# Guideline for the Compilation of a Mandatory Code of Practice to Combat Rockfall and Rockburst Accidents in Metalliferous Mines and Mines other than coal.

## 1. FOREWORD

The majority of accidents occurring at mines are as a result of rockfalls, seismically or gravitationally induced. Over the last few years the fatality rate pertaining to rockfall and rockburst-related accidents has reached a plateau and no real or meaningful improvement has been attained.

In an initiative to solve this problem, a tripartite task group was established under the auspices of the Mining Regulation Advisory Committee. The initial terms of reference of the task group were to investigate and identify root causes of rock related accidents. Current work practices and any compliance and/or non compliance with regulations, standards, directives, guidelines and codes of practice, and their impact on root causes were scrutinised. Research conducted into solutions under the direction of the Safety in Mines Research Advisory Committee was also examined.

Subsequent to the investigation it was concluded that, as a matter of urgency, a **guideline** for the compilation of a code of practice to combat rockfall and rockburst accidents and **proposed regulations** supplementing the code of practice be drafted and presented to the Mining Regulation Advisory Committee. Due to the complexity and variability of conditions at mines pertaining to the design, geometry and support requirements, rigid and prescriptive guidelines would not be in the interests of rock related safety. An approach was adopted which allowed for local expertise, experience and knowledge on the mines to be effectively utilised. In addition, the positive contribution of tripartism to initiate a process to combat rock related accidents would be enhanced.

## 2 TASK GROUP MEMBERSHIP

This document has been prepared by the following appointed members of the MRAC Task Group on Rock-Related Safety:

MR B J ERASMUS (Facilitator) - State

DR W K RYMON-LIPINSKI - State

MR K R NOBLE - Employers

MR J W KLOKOW - Employers

MR R C MORE O’FERRALL - Employee Organisations

MR A T FREDERICKS (Editorial) - Chamber of Mines

The following persons/organisations were also consulted :-

Mr A J Jager - Miningtek

Mr M K C Roberts - Miningtek

Mr P J Terbrugge - S.R.K.

Sub-Committee on Rock Engineering - C.O.M

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## 3 APPOINTMENT OF CODE OF PRACTICE DRAFTING COMMITTEE

The manager must, after consultation with the Health and Safety Committee, appoint a committee responsible for drafting the Code of Practice.

The members of the Drafting Committee assisting the mine manager in drawing up the Code of Practice must be listed on the title page giving their full names and designation, as well as their professional qualifications and/or experience and affiliation. This committee must include a suitably qualified rock engineering practitioner.

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## 4 STATUS OF CODE OF PRACTICE AND RELATED DOCUMENTS

In accordance with Section 9(2) of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996), the Chief Inspector may require the manager to prepare and implement codes of practice. These codes of practice must comply with all applicable provisions in any guideline that the Chief Inspector has issued.

This mandatory Code of Practice is a legal document and non-compliance with the provisions thereof is an offence in terms of Section 91 (1) (c).

All managerial instructions, recommended procedures and standards on the relevant topics must comply with the Code of Practice and must be reviewed to establish compliance.

Such a mandatory Code of Practice and related documents must be used in accident enquiries to ascertain compliance.

The Code of Practice remains in force should the mine change ownership or close temporarily.

## 5 ROCK ENGINEERING APPRAISAL OF CODE OF PRACTICE

The manager of the mine must ensure that the Code of Practice reflects accepted rock engineering practice. The Code of Practice must be technically appraised by an independent and experienced rock engineering consultant to prevent vital design aspects being overlooked and compromised. Where a Mining House employs a full time rock engineering consultant, he is considered as independent and thereby able to fulfil this role. See Appendix 5

## 6 REVISION OF CODE OF PRACTICE

The Code of Practice must be reviewed annually and updated to cater for technological developments, or more frequently should the risk assessment or other evidence show that particular hazards are not adequately addressed.

## 7 ACCESS TO CODE OF PRACTICE AND RELATED DOCUMENTS

The complete Code of Practice and related documents such as recommended procedures must be kept on file by the mine manager. Copies should also be kept by members of the Health and Safety Committee. A registered trade union with members at the mine, a health and safety committee or a health and safety representative at the mine, or, if there is no health and safety representative on the mine, an employee representing the employees on the mine, must be provided with a copy if they submit a written request to the mine manager. A register must be kept of those person/s institutions who have copies in order that they can be forwarded any updates .

A procedure must be instituted by mine management to ensure that all employees are fully conversant with those sections of the Code of Practice relevant to their respective areas of responsibilities.

Relevant extracts must be translated into such other language/s as determined through consultation between management and the Health and Safety Committee and/or the safety representatives, where technically practicable.

## 8 FORMAT OF CODE OF PRACTICE

The chapters should, where possible, follow the sequence laid out under the heading "Contents of the Code of Practice ". Numbering must be consistent to facilitate cross referencing. Each page must be numbered for easy reference. Wording must be unambiguous and concise.

Whenever possible, illustrations must be used to avoid long descriptions and/or explanations.

When reference has been made in the text to publications or reports, those sources must be included in a bibliography as an appendix.

Appendices 1-5 form part of this guideline.

Documents providing additional information to the Code of Practice must be included as appendices.

## 9 CRITICAL ASPECTS TO BE INCLUDED IN THE CODE OF PRACTICE

The following aspects are critical to the drafting of the Code of Practice and must be addressed when compiling it.

### 9.1 Strategies to combat rock-related accidents

The Code of Practice must detail the strategies employed to combat rock-related accidents (rockbursts and rockfalls). These strategies embody various principles, techniques and methodologies employed to combat the hazards peculiar to a particular orebody and include such aspects as layouts, mining sequence, support and monitoring procedure.

Where a strategy is not yet in place, the manager must provide a detailed time table for the preparation and subsequent implementation thereof.

Mine standards are derived from the strategies and are in essence not part of the code of practice *per se*. Mine standards may be changed by management after consultation with the mine's Health and Safety Committee provided these standards meet the requirements of the strategies prescribed in the Code of Practice.

### 9.2 Deviation from proposed Support Design Methodology

Where a support design methodology other than that described in this document is used, it must be scientifically shown to be equally effective to the methodology described in this document and must be properly motivated and documented. This methodology must be technically appraised by an independent and experienced rock engineering consultant.

### 9.3 Competency Criteria / Education and Training Syllabi

The critical competency criteria and education and training syllabi for all employees at the different levels in the organisation on issues covered by the Code of Practice, must be described.

## 9.4 Functions of Departments / Consultants

The functions of departments/consultants and responsibilities of persons in executing aspects of the strategies, must be included in the Code of Practice. Training for these responsibilities must be reflected in the training programme.

## 9.5 Implementation Plan

The mine manager must prepare an implementation plan that makes provision for issues such as structures, responsibilities of functionaries and programmes and schedules that will enable proper implementation and management of the Code of Practice.

## 9.6 Assuring compliance with the Code of Practice

The mine manager must ensure compliance with the Code of Practice and institute measures for monitoring compliance.

# 10 CONTENTS OF A CODE OF PRACTICE

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## 10.1 Title Page

The title page of the Code of Practice must be brief, giving accurate information and all pertinent details about the mine's name, date of issue of the Code of Practice, membership of the Drafting Committee and (where applicable) any revision date.

As an example, the title page could have the following information:

ABC Mine

Code of Practice to Combat Rockfall and Rockburst Accidents

December 1995 (revised December 1996 if applicable)

Reference No

Drafting Committee: Membership

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### 10.2 Origin

State whether the Code of Practice is compiled at the manager's discretion or mandatory in terms of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).

State that the Code of Practice has been drawn up in accordance with Guideline

GME 7/4/118-AB1 issued by the Chief Inspector of Mines.

### 10.3 Status and Review

State that the Code of Practice is a legal document and that it is an offence for any person not to comply with the provisions of the Code of Practice. State that all managerial instructions, recommended procedures and standards on the relevant topics must comply with the Code of Practice and must be reviewed to establish compliance.

### 10.4 Members of Drafting Committee

The members of the Drafting Committee assisting the mine manager in drawing up the Code of Practice must be listed on the title page giving their full names and designation, as well as professional qualifications and/or experience and affiliation. This committee must include a suitably qualified rock engineering practitioner.

### 10.5 Terms and Definitions

A glossary of terms and definitions is given in Appendix 5 of this document and must be incorporated into the Code of Practice. Any other terms and definitions , or jargon of which the meaning is not absolutely clear, must be defined and added.

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### 10.6 Geotechnical / Mine Environment

*The following minimum information must be provided:*

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### *10.6.1 Locality Map*

A locality map must be included to indicate the location of the mine in relation to towns, existing infrastructure and any other relevant features such as mines sharing a common boundary, dams, rivers and any other topographical features which could influence the strategies adopted.

### *10.6.2 Geological Setting*

Geological structures, such as faults and dykes and stratigraphy, around individual orebodies or seams must be described and any dangerous or difficult strata highlighted. A typical section must also be included. A detailed geological assessment may not be necessary but a map showing major geological features in relation to mining outlines and shafts must be included.

### *10.6.3 Orebodies Mined*

A general description of orebodies or seams being mined, including any relevant information such as average and range of mining depth, orebody width, and dip and strike, must be given.

### *10.6.4 Regional Hydrology*

The regional hydrology such as the occurrence of any significant groundwater and/or any other relevant information must be described.

### *10.6.5 Geotechnical Areas*

Geotechnical areas based on known geological hazards, structures, jointing and changes in rock type and strength, or any other factor which may impact on mining, the regional support strategy or the stope and tunnel support strategies must be described and their location and extent depicted on a plan. The nature of the virgin stress field in which mining is to take place, as well as the occurrence of significant pore water and any other local geological features, must be included here.

### *10.6.6 Seismological Setting of the Mine*

The seismological setting of the mine must include a description of the sources of seismic energy emissions experienced or anticipated as well as the rate of current seismicity.

## 10.7 Mine Rockfall and Rockburst Accident Analysis

The Code of Practice must contain a tabulation of the mine's five year history of rock-related casualties (fatals, reportables and disabling incidents) and non-casualty incidents (where available), categorised according to rockbursts and rockfalls per

1 000 employees at work for both surface and underground operations.

This information must be graphically represented depicting annual statistics to facilitate easy interpretation of the data and to highlight trends.

Accident report form 13, as required by the Mine Health and Safety Regulation 34.1 is formulated in a manner which facilitates identification of the root causes of fatal and reportable accidents. The information must be stored in the mine's data bank to facilitate analyses to identify as many root causes as possible.

The Code of Practice must clearly state who is responsible for the completion of accident report forms and the maintenance and interpretation of mine accident statistics.

## 10.8 Rock-Related Risk Management

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

When dealing with the aspect of hazard identification and risk assessment, the risk control programme manager should use the Tripartite Risk Assessment Guidelines on the subject.

The manager is required here to identify and describe rock-related hazards which are likely to arise from the mining of each geotechnical area identified. This information and that arising from the above accident analysis will enable the manager to develop strategies required in each of the following sections.

## 10.9 Strategies to reduce and manage rock-related risks

This section forms the principal element of the Code of Practice.

After the hazards associated with the mining of an orebody have been identified and the related risks prioritised, it is necessary to define the strategies to reduce and manage these risks.

The department or persons responsible for the execution of the particular strategies or portions thereof must be stated in all cases.

Mine standards are derived from the strategies. The Code of Practice specifies **what** is required whilst mine standards reflect implementation instructions or rules.

Where a strategy is not yet in place, the mine manager must provide a detailed time table for the preparation and subsequent implementation thereof.

### *10.9.1 Mining Method, Sequence and Overall Mine Stability.*

The strategy for the overall stability of a mine must include measures to avoid failures that may injure employees or damage mine excavations or equipment. It must take into account the geotechnical environment and potential major rock related hazards identified in the risk assessment process. The overall mining method and sequencing to be followed to manage the risk involved must be described. Where more than one orebody occurs in close proximity to one another, and where the mining of one or more orebodies can be expected to have an adverse effect and induce hazardous conditions on the other, the strategy adopted to manage this risk must be described.

Included in this strategy must be a detailed description of the use of ongoing rock engineering input in mine layout design and performance monitoring.

In the case of:

#### *10.9.1 (a) Opencast and strip mining operations:*

As part of the strategy for the design of pit slope angles, detailed studies of the geology, groundwater and geomechanical properties of the rockmass and discontinuities must be undertaken. The methodology and frequency of these investigations must be described.

It is recognised that in an open pit environment there are risks of failure on bench, stack and overall slopes, and a slope management programme must be described to reduce the impact of such failures on employees and mine equipment. Detailed strategies for an ongoing stability monitoring and geotechnical mapping programme, together with the development of a pit slope hazard plan, must be included in order to reduce risks.

A strategy to reduce the amount of damage behind the slope design line, and thereby reduce the risk of slope instability and potential for rockfalls from both bench and stacks within the pit, must be described, e.g. pit limit blasting.

Methods of "housekeeping" with respect to the dressing of loose material on the bench face and, in particular, the crest areas, to reduce the hazards in and around the mining area, must be described.

*10.9.1 (b) Shallow hard rock mines:*

The design methodology to avoid uncontrolled collapses of the mine or portion/s thereof, and the effects of the mining methods employed on surface structures and topography, must be described. Included here would be the methodology and criteria used for the design of in-panel and barrier pillars. The reasons for selecting a specific type of pillar must also be described.

*10.9.1 (c) Deep hard rock mining:*

The design methodology, criteria and logic used for regional support (pillars, backfilling) and the extraction sequence must be described and motivated.

*10.9.1 (d) The influence of mining activities on neighbouring mines:*

Where the possibility exists of one mine’s activities influencing the activities of another mine, a method to ensure that the mines concerned exchange data concerning mining methods, regional support, mining sequence, common geological features, percentage extraction and the location, magnitude and nature of seismic events must be described. This section must also include the timing and overall sequencing for the removal of the boundary pillar where applicable.

*10.9.2 Rockburst control.*

Bearing in mind that rockbursts are the result of seismic energy emissions, this section is sub-divided into seismic monitoring, seismic energy emission control and rockburst damage control.

*10.9.2 (a) Seismic monitoring and analysis:*

The performance characteristics of the seismic monitoring system that is required for the conditions that prevail at the mine must be described. A procedure must be included to ensure that appropriate analysis of the seismic data is conducted and recorded methodically.

Analytical techniques must be updated as improved methods become available. A statement on how processed seismic data is to be used in the mine design methodology and operating procedure is necessary.

*10.9.2 (b) Seismic energy emission control:*

This must describe all procedures and techniques adopted to prevent or reduce seismic emissions. These include stabilising pillars, backfilling, mining sequencing, limitation of excess shear stress on geological structures, mining of dykes, face shapes, preconditioning, limitation of energy release rate, face advance rate and remnant removal or any other procedures.

The role of the mine’s rock engineering department or consultants must be detailed here. (Appendix 4)

*10.9.2 (c) Rockburst damage control:*

This must describe all measures taken, such as the employment of rapid yielding hydraulic props, backfilling, mining configuration, mining sequence, specialised support tendons or any other energy absorbing support. The measures taken to ensure the maintenance of the equipment employed in support operations and the correct use thereof, including the training of personnel using this equipment, must be included.

### *10.9.3 Stope or panel support*

This strategy must accommodate the conditions expected from the geotechnical and seismological settings and the type of accident encountered. It must also include a description of the sources of seismic energy emissions experienced or expected and their relative locations as well as probable related geological structures. The strategy may vary for different sections of the mine where the geotechnical and seismological environments differ. Reference must be made to the accident analysis and risk assessment done for the identification of problem areas.

This section must include the stope gully support system design methodology as well as the excavation sequence for the gully and siding, if any, in relation to the face. The design must include the location and support of two separate access ways for each panel. The strategy must describe a methodology to select the most appropriate support design requirements (e.g. energy absorption capability, yieldability, and aerial coverage.), to reduce the risk of rockfall and rockburst damage. The recommended design methodology for tabular hard rock mines is described in Appendix 1. However, where a different methodology is used, it must be scientifically shown to be equally effective to the methodology described in Appendix 1 of this document. This methodology must be properly motivated and documented. This methodology must be technically appraised by an independent and experienced rock engineering

consultant.

When experimenting with a mining or support system that differs from that in the code of practice it must be subjected to a risk assessment and fully documented in a manner complying with this guideline.

The design methodology for the support for bord and pillar workings, as well as for high extraction mining, must be described and motivated, where applicable.

### *10.9.4 Tunnel and service excavation stability*

A strategy must be described to ensure the safety of personnel working and/or travelling in tunnels. Opening-up and re-supporting procedures must also be included. Reference to Appendix 2 must be made when compiling the strategy for this section. Cross referencing with the mine standard is necessary.

### *10.9.5 Mine Access Protection*

The strategy for the protection of shafts and/or other main entrances must be described.

This must include a summary of the rock engineering appraisal of the existing access ways’ current stability, procedures employed to monitor ground movement in shafts and access ways where danger of instability exists, the steps taken to minimise the risk associated with such movements and the overall shaft pillar extraction policy. Reports in this regard must be referenced.

### *10.9.6 Special Areas.*

A strategy must be described to identify and deal with an increased risk of rockfalls or rockbursts which may develop during the course of routine mining operations. Such areas shall be designated as "special areas" and require additional attention and precautions. In this strategy allowance must be made for management to make rapid modifications to support and procedures where such action is urgently required. Reference must be made to Appendix 3 of this document when compiling this section.

The strategy must describe the responsibility of rock engineering in designing the layout, mining sequence, support and monitoring of special areas. This strategy must clearly indicate where the management approved procedure, and any subsequent modifications for individual/specific areas, are to be located and to whom copies of these instructions are to be distributed.

### *10.9.7 Monitoring and Control.*

Suitable monitoring strategies must be described which will ensure that the orebody is safely exploited and that early warning of changing conditions is communicated to responsible persons. This monitoring can be done either visually or with the use of appropriate instruments, or using both, depending on the circumstances.

Procedures and the persons responsible for the examination of the safety of the working area, its reporting and control by all relevant categories of employees must be described. The appropriate procedures taken for rendering an area safe and to reduce risk must be specified. In addition, it must outline the controls and procedures to be followed and specify the responsibility for each identified hazard. The key points should be tabulated in accordance with the format shown rather than detailed descriptions. For example the following table contents serve to explain what is required for a particular hazard:-

| **Hazard** | **Controls** | **Procedures, Rules or Standards** | **Responsible Person** |
|---|---|---|---|
| Fall of hangingwall in panel | Early shift examination | Mine Standard No. | Team Leader |
| | Miner’s follow-up examination | Mine Standard No. | Miner |
| | Midshift examination | Mine Standard No. | Team Members |
| | Barring before charging up | Mine Standard No. | Machine Operators |
| | Persons not to work in unsupported area | Procedure No. | Miner |
| | Persons not to enter panel prior to the installation of temporary support | Procedure No. | Miner |
| | Support installation | Procedure No. | Miner |
| | Support design | Procedure No. | Rock Engineering Practitioner |
| | Blast design | Procedure No. | Rock Engineering Practitioner |

The table content must be made site specific. It must be expanded to include all relevant rock-related hazards, controls and procedures.

The mine manager must establish and maintain monitoring programmes and procedures to ensure that the code of practice is being properly implemented and maintained. These must be described in the Code of Practice.

The mine manager must appoint and empower persons who shall be responsible for assuring conformance with particular sections of the Code of Practice. Furthermore, he must institute measures for monitoring conformance. These procedures must be described in the Code of Practice.

A method to ensure that general conditions of the rockwalls in all working places are reported on a regular basis must be described. For example, when changes in conditions are observed, they must be recorded in the shift boss's logbook and communicated to those specified in the Code of Practice. Procedures for analysing the data to identify deteriorating conditions must be specified and described.

The role of the rock engineering department/consultant and the routine input by rock engineering personnel in the monitoring process must be described here.

With respect to the above, a suitably qualified rock engineering practitioner must conduct a regular review of every separate working place in the mine or section of the mine for which he is responsible. The frequency of the review of working places with different risk classifications must be specified in the Code of Practice. The review must describe all facts, trends and matters that may affect current or projected rock-related hazards in each working place as far as reasonably practicable. The review must be systematically and chronologically recorded and must include the practitioner's comments and recommendations for each working place and must be referred to at all planning meetings.

The frequency of visits to working places with different risk classifications by suitably trained personnel must be specified in the Code of Practice.

The procedure for monitoring the influence of mining on adjacent properties must be described.

### *10.9.8 Blast design and practice*

The blasting strategy adopted to minimise blast induced damage must be described. This must include methods to ensure drilling accuracy, types of explosives and method of initiation. Due consideration must be given to conditions in different geotechnical areas.

*10.9.9 Appendices to Code of Practice*

Documents providing additional information to the Code of Practice should be included as appendices.

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## APPENDIX 1

## STOPE SUPPORT STRATEGY AND DESIGN GUIDELINES METHODOLOGY FOR HARD ROCK TABULAR ORE BODIES

### 1. Introduction

Separate strategies must be drawn up for each geotechnical area.

The strategy for stope support must cover rockburst and/or rockfall conditions as necessary, in relation to the following:

(a) the stope face area;

(b) the permanent support area;

(c) stope access and cleaning ways; and

(d) ledging.

The methodology discussed in this document must be used in the design process unless another methodology, shown to be equally effective, is scientifically motivated. Any alternative methodology must be technically appraised by an independent and experienced rock engineering consultant.

### *1.1 Stope face area*

(i) The stope face area is defined as the area between the face and the first line of permanent support. Rapid yielding and other hydraulic and mechanical props are temporary support.

(ii) The support resistance and energy absorption requirements must be determined in accordance with the methodology described in this Appendix. Where support resistance and energy absorption requirements are not determined, the values of 50 kN/m² and 60 kJ/m² must be used respectively.

iii) The spacing of significant discontinuities in the hangingwall must be considered in the design of the support unit spacings. Where headboards for props are required, the performance specifications of these units must be included. Where hydraulic props have been specified without headboards, the design must be fully motivated in seismically active areas. The placement of face support units must also take cognisance of the areas of the occurrence of previous rock-related accidents deduced from historical records.

(iv) The support elements must be selected to cater for the anticipated

stope closure.

(v) The support installation procedure, cycle and time interval must be designed to ensure that mine personnel work under the protection of support whenever possible.

(vi) Special precautions relating to geological discontinuities traversing the stope must be included.

### ***1.2 <u>Permanent support area</u>***

(i) The permanent support area is contiguous to the face area and extends back to the centre gully.

(ii) In shallow mining conditions, in-stope pillars should be used. The design thereof must be detailed and fully motivated in the Code of Practice.

(iii) Where backfill is used, the full cycle of backfill emplacement and integrated movement of face area support must be specified.

In deciding on the type of backfill to be used, factors such as stoping width, strain rate and free standing ability must be taken into account. Quality control measures for the backfill material and emplacement must be stipulated.

(iv) Support units become less effective (or unstable) with increasing stope widths; the minimum width of support units must therefore be specified for selected ranges of stoping width.

### ***1.3 <u>Ledging</u>***

The support systems designed for ledging must provide for the stability of the stope gullies, winch chambers and the ledging stope area. Cognisance must be taken of the relatively low rates of closure, shallow dipping fractures spanning across the stope in deep mines and the stress induced fracturing generated during the development of the raise.

The sequencing of blasting and support installation must be arranged such that unsupported spans are kept to a minimum.

### ***1.4 <u>Access and cleaning ways</u>***

The design and support of access and cleaning ways must take cognisance of the following:

(i) stress induced and blasting damage to the hangingwall and gully shoulders;

(ii) the closure rate and working life of the gully;

(iii) force - deformation characteristics of support units;

(iv) rock reinforcement and area support requirements as deduced from statistical records and the presence of stress fractures and geological discontinuities; and

(v) the performance of the gully support under both quasi-static and dynamic loading conditions.

In large span areas such as strike and dip gully intersections and winch bays/chambers, additional support must be considered.

## 2. Design Methodology

### *2.1 Discussion*

The objective is to define a methodology by which a stope support system may be designed or evaluated in order to determine how effectively it would behave under either rockfall or rockburst conditions.

The variables that must be considered when designing or evaluating a stope support system are:

- the composition and condition of the hangingwall and footwall rocks;
- the force-deformation characteristics of the support units that constitute the stope support system;
- the mining height;
- the stope closure rate;
- the stope closure during rockbursts and the associated velocity of closure;
- the spacing of stope support units;
- the support resistance generated by the stope support system;
- the ability of the support system to absorb energy;
- appropriate stiffness which will minimise damage to the area immediately surrounding the support unit.
- an estimation of the rockfall support resistance criteria for the mining horizon. At least five years of accident data must be evaluated; and
- the construction of any support to not endanger people.

### *2.2 Control of Rockfalls*

In order to control rockfalls it is necessary to analyse the fallout thickness to determine the support resistance criteria that would prevent rockfalls. The cumulative percentage fallout thickness must be determined for a particular horizon and the support resistance of a particular stope support system must be capable of preventing at least 95 % of all fallouts.

### *2.3 Reduction of Rockburst Damage*

Using statistically determined block ejection thickness, it is possible to calculate a minimum energy absorption requirement per square metre of stope hangingwall.

A support system must be able to stabilise the stope hangingwall for 95 % of the fallouts. The velocity of ejection is assumed to be 3 m/s unless verified by measurements.

Therefore the energy absorption criterion or $E_{ac} = \frac{1}{2} mv^2 + mgh$.

*Where:*

m = mass of ejected rock (kg)

v = 3,0 m/s

h = deformation limit of support

$g = 9{,}81 m/s^2$

$E_{ac}$ = energy absorption criterion.

The energy absorption ability of a stope support system must be evaluated against the energy absorption requirement , $E_{ac}$, for the appropriate reef horizon to ensure that they comply.

## 3. Other Considerations

### 3.1 *The influence of the rockmass on support systems*

The rockmass behaviour surrounding stopes can vary widely depending on depth, bedding thickness, jointing and the hangingwall rock types and composition. Depth determines whether the rockmass is defined by geological structures only, as found in shallow conditions, or by stress induced fractures and geological structures, typical of deep mining conditions. The depth of stoping can also influence the stope closure rate, although other factors such as the mining cycle, stope span and the rock types in the hangingwall and footwall also have an influence. The distribution of geological structures, bedding spacing, stress induced fracturing and jointing in the rockmass will influence the spacing of support units in a support system, and the closure rate will influence the choice of support system, particularly if it is required to absorb energy.

### 3.2 *The stope closure rate*

Stope closure may be negligible in shallow or stress-relieved multi-reef stopes, but up to 50 mm/day can be expected in deep stopes. It is important to know the expected stope closure rate and mining cycle when designing or evaluating a support system in order to determine the absolute amount of stope closure that has acted on the support system. This is important in determining whether the remaining yieldability will allow sufficient energy to be absorbed should a rockburst occur.

### 3.3 *Dynamic closure velocity during rockbursts*

For the purpose of assessing support system behaviour, the closure velocity is assumed to be 3 m/s. Use of a different closure velocity must be scientifically substantiated through measurement.

### 3.4 The spacing of stope support units

An important step in the application of a stope support design methodology is the determination of the support system’s resistance and energy absorbing capacity. The support system resistance curves can be derived by simply determining the area associated with each support and dividing the support unit resistance by this area to obtain the average support resistance per square metre (Figure 1). A system's energy absorption capacity is derived in a similar way. Critical to the validity of this approach is that the supports deliver their resistance to hangingwall deformations in a stable manner.

### 3.5 Stope support design methodology for rockfall and rockburst conditions

#### *Discussion*

The stope support system reacts to the rockmass behaviour in the stope under both static and dynamic loading. With respect to the control of rockfalls, the support resistance requirement needs to be at least equalled by the support resistance designed into the support system. With respect to dynamic loading of support systems that occur in some rockbursts, the energy absorption requirement must be compared with the ability of the support system to absorb the required energy.

#### *The evaluation of the support resistance and energy absorption ability of various support systems*

The support resistance of a support system is defined as the force applied by the support system per square metre of hangingwall and is typically represented as kN/m² or as kPa. The support resistance will depend upon the force deformation behaviour of individual support units, their spacing and the amount of stope closure that has acted on the support system.

The determination of the ability of a stope support system to absorb energy with the objective of reducing rockburst damage is not simple since it depends on a number of variables, the most important of which is the ability of the support system to yield during deformation and thereby absorb energy. A good estimate of the normal stope closure rate that would occur prior to any dynamic closure must be established. Other variables which affect the ability of stope support systems to absorb energy are the spacing of the support units and the velocity of the dynamic stope closure.

The following general equation illustrates the process that is used to assess a support system:

*Where:*

$E_{finite}$ - is the amount of energy available to be absorbed by the support system prior to any stope closure.

$E_{available}$ - is the available energy that can be absorbed by the support system during a rockburst, taking into account previous stope closure.

$E_{stope\ closure}$ - is the energy absorbed by normal stope closure prior to a rockburst.

## 4. <u>Worked Examples</u>

### *4.1 Support Resistance*

Any support components installed in a stope are immediately acted upon by stope closure which can be up to 50 mm/day. *In situ* force-deformation curves or suitably downrated laboratory force-deformation curves must be used in calculations.

In order to take the effect of stope closure into account, it is necessary to represent a support system as a number of support resistance-deformation curves which are functions of stope closure and of the distance behind the stope face. Figure 1 illustrates clearly how these graphical representations may be used to determine the support resistance for any distance behind the stope face and for any closure rate.

Considering Point A, some distance behind the stope face, a horizontal line is traced until it intersects with the line representing the stope's closure rate, Point B. From Point B a vertical line is traced to Point C on the support resistance-deformation curve of the support system. From C a horizontal line is traced back to the Y-axis to intersect at Point D where the support resistance of that particular support system for the specific closure rate can be determined from these graphs.

Figure 2 takes the concept further by separating the face and permanent support areas and plotting the support resistance-deformation curves of the support systems used in both the face and permanent support areas. A mine pole support system and a mechanical prop support system are shown in the face area. In the graph representing the permanent support area, a timber pack support system is compared with a yielding timber prop support system. The example shown is for the Ventersdorp Contact Reef where, in order to prevent 95 % of rockfalls, the support resistance requirement would have to be at least 38 kN/m². This criterion is shown as a straight line on Figure 2. What is significant is that some of the support systems clearly fail to meet this criterion. For example, for a closure rate of 10 mm/day, the mine pole support system will fail to meet this support resistance criterion once it is 4,0 m or more behind the face. For a closure rate of 5 mm/day, the equivalent distance is 6,6m. The mechanical prop support system will fail to meet this criterion, 3,5m and 4,5m behind the face for a closure rate of 10 mm/day and 5 mm/day respectively. These support systems can be evaluated for different reefs with different support resistance criteria.

### *4.2 Energy Absorption Ability*

As in the previous example it is important to appreciate that closure degrades the support system’s ability to absorb energy. For example, a profile prop support system, at a support density of 3,0 m²/unit, can absorb 40 kJ/m² of energy before failure; similarly a hydraulic prop support system at a similar spacing is able to absorb 47 kJ/m² of energy before failure. Figure 3 illustrates how this graphical representation may be used to determine the energy that can be absorbed ($E_{available}$) for any distance behind the stope face and for any closure rate.

Consider Point A, some distance behind the stope face, a horizontal line is traced until it intersects with the line representing the stope's closure rate, Point B. From B a vertical line is traced to Point C, on the energy-deformation curve of the support system. From C a horizontal line is traced back to intersect the Y-axis (Point D) where ($E_{available}$) can be determined for that particular support system and for that specific closure rate. The support is assumed to have been initially installed 3,0 m from the face and stoping is on a two-day cycle.

Figure 4 shows some typical support systems plotted in the above described way. The energy absorption requirement for the Carbon Leader Reef is plotted, for illustration, in this figure and it can easily be evaluated whether or not the energy absorption criterion has been met.

## 5. Support Resistance Calculation

The following assumptions must be made in the calculation of support resistance.

These are:

(i) the stope face is not considered to offer any support;

(ii) in-situ force-deformation curves must preferably be used for quasi-static conditions. Where these are not available, laboratory force-deformation curves must be suitably downrated according to accepted techniques;

(iii) the closure rate used for these calculations must be based on field measurements and observations and must be applicable to a particular geotechnical area; and

(iv) the stope face area and the permanent support area must be treated as independent areas and the required support resistance must be met in each of these separate areas.

**Note:- An example of a calculation is shown in Figure 5. The support forces used in the example are purely for illustrative purposes.**

## 6. Reference

SIMRAC PROJECT GAP032, Stope and gully support, final report, December 1995. (Copies are available from the Secretary, GAPREAG: Telephone [011] 498 7100)

Fig 1

Fig 2

Fig 3

Fig 4

Fig 5

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# APPENDIX 2

# TUNNEL AND SERVICE EXCAVATION SUPPORT STRATEGY AND DESIGN GUIDELINES FOR HARD ROCK TABULAR ORE BODIES

## 1. Support Strategy

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### *1.1 General*

A procedure must be established and described to ensure that the potential rock conditions for all tunnels are assessed for their effective working life. The design of support systems must take cognisance of these conditions and the strategy must describe what performance characteristics are required of the proposed standard support systems.

Where conditions in the tunnel are expected to deteriorate as a result of a changing stress field or weathering, the techniques used in identifying the location of such deterioration must be described. Upon identification, the design and implementation of secondary support must be specified.

Particular attention must be given to the support of the area in the vicinity of the working face. In this regard, the timing of temporary and primary support installations is important and, together with examination and making safe procedures, must be specifically dealt with.

When poor ground conditions are encountered in the working face area, the strategy to be adopted to deal with these conditions, such as the alteration of tunnel shape, smooth wall blasting and aerial support, must be described.

The strategy must describe a separate support strategy for wide tunnels (e.g. breakaways), and, where existing tunnels have to be widened, the sequence of mining and additional support installation must be stipulated.

The strategy must describe how the problem of corrosion of support elements is managed in excavations with a medium or long term operating life.

### *1.2 Support Installation*

The majority of rock reinforcing tendons installed on mines are grouted in place and the effectiveness of these tendons is reliant on good quality grouting.

Ever since the introduction of these tendons, the quality of grouting has been of considerable concern. The quality of grouting cannot be evaluated visually and no instrument is currently available that can measure the effectiveness of the grouting. The "pull test" which is often used is destructive, slow and cumbersome and only identifies very poorly grouted tendons. It is therefore necessary that the problem be addressed at source to ensure that the best quality grouting possible is achieved.

Methods must be established and described to achieve consistently good quality grouting, including the training of support crews in tendon grouting and quality control.

Where ungrouted rockstuds are used, procedures must be described to ensure that the tension in the rockstud is tested and kept up to standard while the excavation is in use.

All materials used for support must be subjected to quality control testing according to laid down procedures.

### *1.3 Rehabilitation*

Rehabilitation and re-supporting of tunnels are carried out frequently on many mines. The conditions under which this work is carried out are often dangerous. A specific procedure must be adopted for each situation.

### *1.4 Large Excavations*

The methodology to be followed in designing these excavations and the implementation thereof must be stated. Designs must take into account the stress field and any changes therein, available techniques such as rockmass classification, numerical modelling, seismic data analyses, support design criteria and the influence that the size of the excavation and blasting technique have on the stability of excavations. The long term rockmass monitoring programme must be described.

At depths where stress fracturing will occur during excavation cutting, support sequence and blasting technique employed must take into account the orientation and extent of the stress fracturing at the various stages of excavation to ensure stability throughout the excavating process. The procedures to be followed must be in the form of a reference report from the rock engineering department/consultant.

## 2 Design Guidelines

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### *2.1 General*

To design an appropriate support system, it is first necessary to define the functions required of it. The strategy must define the functions of the different support systems used on a specific mine.

In shallow excavations or in excavations developed in stress relieved ground, the function of support is merely to pin individual potentially loose blocks, generally defined by geological discontinuities, to the competent rockmass.

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.

In deep mine tunnels where highly fractured rock is encountered, the support must reinforce the annulus of fractured rock by the installation of tendons to assist the rock to support itself. In such cases tendons need to be installed in a regular pattern to generate frictional forces between rock slabs. In cases of intense fracturing, aerial support must also be provided to prevent fallout and control the deformation of the rock slabs between tendons.

It is necessary to determine the force-deformation characteristics of the support elements comprising the support system, both under quasi-static and dynamic loading conditions. A record of the force-deformation characteristics of the different support elements used on the mine must be kept.

In broad terms the design process must involve the following:

- Determine or assess the rockmass environment for which the support is to be designed, e.g. the rockmass will be controlled by the geotechnical structure in a low stress environment and stress controlled failure in a high stress environment.

- Determine or assess the probable volume of rock to be supported or reinforced in all the rockwalls as well as the expected deformation of the rockmass.

- Establish criteria for the selection of all the support elements that constitute the support system, so as to cope with the anticipated rockmass structure (fractured/discontinuous) and deformation loading conditions (quasi-static or dynamic). The key characteristics which govern their suitability for different environments are strength, initial stiffness, yieldability, energy absorption capacity, length of tendon, area coverage as well as compatibility with other support elements in order to integrate them into an effective system.

### *2.2 Control of Rockfalls*

The strategy must stipulate the extent of aerial coverage and support resistance required to control the rockfall problem.

The support resistance requirements must be calculated with reference to potential fallout thickness as determined from analyses of accidents.

### *2.3 Reduction of Rockburst Damage*

In service excavations likely to be affected by seismic events, the support system must be capable of absorbing kinetic energy.

Approximately half of the incidents classified as rockbursts are not severe, catastrophic events, but rather the dislodging of blocks of rock in a state of unstable equilibrium. Peak ground velocities experienced in these types of rockbursts are of the order of a few cm/s. For the control of this type of damage, conventional rock tendon and mesh support will suffice.

Where peak ground velocities start exceeding 1 m/s, significant kinetic energy and momentum are imparted to the rock, resulting in potentially large displacements. To control the damage, the support has to absorb the energy and accommodate the displacements. Under these circumstances, a yielding support system is required.

Using block ejection thicknesses determined from accident analyses data, it is possible to calculate a minimum energy absorption requirement per square metre of rockwall.

The energy absorption criterion for the hangingwall is: $E_{hw} = \frac{1}{2}mv^2 + mgh$

The energy absorption criterion for sidewalls is: $E_{sw} = \frac{1}{2}mv^2$

*Where:* E = energy absorption

m = mass of ejected rock

v = peak ground velocity

h = deformation limit of support

g = 9,81 $m/s^{2}$.

In the absence of mine specific data for rock ejection thickness and peak ground velocity, current industry data must be used.

## APPENDIX 3

## STRATEGIES FOR SPECIAL AREAS.

Special areas shall be designated whenever it appears or can be anticipated that there is an increased risk of rockbursts and rockfalls occurring in an existing or proposed working place. This designation allows management to make rapid modifications where such action is urgently required. All such changes must be motivated and documented. The procedure for doing this must be stated in the strategy.

The rock engineering practitioner must pay particular attention to special areas and must record the location of all special areas, the classification and declaration procedure and the monitoring of such areas. The records must be available for scrutiny. This procedure must also be described in the strategy.

### *1. Special area classification*

It is recommended that special areas be classified as either "Restricted" or "Precautionary".

#### ***Restricted (R)***

In this situation the procedures listed become obligatory for the duration of the declaration.

#### ***Precautionary (P)***

Precautionary measures are applied at the discretion of the mine management in consultation with the rock engineering practitioner/consultant and the Special Areas Committee. Such decisions must be documented and be available for scrutiny. This decision might be merely the restriction of entry of persons into a working place

If alternative classification terminology is used it must be clearly defined.

### *2. Special areas declaration procedure*

A procedure must be established which provides for:

(a) the identification of a special area;

(b) the written notification to relevant personnel;

(c) the acknowledgement of receipt by personnel;

(d) the work place entry procedure;

(e) the type and spacing of support to be used; and

(f) a separate file for each working place classified as a special area containing all relevant information regarding the classification, declaration procedure, and monitoring of that area.

To ensure the smooth operation of the entire procedure, the mine manager shall appoint, in writing, a Special Area Officer. The duties must be specified in the letter of appointment.

### *3. Special Areas Committee*

In order to review progress and co-ordinate general mine policy regarding the extraction of special areas, a Special Areas Committee must meet at intervals/ periods not exceeding three months.

The Committee must at least comprise of Senior Mine Management, a qualified rock engineering practitioner/consultant and a representative from the Health and Safety Committee.

### *4. Functions of the Special Areas Committee*

The Code of Practice shall specify the functions of the Special Areas Committee.

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## APPENDIX 4

## THE FUNCTION OF A ROCK ENGINEERING SERVICE

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### 1 Introduction

An efficient rock engineering service is required in a mining operation to apply rock mechanics and strata control principles for the safe and economic design of mine workings.

The level of service required is related to the risk profile of the mine.

Maximum benefit is derived from a rock engineering service when it acts proactively, identifying potentially dangerous situations and taking or recommending remedial action before persons are injured or workings damaged.

To achieve this, it is advisable that such a service be closely associated with mining operations by operating as follows:

- Participate in planning activities in order to identify and advise management on potentially dangerous or damaging situations created by, or likely to be created by mining operations.
- Design and assist in implementing systems, procedures and techniques which will reduce or eliminate rockfall and rockburst hazards.
- Initiate and implement monitoring, recording and reporting systems and procedures which ensure that relevant information is timeously provided to the correct people in planning and operating functions.
- Ensure mining systems are employed which will provide conditions conforming to those required by relevant authorities with regard to surface structures.
- Assist with training of all levels of mine personnel in rock engineering aspects relevant to their occupations.

For the service to operate in this manner, it must be adequately equipped and staffed with properly qualified and experienced personnel closely associated with, but independent of the production department.

When operating correctly, the service performs a number of functions.

The actual priority and volume of work involved in executing these functions will depend on the nature and size of the mining operation.

## 2 The Planning and Design Function

2.1 Select the most suitable mining techniques and regional support for particular deposits by applying rock engineering analysis to ensure that the desired levels of stability will be maintained throughout the required period of operation.

2.2 Develop strategies for the code of practice after consultation with the mine’s Health and Safety Committee.

2.3 Design all protection, control and support pillars on the mine.

2.4 Design the location, shape and support of all tunnels and other service excavations to ensure stability throughout the excavation’s active life.

2.5 Approve plans for mining sequences to ensure that:-

- the probability of seismic events/rockbursts are minimised ; the factors affecting the stability of off-reef excavations are taken into account;

- support systems accommodate current and anticipated rock conditions; and

- all precautions necessary for remnant mining are stipulated.

2.6 Where necessary, the department head/consultant, assisted by seismic specialists using appropriate monitoring equipment, monitors and interprets seismicity and analyses its effects.

2.7 In bord and pillar workings:

- select bord width based on sound rock engineering principles and design bord support systems;

- a suitably qualified rock engineering practitioner to check the application of standard design techniques for correctness.

- approve the design of pillar extraction operations taking rock engineering principles into account.

2.8 The responsible rock engineering practitioner/consultant to provide input into mine planning or review meetings to ensure that the desired sequencing is adhered to and to answer any queries. Where significant departures from the planned layout occur, the rock engineering practitioner/consultant must ensure that variations do not create a hazardous situation. Where necessary, he must indicate what steps are to be taken to rectify the situation.

## 3 <u>Seismic Emission Monitoring And Damage Control</u>

3.1 In seismically active mines, the rock engineering department advises the manager in developing a strategy for their mine’s code of practice to reduce the incidence and the effects of rockbursts.

3.2 On mines or sections of mines where the bulk of ore reserves are located in remnants or pillars, make a periodic detailed analysis of the whole mine with emphasis on sequencing or phasing the extraction of pillars or remnants in such a way as to ensure that they are mined out as safely as possible.

## 4 <u>Routine Monitoring and Special Investigations</u>

4.1 Regularly monitor pillar performance to ensure that they conform to design requirements.

4.2 Visit production and service workings regularly to detect abnormal conditions and departures from planned layout.

4.3 Regularly inspect important chambers during the excavation, to ensure adherence to the designed excavation sequence and support standard and sequence.

4.4 Regularly monitor the performance of support systems in important excavations.

4.5 Where a danger of instability exists in shafts, regularly monitor displacements and, in particular, fault plane intersections.

4.6 Investigate unusual ground conditions, report findings and recommend remedial action.

4.7 Investigate all rock-related fatal accidents and complete rock engineering aspects of the official accident report.

4.8 Inspect all major rockbursts and large or serious falls of ground and submit a report.

4.9 Give input on risk assessment matters pertaining to rock related issues.

## 5 Research And Technology Transfer

Staff must remain aware of new technological developments and actively pursue the introduction of those that can be gainfully employed on the mine.

5.1 Investigate, on an on-going basis, the possibility of improving existing support systems.

5.2 Update mine’s Codes of Practice and related mine standards in consultation with the mine’s Health and Safety Committee.

## 6 Quality Control

6.1 Supervise routine quality control tests to ensure support elements provide the required performance characteristics for the loading conditions expected.

## 7 Training / Examinations

7.1 Assist with the training of underground personnel in strata control applicable to their mines, with particular emphasis on the identification of dangerous ground conditions.

7.2 Instruct training officials in aspects of strata control.

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# APPENDIX 5

## GLOSSARY OF TERMS AND DEFINITIONS

Accelerometer: A seismometer which measures ground acceleration.

Adit: A horizontal opening, started from a hillside, to reach an orebody.

Bord: Roadway driven in orebody or seam.

Back: This is the orebody between a level and the surface, or between two levels.

Burden : Distance between an explosive charge and the free surface in the direction of throw.

Compressive stress: Normal stress tending to shorten the body in the direction in which it acts.

Controlled blasting: All forms of blasting designed to preserve the integrity of the remaining rocks (e.g. smooth blasting, pre-spliting, post- splitting).

Convergence: Reduction of the distance between two basically parallel surfaces (usually the hangingwall and the footwall)

Creep: Time-dependent deformation.

Cross-cut: A horizontal opening, like a tunnel, that cuts the rock formation at an angle to the strike in order to reach an orebody.

Decoupling: Ratio of the radius of a blasthole to the radius of the charge; this causes a reduction in the amplitude of the strain wave by increasing the space between the charge and the blasthole wall.

Deformation: A change in shape or size of a solid body.

Dilatancy: The property of volume increase under loading

Dip: Angle at which a stratum or other planar feature is inclined from the horizontal

Discontinuity surface: Any surface across which some property of a rockmass is discontinuous (e.g. bedding planes, fractures).

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

Elasticity: Property of a material whereby it returns to its original form or condition after an applied force is removed.

Footwall: Mass of rock beneath a discontinuity surface (in tabular mining, the rock below the reef plane).

Gate Road: Roadway at either end of a longwall or shortwall.

Geophone: A seismometer that measures ground velocity.

Geotechnical area: A portion of a 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 minimise the risk resulting from mining.

Force: An action that tries to move an object from a stationery position, or to change its rate of movement or its direction of movement.

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).

Hypocentre: Location in 3 dimensions of the source of a seismic event. Also know as the focus (or source location).

Inelastic deformation: The portion of deformation under stress that is not annulled by the removal of the stress.

Level: All openings at a horizon from which the orebody is opened up and mining is started.

Magnitude (seismic): Measure of the size of a seismic event. May encompass energy, moment or both in its calculation.

Metalliferous mine: Includes all mines that are not diamond or coal mines.

Normal force: Force directed normal (perpendicular) to the surface element across which it acts.

Normal stress: Component of stress normal to the plane on which it acts.

Overbreak: The quantity of rock that is removed beyond the planned perimeter of the final excavation.

Peak particle velocity: Maximum velocity of the rockmass measured directly at a geophone or calculated from ground motion relations.

Permanent support: Support that once installed is not removed.

Pillar: Rock left in situ during the mining process to support the local hangingwall, roof or to provide stability to the mine or portion thereof.

Plasticity: State in which material continues to deform indefinitely whilst sustaining a constant stress.

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.

Primitive (virgin) State of stress in a geological formation before it stress: is disturbed by man-made operations.

Principal stress Stress (or strain) normal to one of three mutually

(or strain): perpendicular planes on which the shear stress

(or strain) at the point in the body is zero.

P-Wave: Primary or compressive wave emanating from the

source of a seismic event. Consists of a train of

compressions and dilations (like a spring). Moves

at approximately 6 000 m/s through quartzites.

Rock A Professional Engineer or a Professional Natural Scientist Engineering specialising in Rock Engineering and practising, or a graduate Consultant: possessing the Chamber of Mines Certificate in Advanced Rock Engineering who has sufficient experience of rock engineering practice in the mining industry that he 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.

Radiated seismic Total elastic energy radiated from a seismic source.

energy: Describes the potential for damage to man-made

structures better than seismic moment, and is

based on the velocity of ground motion.

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).

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 / or underground visits.

Rock: Any naturally formed aggregate of mineral matter

occurring in large masses or fragments.

Rockburst: Seismic event that causes damage to underground
workings.
Rockfall Fall of a rock fragment or a portion of fractured rock
(fall of ground): mass without the simultaneous occurrence of a seismic
event.
Rockmass: Rock as it occurs in situ, including its discontinuities.
Rockmass instability: A softening within a critical volume of rock indicated
by accelerating deformation and a drop in stress.
Suitably qualified A person who is at least in possession of the Chamber of
rock engineering Mines Certificate in Rock Mechanics (Metalliferous).
practitioner:
Suitably trained A person trained in relevant rock engineering / strata
personnel: control competencies.

Seismometer: A device (transducer) that converts ground motion
into an electric signal.
Seismic event: Transient earth motion caused by a sudden release
of the strain energy stored in the rock.
Seismic moment Measure of the strength of an earthquake or of a
(scalar): seismic event and an indication of the amount of
deformation (displacement) at a seismic source.
Seismic moment Describes completely the equivalent forces acting
(tensor): at a seismic source and is equivalent to the total
seismic moment integrated over the source volume
of a seismic event.
Seismic strain: Sum of all moment tensors of all events within a

given volume of the rockmass.

Seismic strain rate: Seismic strain over a specified period of time.

Seismic stress: Seismic energy radiated by all events recorded

within a volume during a specified period of time.

Shaft: Any tunnel having a cross sectional dimension of

3,7 m or over and

(i) having an inclination to the horizontal of 15

degrees or over, or

(ii) 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.

Spalling: Longitudinal splitting in uniaxial compression, or

the breaking-off of plate-like pieces from a free

rock surface.

Special areas: During the course of routine mining an increased risk

of rockfalls or rockbursts may develop. Such areas

requiring additional attention and precautions must

be designated special areas.

Spitting: Violent ejection of splinters of rock from the surface

of an excavation.

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.

Strain burst: Rockburst at the lower end of the spectrum of violent events occurring essentially at the surface of an excavation.

Strength: The maximum stress that a material can resist without failing for any given loading regime.

Stress: Force acting across a surface element divided by the area of the element.

Strike: Direction of the azimuth of a horizontal line in the plane of an inclined stratum (or other planar feature) within a rockmass.

Subsidence: Downward movement of the overburden (soil and/or rock) lying above an underground excavation or adjoining a surface excavation.

Support: A structure or a structural feature built into or around an underground excavation to maintain its stability.

S-Wave: Secondary or shear wave emanated from the source or a seismic event. Consists of elastic vibrations perpendicular to the direction of travel. Moves at approximately 3 650 m/s through quartzites.

Swelling: Constitutive mineralogical nature of the rock by which water is absorbed, causing a measurable increase in volume; swelling can exert very large time-dependent forces on rock or support systems and reduce the size of excavations.

Tangent modulus: Slope of the tangent to the curve of stress versus strain at a given stress value (generally a stress equal to half the compressive strength).

Temporary support: Support which will be removed.

Tensile stress: Normal stress tending to lengthen a body along the direction in which it acts.

Thickness: Perpendicular distance between bounding surfaces (e.g. bedding planes).

Transverse (shear) Wave in which the displacement at each point of the wave: medium is parallel to the wavefront.

Weathering: Process of disintegration and decomposition as a consequence of exposure to the atmosphere, to chemical action, and to the action of frost, water and heat.

Working place: The place where mine workers normally work or travel.