise the underground workforce with the strategies and their responsibilities for the implementation of this

COP. Training will be structured for the different levels of responsibilities and will include strata control and hazard recognition tuition as well as the strategies of this COP.

The training programme will be controlled to ensure that all the necessary persons have attended and a record of this and each person's assent to having understood their responsibilities shall be maintained. After the period of training required for the initial implementation of the COP, the programme will be continuous and will be presented to all employees on induction and re-induction. Where necessary, employees will also be sent for re-training.

6.16 Conformance to the Code of Practice

The ultimate measure of the proper implementation of and conformance to the COP will be the rock related accident rates. Monitoring and control of strategies and the level of hazard awareness exhibited by underground workers will also indicate whether conformance is being achieved. However, people with specific responsibilities for assuring conformance with particular sections/strategies of the COP shall be appointed by the Manager.

The implementation of and conformance to this COP will be monitored by the safety officer. In addition, an annual audit will be carried out by a competent rock engineering practitioner. This will be done prior to the review of the COP.

APPENDIX A

SUMMARY OF STRATEGIES AND RESPONSIBILITIES, RESPONSIBLE PERSON/S AND TARGET DATES FOR IMPLEMENTATION

SUMMARY OF STRATEGIES AND RESPONSIBILITIES, RESPONSIBLE PERSON/S AND TARGET DATES FOR IMPLEMENTATION

The following table summarizes the strategies and responsibilities, responsible person/s and target dates for implementation to combat rockfall accidents at Shallow Tabular Mine. For more detail, the relevant sections of the COP should be studied as well.

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
1.2	Comply with the provisions of this COP	All underground workers	
	Appoint all responsible employees according to their responsibilities	Manager	
	Review existing managerial instructions, standards and procedures to ensure compliance with COP.	Manager	
	Review COP annually or more frequently if risk profile changes.	Manager	
1.5	Issue of copies of this COP to relevant people.	Safety Officer	
	Keep register of persons/organizations who have copies of this COP.	Safety Officer	
	Describe critical competency criteria on issues covered by this COP.	Safety Officer	
	Compile training syllabi on issues covered by this COP.	Safety Officer	
	Train employees on aspects of this COP.	Safety Officer	
	Keep register of trainees.	Safety Officer	
	Post up relevant sections of COP at waiting place.	Shift Bosses	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
2.1	Review mining at neighboring mines and influence on Shallow Tabular Mine.	Manager	
2.2	Pay special attention to presence of flat dipping joints	All underground workers	
	Bar, blast down or support above areas according to standard	Ganger	
3.1	All false hangingwall should be blasted down with the advancing face.	Ganger	
3.2	Accident investigation & completion of accident forms	Safety Representative, Injured person's immediate supervisor, Shift boss, Mine Overseer, Safety Officer.	
	Store relevant accident information in mine's data bank	Safety Officer	
	Maintain and interpret mine's accident statistics	Safety Officer	
4.2	Review Baseline Risk Assessment based on WRAC technique. (See sixth task under 4.3)	Safety Officer and Risk Assessment Team	
	Undertake Issue Based Risk Assessment when a reportable, fatal rockfall accident or near miss incident occurs or when a new support type or layout is considered.	Safety Officer & Risk Assessment Team	
	ID rock related hazards through Critical Task Analysis & Planned Task Observations	Shiftboss	
	ID rock related hazards through regular audits	All frontline supervisors	
	ID rock related hazards at all times during underground shift	All underground workers	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
	ID rock related hazards through pre-work assessment	Ganger & Team Leader	
	Update or design new checklists, shiftboss logbooks, etc. to assist employees in the performing of continuous risk assessments.	Safety Officer	
4.3	Ensure that the safety officer is trained as a risk assessment facilitator.	Manager	
	Define scope of each risk assessment exercise.	Safety Officer	
	Select a risk assessment team for each risk assessment exercise.	Safety Officer	
	Train risk assessment team in risk assessment techniques	Safety Officer	
	Train front line supervisors in Critical Task Analysis (CTA), Planned Task Observations and workplace inspections.	Safety Officer	
	Update existing rock related CTA's and use as basis for next Risk Assessment in 1999.	Safety Officer & Risk Assessment Team	
	Analyse all relevant information such as past accidents, etc. before risk assessment commences.	Safety Officer	
	Present analysed data, describe scope of work and discuss potential hazards with risk assessment team.	Safety Officer	
4.4	Do risk assessments and measure the risk when required.	Safety Officer & Risk Assessment Team	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
4.5	Consider risk control strategies and make recommendations to the manager.	Safety Officer & Risk Assessment Team	
4.6	Report and record all aspects of risk assessment.	Safety Officer	
4.7	Decide on types of preventative and protective measures that need to be provided.	Manager	
4.8	Review risk assessment when work, hazards or risks change, or after an accident.	Safety Officer & Risk Assessment Team	
5.2.3	Ensure that the installation of face area support for stopes, tunnels, gullies, etc. is properly integrated into the blasting and cleaning cycle so that the exposure of workers to undersupported conditions is minimised. This should be done by ensuring that: 1) The distance from the face to the first line of permanent support does not exceed 4,0m at any time during the cycle. 2) Maximum face advance per blast does not exceed 1,2m per blast. 3) Support spacings do not exceed the recommended standard. 4) Temporary support used in the face area or other areas should be installed from a safe positioned not more than 1,0m away from previously installed support.	Ganger	
5.3.1	Leave non-yield pillars on down-dip side of all strike gullies.	Ganger	
	Leave crush pillars as additional support along faults and dykes to support potentially unstable hangingwall due to flat dipping joints and along centre gullies	Ganger	
5.4.1	Review DRMS value used in pillar design formula and optimise pillar layout.	Manager	
5.4.3	Review pillar design when encountering weak hanging or footwall bands in close proximity of chromitite seam.	Manager	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.7.1	Review design methodology for stable stope spans based on outcome of work done by SIMRAC.	Manager	
	Identify changes in composition of hanging or footwall rock or reduction in thickness of hangingwall beam and report to manager.	Shift boss	
	Consider one of the following strategies when the composition of the hanging or footwall rock changes or the thickness of the hangingwall beam decreases: 1) Reduce stope span by cutting additional pillars. 2) Install extra support. 3) Use headboards on existing supports. 4) Redesign stope layout if changes appear to be on regional basis.	Manager	
	Review optimum panel orientation based on latest structural information.	Manager	
	Identify potentially unstable hangingwall conditions caused by faults, dykes, flat dipping joints or other structures. Install extra support or leave pillars along these features.	Ganger	
5.7.2	Review stope support design based on reassessment of rock mass.	Suitably Qualified Rock Engineering Practitioner	
	Identify any potentially unstable hangingwall due to flat dipping joints and report to ganger in charge of working area.	All underground workers	
	Make identified area safe by barring down loose rocks and by supporting potentially unstable blocks of ground. Should this not be possible, the area must be barricaded off.	Ganger	
	Should the fallout thickness of falls of ground increase in a particular area, the manager should be informed immediately.	Shiftboss	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
	The following steps should be taken when the fallout thickness increases: 1) Review the stope support design and standard for that area based on the new fallout thickness. 2) Increase the support density of existing support units or use support units with better load-deformation characteristics. 3) Consult a suitably qualified rock engineering practitioner.	Manager	
	Consider all relevant criteria when designing a new support system or reviewing existing support systems.	Suitably Qualified Rock Engineering Practitioner	
	Control the potentially negative effects of pole diameter, pole length, closure rate, moisture content and quality of installation by: • using mine poles with a minimum diameter of 120 mm; • adjusting support spacing according to pole diameter; • using mine poles with a length to diameter ratio of less than 10:1; • reducing stope spans between pillars where closure rates are too high; • using timber with a moisture content of more than 10%, i.e. timber which has been in the timber yard for less than 4 months; • - providing the necessary tools, equipment and training to install mine poles correctly.	Manager	
	Identify any support or pillar failure and report to manager.	Shift Boss	
	Identify any hangingwall failure and report to mine overseer	Shift Boss	
	Identify potentially unstable blocks between support units and increase support density accordingly.	Ganger	
	Withdraw workers from stope when support or pillar failure occurs	Ganger	
	Consider length of support units when compiling stope support standards.	Manager	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
	Where abnormally friable ground conditions are experienced due to high frequency of jointing, the proximity to major geological structures or other reasons, the following strategies will be considered: - install support units at a higher density and closer to the face and/or; - use support with good areal coverage, e.g. headboards on mechanical and timber props	Shiftboss	
	Safe installation of stope support.	All workers responsible for installation of stope support	
	Work within 1,0m from support.	All underground workers	
	Ensure that permanent support distance from face does not exceed 4,0m after blast.	Ganger	
5.7.3	Only people responsible for making safe and installing temporary support to enter stope after blast.	All underground workers	
	Barricade unsupported areas off.	Team Leader	
	Drill face scraping rig holes prior to blasting	Team Leader	
	Moving of scraper ropes under protection of support.	Winch Drivers & Assistants	
	When making safe, work from safe position and from the top of panel down.	Everybody responsible for making safe	
	Identify all significant and hazardous geological structures	All underground workers	
	Mark significant and hazardous structures with paint and install additional support or cut additional pillars	Ganger	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
	Where unsupported span exceeds maximum allowed standard, consider using additional cluster packs on perimeter of unsupported area	Ganger	
	Install row of cluster packs at the face after every 10m of face advance	Ganger	
5.7.4,5,6	Include strategies in these sections of the COP in mine standard.	Manager	
5.8.1	Identify potentially unstable rock blocks as a result of geological structures	All underground workers	
	Consider changing the size, shape, orientation or location of excavation to overcome potential instability.	Manager	
5.8.2	Design of new support systems or support for a new type of excavation.	Suitably Qualified Rock Engineering Practitioner	
	Identify changes in composition of hangingwall rock and report to manager.	Shift boss	
	Installation of extra support along fault and dyke contact planes.	Ganger	
	Record all FOG accidents and incidents and compile database on fallout thicknesses for future support design.	Safety Officer	
	Review tunnel support design based on reassessment of rockmass.	Suitably Qualified Rock Engineering Practitioner	
	Should the fallout thickness of falls of ground increase in a particular area, the manager should be informed immediately.	Shiftboss	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
	The following steps should be taken when the fallout thickness increases: 1) Review the development support design and standard for that area based on the new fallout thickness. 2) Increase the support density of existing support units or use support units with better load-deformation characteristics. 3) Consult a suitably qualified rock engineering practitioner.	Manager	
	Identify any potentially unstable hangingwall due to flat dipping joints and report to ganger in charge of working area.	All underground workers	
	Make identified area safe by barring down loose rocks and by supporting potentially unstable blocks of ground. Should this not be possible, the area must be barricaded off.	Ganger	
	Where abnormally friable ground conditions are experienced due to high frequency of jointing, the proximity to major geological structures or other reasons, the following strategies will be considered: • install support units at a higher density and closer to the face and/or; • - use support with good areal coverage, e.g. headboards on mechanical props, wiremesh, etc.	Shiftboss	
	Identify any support failure and report to manager.	Shift Boss	
	Identify potentially unstable blocks between support units and increase support density accordingly.	Ganger	
	Identify any hangingwall failure and report to mine overseer	Shift Boss	
	Withdraw workers from tunnel when support failure occurs	Ganger	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.8.3	Safe installation of tunnel support.	All workers responsible for installation of stope support	
	Work within 1,0m from support.	All underground workers	
	Ensure that permanent support distance from face does not exceed 2,0m before and 4,0m after the blast.	Ganger	
	Only people responsible for making safe and installing temporary support to enter tunnel after blast.	All underground workers	
	Install temporary support before any support or shotholes are drilled.	Machine Operator	
	Drill face only after installation of permanent support	Machine Operator	
	Drill support holes at the optimum angle to the plane of potential weaknesses	Machine Operator	
	Remove temporary support only after grout has set properly	Team Leader	
	Barricade unsupported areas off.	Team Leader	
	Ensure that grouting of support holes is done effectively at all times by ensuring that: • the correct procedure is described in the mine standard; • support crews are proficient in the grouting of support holes by regular on the job training; • grouting procedures and discipline are effectively enforced; • follow-up inspections are done on a regular basis; • supervisors do not condone poor practices; • the correct material and equipment is made available at all times.	Manager Training Officer Shiftboss Shiftboss Ganger Shiftboss	
	When making safe, work from safe position.	Everybody responsible for making safe	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.8.4	Assess support elements for signs of corrosion and report to manager if necessary.	Shift Boss	
	Where corrosion is anticipated, one of the following strategies should be considered: • apply shotcrete or other similar protection over the existing support as soon as possible after the installation of that support; • rehabilitate relevant areas ; • abandon relevant areas.	Manager Manager Manager	
	Use non-corrosive grout	Manager	
5.8.5	Assess quality of ground conditions and report any poor conditions to Mine Overseer	Shift Boss	
	If increased density of temporary and permanent support does not improve conditions, then one or more of the following strategies should be considered: • smoothwall blasting; • shotcreting; • wiremesh and lacing; • timber , steel, pipe or bullhorn sets; • changing the tunnel shape; • changing the position of the tunnel.	Manager	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.8.6	Design support for wide tunnels	Suitably Qualified Rock Engineering Practitioner.	
	In cases of developing excavations larger than standard tunnel sizes, the same procedure as for the developing of service excavations will be followed. In addition, the following strategies will be considered: • advance the end as two equal sized split ends, one end leading by not less than 5,0m; • reduce the blast advance to minimize the unsupported span; • smoothwall blasting; • longer support tendons	Manager	
5.8.7	Issue written instructions for widening of tunnels by using the following sequence of mining and support installation : 1) Establish the support requirements for the final width of the tunnel; 2) Install those support tendons as determined in (1) above, that fall within the existing tunnel, before blasting; 3) As tunnel is widened with successive blasts, install remaining support as determined in (1) above; 4) Widening of tunnel and re-supporting of newly exposed hangingwall should be done in short sections of not more than 3,0m at a time; 5) The maximum unsupported span should not exceed 4,0m at any point in time; 6) Issue the outcome of this strategy as a written special instruction.	Manager	
5.8.8	Assessment of development conditions	Shift Boss and other senior officials visiting	
	Undertake external audits	Manager	
	Keep a separate file for large service excavations which are essential for the maintenance of the mine's service infrastructure. Inspect and appraise the support performance of these excavations at least annually or more frequently if deterioration is noted.	Manager Suitably Qualified Rock Engineering Practitioner	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.8.9	Issue written instruction for rehabilitation of tunnels.	Manager	
5.8.10	Design of support for service excavations.	Suitably Qualified Rock Engineering Practitioner	
5.9	Inspect and report on stability of main shaft on weekly basis and ventilation shaft on monthly basis.	Shiftboss	
	Where rehabilitation of main accesses is required, consider strategies outlined in 5.8.9	Manager	
5.10.1	When general rock conditions deteriorate, consider using a suitably qualified rock engineering practitioner for advise.	Manager	
5.10.2	Appoint Special Area Officer	Manager	
	Convene Special Areas Meeting	Special Area Officer	
	Record all proceedings associated with special areas	Special Area Officer	
	Communicate special instructions to everybody concerned	Special Area Officer	
	Receive acknowledgment in writing	Special Area Officer	
	Keep records of all relevant documents	Special Area Officer	
5.10.3	Appoint Special Areas Committee	Manager	
	Identify potential special areas	Special Areas Committee	
	Consider relevant risks and declare special areas	Special Areas Committee	
	Review progress with extraction of existing special areas	Special Areas Committee	
	Coordinate general mine policy regarding extraction of special areas.	Special Areas Committee	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.10.4	Consider the following areas for declaration as special areas: • areas in the vicinity of major geological discontinuities such as faults and dykes; • areas abnormally disturbed by joints or faults with unfavorable density, orientation or quality; • mining at depths less than 240m below surface and below any surface structures; • areas previously mined sub-standard (too small pillars, excessive stope spans between pillars, inadequate support, etc.); • any other areas as decided by the mine manager.	Special Areas Committee	
	Visit all potential special areas before declaring it as a special area.	Special Areas Committee	
5.11	Consider the following aspects when compiling mine standards for blasting: • marking of shotholes; • making safe before charging-up; • drilling of shotholes; • charging- up; • timing; • face shape; • smoothwall blasting.	Manager	
5.12	The following additional monitoring and control strategies should be used: • quality control of support products; • early examination by ganger and team leader; • mid-shift examination by ganger and team leader; • examination before charging up; • regular examination of rock wall conditions and support standards in stopes, development ends, shafts, etc.	 Store Keeper Ganger and team leader Ganger and team leader Team leader Safety Reps., team leaders, gangers, shift bosses	

Rel. Sect. of COP	Strategies and Responsibilities	Responsible Person/s	Target Date
5.13	If conditions are such that support standards cannot be adhered to, report to Manager.	Shiftboss	
	Issue special instruction for the mining of the above area	Manager	
	Do Issue Based Risk Assessment on new support units put on trial.	Safety Officer and Risk Assessment Team	
	Compile new support standard for using as special instruction	Suitably Qualified Rock Engineering Practitioner	
	Issue special instruction on the use of new support units	Manager	
	Monitor performance of new support units	Shift Boss	
	Review support standard after 3 months.	Manager	
5.14	Appoint Suitably Qualified Rock Engineering Practitioner	Manager	
5.15	Implement a training and communication programme to familiarise underground workforce with these strategies and their responsibilities.	Safety Officer	
5.16	Appoint all responsible people to ensure conformance	Manager	
	Monitor implementation and conformance to this COP	Safety Officer	
	Do rock engineering audit by suitably qualified rock engineering practitioner.	Manager	

APPENDIX B

GLOSSARY OF TERMS AND DEFINITIONS

GLOSSARY OF TERMS AND DEFINITIONS

Access way	Normally a gully, which can either be on dip or strike, and which provides access to the stope face. (Also called a cleaning-way because reef is scraped along most gullies)
Adit	A horizontal opening, started from a hillside, to reach an orebody.
Back	This is the orebody between a level and the surface or between two levels. In vertical orebodies, it could also mean the roof or overhead surface of an underground excavation.
Back break	Migration of back area support failure towards the face.
Bedding	It is the general aspect of bedded rocks. It applies to rocks resulting from consolidation of sediments and exhibiting surfaces of separation (bedding planes) between layers of the same or different materials, e.g. shale, siltstone, sandstone, limestone, etc. It could also mean a more or less continuous body of rock between two layers of rock. (Also see strata).
Bedrock	The more or less continuous body of rock which underlies the overburden soils.

Box / boxhole An excavation also known as a reef pass, having an inclination of 40^0 or more to the horizontal, usually connecting the gully system to the crosscut or the haulage for the purpose of rock transportation.

Bord A roadway driven in the orebody or seam.

Bord and Pillar A mining method used where pillars are left in situ to support the hangingwall. The pillars are designed to take into consideration depth, hanging wall conditions, surface protection and width of mineral orebody. Pillars may be reduced in size at a later stage by doing pillar robbing.

The term “Bord and Pillar” is often confused with “Room and Pillar”. For the purpose of this COP, the difference between the two mining methods can be defined as follows:

a) The pillars being used in Bord and Pillar Mining are normally arranged in a regular pattern.

b) Bord widths and pillar widths are of the same order of magnitude. In Room and Pillar Mining, room widths are often an order of magnitude bigger than the pillar widths.

Burden Distance between a drill hole charged with an explosive and the free surface in the direction of throw.

Charge The amount of explosive used in a blast hole.

Chrome	Rock containing much chromium.
Chromite	It is an accessory mineral in igneous rocks and may be concentrated into layers or lenses in sufficient quantity to be worked as an ore. It is the only commercial ore of chromium. In order to add chromium to steel, chromite must first be converted to ferrochrome.
Chromitite	Is the rock being mined and occurs as coarse particles of chromite crystals.
Chromium	The element with the symbol, Cr.
Closure	Reduction in the distance between two basically parallel surfaces, usually the hanging and footwall of an excavation.
Cluster Pack	Is an Active Support Consisting of a number of mine poles in close proximity to one another (can be two or more).
Code of Practice	Is a way or a means to prevent as far as possible any matter affecting the health and safety of employees and other persons, who may be directly affected by activities of the mine.
Consequences	The degree of harm, the potential severity of the injuries or ill health and/or the number of people potentially affected.
Convergence	Similar to closure, but technically referring to the elastic component of closure.

Country rock	The rock surrounding an igneous intrusion.
Crack	A small fracture, i.e. small with respect to the scale of the fracture in which it occurs.
Creep	Time-dependent deformation
Critical Task Analysis	It is a breakdown of a task into a correct, efficient and orderly sequence of steps.
Crosscut	A horizontal opening, like a tunnel, that cuts the rock formation at an angle to the strike of the strata in order to reach the orebody.
Crush Pillar	Means every portion of a reef, mineral deposit or ground left in situ for the support and protection of the surface objects there on or underground working and is not less than 2m x 2m in size. Crush pillars are designed to crush and it is not common practice to remove them.
Deformation	A change in the shape or size of a solid or the rock mass.
Density	Mass per unit volume.

Dip Angle at which a planar feature such as the reef, or an excavation such as a traveling way is inclined from the horizontal.

Dip direction The orientation or direction in which the above features are dipping.

Discontinuity surface Any surface across which there is a break or separation, or some property of the rock mass is discontinuous (e.g. bedding planes, fractures or faults).

Drilling pattern The number, position, depth and angle of the blast holes forming the complete round in the face of the excavation.

Drive A horizontal opening, like a tunnel, lying in or near the orebody, parallel to the strike.

Dyke A sheet like body of igneous rock which is discordant, i.e. cuts across the bedding or structural planes of the host rock.

Elasticity Property of material or rock mass, whereby it returns to its original form or condition, after the applied force to it is removed.

Elongate Support The generic name for timber props which have load bearing capabilities in excess of 3% closure.

Exposure How often and for how long employees are exposed to a hazard.

Face Area The area between the face and the first line of permanent support.

Failure	Failure in rocks means exceeding the maximum strength of the rock or exceeding the stress or strain requirement of a specific design.
Fault	A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture.
Fissure	Big crack.
Footwall	Mass of rock beneath a discontinuity surface (in tabular mining, the rock below the reef plane).
Fracture	A discontinuity in a rock of mechanical origin. It is therefore the collective term for joints, faults, cracks, etc.
Frequency	Occurrence per unit time (usually per year)
Geology	The study of the earth as a whole, its origin, structure, composition, and history, and the nature of the processes which have given rise to its present state.
Geomechanics	The subject which is concerned with the mechanical response of all geological materials.

Geotechnical	The subject which is concerned with the technical response of all geological materials.
Geotechnical area	A section or portion of the mine where similar geological conditions exist, which give rise to a unique set of identifiable rock-related hazards, for which a common set of strategies can be employed to minimize the risk resulting from mining.
Gouge	Finely ground rock along a fault zone.
Gravity	The property of acceleration which the earth produces in a freely falling body.
Gully	An excavation cut in the immediate footwall or hangingwall of the reef for the purpose of enabling the removal of rock from the face or providing access to the face for men or material.
Hangingwall	Mass of rock above a discontinuity surface (in tabular mining, the rock above the reef plane). Also, used to refer to the rock mass in the roof of off-reef excavations.
Harm	Injury or loss
Hazard	Something with the potential to cause harm (also called a fault).

Hydrogeology	The study of all underground water.
Hydrology	The study of all waters upon the earth. It includes surface water and rainfall.
Igneous rock	Rock which has originated below the earth's surface and has solidified from a hot, molten condition.
Inelastic Deformation	The portion of deformation under stress that is not annulled by the removal of the stress.
Inspector of mines	Means an officer appointed in terms of section 49 (1)c of the Mine Health and Safety Act.
Joint	A break of geological origin in the continuity of a body of rock occurring either single or more frequently in a set or system, but not attended by visible movement parallel to the face of the discontinuity.
Joint/fault set	A group of more or less parallel joints/faults.
Joint/fault system	Consists of two or more joint/fault sets or any group of joints/faults with a characteristic pattern.
Key block	A block whose removal would cause the surrounding blocks to fall out.
Ledge (ledging)	An area mined immediately off the reef-raise, in order to prepare and equip the panel for stoping.

Level	All openings at a horizon from which the orebody or reef is accessed and mining operations are started. It is the basis of operations for excavation of ore above and below and is connected to the shaft.
Likelihood	Chance per unit time (usually per year).
Mass	The quantity of matter a body contains
Mechanical Prop	Is an adjustable elongate made of steel and used as a temporary support in development ends. It is removed prior to the blast.
Metalliferous mine	Includes all mines that are not diamond or coal mines.
Mine Pole	The generic name for timber props which have load bearing capabilities less than 3% closure.
Mineral	A natural occurring substance having a fairly definite chemical composition and characteristic physical properties.
Ore	Rocks from which a metal or metals may be profitably extracted.
Orebody	A mass of ore which is economically capable of being worked

Orepass	An inclined underground opening intended for transfer of ore.
Outcrop	The exposure of the bedrock at the surface of the ground
Overbreak	The quantity of rock removed beyond the planned perimeter of the final excavation.
Overburden	The loose soil, sand, silt or clay that overlies bedrock. In some usages it refers to all material overlying the point of interest (e.g. a tunnel crown), also the total cover of soil and rock overlying an underground excavation.
Overburden load	The load on a horizontal surface underground due to the column of material located vertically above it.
Permanent support	Support that once installed is not removed.
Permanent support area	This area is next to the face area and extends back to the centre gully.
Pillar	Rock left in situ during the mining process to support the local hangingwall, roof, or to provide regional stability to the mine or portion thereof.
Plane of weakness	Surface or narrow zone with a strength lower than that of the surrounding material.

Planned Task Observation	It is a formal recorded observation of a task being performed.
Poisson's ratio	Ratio of shortening in the transverse direction to elongation in the direction of an applied force in a body under tension below the proportional limit.
Portal	The surface entrance to a tunnel.
Primitive(Virgin) Stress	State of stress in a geological formation before it is disturbed by man-made operations.
Principal Stress (or Strain)	Stress (or strain) normal to one of three mutually perpendicular planes on which the shear stress (or strain) is zero.
Probability	The likelihood of a given event occurring.
Raise	Any tunnel having an inclination above horizontal in the direction of the working of more than 5 degrees, but not included under the definition of a shaft.

Reasonably Practicable	This means practicable having regard to: a) the severity and scope of the hazard or risk concerned; b) the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk; c) the availability and suitability of means to remove or mitigate that hazard or risk; and d) the cost of removing or mitigating that hazard or risk in relation to the benefits derived therefrom.
Reef	A vein, bed or deposit (other than a surface alluvial deposit) that contains minerals except in the case of coal or diamondiferous formations.
Regular review	Assessment of the conditions of an area through discussions, plan critique, planning, meetings and underground visits.
Risk	(The probability of occurrence of a hazard) x (consequence of hazard in quantitative terms).
Rock	Any naturally formed aggregate of mineral matter occurring in large masses or fragments.

Rock bolt	A steel rod placed in a hole drilled in rock used to tie the rock together. One end of the rod is firmly anchored in the hole by means of a mechanical device and/or grout. The projecting end could be threaded and equipped with a nut and plate which bears against the rock surface.
Rock fall (fall of ground)	Fall of a rock fragment or a portion of fractured rock mass, without the simultaneous occurrence of a seismic event.
Rock mass	Rock as it occurs in situ, including its structural discontinuities.
Rock Mechanics	Theoretical and applied science of the mechanical behaviour of rock. It is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment. It forms part of the broader subject of geomechanics.
Rock Engineering	The subject concerned with the application of the principles of engineering mechanics to the design of rock structures generated by mining activities.

Rock Engineering Consultant	A Professional Engineer or a Professional Natural Scientist specializing in Rock Engineering and practicing, or a graduate possessing the Chamber of Mines Certificate in Advanced Rock Engineering who has sufficient experience of rock engineering practice in the mining industry that is able to advise management on strategic decisions that affect the industry and has sufficient theoretical knowledge to be able to understand and implement new research findings within the industry.
Room and Pillar	See “Bord and Pillar”.
Round	A set of holes drilled and charged which are fired instantaneously or with short delay detonators.
Scattered mining method	A method of mining, whereby haulages and crosscuts are developed at specific intervals to expose the reef. The crosscut/reef intersections are connected by raises along the dip of the reef, and mining of the reef progresses from one raise towards another.
Seam	Stratum of chromitite, coal, etc.

Shaft	Any tunnel having a cross sectional dimension of 3,7m or over and: (a) having an inclination to the horizontal of 15 degrees or over, or (b) having an inclination to the horizontal of less than 15 degrees but more than 10 degrees where the speed of traction exceeds 2 m/s.
Shepherds Crook	A steel tendon (rebar, smoothbar or conebolt) with the protruding end in the form of a double backed loop.
Slips	A break of geological origin in the continuity of a body of rock according either single or more frequent in a set or system to surface of the discontinuity.
Spacing	The distance between adjacent blastholes in a direction parallel to the face.
Spalling	Longitudinal splitting in uniaxial compression, or the breaking-off of plate-like pieces from a free rock surface.
Span	Normally the strike distance between the diverging faces in a stoping area.
Special areas	During the course of routine mining, an increased risk of rockfalls may develop. Such areas requiring additional attention and precautions are designated “special areas”.

Specific Gravity (SG)	The weight of a substance compared to the weight of an equal volume of water.
Stability	The condition of a structure or a mass of material when it is able to support the applied stress for a long time without suffering any significant deformation or movement that is not reversed by the release of stress.
Stiffness	Ratio of force versus displacement.
Stope	An underground excavation made in removal of any ground or mineral, other than coal, but does not apply to excavations made for engine rooms and pump chambers or for development purposes such as shafts, drives, winzes and raises.
Stope face area	The area between the rock face on the reef horizon and the first line of permanent support.
Strata	Depositional layers in sedimentary rocks. An individual layer is a stratum. In everyday language, such layers are commonly called beds if their dimensions are fairly large. If the layers are very thin, they are better called laminae.
Strata control	It is the tactical branch of rock mechanics aimed at controlling the rockwall stability of mining excavations.

Stratigraphy	The study of stratified rocks, especially their sequence in time, the character of the rocks and the correlation of the beds in different localities
Strength	The maximum stress that a material can resist without failing for any given loading regime
Stress	Force acting upon an area divided by the area being loaded.
Strike	Direction of the azimuth of a horizontal line in the plane of an inclined stratum (or other planar feature) within a rock mass.
Subsidence	Downward movement of the overburden (soil and/or rock) lying above an underground excavation or adjoining a surface excavation.
Suitably qualified	A person who is at least in possession of a qualification or the training in a specific field.
Competent Rock Engineering Practitioner	A person who is at least in possession of the Chamber of Mines Certificate in Rock Mechanics (Metalliferous).
Suitably trained personnel	A person trained in relevant rock engineering / strata control competencies.

Support	A structure or a structural feature built into or around an underground excavation to maintain its stability.
Support Resistance	Is the force offered by a support element or system per unit area.
Temporary support	Support which will be removed or blasted out.
Topography	Natural and artificial features of a district.
Uniaxial compression or unconfined compression	Compression caused by the application of normal stress in a single direction.
Veins	Cracks and cavities filled by material solidified from hot, aqueous solutions.
Virgin stress	Also known as the primary state of stress. It is the stress in the rockmass before it is disturbed by man-made works.
Wallrock	The rock in which the ore deposit is enclosed.
Waste	Barren rock of too low grade to be mined economically.

Water table	The groundwater surface below which all openings are filled with water.
Weathering	Process of disintegration and decomposition as a consequence of exposure to the atmosphere, to chemical action, and the action of frost, water and heat.
Weight	It is the mass of a material times the gravitational acceleration.
Winze	A vertical or inclined underground opening driven downwards.
Working place	The place where mine workers normally work or travel.
Yield stress	The stress beyond which the induced deformation is not fully annulled after complete destressing.

APPENDIX C

LIST OF SYMBOLS AND ABBREVIATIONS

LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
$\boldsymbol{\sigma_h}$	Horizontal stress field
$\boldsymbol{\sigma_v}$	Vertical stress Field
$\boldsymbol{\sigma_c}$	Uniaxial Compressive Strength (UCS)
e	Extraction ratio
k	The uniaxial compressive strength of a cubic metre of rock
$\boldsymbol{\rho}$	Density
$\boldsymbol{10^0}$	Ten degrees
AMSL	Above Mean Sea Level
BD	Below Datum
BIC	Bushveld Igneous Complex
COP	Code of Practice
CTA	Critical Task Analysis
CTI	Critical Task Inventory
DC	Drafting Committee
DIFR	Disabling Injury Frequency Rate

DME	Department of Minerals and Energy
dr	Drive
DRMS	Design Rock Mass Strength
E	East
e.g.	for example
Fig.	Figure
FOG	Fall of Ground
FOS	Factor of Safety
f/w	Footwall
g	gravitational acceleration
GME	Government Mining Engineer
HAZOP	Hazard and Operability Studies
H&SC	Health and Safety Committee
h/w	Hangingwall
IOM	Inspector of Mines
J1	Major Joint Set
LG6	Steelpoort Chrome Seam
LG6A	Leader Chrome Seam
kg	Kilogram
m	metre

MH&S	Mine Health and Safety
MPa	Megapascal (1 x 10^6 pascal)
MRMR	Mining Rock Mass Rating
N	North or Newton
No.	Number
Pa	Pascal
PTO	Planned Task Observation
RD	Relative density
RE	Rock Engineering
RIFR	Reportable Injury Frequency Rate
RMR	Rockmass rating
RMS	Rock Mass strength
RQD	Rock Quality Designation
S	South
SAMRASS	South African Mines Reportable Accident Safety Statistics
SG	Specific Gravity
SIMRAC	Safety in Mines Research Advisory Committee
SR	Support Reaction
SRK	Steffen, Robertson and Kirsten
UCS	Uniaxial Compressive Strength

W	West
W:H	Width to height ratio
WRAC	Workplace Risk Assessment and Control
x/c	Crosscut

APPENDIX D

LIST OF REFERENCES

LIST OF REFERENCES

1. Terminology, International Society for Rock Mechanics, Commission on Terminology, Symbols and Graphic Representation, Final Draft: July 1975.

2. The Department of Minerals and Energy - Mine Health and Safety Inspectorate - Guideline for the Compilation of a Mandatory Code of Practice to Combat Rockfall and Rockburst Accidents in Metalliferous Mines and Mines Other Than Coal.

3. SRK Reports.

4. Stacey, T.R. and Page, C.H., Practical handbook for Underground Rock Mechanics. Trans Tech Publications, 1986.

5. The Load/Compression Characteristics of Various Support Elements, HL&H, 7 March 1985.

6. Roberts, M.K.C., Jager, A.J. and Riemann, K.P.,The Performance Characteristics of Timber Props, COMRO Research Report No. 35/87, August 1987.

7. Lawless, M., Lewis, B.,The Requirements, Performance and Surface Testing of Elongate Support - A Manufacturer=s Perspective.

8. Kotze, T.J., Strata Control Problems Resulting from Mining at Shallow Depth in the Hard Rock Measures of the South African Bushveld

Complex, Proc. of the 5th Int. Cong. Int. Soc. Rock Mech, Melbourne, 1983.

9. Kotze, T.J. and Streuders, S.B., A Review of the Pillar Support Strategy Being Followed on Chrome Mines Belonging to the Samancor Group, Rustenburg 1993.

10. Streuders, S.B. and Treloar, M.L., Rock Engineering Experiences with Innovative Stope support Systems and Practical Mine Layouts on the Samancor Chrome Mines, SARES 1997.

11. Spencer, D.A. and Kotze, T.J. Observed Crush Pillar Failure Between Two Regional Stability Pillars at Impala Mines, Static and Dynamic Considerations in Rock Engineering, Balkema, Rotterdam, 1990.

12. Plimmer, F., Pascoe, F., Marx, C. and Purdy, G. Tripartite Working Group on Risk Assessment, Practical Guide to the Risk Assessment Process, SIMRAC.

13. An Industry Guide to Methods of Ameliorating the Hazards of Rockfalls and Rockbursts, COMRO, 1988.