



Presidential Address: The mechanisation of UG2 mining in the Bushveld Complex

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Synopsis

Mechanisation of mining operations is not a new concept in the world of mining. Machinery has been developed, manufactured and used for many decades in massive orebodies and coal mines, both locally and abroad. Because of their size and the huge tonnages available, massive orebodies lend themselves very easily to mechanisation. However, little progress in mechanisation has been made in narrow tabular orebodies in South Africa.

The equipment available for narrow tabular orebodies requires excavations of a size that introduce large volumes of waste dilution. Nevertheless, it is essential for South African miners to experiment with mechanisation and to find a solution to the problem.

This address looks at current conventional mining methods and compares them to bord-and-pillar type mining methods. Off-reef mechanisation is also touched on. It then looks at different hybridised mining methods that are being used, i.e. a mixture of conventional mining and mechanisation. It finally looks at future prospects for mechanisation in narrow tabular orebodies.

Introduction

Narrow tabular orebodies in South Africa have traditionally been mined by the labour-intensive conventional mining method of drilling with hand-held jackhammers, and cleaning stope panels and gullies with scraper winches. This method has been labour intensive and costly but produces a good shaft head grade. To break away from traditional conventional mining experiments in mechanising, narrow tabular orebodies were first conducted on Bracken Mine as far back as 1968. In the early '80s, good progress was made towards mechanisation, particularly on mines with wide and narrow orebody sections, and where a number of reefs could be combined to make a larger package, effectively a wide orebody. In the '90s many chrome mines (and others), introduced mechanised mining methods with much success. However, few gold or platinum mines have been able to make a 1-m wide stoping width viable by moving to mechanisation.

Originally trackless equipment was developed for massive orebodies. Therefore,

economies of scale dictated that bigger equipment would improve returns on investment. Machinery for narrow tabular orebodies had to be scaled down to fit into the narrow confines of a 1-m stoping width. Equipment had to be specially manufactured for South African mining conditions. Because numbers were small, the cost of machinery was excessive. This was exacerbated during the '80s by the rand depreciating against the US dollar. Imported machinery became exorbitantly expensive and many mechanised projects were no longer viable.

The lure of immediate access to the orebody and rapid production build-up, combined with excellent labour productivity, spurred mines on to reintroduce mechanised mining methods in the early 2000s. The strengthening of the rand, from around R13/\$ to around R6/\$ dropped local commodity prices in rand terms, and again many mechanised projects were no longer viable.

Geology

The Upper Group 2 Chromitite seam lies from 12 m to 400 m below the Merensky reef. It is fairly consistently distributed throughout the Bushveld Complex and elsewhere (see Figure 1). Dips range from 3° to 27°.

A typical geological section is shown in Figure 2. On occasion the middling between the leader reef and the UG2 is reduced and the two seams can be mined together. The UG2 also has a tendency to roll, sometimes a few metres deep. Potholes, also a few metres deep, are encountered regularly. Faults and dykes are encountered from time to time. Geological losses are about 20% to 25%.

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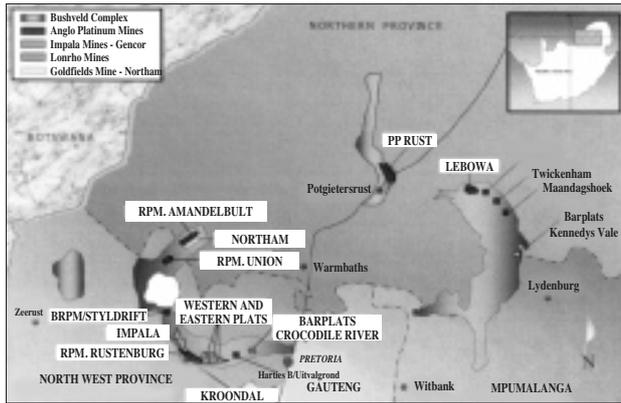


Figure 1—The Bushveld Complex

Reef dip	9°
Reef channel width UG2	75 cm
Reef planarity	Planar to undulating
<i>In-situ</i> channel grade UG2	6 g/t
<i>In-situ</i> grade UG2 @ 100 cm stoping width	4.5 g/t
<i>In-situ</i> grade UG2 @ 180 cm stoping width	2.5 g/t
SG <i>in-situ</i> UG 2 ore @ channel width	4.00
SG <i>in-situ</i> UG 2 ore @ 100 cm stoping width	3.83
SG <i>in-situ</i> UG 2 ore @ 180 cm stoping width	3.37

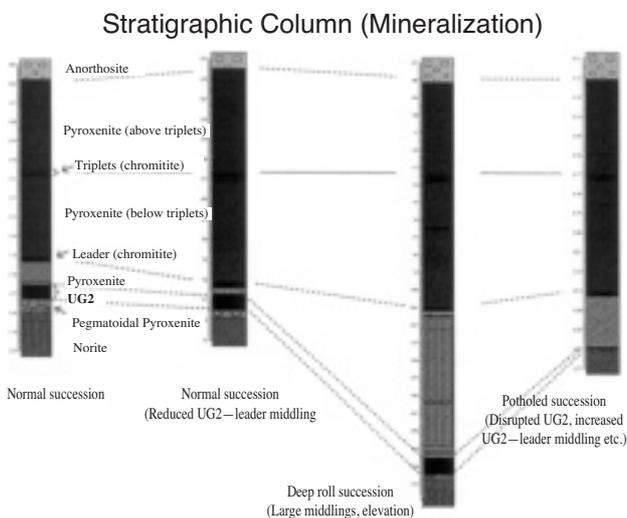


Figure 2—Typical geological section

UG2 chromitite layer

There is little variation in the UG2 reef thickness, which is approximately 70 cm to 75 cm thick. The reef is essentially a chromitite seam in which the platinum group elements (PGE) have a bimodal distribution, with elevated values towards the top and bottom contacts. The reef has a sharp contact with the overlying pyroxenite and a highly undulating, gradational contact with the underlying pegmatoidal pyroxenite.

Conventional mining

In this paper conventional mining refers to the 'standard' narrow tabular orebody mining method for which South Africa is famous. It is, and has been, widely practised throughout the industry in gold, Merensky reef, chrome reefs, and the UG2. The main advantage of conventional mining is that access to the orebody is in the footwall, so the development, waste can be hoisted separately from the reef. Therefore, there is a relatively low level of dilution. A brief description of a typical UG2 stope follows to orientate the reader.

After shaft sinking and associated capital infrastructure development access is established to the reef horizon. Cross-cuts from the shafts are developed to below the reef horizon. Footwall drives break away and are developed 10 m to 80 m below the reef, on strike. Development of the orebody is then done on a grid pattern of footwall drives spaced 240 m on dip and raises spaced 200 m on strike. Pneumatic hand-held jackhammers on air-legs are used for drilling. A pneumatic loader on tracks loads the rock into hoppers. Locos and hoppers are used for tramping to the shaft tips. Support is usually in the form of rockbolts.

Every 200 m a stope cross-cut is developed to reef. After a step over, a raise is developed on dip 240 m to hole into the next level. Ore passes (boxholes) out of the stope cross-cut are developed to intersect the reef in the raise. They are equipped with a manually controlled pneumatic chute for filling hoppers.

The shoulders of the raise are ledged in 6 m on either side, and supported with 200 mm diameter sticks on pre-stressed pods and cluster sticks. The positions of advanced strike gullies (ASGs) are marked off and blasted together with winch cubbies etc.

The stope is equipped with the following, together with their attachments etc. (differing from mine to mine):

- ▶ A 55 kW winch at the bottom of the raise to pull ore to the boxholes
- ▶ A 55 kW strike scraper winch for each ASG
- ▶ A 37 kW face scraper winch for each panel
- ▶ Four rockdrills and air-legs per panel
- ▶ Two mono-rope winches
- ▶ Other miscellaneous equipment.

Breast panels, 30 m long, are stoped on strike. Small diameter holes 1 m in length are drilled with hand-held jackhammers. The holes are blasted with Anflex, fuses and igniter cord at the end of the shift.

Local support pillars, approximately 4 m by 4 m, with a 3 m ventilation holing between, are left at the top of the panel. Temporary support is installed in the form of mechanical props down the face between the permanent support and the panel face, and spaced no further than 1.5 m apart on dip.

Permanent support is in the form of 200-mm diameter pre-stressed, non-yielding timber elongates, typically spaced 1.5 m on dip by 2 m on strike and never further than 4 m from the face. Alternatively, tendons may be installed after each blast, spaced 1.5 m on dip and 1.6 m on strike.

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Panels are cleaned by face-scraping down dip into an advanced strike gully (ASG). The ASG is 1.4 m wide by 2.5 m high. The run-of-mine (ROM) rock is scraped along the ASG to the original raise. It is then scraped down the raise (sometimes up-dip as well), over a grizzly, and into an ore pass. At the bottom of the ore pass it flows through a control chute and into a span of hoppers, which tram it to the shaft. It is tipped down ore passes to shaft bottom and hoisted to surface.

Dilution of the reef comes from planned waste included in the channel width to create the stoping width to enable access to the stope face. Other planned dilution comes from ASGs, winch cubbies, hangingwall stripping, footwall lifting, off-reef stoping and development, shortfall, etc. In addition, there is dilution from overbreak in the stope. Occasionally waste from development finds its way into the reef ore passes.

A stope like this has three crews, which each have two panels. This is a high labour-intensive operation, which makes it costly. However, in narrow tabular orebody mining, in general, it is the method that results in the highest shaft head grade, i.e. the purest product.

Philosophy of mechanisation

Mechanised equipment ties up large amounts of capital. The better it is utilized, the greater the return on investment. Few people are used, hence labour efficiencies are high.

On the other hand, narrow tabular orebody mines employ large numbers of employees in the conventional stoping and development methods. It has been common practice to increase the number of personnel whenever production needs to be increased. In conventional mining there has never been a generally accepted philosophy amongst employees to respect or give way to machinery. On the contrary, emphasis has been on stopping machinery until personnel are well clear, mainly for safety reasons. Obviously this attitude has to change. Employees need to be trained in the change in philosophy to mechanisation.

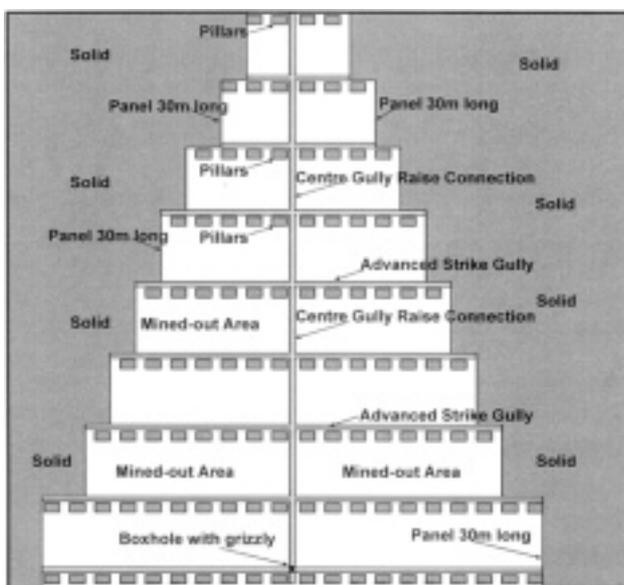


Figure 3—Plan of a conventional stope

- The philosophy must include proper maintenance of machinery, i.e. shift supervisors must ensure that time is made available, even at the expense of production. Mining and engineering personnel need to work closely together. To this extent it may help to institute a production-based bonus system
- Training and re-training must be done continuously. Some experts say that the learning curve for a mine changing to mechanisation may be as long as two to three years. In South Africa it may be even longer because of the mind-set and long tradition of mining conventionally
- Training needs to be done at all levels: management, supervisors, operators and maintenance. For management it is more than just training. It takes about four years for a graduate or diplomate to be skilled in conventional mining. How long will it take for trackless mining?
- Operators need to be equitably paid. In general it has been found that good output-based bonus schemes produce good results
- A mind-set of caring for machinery must be developed, especially among mining personnel. After all, if the machine doesn't work, there can be no production and therefore no bonus
- All employees should give way to mining equipment at all times so that utilisation can be optimised
- Roadways must be kept in a good condition. Graders need to be made available and continuously used
- Gradients should not exceed the manufacturer's recommendation
- Trimming distances for LHDs and trucks, and travelling distances for drill rigs and other equipment should be kept within acceptable limits
- Planning should be done to suit the machine, rather than the machine fit into the planning
- The effect of dilution on narrow tabular orebodies must be carefully considered.
- Standards need to be set for all the above and strictly adhered to at all times
- A mechanisation culture must be developed on the mine that encompasses the aforementioned points
- A system of mentorship should be developed on the mines so that knowledge and experience can be passed on more easily.

Large reef-drive mechanisation

This method is similar to the conventional mining method described above. Large reef drives developed out of the decline are cut up to 5.0 m wide by 5.4 m high. Short mucking bays are developed at 200-m intervals on strike, (60 m for down-dip layouts). The stope is mined conventionally and ore from the raise is scraped directly onto the muck bay floor where it is loaded by 12.5-ton to 15-ton LHDs into 20-ton to 50-ton trucks, which tram it to the conveyor-belt in the decline.

Advantages

- Development rates are faster than for tracked development
- The orebody can be developed more quickly than by tracked methods

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- Ore reserves can be built-up more rapidly
- Shaft head grade is nearly as good as for conventional methods
- Ventilation flow is improved because larger ends are used
- Either conventional scattered-breast or down-dip stoping methods can be used
- Both personnel and material can be easily and efficiently transported from surface to the working place
- Efficiency of transport of ore is high
- Stopping waste dilution is lower than for on-reef mining methods, but the large end development adds waste.

Disadvantages

- High initial capital outlay
- Difficult to implement directly out of a shaft unless especially designed to accommodate large machines
- More air is required because of the use of diesel engines and ventilation costs are high
- Because there are many people in the stopes, a single person walking in the footwall drive can hold up a machine and therefore affect production.
- Safety of personnel is prejudiced because of the size of the machinery
- The high development ends are difficult to bar down and maintain in a safe condition.

On-reef mechanisation

Access to the reef is directly on reef and not from the footwall. Because all development is on reef, all additional waste mined to gain access to the reef etc. is also sent to the plant. This adds to the dilution, and shaft head grades are lower than for conventional mining.

Little if any manual work needs to be done. In the best example, trackless machines perform all operations:

- Electro-hydraulic drill rigs do the face drilling
- Charging-up is done with purpose-designed emulsion explosive charging-up vehicles coupled with the use of shock-tube initiation systems
- The hangingwall and sidewall are made safe through the use of scaling vehicles
- Electro-hydraulic roof-bolters support the hangingwall with rock bolts
- Mucking is done with LHDs
- Specially designed vehicles are used for personnel transport
- Material is carried directly from surface to the working face in utility vehicles
- Mechanised rock-breakers fragment big rocks at the feeders.

Access to the orebody

Access to the orebody is normally via a large single decline developed from surface typically 5 m wide by 5 m high, (Figure 3). (In deeper mines access can also be via a cross-cut from a vertical shaft.) It is equipped with all the services, conveyor belt, power lines, compressed-air pipes, service

water pipes, pump columns, and serves as a roadway and the major intake airway. When the mineable reef position is reached, it splits up into a cluster of five separate declines (6.5 m to 9 m wide by 1.8 m high to 2 m high). The centre decline (No. 3) is equipped with a 1 200 mm-wide conveyor belt, which feeds directly into the decline tip on surface (or shaft). This conveyor belt can extend over many kilometres as one conveyor 'piggybacks' onto another. Declines Nos. 2 and 4 are used as roadways for the trackless machinery and personnel. Declines Nos. 1 and 5 are used as return airways during the development phase and intake airways when stoping starts. There are connecting cross-cuts between declines Nos. 2 and 4 every 70 m.

The cluster is developed until nine rooms (strike drives or roadways) have been established. The fifth room on dip, i.e. centre of the nine rooms, is equipped with a conveyor belt, which is extended on strike as the mining advances. This conveyor belt tips onto the conveyor belt in Decline No. 3. The tipping arrangement requires additional sliping of either the hangingwall or footwall.

The strike conveyor belt in the fifth room is advanced every 25 m. The LHDs tip the run-of-mine rock, onto a feeder situated at the front end of the conveyor-belt. The ROM is fed onto the conveyor belt. Each strike conveyor belt services a section of 150 m to 190 m on dip in room and pillar mining. In other mining methods this distance can increase up to 300 m.

Advantages

- Health and safety are improved because
 - Fewer persons are exposed to hazards
 - Machinery, equipment and systems are intrinsically safer
 - Conditions are generally better

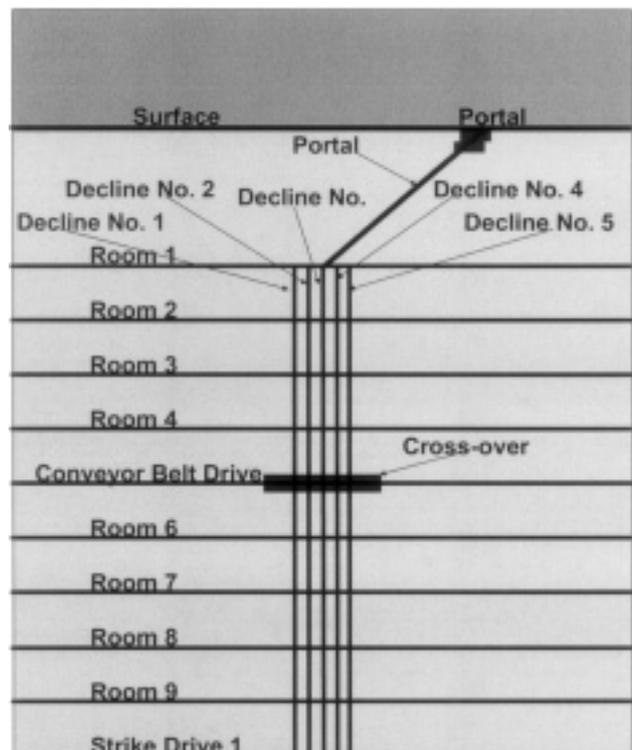


Figure 4—Access to the orebody

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- Quick and easy access to ore reserves
- Drilling accuracy is greatly improved compared to hand-held jackhammers
 - Better rounds can be pulled
 - Improved explosives' efficiency
- Easy re-establishment of reef after encountering potholes
- Significantly reduced labour requirement
 - All operations are completely mechanised
 - No heavy repetitive manual labour is required
 - The labour force is better educated
 - Personnel are well paid because they are employed at a higher grade
 - Communications are improved
 - Supervision is improved because all working areas can be visited with far less effort than for conventional mining
 - Team building is enhanced
 - Transport of personnel is easy to any point in the mine
- Improved material handling
 - Handling and supply is easy, normally in containerised method
 - Material can be carried directly from surface to the working face
 - Less material required where sticks and packs don't have to be installed
- Emulsion explosives can be used
- Logistics are improved.

Disadvantages

- Additional waste is mined with the effect of reducing the shaft head grade
- Low extraction rate
- Increased costs to train operators to higher standards than for conventional mining
- More training and retraining is required than for conventional methods
- Improved training methods must be used
- Maintenance standards must be high
- The system has initial higher mining capital expenditure than conventional methods. These are offset against other capital savings, e.g. compressors, hostels, etc.

The above advantages and disadvantages apply, to a greater or lesser extent, to all the trackless mechanised mining methods described below.

Room and pillar system

The room and pillar (R&P) mining method is best suited to a reasonably wide and flat dipping reef. Best results are achieved with a reef at least 2 m high. Efficiencies improve as the reef gets wider. However, it can be adapted to situations where the reef is only 70 cm. Waste dilution is incurred in an attempt to increase productivity.

Drilling of the rooms is done with low profile electro-hydraulic single boom drill rigs. The length of round drilled is 3 m. Blasting is done with emulsion explosives. Figures 5 and 6 illustrate low profile drill rigs commonly in use.

Cleaning is done with low profile LHDs with 1.8 m³ bucket load capacity. Some LHDs are fitted with EOD

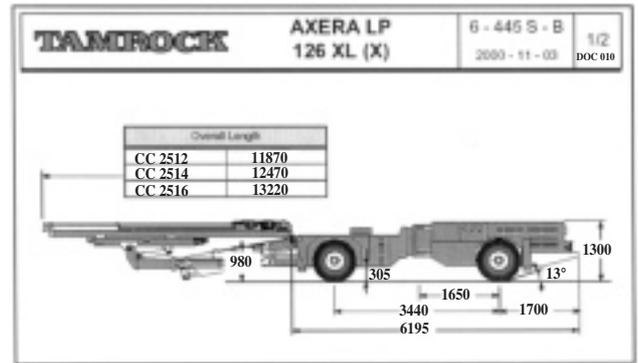


Figure 5—Typical low profile drill rig



Figure 6—Drill rig at work

(Ejector) buckets. They tip directly onto a feeder at the end of an advancing conveyor belt situated in the centre room of the nine rooms. One-way travel distance averages 75 m (Figures 7 and 8).

Roofbolt support spacing in the rooms is 1.2 m on strike by 1.5 m on dip. Roofbolts are 1.5 m long, M16 (14.5 mm diameter), end-anchored bolts. Full column resin grouting is employed where low angled jointing, fissures or ground water is intersected.

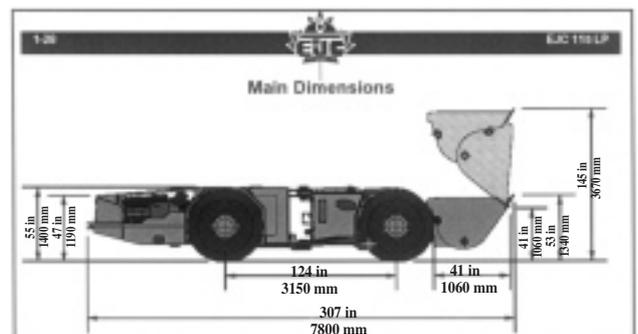


Figure 7—Typical low profile LHD

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Figure 8—LHD at work

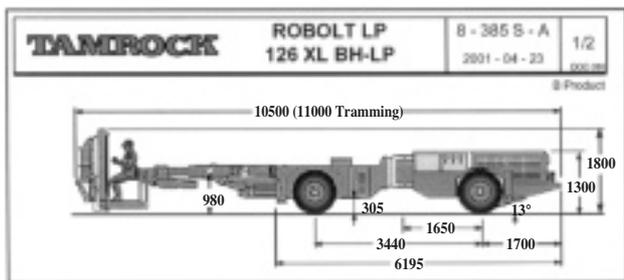


Figure 9—Typical low profile roofbolter

All roof bolting operations are done with a roofbolter; mechanised drilling and semi-manual installation of roofbolts. Remotely controlled roofbolters are being used at some operations see Figure 9.

The layout for room and pillar systems in most narrow tabular orebodies is based on the nine-room method used in coal mining, i.e. four rooms above and below a central room equipped with a conveyor belt (see Figure 10).

Rooms are carried 12 m wide. The lowest height that can be traversed by low profile (LP) machinery is 1.8 m. Low profile equipment is built 1.3 m. Because LHDs and drill rigs are long, they need a height of 1.8 m to negotiate undulations in the reef.

Pillar dimensions increase with depth, as shown in Table II:

Depth below surface (m)	Pillar width (m)	Pillar length (m)	Maximum extraction (%)
50–150	4.0	4.0	90
150–175	4.5	4.0	89
175–200	4.5	4.5	88
200–225	5.0	5.0	88
225–250	5.0	5.0	87
250–275	5.5	5.0	86
275–300	5.5	5.5	85
300–350	6.0	6.0	83
350–375	6.5	6.5	82
375–425	7.0	6.5	81

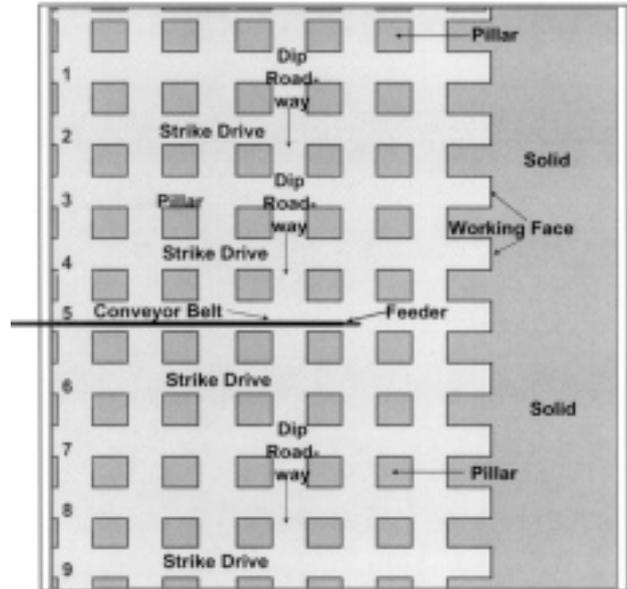


Figure 10—Standard room and pillar layout

Room and pillar with T-cut

Room and pillar mining results in relatively low shaft head grades of less than 3 g/t. In order to reduce the amount of unnecessary waste mined, and increase the shaft head grade, a T-cut can be mined. The T-cut on reef is a portion completely round or halfway round a pillar that is drilled and blasted at normal stope width height (say 1.1 m). The depth of T-cut blasted is limited to 3 m, the length of hole that can be drilled by a drill rig. (Figure 13).

A 4-m wide by 1.8-m high access drive and a dip roadway are developed. The normal pillars are cut in the usual manner. Shoulders, 2 m to 3 m deep, are mined round the full perimeter (or less if necessary) of the pillar at channel width. The shoulders are drilled with a Narrow Vein Telescopic Feed (NVTF) boom, which is mounted on a standard Axera drill rig. The drilling of the shoulders is done at 90 degrees to the face. The NVTF boom allows for full mechanisation and the extraction of the reef channel only, thus increasing the head grade. Maximum productivity from trackless mining equipment can be achieved.

It is necessary to install stick support on the edge of the shoulder. (Figures 11 and 12.)

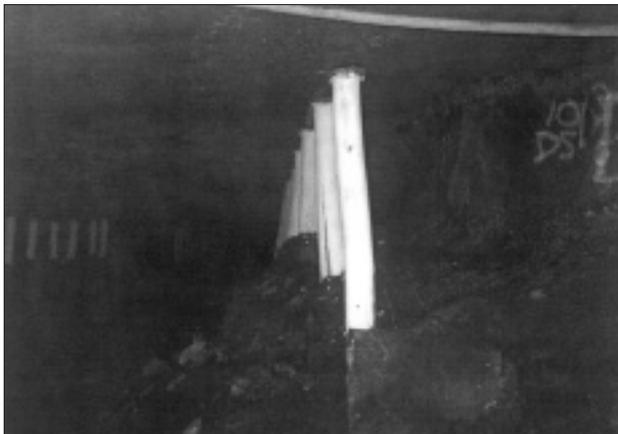
Disadvantages

Although nearly all operations are fully mechanised, it is still necessary to install sticks by hand. This requires an increase in labour. Grade improves but may still not be high enough to maintain mining viability.

Hybridisation

Fully mechanised room and pillar systems in narrow reef conditions, with or without a T-cut, are high in dilution and low in shaft head grade. To keep many of the advantages of mechanisation it is necessary to hybridise the mining method by introducing a degree of conventional narrow tabular orebody mining, i.e. all or part of drilling, blasting and cleaning a stope panel by conventional methods.

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Figures 11 and 12—T-cut support

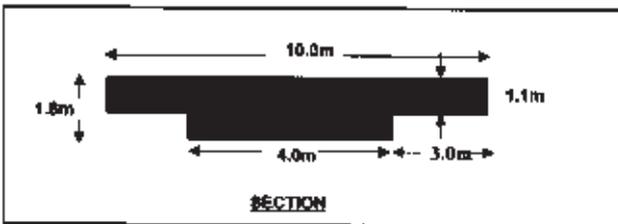


Figure 13—Cross-section of a T-cut

Scattered breast hybrid

Conventional breast stoping is practised at a planned stoping width of 1.1 m. The length of a face is 26 m plus a 4-m pillar and a 4-m drive at the bottom of the face, to give a 34-m repeatable block. A 37 kW scraper winch cleans the face to the reef drives. The faces are planned to advance by 20 m per month. Trackless mining equipment is utilised for developing the advanced strike drives (ASDs) and dip roadways, and deliver material etc. to the stope.

All mining operations take place on the reef horizon in the form of production panels above the drives. Development is fully mechanised, but stoping operations are done conventionally. This brings the interface between men and machinery to the fore. The system is more labour intensive than room and pillar as all stoping operations are done conventionally.

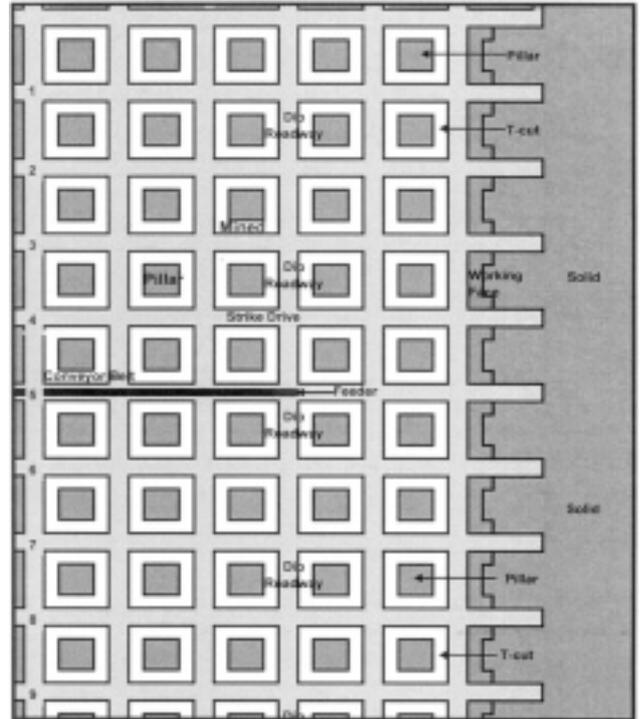


Figure 14—Layout for T-cut

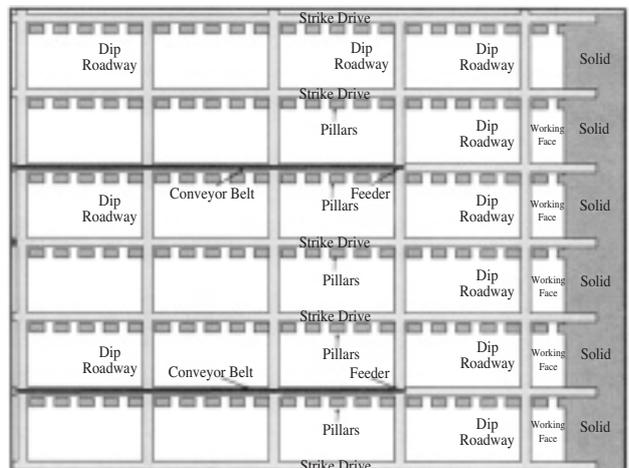


Figure 15—Layout of scattered breast hybrid

Each unit consists of a centrally located strike conveyor with 3 panels, 2 above and 1 below, see Figure 15. Waste dilution at 10% is lower than R&P, but overall efficiencies and utilisation of labour are poorer than for the R&P method. Cost per ounce improves.

Mechanised dip pillar

The mechanised dip pillar strategy incorporates as much mechanisation as possible with as much on-reef stoping at 1 m width as possible (see Figure 16). It introduces a greater percentage of higher grade stoping ore to improve overall grade. All mining operations continue to take place on the reef horizon.

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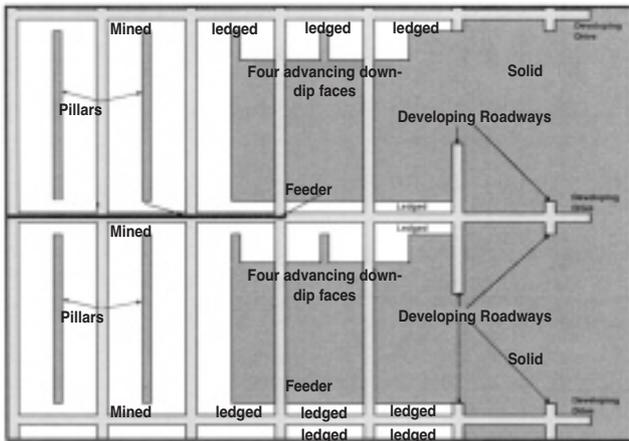


Figure 16—Layout for mechanised dip pillars

Drives are developed 68 m centre to centre on dip. Dip roadways are developed 23 m to 33 m on strike. Development is advanced until two consecutive dip roadways have holed. The drive is then ledged 2.5 m on the up-dip and down-dip sides for a distance

Panels from 8 m to 13 m long, are stoped on either side of two dip roadways, both down dip and up dip at the planned stoping width. The panels are drilled with hand-held rockdrills on air legs. Using emulsion explosives and shock tube, the broken rock is throw-blasted into the dip roadways. Final cleaning of the broken rock remaining in the panel (some 10 to 20%) is done with a water jet.

The ROM is then loaded with a low profile 5-ton LHD and tipped onto a feeder and discharged onto a conveyor belt. There is a centrally located strike conveyor in every second drive serving the panels above and below. The panel is then be supported with prestressed sticks on pods.

The strike span between pillars including the dip roadway varies between 20 m to 30 m, depending on the ability to throw blast.

Advantages

The mechanised dip pillar method has many of the advantages of pure room and pillar mining.

- More than 80% of the ROM can be handled with LHDs directly
- In the panels only drilling, support and a bit of cleaning has to be done manually
- Labour is kept to a minimum
- Stoping efficiencies increase to 74 m² per in-stope employee.
- Results in a purer product at the shaft head, 3.6 g/t
- Results in a reduction in tramming width
- Costs are relatively low.

Disadvantages

- Dilution is still relatively high
- Extraction rate is fairly low.

Two drive on-reef scattered mining hybrid

This method uses the same infrastructure as the room and pillar. A strike conveyor belt is installed every 264 m, along dip of the main dip conveyor decline to establish the stope production sections on strike. There are two strike drives, one 12 m wide and the other on the down-dip side, 4 m wide, see Figure 17. The top drive is equipped with a conveyor belt and its feeder. It is used for ROM rock transportation and loading the ore from the stope. The other drive is used for transporting material and personnel. The drives continue developing past the stope to the next stope position to open up reserves timeously.

At the raise position a mucking bay is excavated, 6 m wide by 16.5 m deep. The raise is developed out of the drive to the next strike drive 240 m up dip.

When the raise has holed, it is ledged in 6 m. ASGs are marked off and blasted together with the winch cubbies etc. After ledging, the stope is equipped in the normal manner for a conventional stope.

Holes of 1 m or longer are drilled with hand-held jackhammers on air-legs at 70° to the breast face. They are charged up with Anflex and fuses, connected up with igniter cord, and blasted at the end of the shift.

Broken rock is scraped down the face into the ASG. The strike winch scrapes the ROM rock to the centre gully (original raise line). The rock is then scraped down (and sometimes up) the gully and into the mucking bay. There it is loaded with an LHD and discharged onto the conveyor from where it is conveyed to the central dip conveyor and out of the mine to the stockpile on surface.

When the panels are clean, prestressed elongate support is installed on pods. At this stage if any additional support is needed, it is installed.

Ventilation enters from the bottom of the stope. It is split east and west by a ventilation barricade in the centre gully. The air courses towards the face and then flows up the face to the top of the stope. Care is taken to ensure that return air wet bulb temperatures are kept below 27.5°C at all times.

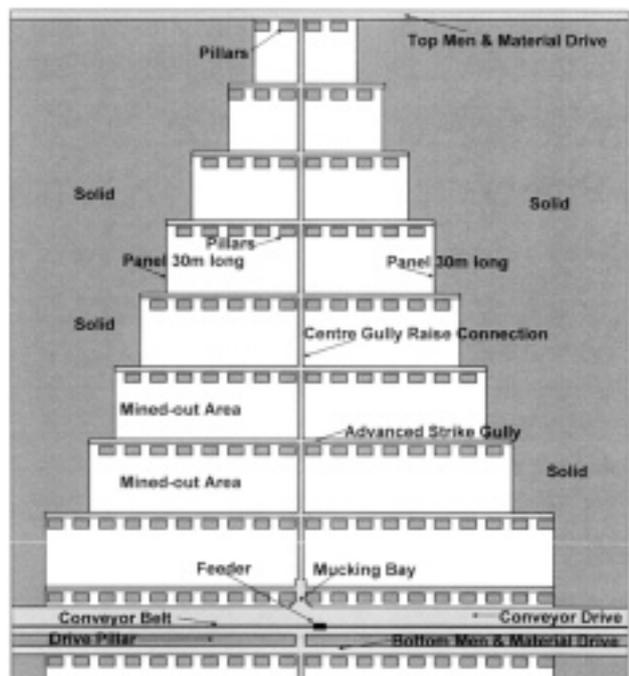


Figure 17—Layout for on-reef two drive method

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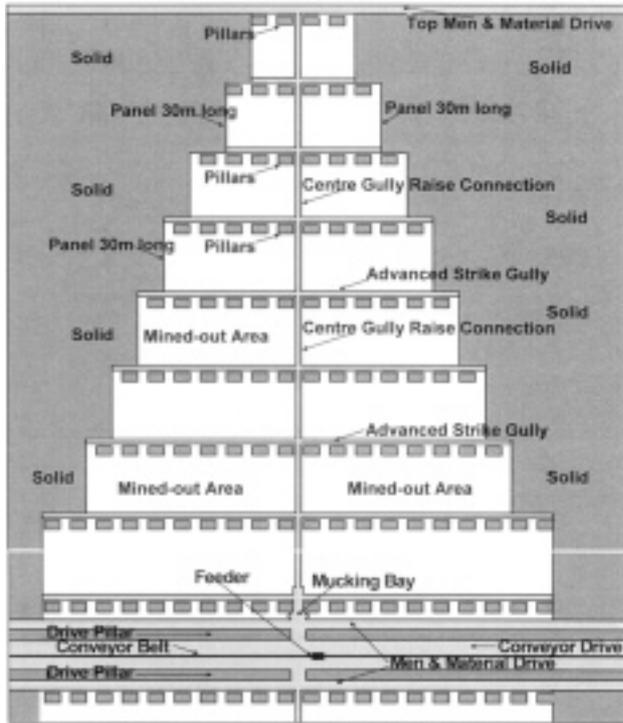


Figure 18—Layout for three drive on-reef method

Three drive on-reef scattered mining hybrid

This method is similar to the two drive method described above. There is a third drive above the conveyor belt drive. The length of back is increased to 324 m. There are ten panels on either side instead of eight. Winzings is done from the top level down, see Figure 18. There is an improvement in grade compared to the two drive method.

Ultra low profile (XLP) mining methods

A number of ultra low profile machines have come onto the market recently and are being tried out on various mines. Machines already available are drill rigs, roofbolters, LHDs and bulldozers. This equipment can operate in a height of less than 1.2 m, which has obvious advantages especially as far as dilution is concerned. Tests have shown that stope widths of as little as 6 cm more than conventional mining can be achieved. Current trials are being carried out using both room and pillar methods and conventional scattered breast mining.

A major safety feature is that the operator controls the machine remotely and can therefore move away from dangerous face areas. Productivity is expected to be well within the realm of normal room and pillar levels. Because all operations are mechanised, working costs will be kept low.

The room and pillar layout (Figure 19) has 12 m rooms on strike and 8 m on dip. Pillars are cut 6 m on strike by 5 m on dip. Drilling is done with an XLP drill rig. An ASG is blasted to give access to the face. There is little dilution outside of the planned stope width. XLP LHDs clean the ROM to a conveyor belt following on behind. 1.2 m grouted rockbolts are installed on a 1.5 m by 1.5 m pattern, a maximum of 1 m from the face before the blast.

Figures 20–25 illustrate the mining equipment currently available.

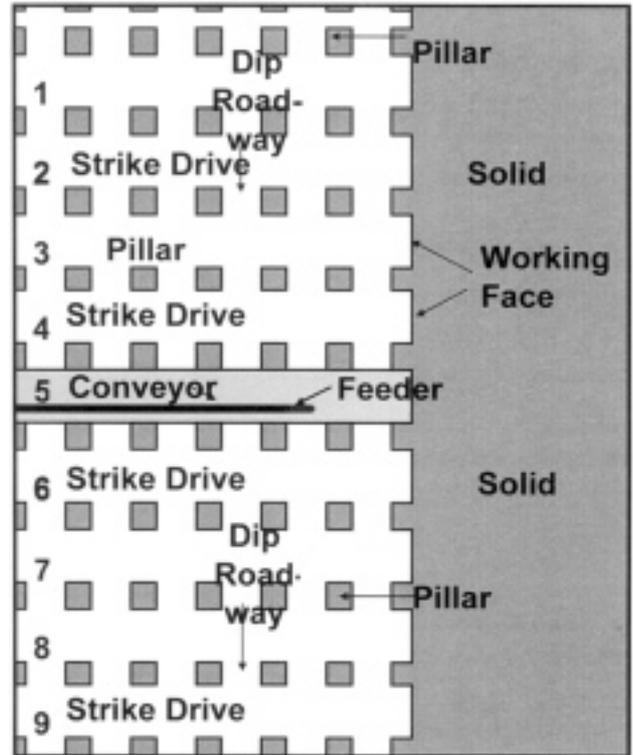


Figure 19—XLP room and pillar layout



Figure 20—XLP roofbolter



Figure 21—XLP roofbolter

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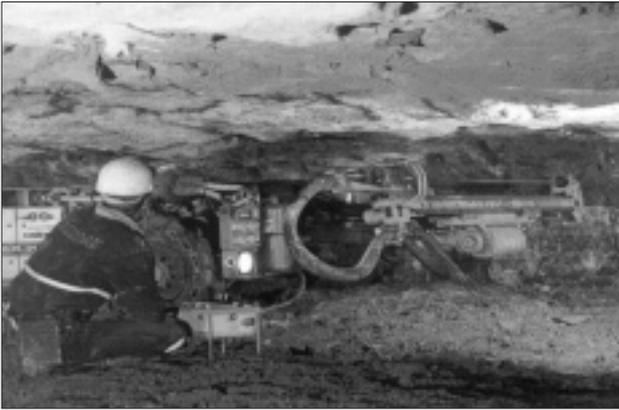


Figure 22—XLP drill rig



Figure 23—XLP (Axera) drill rig



Figure 24—XLP (EJC 88) loader



Figure 25—RHAM dozer

Dilution

Mineral extraction is a process of removing waste material from the ore. Adding waste in the mining process can often exacerbate an already uncertain situation and should be avoided wherever possible. Mining engineers endeavour to design mining systems that do not involve excessive waste mining. When designing mechanised methods, this is not

always possible. It is then essential to ensure that a minimum amount of labour is used and that working costs are optimised.

In order to examine and compare the effect of dilution using the different mining methods, and to compare the effects of costs, a model was developed and comparisons done between the mining methods discussed above, in a typical conceptual design process. The following methods were compared:

- ▶ *Bord and pillar*, 12 m bords on dip and strike and 12 m by 12 m pillars. All mining done at 1.8 m height, (stopping width).
- ▶ *Room and pillar T-cut, with a 2 m shoulder*. T-cut mining at a stopping width of 1.1 m as shown in Figure 14. A hole length of 2 m was used to ensure clean breaking and avoid breaking into the hanging- or footwall.
- ▶ *Room and pillar T-cut, with a 2.5 m shoulder*. As above with a 2.5 m shoulder. With greater success above, experiments were done with deeper holes.
- ▶ *Room and pillar T-cut, with a 3 m shoulder*. As above with a 3 m shoulder. This is the maximum depth that can be drilled in the face with the current drill rigs.
- ▶ *Mechanised/hybrid dip pillar method, with an 8 m panel*
- ▶ *Mechanised/hybrid dip pillar method, with a 10 m panel*. A panel length of 10 m was tried and proved to be successful
- ▶ *Mechanised/hybrid dip pillar method, with a 12 m panel* was modelled
- ▶ *Mechanised/hybrid dip pillar method, with a 13 m panel* was also modelled. This is considered to be the maximum length of panel possible. The skin-to-skin distance between pillars is 30 m, probably the optimum. Beyond this span there is likely to be 'backbreak'.
- ▶ *An on-reef two-drive system* was modelled.
- ▶ *An on-reef three-drive system* was modelled.
- ▶ *A conventional mining system for comparative purposes*.

In all cases the model was based on 100 000 tons per month hoisted. The following design criteria were used:

Design criteria

The orebody is assumed to have the following properties:

- ▶ UG2 Reef seam width 75 cm
- ▶ UG2 Reef seam value 6 g/t
- ▶ Planned stopping width 100 cm
- ▶ Stopping width including overbreak 105 cm
- ▶ Depth below surface 40 m–600 m
- ▶ Chrome specific gravity 4.0
- ▶ Hangingwall waste specific gravity 3.3
- ▶ Footwall pegmatoid specific gravity 3.6
- ▶ Footwall norite specific gravity 2.9

No stopping is done in normal room and pillar mining. The stopping area increases as the method changes from T-cut to mechanised/hybrid dip pillar and finally to the conventional mining methods. XLP has the highest stopping area. This has the effect of sweetening the grade (see Figure 26).

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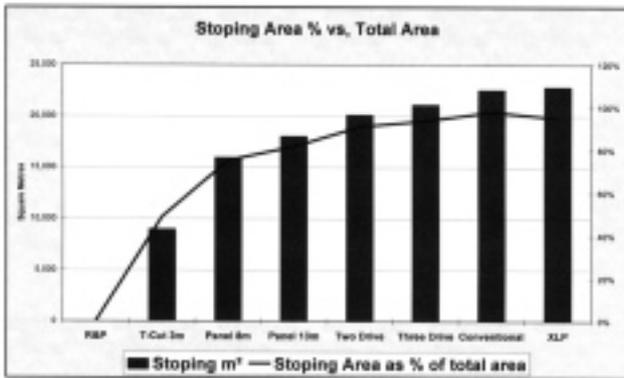


Figure 26—Comparison of percentage stopping area vs. total area

Stopping tonnage increases with the move from room and pillar to conventional. More importantly, the waste dilution decreases. XLP has the lowest waste dilution (see Figure 27).

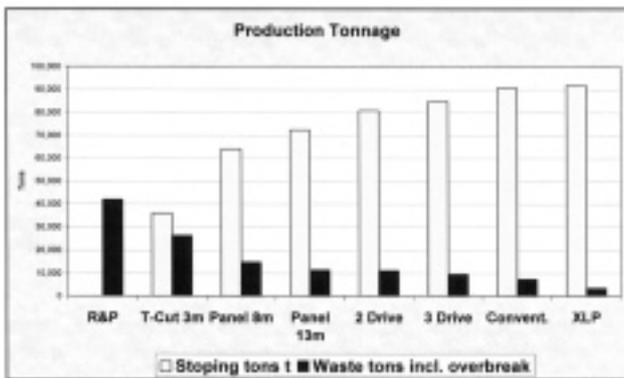


Figure 27—Comparison of production tonnage

Extraction

Figure 28 shows how production square metres increase as the amount of waste mining is reduced. A greater area can be mined to produce 100 000 tons per month. More contents can be achieved as a greater area is mined. The pillar area also shows a marked decrease. Again XLP gives the best results.

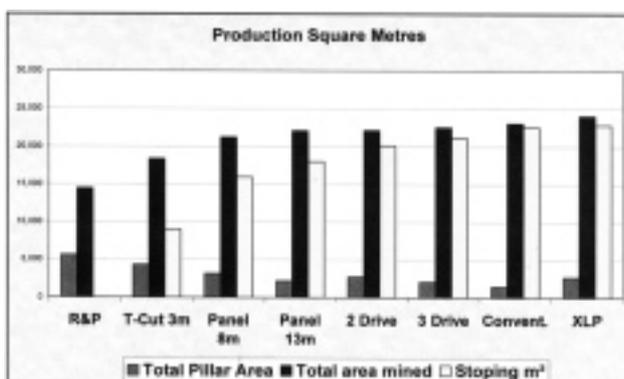


Figure 28—Comparison of production square metres

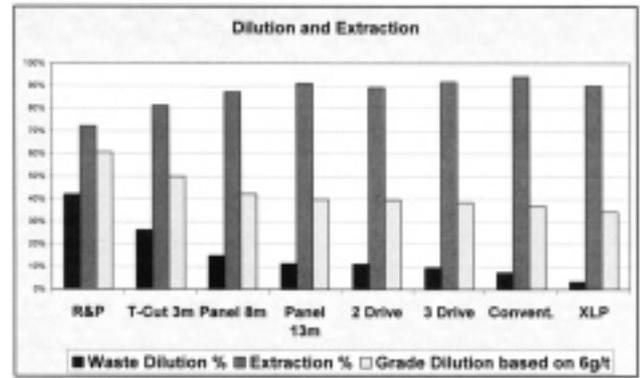


Figure 29—Comparison of dilution and extraction

The higher the level of mechanisation, the lower the extraction rate. However, extraction rates tend to level off at panel lengths of about 10 m. Grade dilution, i.e. tramming width compared to channel width grades, also levels off, except for the conventional case. Grade dilution is lowest for XLP (see Figure 29).

The effect of costs

Costs are shown relative to the different mining methods. Operating costs are generally lower for mechanised mining methods than for conventional mining. Mechanised mining has a smaller labour force, but this is offset by an increase in maintenance costs and a higher unit cost for labour. Normally the trade-off is in favour of mechanisation. Figure 30 shows a comparison of the influence of costs (relative). These costs have been synthesised and are only shown as a trend. On-mine cash costs are highest at the conventional end of the scale. Capital costs are highest at the mechanised end. However, it is important that capital costs should not escalate and kill the project.

Currently costs favour mechanisation. XLP costs will improve with time and usage.

Grade and content

Changing from normal room and pillar mining to T-cut showed a marked increase in the shaft head grade. The move to mechanised dip pillar method again showed a marked improvement. Conventional mining has a better grade but XLP produced the best head grade (see Figure 31).

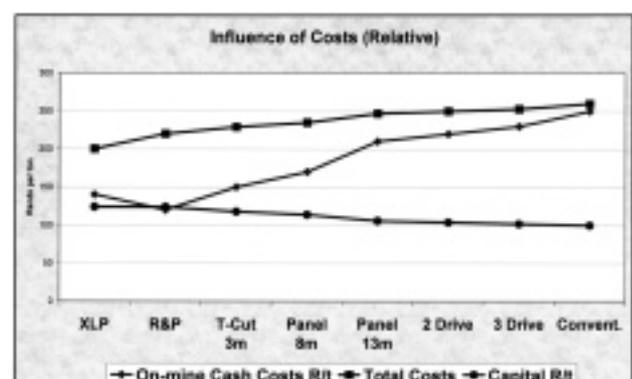


Figure 30—Comparison of relative costs

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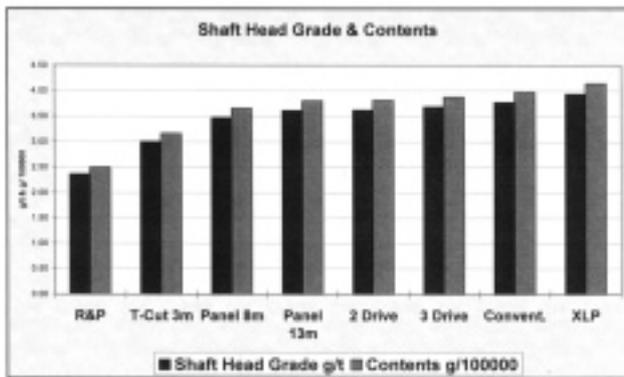


Figure 31—Comparison of shaft head grade and contents

Training and retraining

Australian miners have indicated that the learning curve takes up to three years for a mine to convert to trackless mechanised mining methods. The full potential of mechanised mining has not yet been reached in mining the UG2. The best way to ensure that South African mines have a well-trained competent labour force to meet the challenge of mechanised mining is through training and retraining. The full potential of mechanised mining has not yet been reached. The following may help to achieve this

- The commitment and skilling of senior management is essential
- All levels of management must be involved and trained in trackless mining

- A trackless mining culture must be developed among all employees. This is especially important for those who come from a conventional mining culture. Don't just expect people to know what the new culture is
- An incentive scheme should be developed for all operational and maintenance staff
- Proper selection procedures must be used
- Develop a team spirit with a will to win among all stakeholders.

Conclusion

Trackless mechanised mining methods have had a baptism of fire in recent years. However, progressively more and more operations are proving that trackless equipment is the way to the future. The challenge for mining engineers will be to design and operate mines that can extract the purest product at the lowest cost. The best mining method option is to design a method that can effectively use ultra low profile equipment.

There is still a great deal of room for improvement using low profile equipment, both in efficiency and mining layout. The future looks bright for ultra low profile equipment which can mine at 110 cm stopping width. As and when the equipment proves its reliability and cost effectiveness, more and more mines will change over.

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Displacement meter with logging facility from Vanguard Digital*

Due to the increase in deeper mining and the awareness of safer mining techniques, monitoring of rock movement has become significant in identifying different geotechnical areas, hazardous conditions and improved support design.

Boksburg company, Vanguard Digital, has patented an inexpensive high-speed microprocessor-based displacement meter with logging facility, designed to continuously monitor stope closure. The Closure Meter logs analogue input from a multi-turn potentiometer at periods that are programmable from 1 second to 1 day.

The Closure Meter is telescopically spring loaded and is easily installed between the roof and the floor of the excavation. An extension PVC pipe can be used to extend the operating length of the Closure Meter. Logging is activated by means of the Handheld Communicator and the meter is then left in position to gather data.

The data is stored in a non-volatile flash memory and can be downloaded to the Handheld Communicator or PC/Laptop via its RS232 port. The data is then captured to the PC as a .csv file for use with MS Excel for reports and graph generation.

The Closure Meter requires dc power of +4.8 V (nominal) at 4mA, which it sources from rechargeable 6 V nickel metal hydride (NiMH) battery packs using 1.2 V cells. The battery life is approximately 14 days when logging at 300-second intervals. The unit has an LED for running indication and also displays battery low.

The instrument is made up of thick-walled PVC tubing for the telescopic parts and the couplings and holders of solid PVC material for robustness. All metal components used in the assembly are stainless steel.

The electronic logger and battery pack housed in the PVC pipe and sealed by means of a removable PVC cap. The cap is removed when replacing the battery pack and uploading data.

The Closure Meter is manufactured by Vanguard Digital and marketed with technical support provided by Seismogen. Contact Tony Ward at 018 788 6222. ♦

* Issued by: Vanguard Digital, PO Box 19939, Sunward Park, 1470. Tel: 011 913-3199; Fax: 011 913-1261 Contact: Ken Falconer