**Safety in Mines Research Advisory Committee**

Final Project Report

# INVESTIGATE A POSSIBLE SYSTEM FOR "making safe"

**RW Ottermann**
**NDL Burger**
**AJ von Wielligh**
**MF Handley**
**GA Fourie**

| | |
|---|---|
| **Research Agency** | **RE@UP, University of Pretoria** |
| **Project number** | **GEN 801** |
| **Date of report** | **February 2002** |

# EXECUTIVE SUMMARY

The primary output of this phase1 of the project was to develop a list of alternative designs for “making safe” that may be considered by SIMRAC. Workers responsible for “making safe” in mines will use the device or system, which has to be safe and reliable and reduce the exposure to fall of unsupported ground hazards, and therefore saving life and limb. This project looks at the actual “making safe” and not the detection of loose rock, which is addressed in projects GAP 820 and GAP 822. During phase 2 of the project a working prototype or prototypes will be developed for underground evaluation.

A significant proportion of rockfall accidents occur during re-entry into a workplace, when the initial inspection and “making safe” procedures are carried out to stabilise the rock before work in the area begins. The reason is that “making safe” is one of the most stressful and dangerous activities an underground miner can undertake. The operator often is unable to work at a safe distance and is sometimes forced to work directly underneath unstable rock when attempting to “make safe”. The equipment currently used is archaic and there is a need to devise a simple system to enable operators to stabilise the rock effectively and efficiently from a safe distance before work begins in the area.

A literature and international survey on existing systems was conducted. During a problem survey different mines (gold, platinum and coal) with different stoping widths were visited to investigate and identify the problem. A functional analysis was done from which a specification was drawn up. Different concepts for “making safe” were generated and evaluated against the system specifications. These concepts were presented to SIMRAC.

The ideas developed during this project are to be used by workers responsible for “making safe” in mines. The equipment is designed to reduce exposure to falls of ground, and to assist in reducing stress and fatigue of the operator. The concepts chosen as the preferred concepts are:

- A “lightweight pinch-bar” where the bar is manufactured of composite materials.
- “Mechanical jaws”: A hand held and operated mechanical system, which makes use of hydraulic pressure activated jaws to pry rocks loose.

It is recommended that both preferred concepts be further developed into prototypes, which can be tested and evaluated. It is further recommended that the Canadian mechanised scaling tool developed and tested by Planeta (1995) should be investigated and tested in South African Mines.

# ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Safety in Mines Research Advisory Committee (SIMRAC) for financial support of project GEN 801 and also for the interest and technical input of the SIMRAC Technical Committee. The team would also like to thank the three mines visited for their hospitality and assistance in observing "making safe" procedures.

**TABLE OF CONTENTS** **Page**

**TABLE OF FIGURES**

# 1 INTRODUCTION

A significant proportion of rockfall accidents occur during inspection and "making safe" operations to stabilise the rock before work in the area begins. The reason is that "making safe" is one of the most stressful and dangerous activities an underground miner can undertake. The operator often is unable to work at a safe distance and is sometimes forced to work directly underneath unstable rock when attempting to "make safe". The equipment currently used is archaic and there is a need to devise a simple system to enable operators to stabilise the rock effectively and efficiently from a safe distance before work begins in the area.

The equipment developed during this project is to be used by workers responsible for "making safe" in mines. This project looks at the actual "making safe" and not the detection of loose rock, which is addressed in projects GAP 820 and GAP 822. This equipment will reduce the exposure to fall of unsupported ground hazards, and therefore saving life and limb.

This is the final report on project GEN 801. During this project different concepts for "making safe" were generated and evaluated against the system specification. These concepts were presented to SIMRAC.

# 2 METHODOLOGY

This project adopted the following approach:

- The team carried out a local and international literature survey on existing systems to establish current practice and ideas in the mining industry.
- Three different producing mines (gold, platinum and coal) were visited in South Africa to view current practice.
- A functional analysis based on the findings of the underground visits was done.
- From the functional analysis the requirements for the system were finalised and the system specification and design parameters drawn up.
- The team generated different ideas.
- The different concepts were evaluated against the system specification.
- The selected concepts were presented to SIMRAC.

# 3 LITERATURE SURVEY

The literature survey is split into surveys of the local and international literature.

## 3.1 Survey of Local Literature

From the beginning of the 20th Century, injury statistics for the Witwatersrand Gold Mines showed a steady reduction in the injury rate from all other causes, excepting rockfalls. By 1929 Watermeyer and Hoffenberg (1932) reported that rockfall injuries were responsible for 25% of all injuries in the Witwatersrand Gold Mines. By 1943, the proportion of rockfall injuries on the gold mines had climbed to 50%, because injury rates from all other causes had continued to decline while those from rockfalls continued to remain almost constant (Biccard Jeppe, 1946). Rockfalls are still responsible for a significant proportion of non-fatal and fatal injuries in the gold and platinum mining sector, and there is no significant downward trend in these statistics in either the gold or platinum mines since 1970 (Jager and Ryder, 1999).

This picture suggests that the problem of rockfalls has never really been addressed effectively. The fatal injury rate has declined in the gold mining sector from 0.76 workers per 1000 workers employed per year in 1943 to 0.37 average in the years 1996-2000. Although this represents a 50% reduction, this has taken 50 years to achieve, and can probably be ascribed to the general incremental improvement in support and support products, mining strategy, the implementation of mining regulations, gradual improvements in management and supervision practice, improved levels of education and training, and a gradual improvement in the understanding of the problem.

The mining industry addresses the rockfall problem by the process of “making safe”, which consists of the following three components:

1. A qualified person first enters the working place and carries out a visual inspection;
2. Unsafe hangingwall rock and sidewalls identified in the visual inspection are barred down;
3. The excavation is supported, either with temporary or permanent support.

Once this process is complete, mining activities may begin in the working place.

The problem has been discussed for many years, often omitting points 1 to 3 above, instead emphasising mining strategy, mine planning, regional support strategy, local support, and supervision. Reviewing transactions in the *Papers and Discussions of the Association of Mine Managers of South*

*Africa*, covering stoping, stoping methods, safety and safety and health, it appears that there is no mention of the procedures for visual inspections in any of the papers spanning the years 1931 to 1996, including for example the reply by Hildick-Smith (1948, pp 998-1014) in which the Standard Stoping Practice at Modderfontein B Gold Mines Limited is set out in detail.

There is very little covering the second point. The only explicit references to barring can be found in Batty (1948, p1055), Stobart (1962, p771), Pretorius (1972, p356), and Tupholme (1975, p389). All these references say very little about the process of "making safe", and most only mention the pinch-bar, with the exception of Pretorius (1972), who describes a short hammer-pinch-bar combination for sounding and then barring the hangingwall by the "spanner boy", who was recognised on Crown Mines/City Deep to be the most exposed to injuries from falls of ground.

There is strong emphasis on the third point, e.g. Heywood (1948), Hildick-Smith (1948), Meyer (1968) and Wilson (1972). There are many other additional references on stope support in the same publications, which make no references to either the first or second points mentioned above.

"Making safe" has therefore been confined to being a requirement by the government, accepted and practised by the mines, but never seen as an area in which innovation or development was necessary. The reasons that work should be done in this area include:

1. Baring is a stressful and dangerous practice;
2. Inspections of working places often fail to identify dangerous situations;
3. Barring of potentially dangerous rock is either not carried out, or when it is, can induce unexpected problems later (e.g. Pretorius, 1972);
4. Barring can induce falls of ground;
5. Support systems both previously and currently in use are equally ineffective in totally preventing falls of ground, i.e. advances in support technology and its application underground have had an insufficiently positive effect to eliminate the problem in the long term;
6. A strong emphasis over the last 60 years on mine planning, stope layout design and support design, has not been successful in significantly reducing falls of ground;
7. Blasting can create undesirable situations with a rockfall potential that cannot be adequately addressed by the currently applied process of "making safe".

It appears that a quantum leap is only possible with a totally new approach.

## 3.2 Survey of International Literature

A worldwide search of published literature on barring or scaling has turned up very little. It appears that this is a subject neglected by all, and taken for granted as a technique as old as mining. It could be likened to a repetitive action an individual might do such as walking, which is done subconsciously.

Thus, barring, done by all mines all the time, is done “subconsciously”, without much reference to it anywhere. The only two references that will be covered in this report are a scaling guideline from the Department of Minerals and Energy, Western Australia (1997), and a study on hand barring undertaken in Canadian mines together with the development of a hand-held mechanised scaling tool (Planeta, 1995).

The Australian scaling guideline appears in full in Appendix A, and covers barring procedures with the emphasis on maximum safety. No innovations are mentioned, although mechanical scaling is discussed in one sub-section. The guidelines specifically advise against using drill jumbos for scaling purposes because loose rock detection is ineffective, and the machinery is not designed to carry out scaling. No mention of the mechanical scaling equipment available or how it works appears in the guidelines, although it appears by implication that the mechanised equipment is acceptable for scaling in the Australian mines. This guideline is widely considered to be the best available because of its comprehensive coverage of the hand scaling procedure.

The only English reference to scaling is the work reported by Planeta (1995) and possibly an in-house report on scaling and hangup removal by Ludwig (1988) for Inco Limited. All other references listed by Planeta (1995) are in French. Planeta (1995) concludes that hand scaling is one of the most stressful, labour-intensive and dangerous activities in underground mining. He defines a scaling factor, which gives an indication of the area to be scaled in proportion to the mass of material removed:

$$SF = \frac{SS}{T} \quad m^2/\mathrm{t}$$

where:

*SS* is the scaling surface created by blasting *T* tons of rock in an excavation;
*T* is the tonnage blasted in the mining cycle.

A typical development end will have a scaling factor of 0.3 to 0.5 $m^2$/t depending on the dimensions and profile of the tunnel, while a tabular stope 1 m high and 30 m long will have a scaling factor ranging from 0.37 $m^2$/t if the face is not scaled and 0.74 $m^2$/t if the face is scaled. A 1 m face advance has been assumed for these calculations. A four metre high breast stope 30 m long will have a scaling factor of 0.46 $m^2$/t assuming a 1 m face advance and that the face itself must be scaled.

Underground studies (Planeta, 1995) reveal that physically fit miners have an endurance of about 8 minutes when scaling, after which the rest times become unacceptably long and the ability to detect and remove loose rock drops to a low level. This study suggests that most scaling requirements in hot, deep, confined hard rock mines in South Africa are probably physically impossible to comply with. As far as the authors of this report know, there has never been a study of barring or scaling undertaken in South Africa.

Planeta (1995) then describes a mechanised hand-held scaling tool that he claims will significantly reduce physical demand and hence stress on the operator when compared with the standard hand-held pinch-bar (see figure 3.1). The mechanised scaling tool was tested in four Canadian mines, from which he found:

- The enormous physical effort required for tool penetration into the rock was almost eliminated;
- Over a similar scaling area, the mechanised tool requires less (operator) energy to remove the rock;
- The onset of Raynaud's syndrome (the blanching of fingers due to impact and vibration) took three times longer than with a conventional scaling tool;
- Operators perceived that using the mechanised tool required less physical energy.

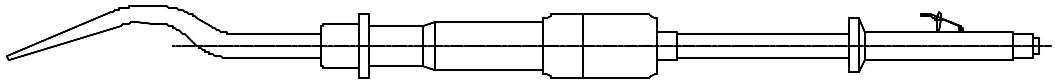


**Figure 3-1 Mechanised scaling/tool (Planeta. 1955)**

The mechanised scaling tool developed and tested by Planeta (1995) should be investigated and tested in South African Mines.

# 4 PROBLEM DEFINITION

The above literature survey clearly shows that little new concerning "making safe" procedures has arisen either in the South African mining industry or internationally in the last 60 to 70 years, excepting for the mechanised scaling tool described by Planeta (1995), the hammer – pinch-bar described by Pretorius (1972), and the recent introduction of lighter aluminium-based pinch-bars into the South African mining industry. In order to bolster the literature survey, the team decided to visit a representative selection of producing mines across the South African mining industry to observe current "making safe" procedures. The team visited three mines, a platinum mine, a coal mine and a gold mine to view practices in both deep and shallow mines, as well as hard and soft rock environments. Each visit is described separately below.

## 4.1 Platinum Mine

The design team visited a platinum mine at night shift on 23 August 2001. The reason for the night visit was to observe "making safe" procedures upon re-entry after the blast. The shift boss, crew captain, rock mechanics practitioner and two rock mechanics observers from the mine accompanied the team on the visit.

The team visited a stope on the Merensky Reef, which had been blasted that afternoon. The rock mass in the gully hangingwall was extensively jointed and blocky, and these conditions extended into the toe of the panel. The ground conditions were poor, with local falls of ground because the support in the bottom half of the panel had been damaged by the blast and by the face scraper.

All barring on the mine is done manually, using solid steel 25 mm diameter hexagonal cross-section pinch-bars 1.2 m long in the stopes, 3 m long aluminium pinch-bars in the development ends and other large excavations. Barring in the conditions described in the stope was difficult and dangerous, and it was not possible for the crew captain to remove all the hazards. It seemed to the team that the problem did not lie with the pinch-bar itself, but arises from a combination of blasting practice, support practice, and finally barring practice in the stope. It appears that barring practice might receive little attention on the mine, and that the crew captain may be unaware of the connection between blasting, support, and barring and safe ground conditions.

## 4.2 Coal Mine

The team visited a mechanised coalmine in Mpumalanga to observe "making safe" procedures on Tuesday, 11th September 2001. Because the seam height varies from 3 to 4 metres, pinch-bars are 3.3 m long and made from 1.5mm wall thickness square tubing. The pinch-bars are relatively light and easy to handle. Barring is carried out three times per shift, at the start, the middle and at the end. Sounding of the roof is done with a 3 m long 50 mm diameter wooden dowel with a copper cap placed on one end. It is effective in determining when loose rock is present in the roof.

Generally, roof conditions are good in the coalmine because mechanical mining methods are used. Hence pillars and excavations are cut to the right size with no damage to the surrounding rock mass. Falls are controlled by joints and loose shaly material in the hangingwall. Bad ground conditions are encountered in the vicinity of dykes, small faults and sometimes in rolls in the coal seam.

The roof is routinely supported in the 6.5 m bords with roofbolts, which consist of 0.8 m long by 12mm diameter smoothbar shank with expanding end anchor and 100 by 100 mm faceplate. The bolts are installed at 3 m by 2 m spacing, but density may be increased near geological structures, which are marked with red paint. All bolts are fitted with an approximately 0.5 m long strip of red and white striped barrier tape, except the last row of bolts in a face, which are fitted with approximately 2 m long strips of barrier tape to indicate that no bolting has been done beyond this point. Drill rigs mounted on the continuous miner install the bolts.

There are no unconventional methods of “making safe” employed on the mine, which has an excellent safety record purely by the proper implementation of standard procedures. It was noted during the visit that much care was taken to ensure that all procedures were properly implemented and supervised, and that equipment used was neatly stored and easily accessible whenever it was needed.

## 4.3 Gold Mine

One team member visited a deep level gold mine on 12 December 2001. Here, blasting and scaling practice were strictly controlled, and the ground conditions benefited as a result. Standard 25 mm diameter hexagonal cross-section solid steel pinch-bars were in use in the stopes, with the longer aluminium pinch-bars in the drifts and development ends. All barring is still done by hand, with management emphasising proper procedures to maximise safety. Mechanical scaling is being tried on the mine using the Scamac, manufactured by Tamrock, but with mixed results – some observers said that it created as many new loose fragments as had been removed. On many occasions hand barring had been necessary after mechanical scaling to reach an acceptable safety standard.

## 4.4 Concluding Remarks on Barring Practice on South African Mines

Barring is still done by hand throughout the industry. The three visits were not sufficient to draw clear conclusions on the overall standard of barring in the industry, except to say that all the mines visited understood the benefits of barring. New developments and changes in practice in barring seem to be almost non-existent. Long pinch-bars are now constructed from hollow aluminium tubes, with 25mm hexagonal steel end-pieces fitted. The shorter pinch-bars are the 19mm and 25 mm diameter hexagonal cross-section solid steel bars. There does not appear to be much thought given to developing new ways of barring, or of mechanising it, although some mechanised trials had been carried out in the gold mine with mixed results.

## 4.5 Determination of Requirements

The literature survey and mine visits clearly show that virtually no new techniques for “making safe” have been introduced in the mining industry worldwide in the last 60 to 70 years. Adequate safety standards are maintained by proper supervision and management of the “making safe” process. The problem must first be clearly defined in order to create a framework for brainstorming. The definitions that follow below are drawn from the experience and observations of the team members, and will be used as criteria for innovation.

*Loose rock:* defined as rock fragments ranging in size from pebbles to large blocks that will fall under their own weight if subjected to an upsetting force less than their own weight. They are potentially extremely hazardous. Not all loose rock is visibly loose, and there are currently two projects, namely GAP820 and GAP822, which are studying the potential of thermographic and acoustic techniques respectively to identify loose rock. The definition given above will therefore be broadened or even changed to include the results of the two projects once they are complete.

*Critical dimensions, size, and shape:* using the results of a visual inspection (and not an analysis of joint data) to determine factors that influence the potential of a loose rock to be a keyblock or not. Here, joint orientations and the boundaries of the keyblock must be sufficiently visible to infer the block's shape from the inspection and to allow a decision as to whether it is a keyblock or not. Detailed knowledge of the typical immediate hangingwall geology and structure, and of the root causes of previous falls of ground may be necessary to make a decision.

*Critical gaps:* determine the size of critical gaps between rock fragments and blocks that allow them to be sufficiently loose to rotate and fall. This assessment is closely related to the two above. At this stage it would appear that any previously closed fracture or joint that has opened up 1 millimetre is considered to be a critical gap. The choice of 1 millimetre is made because this gap size is easily visible to the naked eye, and any opening to this extent of a previously closed discontinuity indicates sufficient rock movement to allow the block to fall.

*Minimum distance of people from loose rock:* There is no minimum distance, because a loose rock will never indicate the size of the potential rockfall that may take place. Instead, a person must be protected by a support that will prevent rock from falling on him/her. The minimum distance from a loose rock could therefore be zero, if a support capable of arresting the fall of blocks surrounding the loose rock is installed next to it. Conversely, the widely applied rule that no person should be more than an arm's length away from any support can also be applied.

*Forces required to loosen and remove loose rock:* This is closely related to the definition of loose rock. In most cases, barring, which is a hand-operated system can generate up to 25kN force at the tip using a 25mm diameter hexagonal cross-section steel pinch-bar. Sometimes large loose rocks must be blasted down, and here forces of 1 MN or more may be required.

*Range of "making safe" tools:* Tools for "making safe" can be safely limited to 4 m. This is the upper limit of the typical dimension of an underground tunnel, and the size of the first cut to create a much larger excavation.

*Physical stress*: Barring should not require great strength and effort, because in underground conditions this will quickly lead to worker fatigue, and poor concentration. This will almost certainly lead to sub-standard barring, and in many cases, workplaces may not be barred at all.

# 5 FUNCTIONAL ANALYSIS AND SPECIFICATION

## 5.1 Functional analysis

A functional analysis based on the requirements for “making safe” from which a system specification and design parameters were compiled. In figure 5 the system level of the functional analysis is shown and the complete functional analysis is listed in Appendix B.

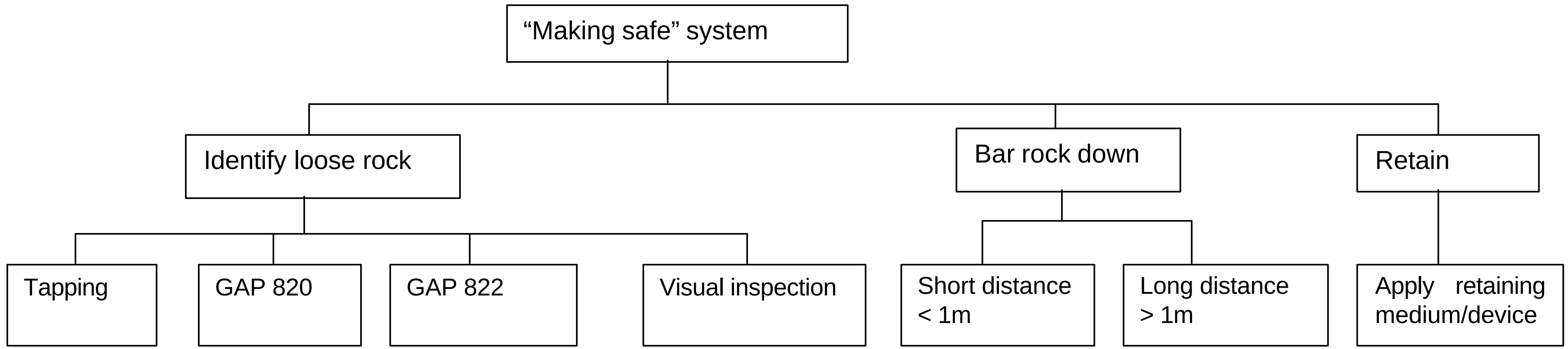



**Figure 5-1 System level functional analysis**

## 5.2 System specification

The objectives of “making safe” are:

1. Temporary prevention of potential gravity falls of ground to allow conventional support installation;
2. Identification of potentially dangerous areas that need more work than the first pass procedures named in point 1 above.

The specifications will concentrate on point 1 above. The effects of “making safe” are expected to be only temporary, to allow work teams to enter in order to carry on with the mining process whatever it may be, e.g. cleaning, preparation for the next blast, installation of temporary and/or permanent support, and so on. Note that the “making safe” process will not protect an excavation in the event of a rock burst – far more stringent measures would be necessary. The following specifications are put forward for discussion:

1. Determine from geotechnical area information, stress, and blasting method, the minimum unsupported span stand-up time, and then decide on a minimum period after the blast in which “making safe” procedures must be completed;
2. Determine the minimum procedures to ensure at least an 8-hour stand-up time from completion of “making safe” measures;
3. After “making safe” the working place can be declared safe for entry by work teams for a maximum period of 8 hours (one working shift);
4. Support or other measures to prevent falls of ground to render the working area safe for longer periods of entry must be installed during this initial 8-hour period;
5. It must be possible for one or a maximum of two qualified persons to carry out the actual process of “making safe”;
6. The process must be complete within a period of thirty minutes;
7. All the equipment necessary to carry out the “making safe” process must be carried into the working place by the qualified person(s) without any assistance from anyone else i.e. the equipment must be small and light;
8. The equipment must be easy and safe to operate, non-toxic, pose no fire hazard to the mine as a whole and the working place in particular, and be cost-effective;
9. The qualified persons must be trained to carry out the process properly and to use the equipment effectively;
10. The equipment should never require the qualified person(s) to place themselves in a potentially hazardous situation in order to carry out the work;

11. The equipment should be of sufficient variety to enable the qualified person(s) to make choices in the interests of their personal safety in all situations;
12. The results of the “making safe” process should be the elimination of all incidents that take place during the process itself, and all incidents during the 8-hour period work teams have to install support (i.e. the “safe” 8-hour window);
13. The process must not be unduly complicated, and people with minimal education should be able to qualify to carry out the process;
14. “Making safe” should not add to the onerous burden of underground tasks work teams already have to carry out, i.e. it should *contribute* to safety and productivity.

# 6 CONCEPT DESIGN

Different concepts making use of different power sources and techniques were generated. The power sources investigated include mechanical, pneumatic, hydraulic, electrical, vibrations and chemical and combinations of them. The following concepts were evaluated:

## 6.1 Air bag

Insert an inflatable bag into the crack and apply pneumatic pressure to the bag. By inflating the bag, pressure is applied to the rock, wedging it out. Figure 6-1 shows an air bag in a crack.

Inserting the bag into the crack will be difficult to do from a safe distance especially in high roof situations. In small cracks it will be impossible to insert an air bag. The supply of pressurised air or a compressor may also be logistically difficult.

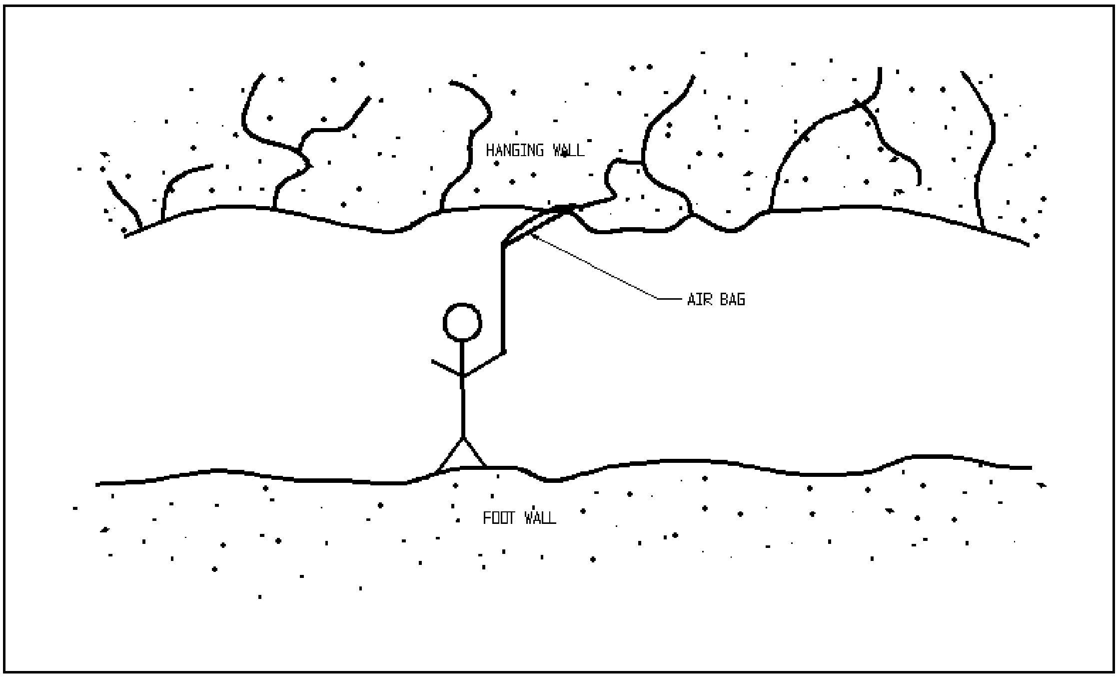



**Figure 6-1 Air bag in crack**

## 6.2 Vacuum suction

Apply vacuum induced by pressure via a suction cup to the loose rock and pull rock down by mechanical force. Figure 6-2 shows a schematic layout of the concept.

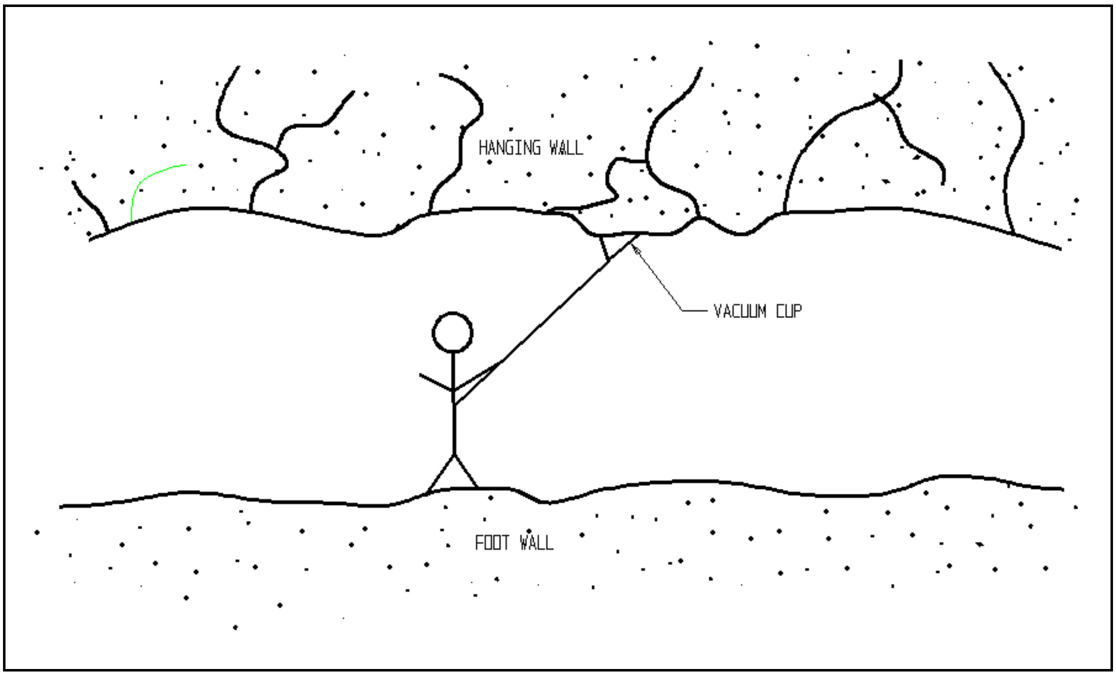



**Figure 6-2 Vacuum suction concept layout**

Applying the suction cup from a safe distance without being under the loose rock will be difficult. The system is complex, requires a lot of logistics and will be time consuming.

## 6.3 Water pressure

This concept is similar to the concept described in paragraph 6.1 except that water pressure is used in place of pneumatic pressure. This could be used in mines where hydraulic pressure is more readily available.

## 6.4 Vibrations

Apply mechanical vibrations to the loose rock and in doing so dislodge it. If the vibrations applied to it can dislodge the loose rock, it is also possible that the vibrations may be transferred to other rocks and dislodging the keyblock as well. The complexity of the system and the problem of effectively transferring the vibrations to the rock are negatives of this concept.

## 6.5 Mechanical scaling

Several machines have been developed doing mechanical scaling. These machines have however not been implemented on any scale in mines. Their complexity, manoeuvrability, cost and effectiveness limit the application. In figure 6-3 a mechanical scaling machine is shown.

**Figure 6-3 Mechanical scaling machines**

## 6.6 Mechanical jaws

The concept consists of a prying mechanism connected to a rod. The rod is carried by the operator who manoeuvres the prying mechanism into the crack (see figure 6-4). The prying mechanism comprises of a pair of jaws with sharp tips, which are opened hydraulically to apply a prying action to the loose rock when the tip is inserted into a crack. The apparatus also includes a lever operated hydraulic pump situated in the rod for supplying the hydraulic fluid under pressure. The rod is hinged at a position close to the operating end to be able to direct the prying mechanism towards the crack. A slide hammer, remotely operated, is positioned behind the prying mechanism to force the tips of the prying mechanism into the exposed crack prior to the actuation of the prying mechanism.

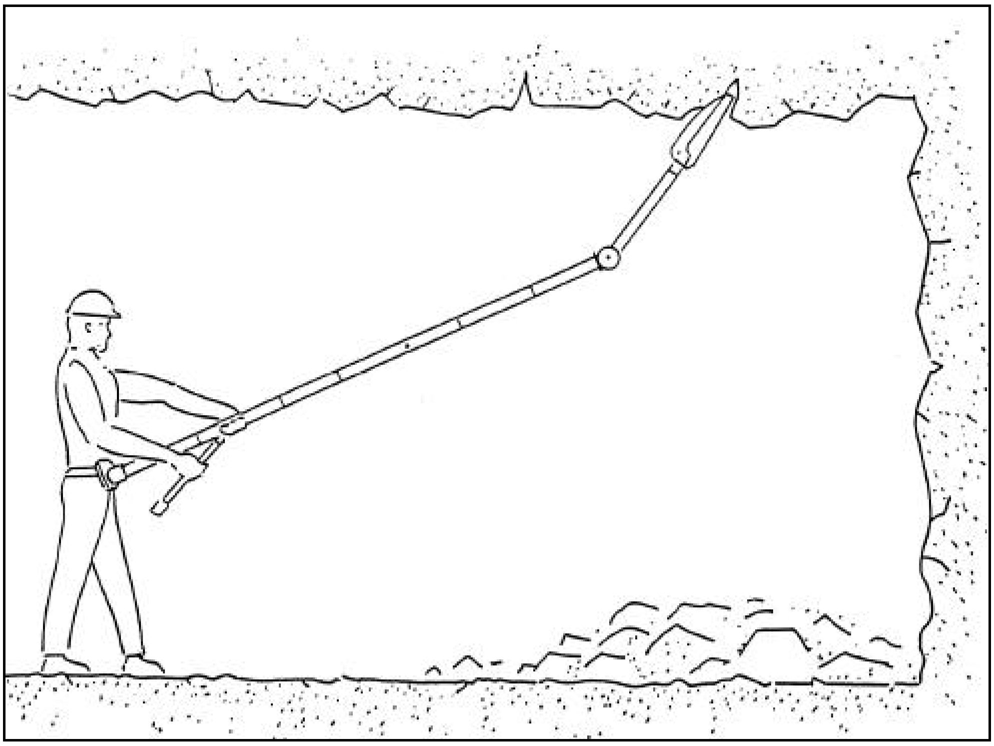


**Figure 6-4 Rock prying apparatus in use**

## 6.7 Lightweight "pinch-bar"

The concept consists of steel end tips similar to those on existing steel pinch-bars. The two tips are connected by a lightweight composite material tube, which will decrease the weight. It is also suggested that a changed shape of the pinch-bar be investigated to establish whether this can improve the application of the pinch-bar from a safe distance.

## 6.8 Secondary explosion

Make use of small secondary controlled explosion to dislodge the loose rock. In addition to safety risks the mining procedure will have to be changed, as workers will have to leave the area before the blast making the method very time consuming. A secondary blast may also loosen other rocks and thus leaving the area unsafe again.

## 6.9 Glue into cracks

Inject quick setting glue or fast reacting cement into the cracks. This glue can be water reacting adhesive so that the moisture prevalent is used as an advantage. An advantage of this concept is that the loose rock is not dislodged but kept in place thus eliminating the risk of dislodging the keyblock. Safety is however questionable as two or more adjacent rocks may fall together. The bigger the cracks the more costly the operation will be and the lower the effectivity. This concept could be used in conjunction with another method where the loose rocks are dislodged and the questionable ones are glued together.

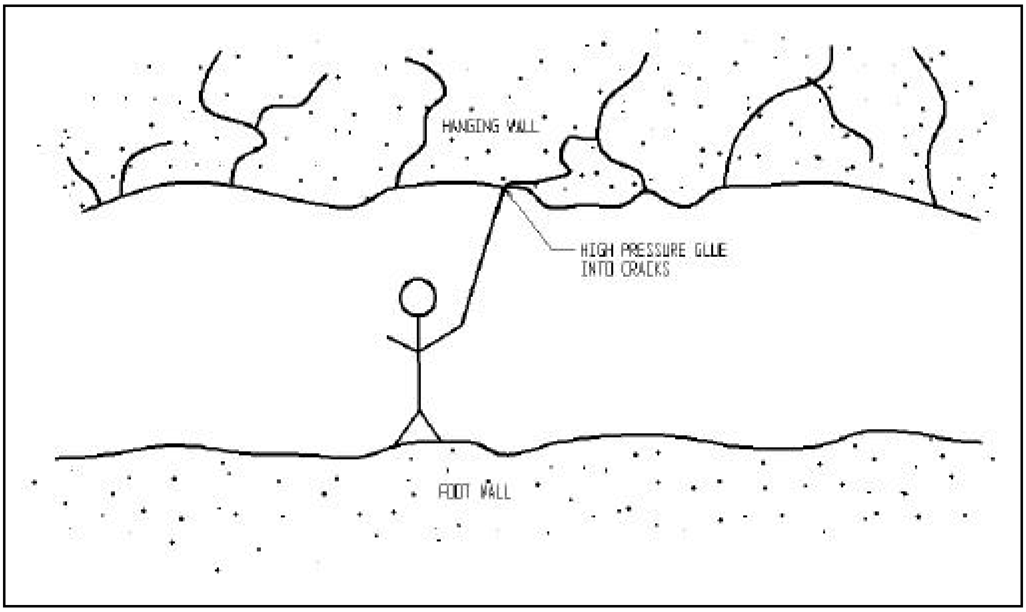



**Figure 6-5 Glue into cracks**

## 6.10 Coating of roof

Coat the roof with an epoxy linking the rocks together preventing them from falling down. The epoxy can again be water activated so that the moisture prevalent underground is used as an advantage. An advantage of this concept is that the loose rock is not dislodged but kept in place thus eliminating the risk of dislodging the keyblock. Safety is however questionable as the whole roof area may fall. This operation will be very costly, as the whole roof has to be coated. As with the previous concept (glue concept) this concept could be used in conjunction with another method where the loose rocks are dislodged and the questionable ones are glued together.

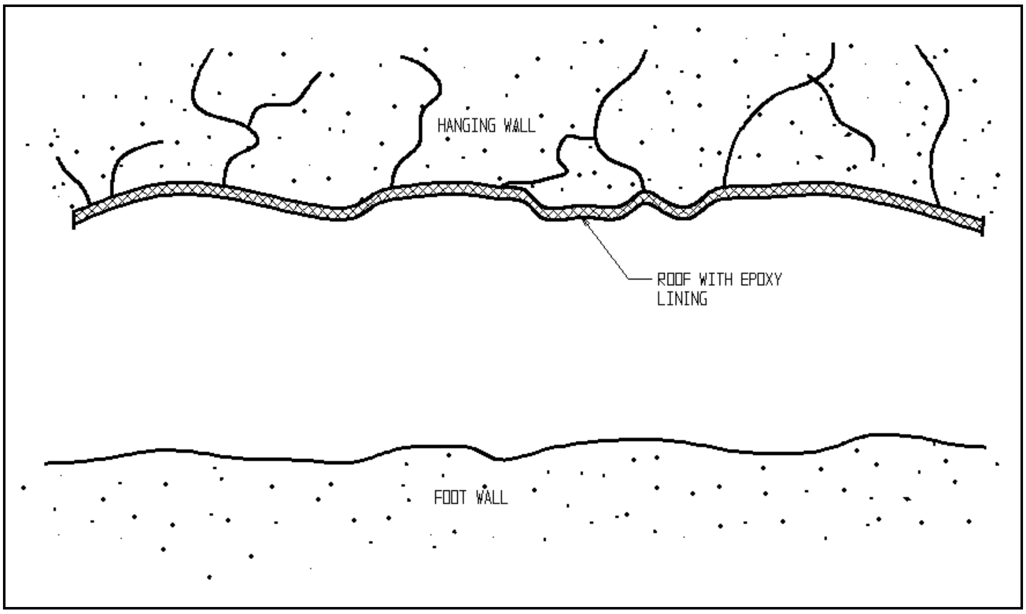



**Figure 6-6 Coating of the roof**

# 7 CONCEPT EVALUATION

The different concepts were evaluated against the system specifications as described in paragraph 5.2. The different criteria were weighted to derive at an average figure for each concept. The following weighting was used:

0 - Impractical
1 – Very bad
2 – Bad
3 – Average
4 – Good
5 – Excellent

Table 7.1 summarises the evaluation of the different concepts described in paragraph 6. A higher average indicates a better concept.

Table 7-1: Evaluation results of different concepts

| Concept | Safety | Develop. Risk | Effectiveness | Complexity | Size / weight | Manoeuvrability | Operation | Logistics | Cost | **AVERAGE** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Air bag (pneumatic pressure) | 2 | 2 | 2 | 3 | 3 | 2 | 3 | 1 | 3 | **2.3** |
| 2. Vacuum suction | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | **1.8** |
| 3. Hydraulic pressure | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 1 | 3 | **2.2** |
| 4. Vibrations (mechanical) | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | **2.3** |
| 5. Mechanical scaling | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | **2.8** |
| 6. Mechanical jaws | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | **3.9** |
| 7. Lightweight “pinch-bar” | 3 | 3 | 3 | 4 | 4 | 5 | 4 | 4 | 5 | **3.9** |
| 8. Secondary explosion | 1 | 2 | 1 | 2 | 4 | 2 | 1 | 2 | 3 | **2.0** |
| 9. Glue into cracks | 2 | 3 | 2 | 3 | 4 | 4 | 3 | 4 | 2 | **3.1** |
| 10. Adhesive coating of roof | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 2 | 2 | **2.9** |
| | | | | | | | | | | |

From table 7-1 it can be seen that the preferred concepts are the “Lightweight pinch-bar” and the “Mechanical jaws”. These concepts were discussed with safety officers of different mines, who were very exited about the concepts. In the next paragraph the two concepts are described in more detail.

# 8 REFERRED CONCEPTS

## 8.1 Lightweight pinch-bar

The concept consists of steel end tips similar to those on existing steel pinch-bars. A lightweight composite material tube connects the two tips. A realistic design aim of the tube is for it to have the same strength as that of steel pinch-bars with less flexibility. It is estimated that the weight of this lightweight pinch-bar will be close to that of aluminium pinch-bars. The weight of a 2.6 m lightweight pinch-bar with 25mm steel tips is estimated at less than 5 kg (aluminium: 4.8 kg). In figure 8-1 the lightweight pinch-bar is schematically shown.

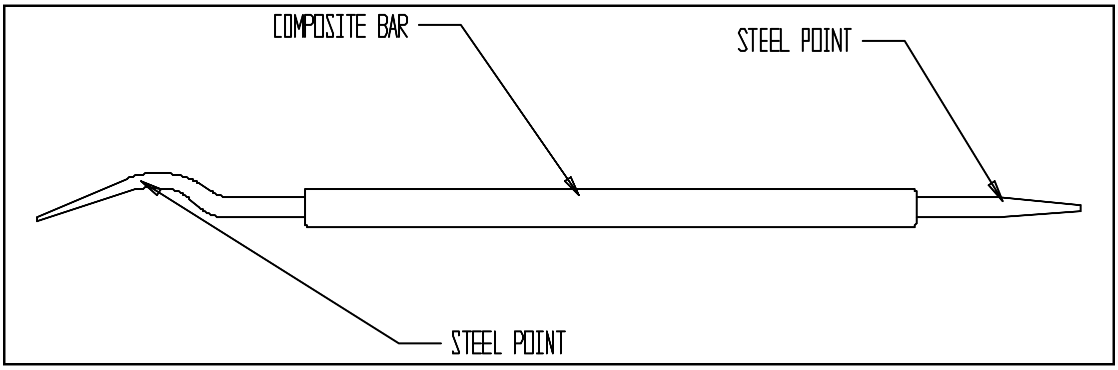



**Figure 8-1 Lightweight pinch-bar**

It is suggested that a changed shape of the pinch-bar be investigated to establish whether this can improve the application of the pinch-bar from a safe distance.

## 8.2 Mechanical "jaws"

The concept consists of a prying mechanism connected to a rod. The rod is carried by the operator who manoeuvres the prying mechanism into the crack (see figure 8-2). The prying mechanism comprises of a pair of jaws with sharp tips so that they can be inserted into the crack. The jaws are opened hydraulically to apply a prying action to the rock when the tip is inserted into the crack. A lever operated hydraulic pump placed at the base of the rod supplies the hydraulic fluid under pressure. The hydraulic reservoir forms part of the rod making it a self-contained system. The rod is hinged at a position close to the operating end to be able to direct the prying mechanism towards the crack. The direction of the prying mechanism is preset before the jaws are inserted into the crack. A remotely operated slide hammer is positioned behind the prying mechanism to force the tips of the prying mechanism into exposed crack prior to the actuation of the prying mechanism. In figure 8-3 the layout of the system is shown and in figure 8-4 the detail of the front end of the rock prying apparatus is shown.

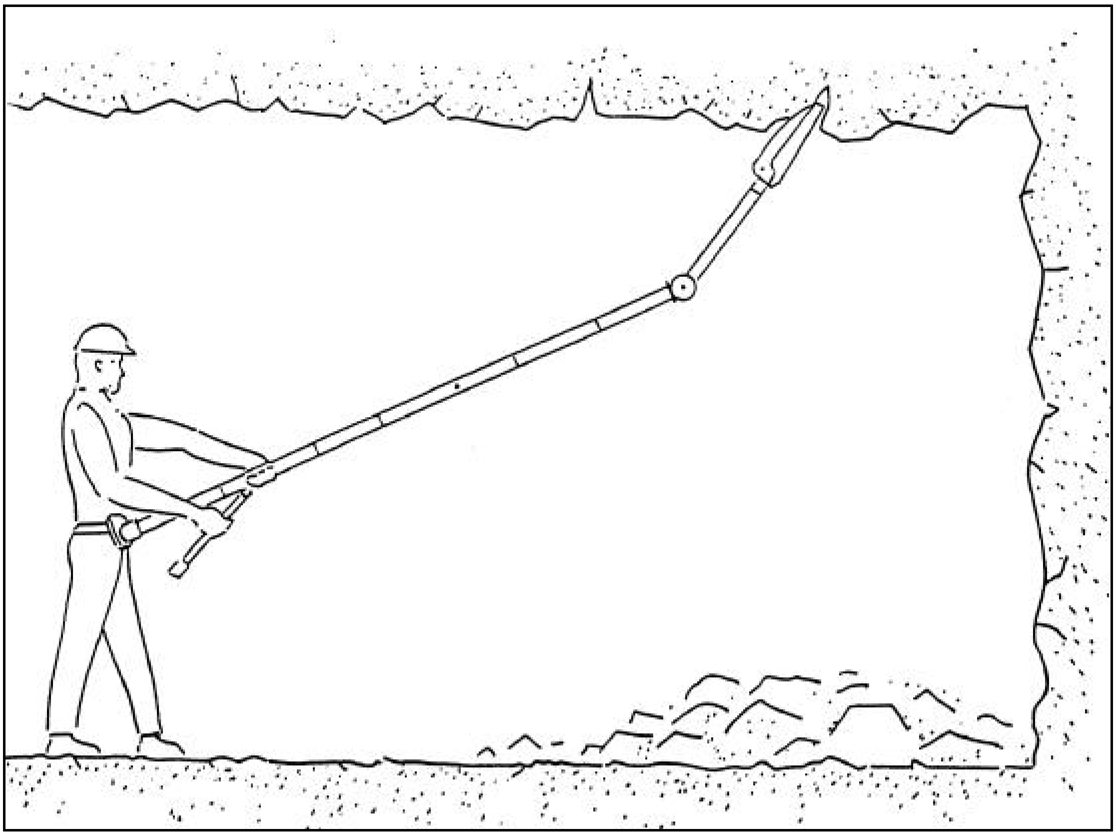


**Figure 8-2 Rock prying apparatus in use**

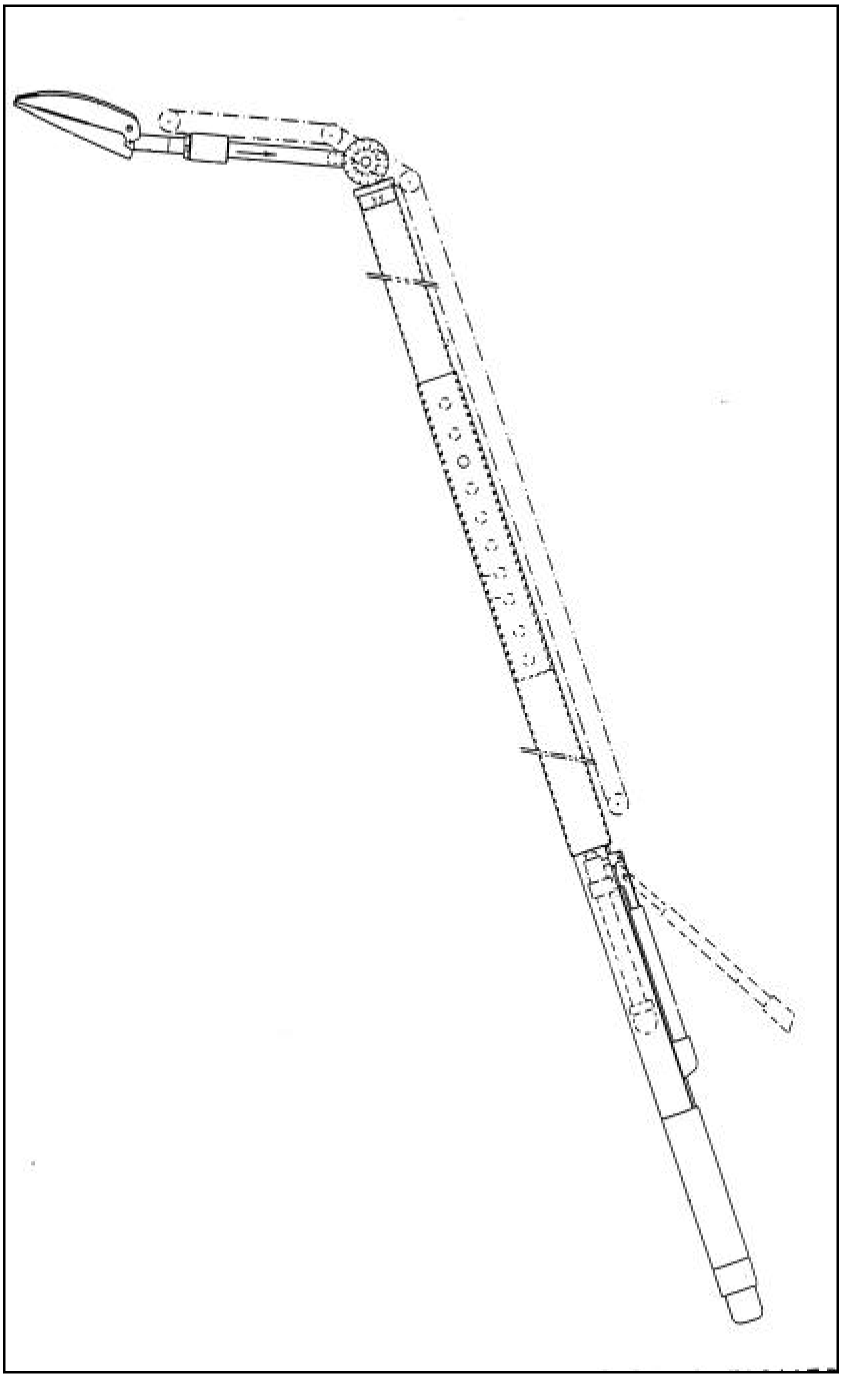


**Figure 8-3  Layout of rock prying apparatus**

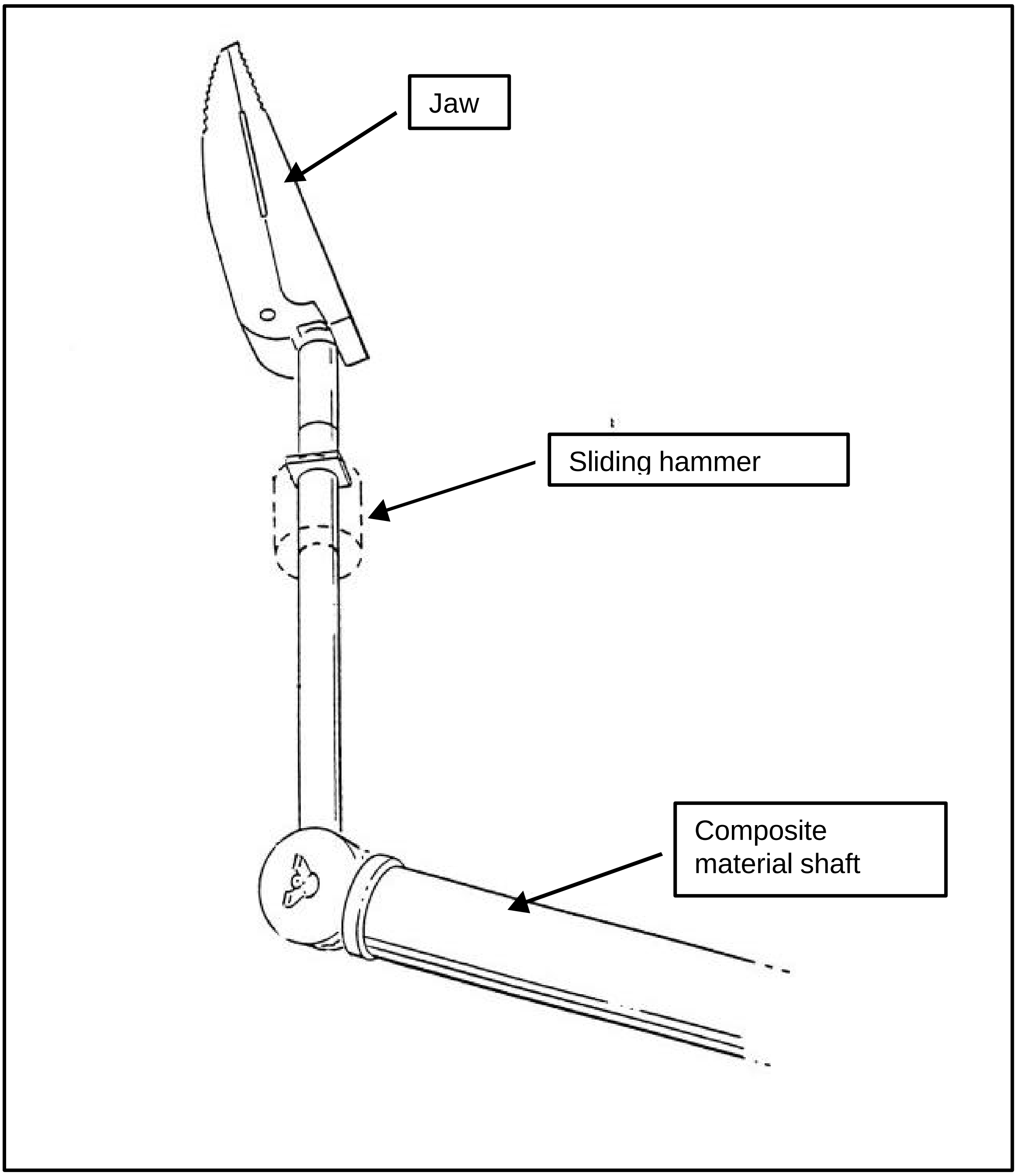



**Figure 8-4 Front end of rock prying apparatus**

# 9 CONCLUSION AND RECOMMENDATIONS

The equipment currently used is archaic and there is a need for a simple system to enable operators to stabilise the rock effectively and efficiently from a safe distance before work begins in an area. The operator often is unable to work at a safe distance and is sometimes directly underneath unstable rock when attempting to "make safe". Furthermore, current methods are physically demanding on the operator, which can lead to poor concentration, improper completion of tasks, and accidents.

Different concepts were generated for "making safe". These concepts were evaluated against the system specifications. The concepts chosen as the preferred concepts after the evaluation are:

- A "lightweight pinch-bar" where the bar is manufactured of composite materials.
- "Mechanical jaws": A hand held, mechanically operated system, which makes use of hydraulically activated jaws to pry rocks loose.

It is recommended that both preferred concepts be further developed into prototypes, which can be tested and evaluated. It is also recommended that different existing pinch-bars be tested for strength, flexibility, manoeuvrability and durability to determine the specifications for the lightweight pinch-bar.

During the literature survey information about a Canadian mechanised scaling tool developed and tested by Planeta (1995) was obtained. It is recommended that this scaling tool be investigated and tested in South African Mines.

# 10 REFERENCES

Batty GB (1948): Some notes on underground accident prevention. *Association of Mine Managers of the Transvaal Papers and Discussions, 1942-1945*, Vol II, pp 1047-1058. The Transvaal Chamber of Mines, Johannesburg, 1948.

Department of Minerals and Energy, Western Australia (1997): *Guidelines: Underground Barring Down and Scaling*. Department of Minerals and Energy, Western Australia, June 1997.

Heywood GR (1948): Some aspects of mining practice. *Association of Mine Managers of the Transvaal Papers and Discussions, 1942-1945*, Vol II, pp 959-1046. The Transvaal Chamber of Mines, Johannesburg, 1948.

Hildick-Smith G (1948): Contribution to the discussion on paper by Heywood GR: Some aspects of mining practice. *Association of Mine Managers of the Transvaal Papers and Discussions, 1942-1945*, Vol II, pp 998-1014. The Transvaal Chamber of Mines, Johannesburg, 1948.

Jager AJ and Ryder JA (1999): *A Handbook on Rock Engineering Practice for Tabular HArd Rock Mines.* SIMRAC, Johannesburg, 1999.

Jeppe CB (1946): *Gold Mining on the Witwatersrand*. The Transvaal Chamber of Mines, Johannesburg, 1946.

Meyer JM (1968): Stoping method and control at Hartebeestfontein Gold Mine. *Association of Mine Managers of South Africa Papers and Discussions, 1966-1967*, pp 391-402. Chamber of Mines of South Africa, Johannesburg, 1968.

Pretorius PGD (1972): Techniques used to implement the falls-of-ground campaign at Crown Mines, Limited and City Deep, Limited. *Association of Mine Managers of South Africa Papers and Discussions, 1970-1971*, pp 343-364. Chamber of Mines of South Africa, Johannesburg, 1972.

Stobart WT (1962): Accident prevention – underground native labourers. *Association of Mine Managers of South Africa Papers and Discussions, 1960-1961*, pp 761-770. Chamber of Mines of South Africa, Johannesburg, 1962.

Tupholme ER (1975): Techniques of strata control as applied to Stilfontein Gold Mining Company, Limited. *Association of Mine Managers of South Africa Papers and Discussions, 1972-1973*, pp 335-392. Chamber of Mines of South Africa, Johannesburg, 1975.

Watermeyer GA and Hoffenberg SN (1932): *Witwatersrand Mining Practice*. Transvaal Chamber of Mines, Gold Producer's Committee, Johannesburg, 1932.

Wilson JW (1972): A study of falls of ground fatal accident scenes and strata control in stopes, with particular reference to the Anglo American mines in the Orange Free State. *Association of Mine Managers of South Africa Papers and Discussions, 1970-1971*, pp 365-409. Chamber of Mines of South Africa, Johannesburg, 1972.

## APPENDIX A SCALING REGULATIONS IN WESTERN AUSTRALIA

GUIDELINES
UNDERGROUND BARRING DOWN AND SCALING
DEPARTMENT OF MINERALS AND ENERGY WA

CONTENTS

GUIDELINES
UNDERGROUND BARRING DOWN AND SCALING
DEPARTMENT OF MINERALS AND ENERGY WA

## FOREWORD

This Department of Minerals and Energy guideline has been issued to assist in the development of procedures relating to scaling of loose or potentially unstable rock in underground metalliferous mines.

It is emphasized that this guideline is not totally inclusive of all factors concerning scaling procedures in an underground metalliferous mine. It may not be totally suited to the specific requirements of every mine.

Comments on and suggestions for improvements to the guidelines are encouraged. The guideline will be revised where appropriate to reflect legislative changes and to accommodate new information, improvements in technology and improvements deriving from operational experience.

GUIDELINES
UNDERGROUND BARRING DOWN AND SCALING
DEPARTMENT OF MINERALS AND ENERGY WA

## 1.0 INTRODUCTION

The objective of this guideline is to provide an outline of a systematic approach to the task of scaling and to identify the issues that should be addressed when carrying out scaling to provide a safe underground work environment.

Scaling, also known as barring down, is a basic skill that every person working underground should understand and be able to demonstrate to a minimum level of competence. Scaling may be described as the art and function of making the ground safe using a scaling bar to locate and remove loose rock from the walls, face and backs of the workplace. In manual scaling, loose or potentially unstable rock is prised off the rock surface with an appropriate scaling bar. The ability to correctly "read the ground", or assess the ground conditions, is essential to all people carrying out scaling, no matter how small the area to be scaled. The importance of the ability to correctly read the ground can never be over-emphasised in relation to scaling and ground control in general.

The physical work associated with manual scaling is amongst the most arduous underground mining work and can only be done effectively for a comparatively short period of time before rest is required. A high level of mental and physical alertness is required at all time while scaling. During rest periods, the person should be actively observing the area around where they are standing, in all directions, to look for planes of weakness in the ground that have the potential to form unstable blocks or wedges.

Scaling skills are vital for all people working underground to ensure that their workplace is made and kept safe from loose and/or potentially unstable rock. Manual scaling is potentially one of the more hazardous activities in underground mining. The person carrying out the scaling is working in close proximity to the rock face and can be exposed to potentially unstable ground that may fall unexpectedly. In addition, the conditions underfoot may be very uneven which can hinder rapid evasive action.

A range of issues need to be considered when scaling, these include:
identifying the ground conditions:

- scaling equipment;
- scaling procedures;
- scaling in high headings;
- scaling in narrow headings; and
- regular check scaling of main access ways.

Scaling is an on-going process in each workplace with exposed ground that is never finished until the mine closes. No ground should be assumed to be stable until it has been sounded with a scaling bar. Recognising that large potentially unstable blocks may appear and sound stable, other means should be employed to make the area safe where doubt exists.

GUIDELINES
UNDERGROUND BARRING DOWN AND SCALING
DEPARTMENT OF MINERALS AND ENERGY WA

Ground conditions should be checked using appropriate scaling procedures before starting work and confirmed on a regular basis during the shift in ALL workplaces where ground is exposed.

## 2.0 LEGISLATIVE REQUIREMENTS (WA)

Reference should be made to relevant legislative provisions of the Mines Safety and Inspection Act 1994 and the Mines Safety and Inspection Regulations 1995.

### 2.1 Duty of Care

Section 9 of the Mines Safety and Inspection Act 1994 includes obligations on employers to provide and maintain workplaces, plant and systems of work such that employees are not exposed to hazards. Section 10 of the Act requires employees to take reasonable care to ensure their own safety and health, and to avoid adversely affecting the safety and health of others.

### 2.2 Regulations

Regulation 10.13 of the Mines Safety and Inspection Regulations 1995 states:
*The regulation is not included in the original document*
Regulation 10.28 of the Mines Safety and Inspection Regulations 1995 states, amongst other things, that:
*The regulation is not included in the original document*

## 3.0 IDENTIFY THE GROUND CONDITIONS

It should never be assumed that the ground in a Workplace is safe unless it has been checked by those working in the area using correct scaling procedures. All underground workplaces are kept safe by regular, on-going, checking and scaling as required. This is vital to the safety of all people working underground.

Ground conditions may be identified by:

- Sight
  see if the rock looks to be stable - look for intersecting joints, cracks, zones of weakness in the rock; and
- Sound
  listen for rock noise caused by high stress;
  strike the rock with the moil tip on the bar and listen to the sound the rock makes.

Scaling requires a person to:

- Evaluate
  close-up inspection of the area is required to adequately inspect the ground conditions to determine if the conditions are appropriate for scaling or if other action is required; and
- Act
  take appropriate action to remove the unstable rock by scaling; or
  arrange for other action to be taken, see section 5.0.

Rock stability is controlled by a number of factors including:

- natural planes of weakness or joints in the rock;
- rock stress levels;
- rock mass strength; and
- blast damage to the rock around the perimeter of the opening.

Natural planes of weakness, or joints, in the rock play a very important part in forming the potentially unstable blocks, wedges and slabs that should be removed by scaling. Before scaling it is vital that the ground be observed for an appropriate period of time to determine the orientation, length, spacing and roughness of the exposed trace of the joints or cracks in the backs, walls or face.

The intersection of two or more joints, rock fractures due to blast damage and/or intact rock failure can form potentially unstable wedges or slabs of varying shapes and sizes. Some of these wedges or slabs may be unstable and on the verge of falling or sliding. These potentially unstable wedges or slabs can be located by sounding the rock with the bar during scaling. The application of water to the backs, walls and face can assist with the visual detection of joints, cracks, etc. The application of water to certain ground conditions, eg some highly stressed ground, can cause pieces of rock to spall off the areas where the water has been applied.

Key blocks or wedges may be holding a number of other blocks and wedges in place behind or above the exposed face. The removal of the key block may "free up" other blocks or wedges, that were previously held in place by the key blocks, thus triggering the fall of a number of other blocks.

The use of a stope light held from the side and directed at the rock face may provide shadows that highlight the outline of a potentially unstable block or slab that can be removed by scaling.

## 4.0 SCALING EQUIPMENT

Scaling bars come in a variety of lengths and materials. Bar types include:

- solid steel hexagonal bar, 1.2 m to 2.4 m long, with tips forged at each end; and
- hollow aluminium tubes, 2.4 m to 3.6 m long, with steel tips securely attached to each end.

One end or tip of the bar has a straight chisel point, the other end has a heel and chisel point toe to give greater leverage.

Generally, solid steel bars are shorter than the aluminium bars because they are heavier. The longer aluminium bars may be preferred in areas with high backs because the operator can stand further away from the potential rockfall. However, hollow bars are not as effective for sounding and are more flexible than a solid hexagonal steel bar. This can make their use awkward or impractical particularly in confined spaces and in high headings.

In ALL workplaces more than 3.5 m high, appropriate purpose designed and built equipment should be used to access the backs and upper areas of the walls and face when ever manual scaling is being carried out.

A variety of other equipment may also be used for mechanised scaling, including:

- rock drilling jumbos; and
- mechanical scaling units.

It is important to recognise that rock drill jumbos have NOT been specifically designed for the purpose of scaling. It is understood that these machines are sometimes being used for scaling or rehabilitation purposes, however their limitations with respect to scaling should be recognised and understood by all operators and mine management.

Regardless of the method used for initial scaling, MANUAL SCALING should be the FINAL means of scaling in ALL workplaces.

The bucket of a load-haul-dump unit (loader) should NOT be used for scaling.

# 5.0 MANUAL SCALING PROCEDURES

## 5.1 Introduction

Before commencing manual scaling you should have and be using, where appropriate, the required personal protective equipment including: gloves, safety glasses, safety helmet, cap lamp, self rescuer, protective clothing (long sleeved), safety boots, hearing protection and safety rope and harness if there is a potential for the person to slip or fall.

It is also necessary to ensure that the workplace ventilation is operating and is adequate to dilute and disperse flimes and dust and that the area has been thoroughly watered down particularly after blasting.

Scaling bars are used to lever or prise loose rocks off the backs, walls or face. The tip is inserted into joints or cracks in the rock. Using the procedures, summarized below, loose potentially unstable rock can be removed with the minimum risk to the person involved.

The rock surface is regularly tapped firmly with the bar tip (sounded) to identify loose rock. Good ground will tend to make a high-pitched ringing sound when tapped with the bar. Bad or suspect ground will generally tend to make a hollow, lower pitched, dull thud or drummy sound when struck with the bar tip.

## 5.2 Large potentially unstable blocks

In some circumstances, very large, potentially unstable, block(s) or wedge(s) may NOT make a hollow or drummy sound when vigorously struck with a bar tip. In these situations the prudent course of action should be to:

- use a mechanised scaling unit that has been specifically designed and built for mechanised scaling work in underground mines; or
- bore stripping holes above and if necessary into the large potentially unstable block
- using a method of remote drilling, charge the holes with explosives and fire down the block(s); or
- install adequate ground support and reinforcement into the potentially unstable block using a REMOTE means of DRILLING and INSTALLING the ground support and reinforcement.

## 5.3 Ravelling ground conditions

Some ground conditions are such that they can be scaled for a very long time before they may ultimately reach a stable arch shape. Some examples of this ravelling condition may include very closely jointed, blocky ground and some very low strength, sheared ultrarnafic rocks. The ground conditions may be such as to produce the fall of a large number of rocks as soon as scaling commences. In these situations extremely hazardous conditions or excessively long scaling times may exist. Manual scaling under these conditions is extremely hazardous and should not be undertaken.

The techniques for managing this situation include:

- where possible avoid mining in these types of ground conditions - this requires a knowledge of the ground conditions ahead of mining;
- use mechanised scaling equipment to remove the larger potentially unstable material; and then
- apply shotcrete to the freshly exposed rock surface soon after the blast as possible (generally before any broken rock is loaded out of the heading or stope).

### 5.4 Progressive scaling and support

Excavations should be scaled and supported progressively in a systematic manner having due regard for the prevailing ground conditions. Large areas of backs should not be scaled before the installation of appropriate rock support and reinforcement commences. The exposure of employees to large areas of unsupported scaled backs is a potentially hazardous situation in most ground conditions. The removal of key block(s) during the scaling process may result in major falls of ground, particularly in wide excavations.

The progressive installation of rock support and reinforcement promotes the development of arching forces that assist in stabilizing the rock, particularly where large back areas are exposed. The development of these arching forces necessarily requires slight inward movements of the rock mass into the excavated void. The installed rock support and reinforcement plays a vital role in limiting movement on planes of weakness in the rock mass. If the rock support and reinforcement is not progressively installed, the full development of these arching forces is unlikely to occur and the excavation is potentially unstable.

Systematic scaling with the progressive installation of rock support and reinforcement are considered to be one of the basic fundamentals of sound mining practice.

### 5.5 Scaling Procedures

When using a scaling bar always follow the correct procedures, which can be summarised in the following five points:

1. USE A BAR OF THE CORRECT LENGTH AND IN GOOD CONDITION
2. HAVE A FIRM FOOTING AND A CLEAR SAFE RETREAT
3. SCALE FROM GOOD GROUND TO BAD GROUND
4. WATCH FOR UNEXPECTED FALLS
5. DROP THE BAR IF A ROCKFALLS TOWARDS YOU

If the area cannot be made safe by manual scaling or if the suspect area cannot be reached effectively using the longest bar available, barricade access to the area by use of appropriate warning signs and report to the supervisor so that alternative means of “making safe” can be used, eg mechanised scaling, stripping or ground support and reinforcement.

*5.5.1 Bar*

Use a bar of the correct length and in good condition

The correct length bar that is straight and has sharp tips should be used for scaling. The bar should be long enough to safely reach the area to be scaled. In workplaces less than 3.5 m high manual scaling can be done by most people of average height using a 2.4 m long scaling bar.

In high headings, ie those headings more than 3.5 m high, where a normal length bar will not allow the backs to be reached, other means should be used to reach the backs for inspection and scaling. These are discussed in section 6.

When scaling, NEVER hold the bar in front of you when scaling. A sudden fall of rock could result in the bar being pushed against you and cause an injury.

When levering a rock from the back, it is better to push or pull the bar in an upward direction as there is less chance of loosing your balance and stumbling into the danger area if the rockfalls suddenly. Similarly, when levering a rock from the sidewalls or face, it is better to push or pull the bar in an upward direction wherever possible to minimise a loss of balance.

*5.5.2 Footing and retreat*

Have a firm footing and a clear safe retreat

Have a firm footing before starting to scale. Always plan the scaling of the suspect area. Never just "barge in" and start. Know where you are standing and ensure the immediate area is clear of obstacles.

Check that the area behind you is clear so that you can move back quickly if required. Remember when scaling, as you work towards the face, rocks that have come down will become obstacles in your retreat path, so continuously observe and plan your retreat route.

*5.5.3 Scaling direction*

Scale from good ground to bad ground

Plan your approach so that you are always working under ground Which you have already scaled and checked and if necessary had supported. Never assume the ground in a workplace is safe. Scale the back first, then the sides progressively from the top of the walls down.

Do not use a pick to scale the walls or face above shoulder height.

Do not over reach when scaling, especially near open holes.

*5.5.4 Unexpected falls*

Watch for unexpected falls

Never assume an area will remain stable after it has been scaled. Regularly check the working area before commencing work and during the working shift. Exposure of the ground to air, water and changing rock pressure or stress, caused for example by drilling activities for blasting or the installation of rock reinforcement, will tend to loosen the ground. Loose ground may fall without warning.

*5.5.5 Evasive action*

Drop the bar if a rockfalls toward you.

Be prepared for rockfalls to happen at any time when scaling. If this does occur, be prepared to drop the bar and retreat quickly to avoid injury from the bar, the rock or obstacles on the floor.

## 6.0 SCALING IN HIGH HEADINGS

### 6.1 Manual scaling from a work platform

When manual scaling is to be done in areas where the backs, walls or face cannot be reached comfortably when standing on the floor, other safe means should be used to permit inspection and scaling to be carried out. A high heading situation is considered to exist when the standard length bar (usually 1.8 to 2.4 m long) cannot be used effectively and comfortably to scale the backs when standing on the floor. A high heading is any heading more than 3.5 m in height. It is strongly recommended that additional lighting should be provided and used to supplement the cap lamp when inspecting the backs, walls or face in a high heading.

The methods used to reach the high backs; etc should be robustly designed to cope with scaling conditions. Rockfalls may accidentally apply large impact forces to equipment during scaling. The equipment used to provide access to the high areas should be sufficiently strong and robust to withstand these large sudden dynamic loads. Some access methods that may

- work platform (purpose designed and built) securely attached to a be suitable for these conditions include: loader bucket;
- work platform (purpose designed and built) mounted on an articulated or telescopic boom on a diesel unit; or
- work platform (purpose designed and built) mounted on a scissor lift unit.

Scaling from a loader bucket is not a safe work practice and should NOT be done.

When scaling near operating diesel powered equipment the noise from the engine or engines will tend to make sounding the rock much more difficult due to the higher noise levels. Precautions should be taken to ensure a minimum level of equipment noise when sounding the backs, walls or face of the workplace.

Prior to conducting manual scaling from a work platform it is recommended that the following issues should be addressed:

- ground conditions;
- position of the loader or service unit when it is parked in an excavation;
- duties and training of the operator at the controls of the vehicle;
- means of communication to be used by the people involved;
- means of entry to and exit from the work platform;
- amount of lighting required to adequately inspect the backs, walls and face;
- scaling procedures and rules that will apply when scaling from the work platform;
- design and construction of the work platform;
- means used to correctly and securely attach the work platform to the service unit;

- requirement to prevent rapid descent of the work platform following damage to or
- failure of the hydraulic system (see AS 1418.10 1996);
- position of person in the work platform whilst it is being raised or lowered;
- condition of the work platform floor;
- tramming of the work platform;
- positions of people on the service unit and the work platform when tramming,
- general operation of the service unit; and
- maximum number of people permitted in the work platform at one time.

Each mine should develop its own work procedures for manual scaling from a work platform to suit its unique combination of ground conditions, heading geometry, equipment and mining method(s).

### 6.2 Drill Jumbos

A large number of mines in WA use drill jumbos to remove rock from the excavation perimeter. Phrases such as "rattling the backs", "dollying the backs", "power scaling", etc. are used to describe the process of using a drill jumbo to "scale" a rock surface. This attempt to "scale" is used in areas with high backs, walls or face that cannot be reached from the floor by manual scaling.

The drill bit is run on to the rock surface, with the drifter operating, and drilled into the rock a short distance. Alternatively, the drifter feed and/or boom hydraulics may be used to rake the bit across the rock surface, with the drifter operating. Both approaches attempt to dislodge any loose rock using the drill jumbo in a manner for which it was not designed. These methods use the power of the drifter and the boom hydraulics to provide large impact forces in an attempt to dislodge potentially loose rock in a very indiscriminate manner. The angle at which these large impact forces can be applied to the rock surface is restricted by boom length and geometry relative to the size of the excavation and may not be the optimum angle required to dislodge the material.

No effort is made to sound the area to detect potentially loose material. As a result pieces of loose rock may be left on the backs or wails presenting a potential hazard in an area that has apparently been scaled. The high noise levels produced when rattling the backs, etc. do not allow the correct sounding procedures to be carried out to check for loose rock.

It should be clearly recognised by all concerned that the booms and drifters of conventional drilling jumbos have NOT been designed and built to be used for scaling.

Substantial damage to boom components regularly result from this activity.

Manufacturers, importers, suppliers of drill jumbos are reminded of Section 14 of the Mines Safety and Inspection Act 1994, which, amongst other things, states:

Plant is defined in the above Act as:

"plant" includes machinery, equipment, appliance, implement, or tool and any component or fitting of or accessory to any such article.

If the principal employer and the manager determine that jumbo scaling of the backs, walls and face of the workplace is an appropriate method of work, they should be able to justify why it is considered to be a safe work practice, having regard for:

- ground conditions;
- size of the excavation;
- suitability of the equipment for the purpose of scaling;
- alternative methods of scaling;
- hazards to the workforce; and
- quality of the mining practices, particularly the drilling and blasting aspects.

The importance of using the appropriate drilling and blasting practices cannot be over-emphasised. The use of controlled drilling and blasting techniques is considered to be vital to reducing excessive rock damage from blasting. The lack of half hole barrels visible in the backs and side walls of many excavations is clear evidence that considerably more needs to be done to reduce unnecessary damage to the rock mass.

This should greatly reduce the need for reshaping the excavation perimeter with the drill bit. Each mine should develop its own work procedures for scaling to suit its unique combination of ground conditions, drilling and blasting techniques, heading geometry, equipment and mining method(s).

### 6.3 Mechanised scaling

The more widespread use of purpose designed and built mechanised scaling units is encouraged. These robust units have been specifically designed for heavy-duty work in the hazardous role of removing potentially unstable blocks from wide and/or high excavations. The use of mechanised scaling equipment should be an integral part of the mining cycle.

The over-reliance on development jumbos to perform up to three unit operations in the mining cycle for which they were not designed, ie charging-up, scaling and rock bolting, should be recognised as lacking the necessary operational flexibility for efficient high speed development advance. Rockfall damage to these high capital cost items of equipment can halt mining advance with adverse implications for contract payments.

Single heading advance requires a high level of equipment co-ordination, availability and utilization, however this should not be used as an excuse for not using mechanised scaling. Multiple heading advance provides considerably more operational flexibility, particularly with multi-skilled mining crews, such that different pieces of equipment can be productively employed in different headings in various parts of the mining cycle.

A comprehensive review of all the direct and indirect costs associated with:

- excessive use of drilling consumables (bits, rods, couplings, adaptors, etc.);
- maintenance of jumbo booms damaged by rockfalls;
- loss of productive work due jumbo unavailability caused by rockfall damage; and
- loss of development advance or tonnes broken by jumbo being used for non-drilling activities (eg scaling, charging-up and rock bolting) should provide great incentive for more active consideration of mechanised scaling equipment.

Prior to using mechanised scaling it is recommended that a range of issues should be addressed including:

- ground conditions;
- size of excavations where the equipment is intended for use;
- ensure that controlled drilling and blasting practices are being used in all development headings and stopes;
- arrange for regular and on-going training of all the people who will operate and maintain the mechanised scaling unit;
- review operation and maintenance of the unit on a regular basis by involving all concerned with its use and maintenance;
- availability of spare parts; and
- experience of other mining operations with similar items of equipment.

Each mine should develop its own work procedures for mechanised scaling to suit its unique combination of ground conditions, drilling and blasting techniques, heading geometry, equipment and mining method(s).

## 7.0 MANUAL SCALING IN NARROW HEADINGS

The application of appropriate scaling procedures in narrow stopes or development headings raises a number of issues that should be addressed. Confined working conditions in narrow headings can be found in situations ranging from wide flat dipping stopes to narrow ladder rises.

In narrow flat dipping stopes, approximately 1 m high, where the footwall dip is much less than the ore nil angle, it is necessary to traverse the stope in a crouched or kneeling position. This position restricts the free movement of the person doing the scaling and may reduce the effectiveness of scaling.

In a narrow unfilled slot stope, where the footwall dip exceeds 35º to 40º (ore nil angle), the ability to move around freely in the stope is hindered by the requirement to use a safety rope. The requirement to use a safety rope in a steeply dipping unfilled stope would also tend to reduce the effectiveness of scaling.

In narrow ladder rises the ability to clearly and adequately observe, reach and scale the face, from a safe position, is made more difficult by the length, inclination and straightness of the rise.

The issues that should be recognised and addressed when scaling in narrow headings, ranging from flat dipping narrow stopes to steep ladder rises, include:

- ground conditions;
- confined working environment;
- secure footing with the use of a safety rope where there is a danger of the person
- slipping or falling;
- adequate illumination;
- adequate inspection of the face, walls and backs from a safe area;
- adequate sounding of the backs, walls or face as required from a safe area; and
- use of standard scaling procedures.

Each mine should develop its own work procedures for scaling narrow headings to suit its unique combination of ground conditions, heading geometry, equipment and mining method(s).

## 8.0 REGULAR SCALING OF MAIN ACCESS WAYS

Ground conditions in an area can change with time for a number of reasons including:

- vibrations from drilling and blasting operations;
- groundwater or water from stope filling operations (hydraulic fill);
- time dependent behavior of the rock (this issue is often not well understood); and
- changes in rock stress levels caused by the removal of ore or rock from nearby stopes or development headings.

Consequently, it should not be assumed that the ground conditions in any excavation will remain as good as they may have been when the access was first mined, scaled and supported. The use of the main access ways by a large number of employees, each shift, results in a considerable exposure of the workforce to these ground conditions. The risk of injury to an employee occurring, if a rockfall takes place in the main access way, is higher because more people use the access way.

Regular scaling of all main access ways is considered to be an appropriate method of ensuring that the risk of unexpected rockfalls is minimised. The frequency of checking scaling is dependent on the local ground conditions and nearby mining activity. A thorough close-up inspection of the backs and walls of the main access ways is essential to ensure the safety of those travelling in the mine. The sections of the main access ways that have been scaled should be permanently recorded with details of the areas checked, adverse ground conditions encountered, the date and any remedial action taken.

Where total coverage of the rock surface exists (eg concrete lining, shotcrete, timber sets and lagging, rock bolts and mesh, etc) common sense action is required to check the integrity of the lining for signs of deterioration, corrosion, etc. Sounding of shotcrete with a bar or geology pick may be an effective means of checking its integrity.

## 9.0 ACKNOWLEDGMENTS

The DME acknowledges that the information presented in this guideline has derived from a number of sources including a Mount Isa Mines Lirnited (1991) booklet, as well as Mining Operations Division staff.

Additional information on scaling issues may be found in SAFE MINING - CCH/ANZMEC/MCA (1996):

1. Underground excavations, page 43-250.
2. Loaders as elevated work platforms, page 48-450.

## 10.0 BIBLIOGRAPHY

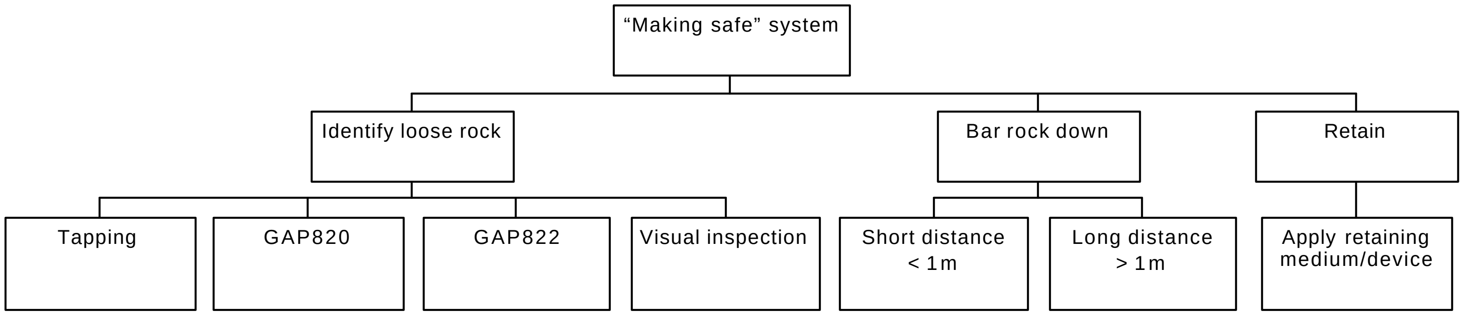
Mount Isa Mines Limited, 1991. Introduction to barring down, level one group worker trainee module. Mining Department, September 1991.

AS 1418.10-1996. Australian Standard: Cranes (including hoists and winches), Part 10 Elevating work platforms, 60 p (Standards Association of Australia: Homebush,
NSW).

CCH/ANZMEC/MCA, 1996. SAFE MINING - Practical guidance for managing safety and health in the mining and extractive industries, complied by the Conference of Chief Inspectors of Mines under the auspices of the Australian and New Zealand Minerals and Energy Council (ANZMEC) and the Minerals Council of Australia (MCA), (CCH Australia Ltd: North Ryde, New South Wales).

## APPENDIX B FUNCTIONAL ANALYSIS

# SYSTEM ANALYSIS



# MISSION LEVEL

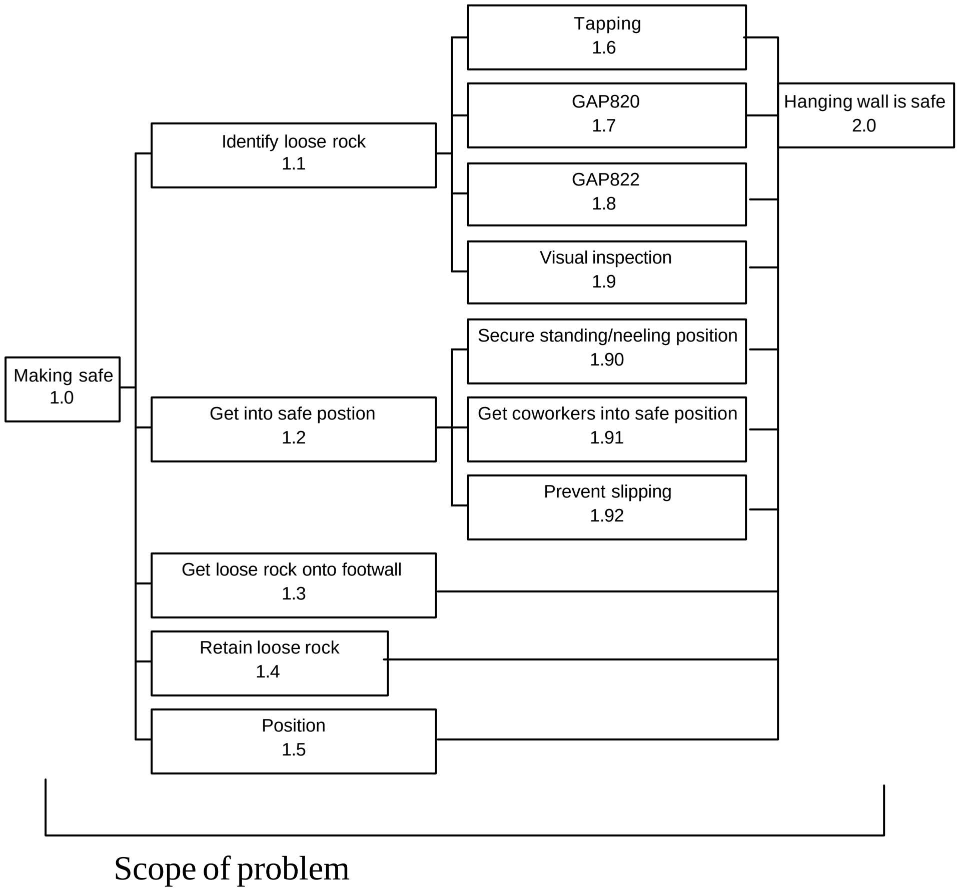
- PAccetable life expectance
- PCompatibile
- PMaintainable
- PReliable
- PCompact
- PLight
- PRobust
- PSimple process
- PSelf contained
- PNo loose parts
- PVisible
- PSafe
- PFire resistant
- PManoueverability

Design parameters

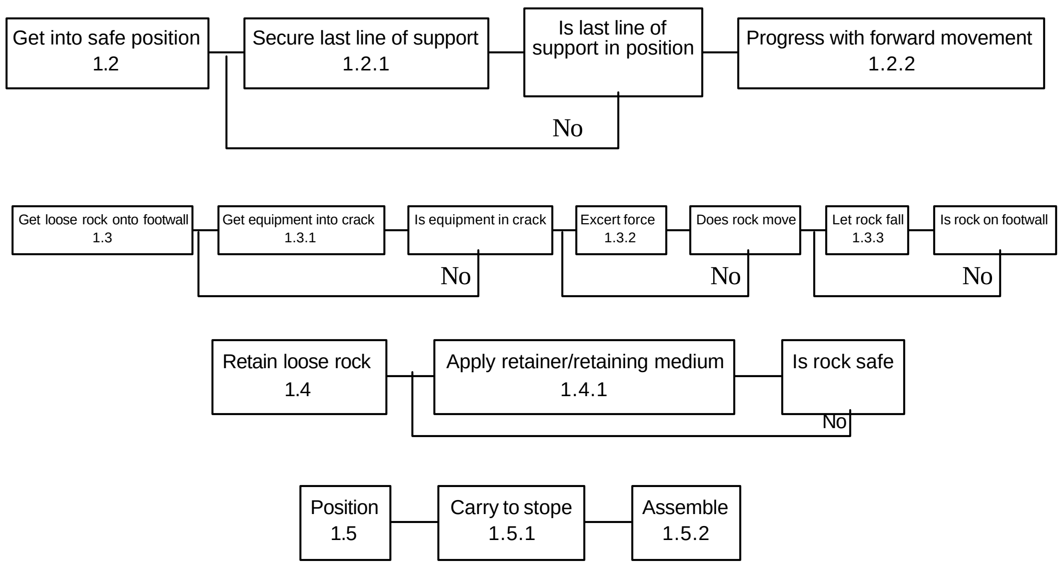
SUPPORT MINING ACTIVITY 0.0 — MAKING SAFE 1.0 — HANGING WALL IS SAFE 2.0

SCOPE OF PROBLEM

## SYSTEM LEVEL FUNCTIONAL DIAGRAM



# FIRST LEVEL FUNCTIONAL BREAKDOWN



# FIRST LEVEL FUNCTIONAL DIAGRAM