Selective blast mining in gold mines

by I. Bock*

Summarized overview

This presentation describes a technique under development referred to as Selective Blast Mining. The technique involves millisecond sequential blasting. It applies to mines where the gold bearing conglomerate band is clearly demarcated, and separated from the waste rock in the foot and hanging wall. The width of the conglomerate band should be less than ± 0,7 metres.

A research program was initiated in August 1994 by Drs R.E. Robinson and I.E. Bock. The objectives were to develop new blasting methods that can reduce:

- the losses of gold in narrow reef stoping. Losses of gold can be as much as 10–15%
- and to introduce selective mining to reduce ore dilution with waste rock.

Solutions to these problems seemed possible with the advent of new blast initiation techniques.

The newly developed ability to detonate individual holes in a prescribed sequence at time intervals of the order of milliseconds provides for an interactive and reinforcing effect which throws the broken rock at right angles from the stope face at high velocity. These initiation systems also offer opportunities to improve safety at the stope face by introducing well distributed roof support immediately after the blast.

The techniques being developed represent a rejuvenation of the known Resue Mining practices. Resue Mining's limitations of intermittent face advance, and hanging wall problems until the ore is lifted can be overcome by Selective Blast Mining.

- In Selective Blast Mining the waste rock is cast blast into the back-fill region. The cast blast gives an immediate roof support, and might replace roof support, and/or back-fill. This can (potentially) dramatically reduce the occurrence of pressure burst at the face.

  A second stage of the same blast then fragments the gold bearing ore, with minimal explosive energy being applied in the ore body, and with minimal spatial displacement of the rock. The gold bearing conglomerate is thus only fractured. Robinson has been examining the problem of gold losses during blasting for many years. He points out that the gold is situated in fine particles in the fracture planes of the conglomerate. A significant portion of the gold is released as fine particles (often associated with light carbonaceous material) which can be carried away from the collection areas by the large volumes of gases released when the rock is blasted conventionally. The gold ends up dispersed throughout the stope and gully and is lost. This loss can be avoided in Selective Blast Mining.
- Only the gold bearing material need be sent to the surface so that up to 60% of the material blasted is left underground.
- In certain stope conditions, where the waste rock stope height can be increased, the face advance per blast can also be increased. This tends to maintain the mass of ore sent to the mill, while the grade of the ore is now approximately doubled.
- There are potential advantages for Selective Mining at all depths: These advantages become more significant when ultra deep mining has to be undertaken. Radically different approaches to material handling and metallurgical extraction can be contemplated. Crushing might be undertaken underground, say, in gullies close to the stope face so that crushed material can be conveyed to a central point in the mine by hydraulic or pneumatic conveying in pipes. Robinson estimates that as much as 70% of the gold in the crushed product can be recovered by simple gravity separation or even froth flotation in the form of high grade concentration, and this should be possible underground.

Selective Mining has a dramatic impact on the profitability. A model is given for stope costs and gold income.

For normal stoping with an ore grade of 5.2 g/ton, a cost of R303.53 per metre of stope face per blast is derived. This covers development, drilling, initiation, explosives, backfill, material transport, and milling. The value of the gold recovered per blast (with a call factor of 0.85) is R610.93 per metre of stope face per blast.

For Selective Blast Mining, (with increased stope height and face advance, with cast blast roof support and with a call factor of 0.95), the total cost per metre of stope face per blast is R444.93 and the value of the gold recovered is R1280.25 per metre of stope face per blast.

Thus for Selective Blast Mining, the cost/metre of stope face per blast increases by R141.40, the income increases by R669.32 per metre per blast, showing an overall gain of R527.92 per metre per blast.

Experiments on Selective Blast Mining commenced in June 1995 and showed that:

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- cast blasting is possible.
- the fragmentation is finer than for normal blasting.
- the potential for roof support with the cast blasting seems good and is now being investigated further.

Fracturing of the exposed ore body is a well-known process. Further experiments are required to determine the optimum fragmentation for gold recovery and material transport.

To date the tests have been privately financed. The tests have been conducted using the ZEDET Electric Initiation system, developed by Johannesburg Construction Corporation (Pty) Ltd, who also supported the adaptations of the system that are required for this application. At the commencement of the study a detailed literature search was conducted in the library of AAC Research Laboratories. Mines have provided stopes and staff for tests. The suppliers of explosives have made engineers available to assist in and to give guidance during the tests. It is now necessary to undertake more intensive testing underground and this will require both practical and financial support from industry and/or government. The chances of success are good.

Selective blast mining concepts

Selective Blast Mining is an advance on the concepts of Resue Mining, as used in Sub-Nigel in the 1930 era, and further developed in the period 1955 to 1965 by R.S. Pearson[1] and D.V. Baum[5] at President Steyn and R.H. Bryson[2] at Loraine and others. In Resue mining, the waste rock is first blasted by creating a 'secondary footwall' above/below the ore body, and advancing the blast in the waste region by several metres. The ore body above the true footwall is then lifted and collected. The ore is shattered but not displaced.

Bryson[2] listed the disadvantages of Resue mining as:

- *intermittent face advance:* Faces are stopped at the end of every cycle of advance for reef lifting, etc.
- *hanging control:* Permanent support can only be installed after the reef lift cycle is completed. During the waste overcut and reef lift period temporary supports only can be used
- irregular supply of reef depending on the daily number of panels on reef lift and this fluctuates
- labour variations as the waste overcut is hand packed
- excessive waste must be trammed and in many cases this holds up work on other reef panels.

Selective Blast Mining is designed to overcome these disadvantages by,

- continuous face advance
- permanent hanging wall support after each blast (temporary support at the face will still be required)
- regular supply of reef
- the waste overcut is cast-blasted into the backfill region so that hand packing is not required.

Selective Blast Mining (to achieve these objectives) is now possible through the advent of millisecond blast initiation systems such as ZEDET and Shock-tubing. The ZEDET system has been used in all the Selective Blast Mining experiments. ZEDET was originally developed and tested for conventional millisecond stope blasting. The additional cost of this millisecond system acted against its general adoption (this experience is shared by all systems in this market). However, ZEDET proved to be a very flexible system and to be readily adaptable to different initiation schemes, such as Selective Blast Mining where 'value added' concepts bring economic reasons for its acceptance.

The ability to blast at millisecond intervals with ZEDET provides a means of cast blasting rock over considerable distances, while at the same time maintaining a controlled cut between the waste rock and the gold bearing rock. The initiation system also makes it possible to do compound blasts in one operation. The cast blast of waste and the subsequent fragmentation of ore are initiated in one sequence.

The selective blast stope conditions are shown in Figures 1 and 2. Figure 1 shows a side elevation of the stope. It is

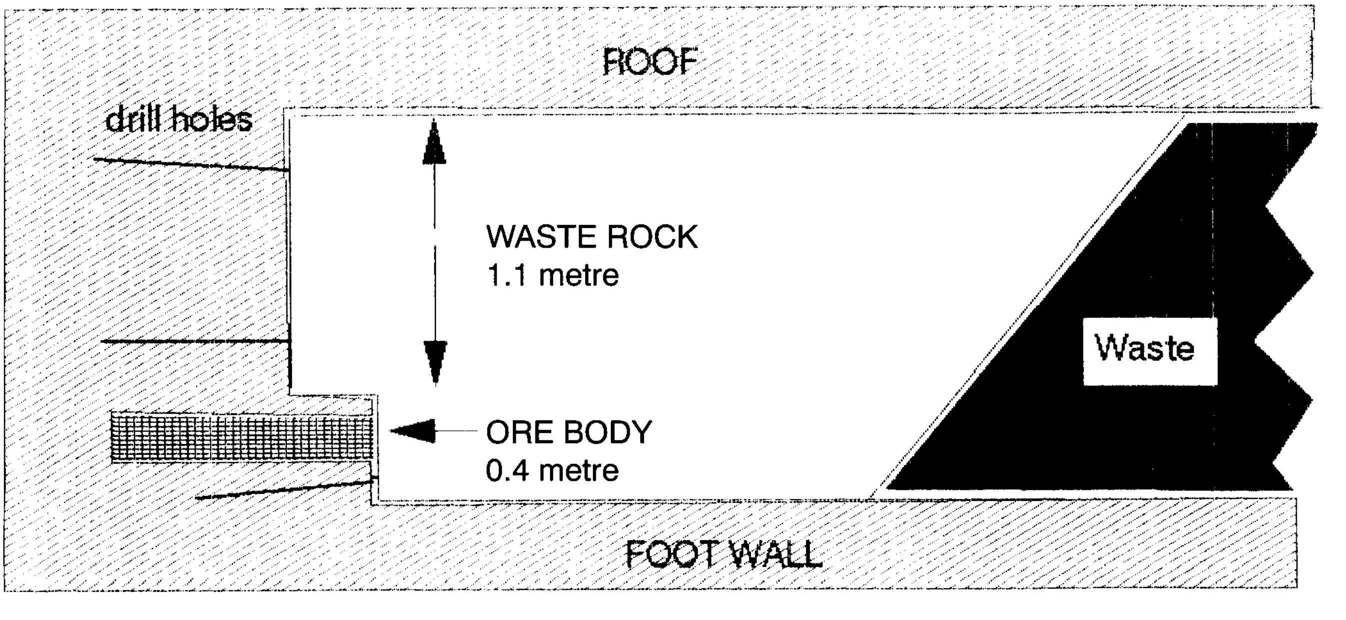

Figure 1—Side elevation of a selective mining stope

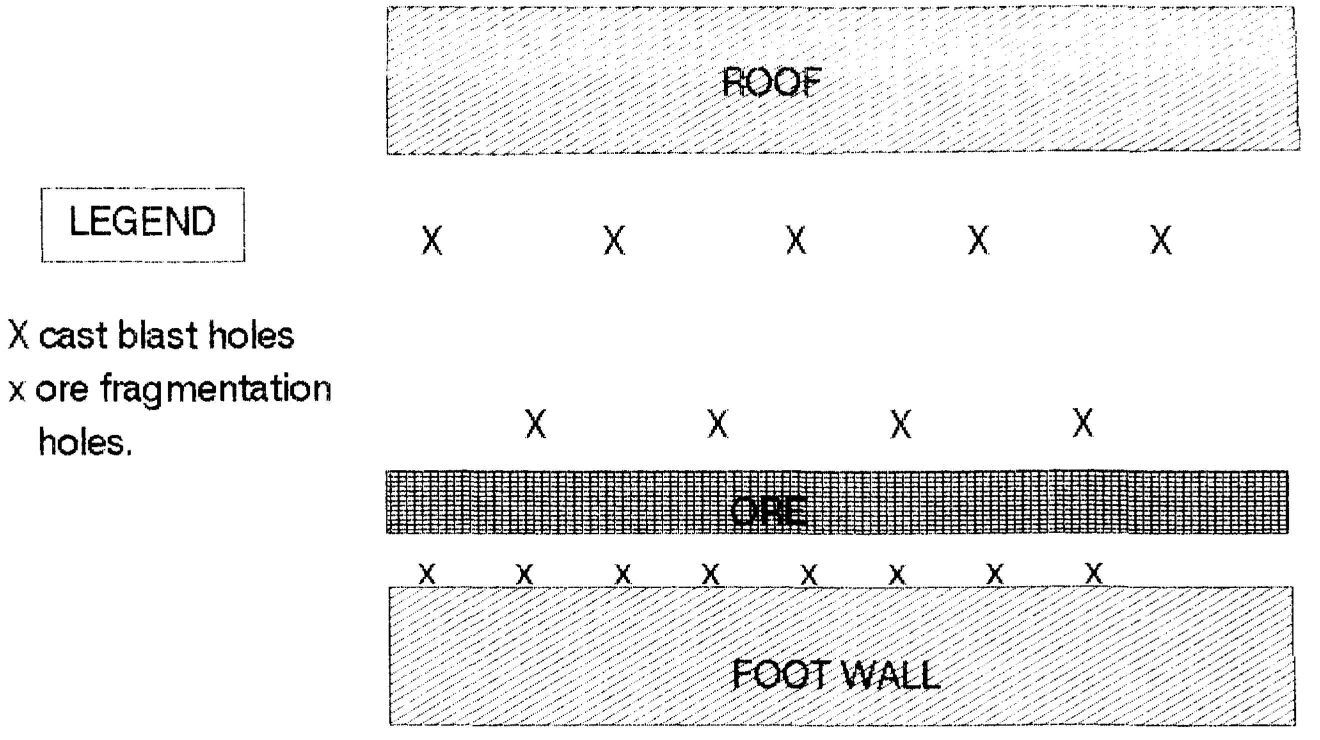

Figure 2—Front elevation of a selective blast mining stope indicating blast drill holes

assumed that the ore bearing rock is in the lower 0.4 metre of the stope. The waste rock is above the ore body. A step is introduced in the stope face to act as a secondary footwall to prevent excessive erosion of the ore body region by the blast in the waste rock. Figure 2 shows a possible drilling pattern.

The stages in Selective Blast are:

1. Create a secondary footwall between the ore and waste regions by blasting the waste on a reduced stope height and then fragmenting the ore body with less face advance. Or, create a pre-split shear plane between ore and waste.
2. Cast blast the waste rock into backfill region to introduce immediate roof support.
3. Fragment the ore without displacement.

Productivity improvements are achieved by:

- ore of higher grade transported and milled
- reduced volume of backfill brought from surface
- increased safety for workers with the immediate and distributed roof support. R.G. Gürtunca[3] reported that when 60% backfill is introduced, the accident rate reaches a minimum of <1/3 the normal
- increased gold recovery because less explosive energy is released in the ore body. If this stage is done correctly the additional ore recovery is possible even without sweeping, thus presenting a huge labour saving mechanism.

The additional cost to achieve these improvements are:

- increased number of holes drilled
- in some cases rock conditions may permit sympathetic initiations in ANFO and this will introduce the need to use more expensive cartridge explosives
- more expensive initiation systems.

Increased stope heights and face advances

If Selective Blast Mining is introduced in a mine without making an adjustment to the overall stope height, the face advance per blast is reduced. This is because a geometric relationship exists between stope height and the face advance that can be achieved. Pickering and MacNulty[4] report that stope advance has a dramatic impact on mining economics. The present average advance per blast is 0.75 m which is of the same order as the stope height.

In conventional mining, if the stope height is decreased in an attempt to reduce ore dilution of narrow reefs, the number of holes drilled per metre of face must be increased. The explosive charge per hole remains the same, so that the specific explosive energy/m^3 is also increased. Thus, not only does the blasting cost go up but also the potential for gold losses.

In selective mining, without changing the stope height and for the same face advance, the amount of rock transported to the mills and processed is reduced by 50 to 60%. The mine would now have unused capacity for materials handling and milling.

However, because the waste rock is cast blast into the backfill region by the explosive and this is a very cheap chemically driven process, the total stope height can be increased, and the face advance per blast maintained, or even increased *provided the rock mechanics conditions permit this development.*

Consider a new overall stope height of 1.5 metres as shown in Figures 1 and 2. The blast in the waste rock has a height of 1.1 metres. The proportional 'ore height' is 0.4 m so that the gold content in the ore transported is now increased by 2.5 times. A face advance of 1.5 metres per blast should be possible.

Table I

Stope economic model

Assumptions:		
Selling price of gold	395 $/ounce	
Gold content for 1m stope height	5.2 g/ton	
Material Handling	36 R/ton	97.2 R/m^3
Milling costs	30 R/ton	81 R/m^3
Development costs	45 R/ton	121 R/m^3
Back-fill costs	16.3 R/ton	44 R/m^3
Total Working Costs	**248 R/ton**	**669.6 R/m^3**
Stope conditions:		
	Normal Mining	Selective Blast Mining
Stope height (m)	1.0	1.5
Face advance (m)	0.8	1.5
Drilling holes/m	3	6
R/hole	6	8.25
Explosives R/kg	2	2
kg/holes	0.56	0.9
Blast Initiation R/hole	2.4	7.0 (a)
Back-fill, %	100	0
Material transported, %	100	40
Milling, %	100	40
Mine call factor, %	85	95
Costs of various operations: R/blast/metre stope face		
	Normal Mining	Selective Blast Mining
Drilling	18	49.5
Initiation	7.2	42
Explosives	3.36	10.8
Back-fill	35.21 (b)	0
Development	97.2	182.2 (c)
Material	77.76	87.48
Milling	64.8	72.90
Total cost listed above	**R303.53**	**R444.93**
Income from gold recovered/blast/metre stope face		
	Normal Mining	Selective Blast Mining
Value of gold recovered	**R610.93**	**R1280.25**

Notes: (a) this is typical for ZEDET and shock tubing
(b) hydraulic roof support costs R90/m^2
(c) the development cost is dependent on the face advance.

The mass of gold bearing rock transported and milled is now 85% of that normally handled. The amount of gold recovered per blast can be increased by 100%. The impact of this development on mining profitability can be dramatic. (The calculations are given in Table I.) The increased stope height will make stoping far more comfortable for both man and machine. The need for accurate drilling is also relaxed when the stope height increases. The reduced fatigue experienced by personnel, now working under more comfortable working conditions, will also impact on productivity and the cost of cooling working areas at ultra deep levels. Mechanization of drilling operations also becomes possible.

Experiments have also shown that damage to hanging walls can be reduced by Selective Blast Mining.

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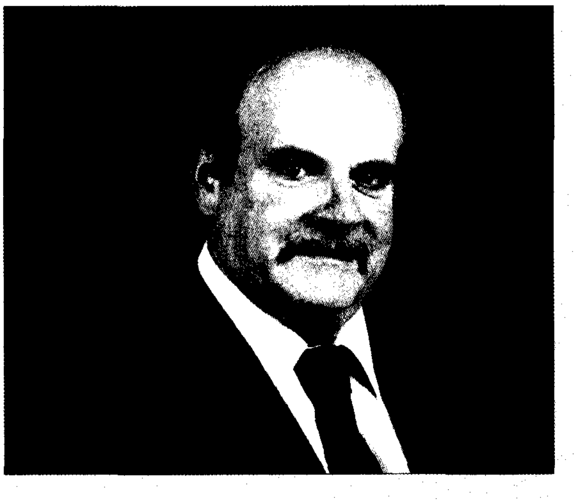
Mintek's Nic Barcza heads up SAIMM*

Mintek Vice President, Dr Nic Barcza, has been inaugurated as the 100th President of the South African Institute of Mining and Metallurgy (SAIMM). Dr Barcza will be President for the 1996/7 year, and he will be carrying on a family tradition, as his father, the late Mr Michael Barcza, was SAIMM President during 1958/9.

Other SAIMM Presidents from Mintek include Prof. Robbie Robinson (1975/6), Dr Peter Jochens (1980/1), and Mr Henry James (1985/6).



Dr N.A. Barcza

In his speech titled 'The role of pyrometallurgy in the development of South Africa (past, present and future)' Dr Barcza predicted that the total revenue from South African pyrometallurgical products could well grow from $10 billion in 1996 to double this figure around 2020. ◆

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