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# South African Mining Industry in the New Millenium and New Technologies For The Future

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ABSTRACT; The South African Mining Industry has always been faced with immense challenges to mine safely and profitably. The current situation in the mining industry, particularly, gold, coal and platinum group metals are discussed. The new research initiatives and some emerging technologies that will provide solutions to those challenges are also described in the paper.

## 1 INTRODUCTION

The South African mining industry can look back at a century in which it has proved to be the economic mainstay of South Africa and in many ways of some of us neighboring states. However, a number of new challenges face the mining industry as we enter the next millennium, which have necessitated the creation of major initiatives to ensure sustainability of this industry in the long term.

South Africa is rich in mineral reserves as listed in Table 1 and also produces significant amounts of gold, coal, platinum, palladium and rhodium. The total revenue generated by the South African mining industry in 2001 was around R1I6 bullion (about $15 billion USA) and about 80 per cent of the total revenue is generated from exporting these minerals.

The paper reviews the current situation in the mining industry, particularly gold, coal and platinum group metals and discusses some of the challenges facing those three mining sectors to stay competitive well into the new millennium. The paper also describes the new research initiatives and some emerging technologies that will provide solutions to those challenges.

## 2 CURRENT SITUATION IN THE MINING INDUSTRY

### 2.1 *Gold nulling industry*

Gold production in South Africa has decreased from 1 200 tonnes in 1970 to 395 tonnes in 2001. There are three major reasons for the reduction on gold output: low productivity, high costs coupled with a low gold price and depletion of high grade gold reserves.

The need for gold producers to go ahead with mine restructuring and re-organization, coupled with a low gold price led to the reduction of workers employed by the gold mines from about 500 000 in 1987 to about 200 000 in 2001.

Safely has always been a key priority for South African gold mining industry. Safety statistics, quoted as reportables per 1 000 people at work per year, improved consistently since the 1960s to the I980's. However, for the last 10 years these statistics have remained stubbornly constant with little improvement. Improvement is undoubtedly possible through the implementation of current technologies and systems.

At present, only 5% of production occurs below three kilometers and it is estimated (Willis, 1997) that some 40% of total South African production will be sourced from below these depths by 2015. assuming a favourable economic environment.

### 2.2 *Coal mining industry*

The South African coal mining industry produces about 225 million tons of coal and about 65 million tons of it is exported. South Africa is the third largest hard coal exporting country and the fourth largest hard coal producer in the world. South Africa ranks fifth largest coal reserves in the world and these reserves are sufficient to last for about 180 years at current run of mine production rates. Almost half of the coal production is from opencast operations. The underground mining methods are bord and pillar, stoop recovery and longwall mining.

Coal meets three quarters of South Africa's primary energy needs. In 2001, 88,2 million tones (nit) of coal was burnt at Eskom power stations and total electııcıty sold was 171 7222 Gwh ot which 91,4 percent was geneiated by coal-tiied powei stations

The South Atncan coal industry employed an aveiage ot 51 000 workeis in 2001 The average productivity tiguies at coal mines is 4 845 saleable tonnes pel employee

Table I Total mineral sales and expoits loi South Africa

| Commodity | Total salts R1 000 | Export sales R1 000 | Peiccnliige expoits to total s îles <ƒ | Woild Rank | Pcicentage ot World Reseives <A |
|---|---|---|---|---|---|
| Pieuous metals | | | | | |
| Gold | 29 011 598 | 28 651912 | 98 8 | 1 | 40 |
| PGMs | 11 170 849 | 29 181 009 | 88 0 | 1 | 56 |
| Sılveı | 141721 | 116 956 | 96 6 | | |
| Sub tot il | 62 524 170 | 58 171 S77 | 910 | | |
| Otliei Metals | | | | | |
| Chiome | 1 002 109 | 177 286 | 17 6 | 1 | 68 |
| Coppei | 1 927 165 | 870 108 | 45 1 | | |
| It on oic | 4 12X901 | 1444 701 | 814 | | |
| leid | IIS 912 | 91 764 | 80 9 | | |
| Manganese | 1 101 440 | 877 819 | 67 4 | 1 | 81 |
| Nickel | 1 809 686 | 707 110 | 19 1 | | |
| Otliti metallic | 148 297 | 61758 | 181 | | |
| Sub total | 10 611712 | 6 414 566 | 60 5 | | |
| Non metallic mtneials | | | | | |
| Coal | 26 524 190 | 16 956 659 | 619 | 5 | 11 |
| Fluoispai | 274 901 | 220 221 | 80 1 | 1 | 12 |
| Veinnculitc | 128 782 | 125 096 | 97 1 | 2 | 40 |
| Granite | 717 192 | 677 698 | 94 5 | | |
| Othei non metallic | } 187 716 | 192 868 | 57 | | |
| Sub total | 11 012 801 | 18 172 544 | 58 6 | | |
| Miscellaneous* | 12 011 915 | 8 164 275 | 67 9 | 2 | 10 |
| Tot ils | 116 222 600 | 90 941 262 | 78 2 | | |

Includes strategic and minoi commodities not othei wise enumeiated

Souice Mineidls Bureau 26 luly 2002

Employment levels on Chamber ot Mines member collieiies have declined by more than 25 pet cent since 1991 despite a more than 20 per cent use in total output during the same period This attnbutable to increased mine mechanization and aggtessive el totts to teduce costs, which improves the South Atncan coal ındustıy s international competitiveness

Concerns ovei the quality of the environment at global national and iegional levels and tighter environmental constraints are increasingly pressurizing the pioducets and users of fossil fuels to clean up and leduce pollution The important environmental issues aie increased coal extiaction cleanei coal pıepaıatıon closuie ot coal mines and coal combustion

## 2 3 *Platinum group metals (PGM)*

Platinum group metals are platinum, palladium and rhodium South Africa s pioportion ot the world's roduction ot PGMs amounted to 46 per cent in 2001 and about 229 tons were produced The geneiated tevenue of about R13 billion (ı e $4 billion USA) in 2001 The South African platinum production is planned to increase by almost 100 per cent by the year 2010

Although PGM prices are at record high, the platinum mining industry has a few challenges ahead ot them The industry costs structures are heavily weighted to the mining operation

Operating costs can be typically 65% - 75% mining, 8-12% concentrating, less than 10% smelting and about 10% refining (Cramer, 2000) The underground mining operations have to increase pioductıvıty by using mechanization and reducing labour involvement undergiound The Achilles heel of the platinum industry in South Africa is its high mining costs and, in this respect particularly, its high proportion of labour in those costs. The industry must break out of the low level of training, the unskilled job content, and large numbers required underground (Cramers, 2000).

## 3 NEW MINING TECHNOLOGIES USED IN SOUTH AFRICA

### *3.1 Dispersed Bagged Stone Dust Passive Barrier System*

The prevention of the propagation of coal dust explosions by means of explosion-suppression systems in underground coal mines is a very important activity. For many years, the most commonly used passive barrier system was the Polish Light Barrier. This type of barrier system was developed mainly for long, single-entry mining practices. As the basic design of this barrier system did not changed over the past 5 decades, it suitability to modern day mining practises was questioned. Besides this, the installation cost of these barriers is high and they are difficult to install and maintain, making them more of a hindrance than a benefit to modern day underground coal mining practices.

This led the Kloppersbos Test Facility of CSIR: Miningtek to develop a new method of building passive stone dust barriers (Du Plessis et al, 2000). The new system, the bagged stone dust barrier, is based on an array of specially manufactured bags suspended from the roof containing the stone dust. What makes this barrier system different from similar concepts is the newly developed method of rupturing the bags during a coal dust explosion. This is achieved by the special closing mechanism of the bag, and balancing the stone dust content with the void in the bag. Testing of the barrier has shown it to be just as effective, or more so, than conventional barriers, while offering advantages in terms of minimum pressure requirements for operation, improved operational time, reduced costs and ease of installation and maintenance.

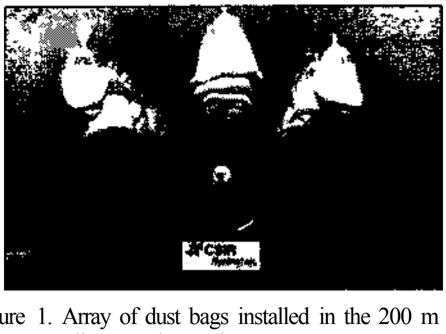


Figure 1. Array of dust bags installed in the 200 m test gallery at Kloppersbos

In the development phase of the new system, the bags were tested extensively in the 200 m coal dust explosion gallery at Kloppersbos (Figure 1). The barrier was evaluated against a baseline explosion, which developed a dynamic pressure of 20 kPa with a flame length of 236 in. With the new barrier system installed, the flame length was shortened by at least 100 m, with the static pressure less than half of the base explosion, and the dynamic pressure less than a quarter. From the tests, it became evident that these bags could be made to rupture and spread stone dust when subjected to smaller forces than those required for the more commonly used Polish Light Barrier.

To gain international acceptance of the new South African bagged barrier system and prove its ability to effectively inhibit the propagation of a coal-dust explosion, further testing was carried out at the DMT's Tremonia test gallery in Germany and at the U.S. National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Research Laboratory Lake Lynn Experimental Mine. This proved the bagged stone dust barrier system to be effective in stopping flame propagation in small (5 m" cross-section at Kloppersbos), medium (12 rti" cross-section at Lake Lynn Laboratory) and large (20 irr cross-section at Tremonia) explosion galleries. It also proved that that system is effective in stopping coal dust explosions in the multiple entries. Through these extensive test programmes questions such as what influence mine size would have on the design and operation of the bagged barrier was successfully resolved. Furthermore, the question of whether the bagged bagged barrier system would operate in bord-and-pillar workings was positively answered. It has to be remembered though that barrier operation still depends on the type and strength of the explosion to be extinguished and that there are limits to the operational extremes of all barrier designs.

The new bagged stone dust barrier system has been implemented in South Africa and Australia and is considered well suited to modern-day underground coal mining practices. In South Africa, approximately 90 % of all underground coalmines are currently using the new dispersed bagged barrier system.

### *3.2 CADSminc in Mine Layout Design*

A mine layout forms the basis of mine scheduling and production planning. Prior to the implementation of a scheduling procedure, a layout has to be arrived at, therefore. The CADSmine tool, an AS&T-GMS1 proprietary software package, has the ability to design and schedule very complex mine layouts for tabular deposits, and the ability to generate multiple scheduling scenarios by varying numerous input parameters (Vieira, 2003).

CADS mine is a mineral resource management tool that provides the user with graphical interfaces for mine planning. It integrates three-dimensional mine layout design and mine-wide layout scheduling in the same three-dimensional space.

CADSmine has two separate modules, namely: the mine design module and the scheduling module. The mine design module generates CAD-type three-dimensional models that represent underground workings through the use of graphical interface MicroStation®. Mine planners are able to create complex layout designs against the background of a geological model and overlaying valuation information. The scheduling module processes certain "sequential rules" in order to output production results in graphic or text format, which include numerous peitormance variables such as: the time required to develop tunnels, the time required to prepare and mine stopes, amount of rock removed, amount of gold removal, etc.

### *3.3 Minsim 2000*

MinSim 2000 is an efficient, three-dimensional mine layout analysis package built around a linear elastic boundary element solution utilising displacement discontinuity elements (MinSim 2000 Manual, 2003). It facilitates the analyses of mine layouts through the full life of mine for tabular ore bodies on a regional-scale, including haulage locations, sloping sequence and regional support strategies. The suite is highly optimised for solving underground tabular mining problems such as the Wilwatersrand gold and Bushveld platinum deposits and is applicable to multi-reef geometries. Although MinSim was originally designed for hard-rock, deep-level mining situations, it has been modified to address other underground tabular mining situations including shallow workings and soft seams such as coal.

MinSim computes the solution in two stages: During the first stage the interaction between significant surfaces, such as mined out seams and faults, is established. Thereafter, stresses, displacements and other design criteria (e.g. average pillar stiess. energy release rate and excess shear stress) at predefined points of interest within the model. The results tor any chosen variable can be viewed as eiıheı two-dimensional sheets or in true 3D. It is important to note that, since the solution methodology assumes the rock mass to be linear, elastic, homogeneous and isotropic, the program is not capable of modelling rock failure and plastic deformation.

MinSim 2000 has been designed to be flexible and extendable enabling future developments and to ensure that MinSim 2000 does not exist in isolation. MinSim 2000 integrates visualisation of stress-strain analysis with recorded mine seismicity as shown in Figure 2. A significant amount of work has been undertaken towards developing integration with mine scheduling software to enable the evaluation and comparison of proposed mining layouts and schedules.

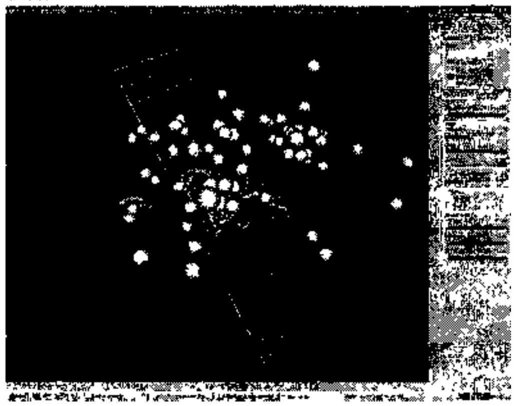


Figure 2. MinSim 2000: integrated visualisation of stress-strain analysis with recorded mine seismicity

Within the realm of numerical modelling tools available to rock mechanics engineers, MinSim 2000 is a user-friendly package. It is, however, designed for use by experienced rock mechanics engineers as its use assumes a significant degree of rock mechanics experience and education. MinSim has been an indispensable mine design and analysis tool within the South African rock mechanics fraternity since the early 1980s and is currently the most widely used tool of this nature in south Africa

### *3.4 Thin SprawdLinings (TSL)*

According to the accident statistics, the rock related accidents (rockfalls and rockbursts) are the major cause of injuries and fatalities in South African underground mines and the majority of these accidents are due to rockfalls. The investigations of accidents caused by rockfalls showed that many of these accidents could have been prevented if there was an effective areal support coverage between support units.

If the rock is highly fragmented, support units such as tendons or mine poles (i.e. elongates) do not provide adequate rock reinforcement and the potential for separation of rock from the rock surface, due to gravity and/or seismicity, exists. In tunnels, the most conventional way of overcoming this problem is the use of mesh and lace as an attachment to the rock surface. Increasing use of shotcrete (or fibrecrete), which has the advantage that it provides immediate support to the substrate, is also made. However, these conventional support components have some disadvantages. The application of mesh and lace is expensive and time consuming, while the required shotcrete thickness results in logistical problems due to large material volumes which need to be supplied. In addition, the use of these support types in narrow stoping horizon (e.g. 1.2 m) is almost impractical.

CSIR/Miningtek has been carrying out a research programme on alternative support types in the form of "Thin Sprayed Lining" (TSL) for more than a decade (Yilmaz et al, 2003). To date, a series of laboratory and *in-situ* tests has been conducted and a significant amount of knowledge on the support effects of TSLs has been gained. Figure 3 shows the spraying application of TSL.

Currently, the research team is focusing on the development of the standard testing methodologies for TSL products as well as the determination of the required physical properties of these products. Additionally, a series of comparative evaluation of the support performance of these products in various mining environments is being carried out. Once rational testing procedures are developed, the support requirements in different mining environments are defined and the support effects of TSLs are quantified, it is believed that South African mining industry will use TSLs more effectively and widely, and significantly safer working environments will be created.

Figuie 3. Spraying application

### *3.5 Borehole Radar Research at Mininglek*

The driver for borehole radar is the need for advance information about the topography of the reef horizon ahead of mining. If mechanization is introduced, face advance rates will increase while the number of faces will decrease, so the cost of losing a face to an unexpected fault becomes far higher. Borehole radar is an application of Ground Penetrating Radar (GPR) in a borehole. The borehole allows the excellent high resolution capability of **GPR** to be employed over significant distances with respect to the target.

Recent research at Miningtek has concentrated on the development and application of a state of the art borehole radar - the Aardwolf BR40 (Figure 4). The tool digitizes down the borehole with instantaneous sampling at up to 400 MSa/s. It is designed to operate in boreholes of 48 mm or less diameter, up to 1000 m long. The bandwidth is 40 MHz, which translates to a range of better than 50 m in typical Witwatersrand Quartzites or Bushveld Igneous Complex rocks. The first results achieved with the system, in October 2001.are for the surface lest site illustrated in Figure 5. The borehole starts above the Ventersdorp Contact Reef (VCR), crosses the reef at 50 m. then travels away from the VCR in the footwall quartzites at a relative angle of 15°. The VCR reflector is clearly visible in Figure 6, together with other reflectors due to bedding planes in the quartzite. The system has since been applied successfully at a number of underground sites.

### *3.6 Goafwani*

The investigations Canbulat and Jack, (1998) into the falls of ground fatalities concluded that pillar extraction is the least safe method in South Africa collieries. This highlighted a need for a device that can provide timely warnings of large goafing in pillar extraction sections. Large goafing in this environment is a safely threat and also has the potential economic loss by trapping the continuous miner.

Such a device should provide enough warning for the operator to withdraw the continuous miner and to ensure that everyone is protected by a safety barrier. Ideally, all large goafing should be preceded by an alarm.

CSIR-Miningtek developed a stand-alone warning device, called GoafWarn (Figure 7) to provide early warning of pending goafing. The warning algorithm is based on the temporal behaviour of the micro-seismicity in the immediate roof area.

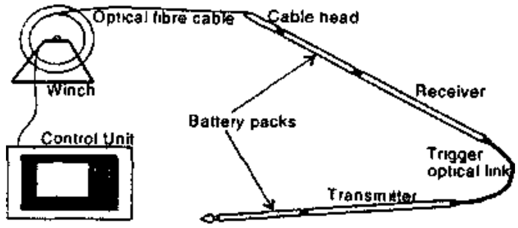
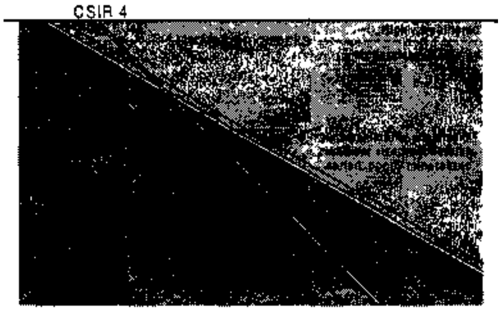
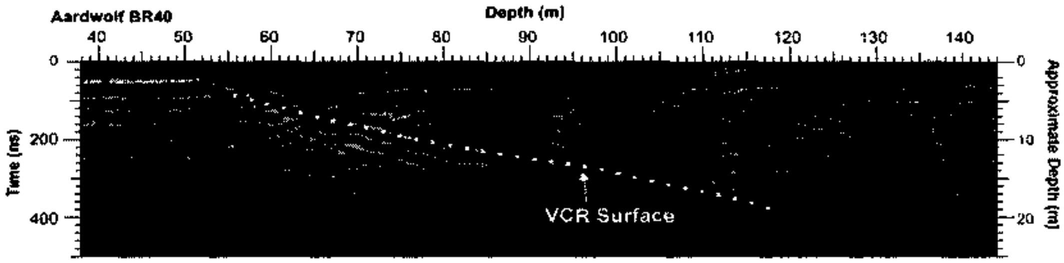



Figure 4. The Aardwolf BR40 borehole radar system.




Figuie 6. Results from the test site

The basic specifications lor GoafWam are as follows:

- An integrated and digital seismic event detection device with local storage and decision-making.
- An early warning goal alarm based on the tempoial behaviour of the recorded seismicity.
- Effective discrimination between man-made vibration and seismic events associated with failure in the root strata.
- Portable and easy to install - no communication cabling or power connection required.
- Intrinsically safe.

### *3 7 A New Mine Ventilation Software VUMA*

Effective tools are essential for the practical and efficient design of mine ventilation and coolingsystems, to enable both the development and the interactive simulation of mine layouts. To satisfy these requirements, new technology that was developed to assist mine operators in optimising thermal conditions is the mine ventilation and cooling network simulation program, VUMA- network, developed as a joint initiative by the South African Council for Scientific and Industrial Research (CSIR) and Bluhm Burton Engineeiing.

Figure 7. Goafwam

VUMA-network simulation software is specifically designed and developed to assist underground ventilation control engineers and practitioners in planning, designing and operating mine ventilation systems. VUMA-network is an interactive network simulation program that allows for the simultaneous modelling of airflow, air thermodynamic behaviour, as well as gas and dust emissions in an underground mine (Figure 8). The program includes user-friendly interfaces and three-dimensional graphics designed to facilitate the construction and analysis of networks, as well as perform "what-if ' and optimisation studies. The software is Windows-based and produces full thermodynamic simulations for the operalion ol underground environmental control systems. Ventilation for all major mining configurations, including coal deposits, massive ore bodies and tabular ore bodies, are provided for.

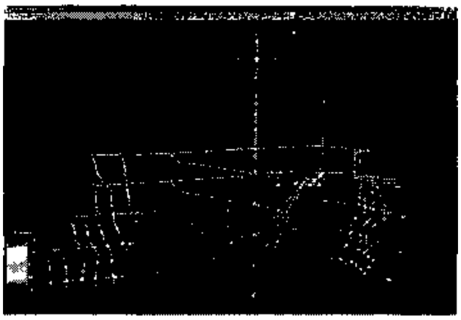
*J.S Ac nvatecl Rock Culling*

Activation is a method ol superimposing an oscillaloiy motion on mechanical rock breaking tools, such as disk culteis, saws and drum culteis. The additional oscillation has shown to reduce operating loices to a third to cutting without activation.

The principles and benefits of activation have been researched for many yeais and are well documented. As a result ol activated roller cutting tests on granite (Knickmeycr and Banmamı, 1981), expenmental results ot hydraulic activated lock cutting tests (Kaci. 1993) and tests on vibrating tool coal cutting (Yuanchang, 1996), some parameters, i.e. influence oi vibration frequencies, vibration amplitude, vibration wave lot in. cutting object, culling pitch, relative direction between vibration and cutting, and relative direction between cutting and bedding, have been more clearly defined. These studies also concluded that the vibration cutting method could signiticantly reduce the main culling force and specific energy consumption. Some of the advantages of activation are summari/ed as follows (Willis *cud.,* 2001):

- much higher hieaking rate than /or similar non-activated devices,
- tool heating is significantly reduced, resulting in up lo 10 times lower tool wear,
- reduced fines and more lumpy product.
- i educed fnctional ignition (coal).
- very high production rates possible in hard rock.
- much lighter and smaller mining machines possible for similar production rates, and
- much lower installed power.

Although activation and its benefits have been known for a long time, no applications materialized because the generated oscillations either caused destructive vibrations in the machine or else required massive vibration damping equipment. This has been overcome by a recent patent, which provides an internal rotating counterweight, thus permitting simple and smaller cutter designs. II this technology is demonstrated to be successlul, it could revolutionize hard rock mining. For the first time, a method would be available to economically mecham/e and evenlually automate the rock breaking operation in all rock conditions.



Figtue 8. 3-D View of mine ventilation network

CSIR: Miningtck has made a considerable investment in laboratory testing facilities to enable testing of mechanical rock breaking methods, such as activated rock cutting. The project involved both laboratory testing of platiniferous orcbodies and conceptual design of a long-wall type machine. A prototype machine was commissioned and tested underground at the Townlands Business area, Anglo Platinum Ltd.

This mining system consists of a movable sprocket driven machine body mounted on a steel plate conveyor that runs parallel to the mining face. The machine body is equipped with a head arrangement incorporating two tungsten carbide activated rock cutting discs (Figure 9). The cutter head units can be engaged to cut the orebody in controlled forward motion along 30 m of the mining face. The machine body is also fitted with a drum equipped with rock cutting picks, behind the activated cutting discs, to maintain the hangingwall and footwall stopc dimensions.

Subsequent lo initial problem solving and the identification and implementation of the necessary technological developments, the individual components were manufactured and tested overseas. Concurrent with this South African made components were developed and manufactured. Special lubricants that surpassed German specifications for the unique equipment were also developed and produced in South Africa.

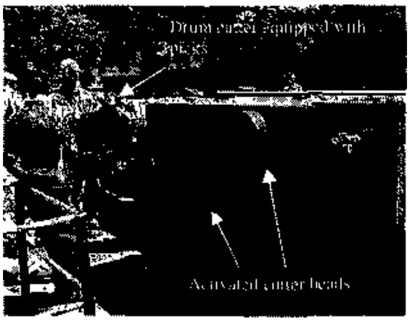
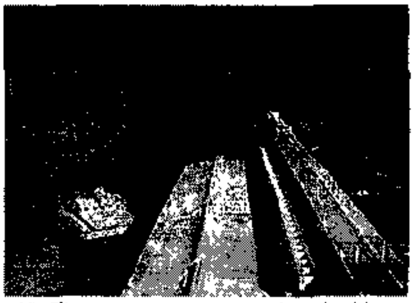


Figure 9. The Hard Rock Miner (HRM) with a head arrangement incorporating a set of two tungsten carbide activated rock cutting discs (cutter heads) and a drum equipped with rock cutting picks.



Figuie 10. The conveyor system equipped with a row of hydraulic cylinders and sprags.

A conveyor system, linked to the activated rock cutting machine, is equipped with a row of hydraulic cylinders and props (sprags) that allow the conveyor to be shifted forward in a snake-wise manner and locked in position, respectively, after the completion of each cut (Figure 10). Broken rock is ploughed onto the steel plate conveyor that delivers the rock to conventional materials handling equipment and a belt conveyor system in one of the gullies.

In July 2001, all the components of the system were completed and delivered to South Africa. The system was then assembled on surface for full compatibility testing, simulating as far as possible conditions that would be experienced underground.

The underground test programme commenced in September 2001. The main outcome of the testing programme is that no fundamental technological reason to doubt the ability of the technology to succeed could be found and proven after three main bearing failures. Bearing failures can be overcome. It is possible to increase the bearing load carrying capacity to the required limit as measured underground. It is also highly recommended that a new generation activated disc cutter has to be redesigned and may include design changes to the hard rock miner.

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