Presidential address: Has the South African narrow reef mining industry learnt how to change?

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Synopsis

The South African narrow reef hard rock mining industry has been stuck in a time warp with relatively little change in the mining process in the last century. This paper presents a methodology on how to implement change in narrow reef hard rock mining. It then explores a number of technologies that have been introduced into this mining industry and the impact that they have had on the mining process. The author then presents his view on whether the defined change process has been followed and sets out to identify the most critical aspect of ensuring that change is successfully implemented. Future demand will also be speculated on.

Introduction

For the last hundred years the South African narrow reef mining industry, typically the gold and platinum mines, has battled to control working costs in a labour intensive industry. The conventional mining methods used in the majority of the narrow reef mining operations were established over many years. The technology developed for these stoping operations, can be categorized as follows:

- ➤ The introduction of pneumatic rockdrills early in the last century. The cumbersome rig mounted units were replaced by smaller, lighter, handheld units that were then made easier to use with the addition of an air leg. (The so-called Swedish method of mining.) As late as the early 1970s some drilling was still being carried out without the assistance of an air leg.
- ➤ Scraper winches to replace gravity and shovels to move rock both in the face and the gullies were first introduced in the late 1920s.
- ➤ Hydraulic props installed close to the face are capable of applying force against the hangingwall as well as yielding in a controlled manner under dynamic load, arrived in the 1960s. In many instances these have now been replaced by yielding elongates fitted with water hydraulic loading devices.
- ➤ Some people argue that the introduction of tungsten carbide inserts, to improve drilling, was also a major change in technology.

The match between current technology and current conventional mining methods has been optimized over many years of practical application. To move forward in a changing world requires the development of appropriate technology and the integration of that technology into an improved stoping system.

Is change important? Should a mining industry with an optimized mining process seek to change? Natural selection is a process by which organisms best suited to their environment become the ones most likely to survive and leave descendants. This process is sometimes called survival of the fittest. In the last twenty years we have seen the gold mining industry remain unchanged in a changing world and the result has been a substantial reduction in the importance of gold mining in South Africa. On the other hand, platinum mining has been driving forward to take advantage of a very strong market.

Where will change add the most value? Safety in all South African mining has improved but the rate of change has started to flatten out (see Figure 1). In June 2007 Lazarus Zim, Chamber of Mines President, when referring to the mining industries commitment to health and safety performance stated: 'The fact that we lacked improvement in 2006 is a considerable blow to us all. It rather invigorated us to a different course of action. More of the same is not going to do the trick.' To kick-start a substantial improvement

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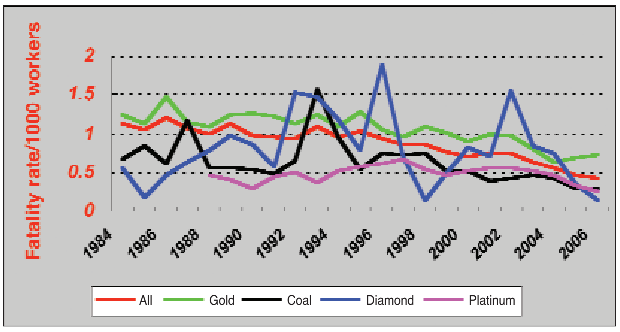

Figure 1—Annual fatality rates in South African mines

in safety a new initiative to change the mining process is required. The more traditional approaches to increase safety are having a reduced impact and 'more of the same is not going to do the trick'.

In the late 1980s and early 1990s COMRO developed an economic model of narrow reef mining processes. The motivation for the development was to gain a better understanding of the mining process and hence the most sensitive activities where change would have the most impact. The model was an activity-based model and was applied to five substantially different mining operations. The operating costs of these mines varied by a factor of 1.6 but the overall cost distributions were substantially similar and are summarized in Figure 2.

Further investigation of the data shows that in a comparison between stoping tons and development tons mined, the cost of breaking and loading a development ton is approximately 1.8 more expensive than breaking and loading a stoping ton. These relationships serve to demonstrate that appropriate measurement tools do exist and that they can be applied to identify where change should be implemented.

There have been numerous attempts to introduce different technologies into stoping, the most obvious being the use of trackless equipment. This trackless equipment was usually developed for other mining operations and 'shoe horned' into narrow reefs. In many cases the outcome has been what is referred to as 'hybrid' mining. The mining is carried out using conventional methods; and access to the ore body and transportation of the reef is carried out using trackless equipment. Generally, where the stoping layout suits the technology, trackless mining has been successful.

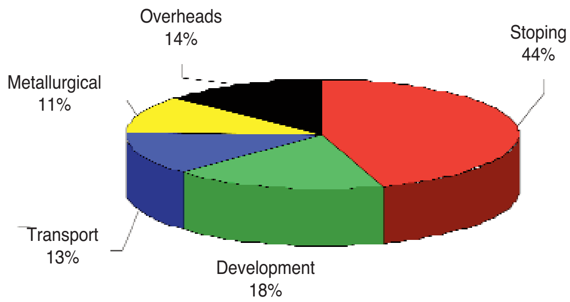

Figure 2—Distribution of activity based costs for narrow reef mining

However, in the history of our mining industry there have been too many instances where a technology has been installed because it is fashionable and not because there has been a clear understanding of the 'added value' that such a change will bring.

We have to change and the introduction of change is something that none of us is good at. At the end of the day the result of change has to be safer and more cost-effective mining systems. Change is likely to be effective only if the introduction and application of appropriate technology can be integrated into the development of a suitable mining system.

Application of new technology

The following section is a basic change management process. It is applicable equally to the development of new mining technology as it is to the application of existing technology in a new mining method.

The implementation and application of new technology in the mining industry is a difficult process and has often been unsuccessful. However, it is also important that we are able to learn from our previous experiences to ensure that the installation of new technology is more successful in future. It is well known that safe production can be achieved only with a combination of the right equipment, trained people, and appropriate operating procedures. The purpose of any technology implementation plan or technology transfer process is to ensure that the identified objectives are achieved. At a workshop attended by senior people in the mining industry it was determined that the most important issues that govern the successful transfer of technology are as follows:

- **Recognizing needs and understanding benefits**
  - People at all levels in an organisation must see the benefits of the technology for themselves.
  - The need addressed by the innovation and the corresponding benefit may have to be described differently to the various levels in the mine or organization.
  - Mine staff should be involved in the need definition process at an early stage to ensure that real needs and quantified benefits are recognized and appropriately described.
- **Appropriate technology**
  - A new technology must be appropriate to the skills of mine production and maintenance staff, and it must be sufficiently robust to withstand the underground environment.
  - It must address real and current needs.
  - Sophisticated technology must be 'invisible' to the end user.
- **Champions and leaders**
  - Champions are essential at all levels in the mining hierarchy. They must be identified early and adequately supported by their superiors and the staff involved in the technology transfer.
  - Championship is a managed process, and champions should be created at all the stages of the transfer process.

- Good champions are innovative, successful leaders with credibility and integrity.
- Champions are more objective than passionate about the technology they are promoting; they put success of the technology above personal ambition.
- Leaders create the environment that will allow change to flourish.

➤ **Management of the technology transfer process**
- The introduction of new technology, although a complex process, can and must be carefully planned and managed.
- Technology transfer plans must be compiled early and reviewed regularly, to ensure that the need and the solution remain relevant.
- It is easier to transfer incremental change than it is to transfer technologies that result in significant changes in work practices.

➤ **Mining people**
- People in the mining industry rely heavily on word-of-mouth to gauge the effectiveness or otherwise of equipment trials.
- The training of people in the application of new technology requires a professional approach and is required at all levels of the mine.
- People must be educated in the concepts on which the new technology is based.
- Unanticipated consequences during the introduction of new technologies can lead to failure of the technology transfer process.
- Technology suppliers should underpromise and overdeliver.

The most important issue when introducing change is to understand the nature of the change and the impact that it will have on the mining process. The mining engineers are responsible for devising the mining process, and other engineering disciplines are responsible for developing appropriate technology. There are a number of different ways that the process and technology can interact.

Existing mining system	and	Existing technology
Existing mining system	and	New technology
New mining system	and	Existing technology
New mining system	and	New technology

The important thing to remember is that new is not necessarily totally new; in many cases it is just new to that segment of the mining industry.

Existing mining system—existing technology

In this case the mining process is not changed and an existing technology not currently used in the industry is introduced. This technology exists in a different application. A good example was the use of water jets to move rock. Water has been used to assist in the scraping of rock down the stope face and for 'monitoring' china clay for many years. The use of high pressure concentrated water jets to provide a more positive movement to the rock in the stope face was relatively easy to introduce and resulted in better and more efficient stope cleaning. COMRO demonstrated face cleaning rates twice those achieved with scraper cleaning only.

However, even such a small change resulted in much debate and there were two diverging views as to the efficacy of a small diameter, high pressure jet as opposed to a larger diameter, lower pressure jet. Another issue was gold loss, with some swearing that mine call factor improved and some that it decreased; in different applications it is possible that both arguments were correct. The dominant technological issue was how to design the pumping system to provide the high pressure water. Many different pump designs were purchased and installed with varying life times and return on capital invested. The ultimate solution was probably the introduction of hydropower.

The need was for a better face cleaning system. Almost any water jetting system will give a faster face cleaning system. However, the bottleneck in stope cleaning is usually the strike gully cleaning and this was not improved by water jetting. The benefits to the mine were not clearly quantified, as demonstrated by the ongoing argument about gold recovery/loss from water jetted stopes. If they had been better understood then there would have been less argument about the water jet configuration and how it was to be used.

The technology was seen as simple and not complex and was quickly adopted by the gold mining industry. However, almost any one who had a pump to sell made good money and there was a large variety of water jetting guns, some of them downright dangerous.

All the mining houses had their own **champions** who swore that their solution was the best. There was little real attempt to systematically quantify the real benefits.

Judging by the large number of different water jetting systems implemented by the industry it is fair to say that the **technology transfer process** was not managed but just happened. Much of the gold mining industry embraced water jetting. Water jetting was not used in the platinum mines as water is generally regarded as causing complications in platinum mining. However, the first hydropower equipped mine, which makes extensive use of water jetting, was Northam Platinum.

Existing mining system—new technology

This change is relatively easy to implement, as is any change that does not affect the existing mining process; the main issue relates to the effectiveness and efficiency of the new technology to replace the existing technology. A good example is the introduction of water hydraulic rockdrills in place of pneumatic rockdrills. As gold mining got deeper the effectiveness of pneumatic rockdrills decreased. This reduction in drilling rate was partially caused by poor maintenance of the compressed air distribution system and a corresponding reduction in rockdrill operating air pressure, and partially by the more intense face fracturing of the rock. The fractured rock acted as a brake on the drill steel and more of the available energy in the rockdrill was used to rotate the drill steel, with less energy being available for breaking the rock. The water hydraulic rockdrill was designed to have a separate rotation mechanism with a higher torque and though the blow energy was the same as the pneumatic rockdrill operating with design air pressure, the frequency of the blows was twice that of the pneumatic rockdrill. Thus, the water hydraulic rockdrill was capable of drilling in fractured rock conditions at twice the rate of the pneumatic rockdrill.

The need being satisfied by the developers of the water hydraulic rockdrill was to develop a more productive blast-hole drill that could operate at a higher rate and in fractured ground conditions. The operators initially enjoyed using the drill as it was quieter and did not produce fog. The expectation of mine management was that they would be able to halve their drilling crews and achieve the same output.

The technology took longer to develop to a satisfactory reliability level than was initially anticipated. The introduction of water hydraulic drilling was further complicated by the need to introduce a high pressure water generation and reticulation system. The maintenance of both the drill and the high pressure water system required a higher level of skill than that required for pneumatic rockdrills. Ultimately, water hydraulic rockdrills became a practical proposition only with the introduction of hydropower.

There were definitely **champions** of the technology development as this was a major initiative of COMRO in collaborative partnership with a number of equipment manufacturers. Subsequently, there were champions and leaders in Gold Fields who determined that Northam Platinum would be a hydropower mine and that water hydraulic rockdrills would be used for blast-hole drilling. They were also implementation champions who took on the challenge of starting a new deep level mine together with the introduction of new technology. Water rockdrills are currently being used at Northam, Tau Lekoa, Kloof and Beatrix mines.

Being a new mine Northam started with new labour so there had to be a start-up process. However, the implications of mining with hydropower were not fully appreciated and much of **the technology transfer process** had to be resolved as and when the different issues were identified. The technology transfer process could have benefited from a closer partnership between the developers and the mine.

New mining system—existing technology

The technology has been developed for a different application. The technology is proven but the process needs to be developed. Hybrid mining is a good example of this process. In the 1980s a number of narrow reef mines in gold and platinum mining introduced trackless mining. This was a substantial departure from conventional narrow reef mining as practised in South Africa. Existing equipment, used in other trackless mining operations, was applied to novel mining layouts. There were a number of mines that used trackless equipment for narrow reef mines but the only mining operation that has stood the test of time and is still in operation today is the Declines at Union Section. The information contained in this paper is taken from Alistair Knock's MSc dissertation.

The UG2 reef at Union Section is approximately 1.5 metres in width and dips at an angle of 16°. The mining method of choice was to carry out all development on the reef horizon. Basic development consists of roadways and ramps sized to accommodate 25 ton trucks. The width of the roadways was set at 4.5 metres to suit the trucks that were 3 metres wide plus clearance of 0.75 metres per side. The hangingwall of all excavations was profiled by the top contact of the reef and was 4.8 metres high at the highest point, to accommodate a 1.015 metre diameter exhaust ventilation column, and 4.4 metres high at the lowest point. Roadways were positioned on apparent dip and 300 metres apart. The advance strike drives (ASDs) were driven just above strike to ensure a negative gradient for water control. The width of the ASDs was 3.5 metres to suit the ST3½ LHD with a clearance of 0.8 metres on either side. The height of the ASD was 3.5 metres, in the centre, to accommodate the face drill rig and the roof bolter and 3 metres high at the down-dip side.

All development drilling was with a Secoma Pluton 17 single boom drill rig, drilling a 3.3 metre blast hole and giving an average face advance of 3 metres. Support was with a diesel powered automatic roof bolter designed to drill support holes, install resin cartridges, insert a ripple bar while spinning to mix the resin, and finally to tighten the nut against the washer to tension the bolt. Given the 3.5 metre height of the smaller development ends the maximum length of bolt that could be installed was 2.1 metres, the bolting pattern was five bolts per metre advance.

Ore and waste hauling was with LHDs in the ASDs. The length between roadways was 300 metres, giving a maximum haul distance of 150 metres. The LHDs loaded into trucks in the roadways for hauling to surface.

Stoping differs little from that practised in the longwall mining sections at Union. Panel lengths are confined to 33 metres between ASDs. Drilling is with conventional lightweight pneumatic rockdrills, drilling three rows of 1.4 metre deep blast holes at 85° to the face, using 32 mm to 28 mm integral drill steel. Blasting is with 25 mm emulsion sausages initiated and timed using Nonel Reefmasters. This has resulted in extremely good fragmentation and in excess of 50% of the broken rock being thrown into the lower ASD.

Support in the panel was achieved using 5 m x 5 m reef pillars at the top of the panel, sticks without headboards on a 2 m x 1.5 m pattern, grout packs on a 5.5 m x 4.2 m pattern and camlock props for temporary support in the face.

One of the main issues was that of dilution as a result of the large size of the development and because all the development was on reef. To control dilution all reef ends were double blasted. The bottom or waste cut was blasted first, leaving a waste bridge of 400 mm intact below the reef. The LHD cleaned out the waste before the reef band was dropped by blasting the top two rows of holes.

The conclusion reached by Knock was that 'The introduction of a trackless mechanized mining method to Union Section can be termed a significant success. Union Section has proved that mechanized methods can be installed in narrow seam environments as an alternative to labour intensive methods without sacrificing operational costs. However, the section has also highlighted the limitations of mechanized mining methods in a narrow reef orebody. In particular the generation of waste and the cost of dealing with it were higher than expected.'

The need addressed was partially to keep development on reef to give a quick return on capital expenditure. A second objective of introducing mechanization onto the mine was to reduce the labour required. In practice the reduction in labour over conventional mining methods is often less than predicted in feasibility studies, with a corresponding adverse effect on profitability. At Union the productivity in the mechanized section, measured in reef tons mined per total worker, was about 80% higher than in the conventionally mined section.

The technology employed resulted in an overall operating cost of the mechanized section being similar to the operating cost in the conventionally mined section. However, in more recent times the design of the trackless section has been revisited. Conveyors have been installed in the declines and the ASDs and low profile mechanized mining equipment has been used for all the development and for loading the conveyor belts. Sandvik has supplied the Axera LP-126, the EJC 115 and the Robolt LP. This equipment can all operate in a minimum height of 1.8 metres. The corresponding reduction in the size of the access ways has resulted in the waste dilution being reduced from 18.8% to 11,1%. Thus, further refinement of the process and of the technology has increased the profitability of the mining operation.

The champions for the introduction of trackless mechanized mining were clearly part of the old JCI stable as they started a number of trackless mining operations.

This was a new mining operation and managed separately from the conventional mining operations. It is clear from the study carried out by Knock that the **technology transfer process** was a managed activity.

Production at Union Section commenced with about one million tons per year in the early 1980s, from one decline, and is currently producing 2.9 million tons per year from four declines with plans to further increase production to 3.4 million tons per year. What is surprising is that despite the number of mechanized mining operations introduced into the platinum mines in the last eight years, the mining industry has not chosen to apply this particular mining method to more new mines.

New mining system—new technology

This is the most difficult of all the change mechanisms and requires real vision to be able to see how the new technology can be integrated with a new process and produce a real benefit, particularly when the benefits of the process and the effectiveness of the technology are unverified. This is also the change process that is most likely to have the maximum impact on the safety and cost-effectiveness of mining. Because it is so radical it requires a more thorough understanding of mining processes, and the maximum impact will come from the change together with a comprehensive understanding of exactly what can be achieved with technology.

In September 2001 a project was initiated with the objective of developing a mechanized mining system that could operate in a narrow reef, hard rock mining environment having a stope width of 1.1 metres. The suite of equipment developed was known as extra low profile (XLP) or ultra low profile (ULP). The process started with an extensive get-together of the Sandvik manufacturing companies' representatives and the representatives from Lonmin.

It was recognized that changing the technology without changing the mining method was unlikely to result in an optimum mining method. By this time the chrome mining industry had made extensive use of low profile mining equipment to successfully mechanize mining with a stope width of 1.7 metres, the mining method of choice being room and pillar mining. Mining at 1.1 metres would create its own specific system problems but it was not necessary to create a totally new mining method. However, its application would be new in platinum mining. It was recognized at an early stage that it would be difficult to integrate mechanized stoping with the use of sticks or hydraulic props as a support methodology. This, in turn, highlighted the importance of developing and integrating a suitable roofbolting support strategy. Figure 3 shows a typical room and pillar mining layout, with room and pillar dimensions designed for platinum mining.

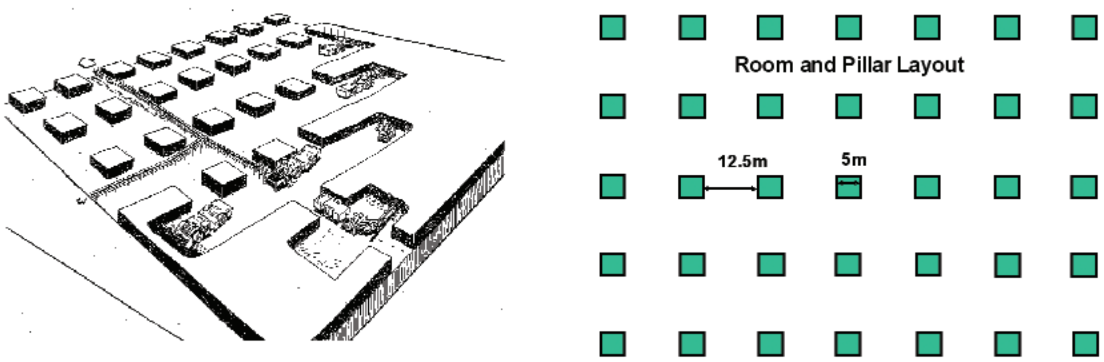

Figure 3—Room and pillar mining layout

Conventional platinum mining had a shaft head cost of about R120.00 per ton. In areas where mechanized low profile room and pillar mining was practised in platinum mining the shaft head cost was R75.00 per ton. However, the higher mining width of 1.7 to 1.8 metres results in cost per reef ton being similar to conventional mining. About 35% of areas currently being mined, or planned to be mined, consist of the UG2 reef at dips of less than 14°. This was determined to be the market tackled by this project as the UG2 mineralization is typically less than 800 mm in width.

The equipment fleet was required to be not more than 850 mm in height, giving a clearance of 150 mm under and over the machines; the total fleet was specified as being:

➤ A two-boom face drill, drilling 1.6 metres long blast holes. It was possible to drill longer holes but it was decided to limit hole length to cater for reef rolls. This rig would drill the face and the splits.
➤ A roofbolter to install bolts in the stope face area, typically between 1.2 and 1.6 metres in length. This bolting requirement necessitated the development of a new drifter only 300 mm in length.
➤ A new xtra low profile LHD capable of operating in this very restricted environment. The LHD was used to collect ore from the blast and transport it back to a conveyor belt loading point not more than 50 metres behind the face.

The equipment was designed and manufactured in a period of one year before being shipped to South Africa and the start of mining. The short time between start of manufacture and shipment, together with the unavailability of suitable test sites where the equipment was manufactured, led to only functional testing of the equipment before installation on the mines. When operating underground a number of design flaws were encountered and it was not possible comprehensively to evaluate either the mining method or the equipment. This situation was exacerbated by different mining companies running separate trials of different mining methods. The main problem with room and pillar mining was the long distances that the LHD was asked to travel. In traditional mechanized mining it is normal to look at a one way travel distance of 75 metres. With the relatively small capacity of the LHD and the necessary slow speed because of the restricted height the LHD became the bottleneck. Over a period of time it became obvious that a different mining method was more appropriate for this narrow reef mechanization and mechanized breast mining was conceived and developed.

Mechanized breast mining is described below and the mining layout and equipment used shown in Figure 4.

Reef access is on the reef horizon, rather than in the footwall. The major benefits are advance information on the orebody and that the excavation pays for itself. The major disadvantages are that the excavation has to follow the reef and is not suitable for traditional railbound transport. To cater for reef variations and the need for water drainage, this excavation has to be substantially above strike. Access dimensions will be determined by the equipment used, typically 3.5 metres wide and 1.7 metres high on the down dip side of the strike gully.

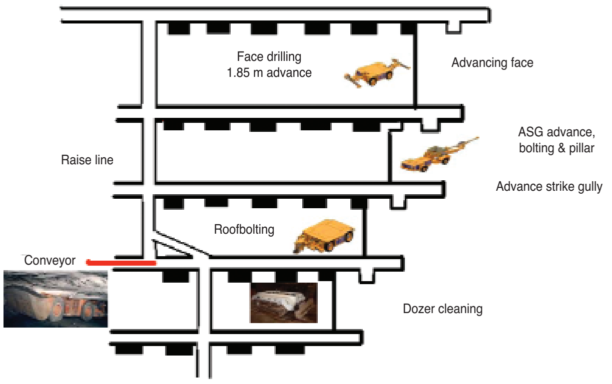

Figure 4—Mechanized breast mining

Stope faces are as long as is practical, given the constraints of face drilling equipment and minimum pillar spacing determined by rock mechanics considerations:

➤ The face drilling constraint is a function of shift time and equipment drilling rate
➤ The maximum skin to skin dimension between pillars is currently about 33 metres
➤ There has been good experience from Union Section over the last twenty years that these pillar dimensions and the use of elongate support elements provides practical and safe mining.

The extraction ratio is higher than room and pillar mining. Work by CSIR for PlatMine has shown that grout packs can be used to replace pillars. With advance orebody information it is also practical to use ore loss from potholes as regional support, grout packs for area support and roofbolts for face area support.

Assuming a mining process that allows two blasts per twenty-four hours, then a minimum of three stope faces is required: one to support, one to drill prior to blasting and one to clean. In practice, to accommodate the ground loss due to potholes and other discontinuities, there should be at least five and preferably six faces available per equipment fleet.

Roofbolts are installed as face side support, leaving an open area between the face and the first row of elongates or grout packs of five to ten metres.

The advance strike gully is carried between five and eight metres ahead of the panel face. Gully roofbolts are installed after the roofbolt holes have been drilled with the Axess Gully Rig and then the face is drilled by the same rig. Where

Figure 5—Axess rig for gully development

necessary this unit also drills the down-dip sidewall to create what will be the pillar holings as the down-dip face advances. This procedure ensures that ventilation is kept along the face. The Axess Rig is shown in Figure 5.

At Karee Mine, in the Merensky reef, face drilling is 2.0 metres in length and advance per blast is 1.95 metres.

A large portion of the reef is blasted into the reef gully and the balance is pushed into the gully by the remotely operated bulldozer. The rock in the gully from both the face blast and the gully blast is loaded by the 777 LHD and trammed to the conveyor loading point. The conveyor tipping point is advanced after every 60 metres face advance.

Conveyors are installed every fourth gully and the LHD loads from the three faces above and the one face below the conveyor. To provide access to the loading point, the stope width is opened out to a height of 1.7 metres and a width of 4 metres in the raise line, using the XLP face rig. Following the second blast in this higher section the broken rock is levelled by the bulldozer and the next round is drilled at the normal stope width of 1.2 to 1.3 metres.

After completing their face activities, the face drill rig and roofbolter are returned to the top of the panel, back along the gully, down the raise, along the gully and into the lower face. When they reach the bottom of the section, the units are loaded onto a skid and dragged to the top of the series of faces by the 777 LHD. The cycle is then restarted. To maximize equipment utilization it is imperative that the cycle of activities is maintained.

The need for mechanization in the platinum mines is driven primarily by the need for *safe, cost-effective production.* It is also getting more difficult to recruit handheld rock drill operators. The job is dangerous and 25% of the platinum mining incidents/accidents occur within five metres of the face. It involves hard physical effort and has lost the 'macho' status that it once occupied. HIV/AIDS is also an issue, with probably up to 30% of the workforce being infected. When feeling sick the last thing on an individual's mind is hard physical effort. The average age of the current rockdrill operator work force is greater than 45 and the high noise levels have resulted in ever increasing occupational health costs.

Mining at a stope width of 1.8 metres, as with the LP equipment, compared with the targeted 1.1 metres results in a lower grade product. This, in turn, results in less precious metal recovery and an increase in cost per ounce.

Figure 6—Remotely operated bulldozer

Implementation of the technology will require recognition of different needs. Mechanization is a substantial departure from conventional mining and all levels in the mine, from operators to senior management, will require training to learn the necessary skills.

The **appropriateness of the technology** was determined in underground trials. Underground trials have two main components: firstly, the need to demonstrate that the equipment carries out the function that it was designed for, and secondly, that the mining method employed is adequately productive.

With the XLP fleet of a face drill, roofbolter and LHD there were a number of teething problems. This was mainly because in developing the XLP fleet Sandvik followed a different development route. The more normal approach is to develop a new machine and then conduct extensive trials in a controlled environment. In this case the new machines were rushed into production environments and the result was an integration of the equipment performance trials and the mining method trials. The performance and reliability of the individual pieces of equipment varied.

- The face drill was very much the star of the three machines and has seen relatively little further development. The incorporation of independent wheel movement was a big success, and these machines have not experienced any problems of grounding the frame and the machine getting stuck.
- The roofbolter body was fine but the drilling feed has seen a number of developments and is currently on about the fourth generation. A big breakthrough was the successful introduction of the ultra-short drifter. This drifter was developed specifically for this bolter and is only 300 mm in length compared to the more normal dimension for a drifter of this power of 650 mm.
- The loader was a different story. To operate successfully it needed to push into the rock rather than load up the front of the rock pile as in conventional LHD operation. This put high tramming loads on the tyres, and these were originally fitted with chains to provide good traction. This solution was expensive and it was difficult to keep the chains tight and effective on the small wheels. A second solution was to develop a new tyre that gave a reasonable life and good traction. It was also impossible to design a machine having a relatively small footprint with a conventional mechanical drive transmission. Consequently, the loader was designed with a fully hydraulic powering system with hydraulic wheel motors. The hydraulic solution employed was not entirely successful and much effort was expended to get the hydraulics to work efficiently.

However, the choice of mining method and the application of the equipment were equally problematic, probably even more problematic than the equipment issues. This is probably because the technical issues can be seen and understood by equipment designers and solutions quickly developed and tested. It is more difficult to bring about major changes in the mining layout expeditiously and this was coupled with a shortage of mechanized mining expertise that was available to design optimal layouts to maximize the potential of the equipment.

- ➤ The low profile equipment had mainly been used in a room and pillar mining layout, and at an early stage it was decided that the XLP fleet would be used in a similar layout. Initial trials were using the equipment for room and pillar mining. Some of the early problems encountered were related to blasting, and a full advance of the face was rarely achieved despite the input of 'blasting engineers'. Room and pillar mining has a relatively large number of faces, and moving equipment from one short face to another consumed a lot of production time. The tipping points for the LHDs were often 60 to 100 metres away from the loading point and it was soon realized that the constricted mining height limited tramming speeds and equipment productivity. This was the biggest drawback of room and pillar mining. The implementation of XLP mining was further complicated because there were three different XLP room and pillar mining trials going on at the same time.
- ➤ Attention was then focused on a mining layout that has a closer relationship to conventional mining. Longer panels cleaning into a gully with rock movement in the gully with larger, more traditional LHDs, would tip onto belt conveyors. Thus, the merits of on-reef mining with no footwall development would be realized; extraction ratios would improve; and the mining sequence was more easily understood. The layout was called mechanized breast mining.

To make all this happen in the period of five years there were a number of **champions** both on the equipment suppliers side and in the mining companies operations. However, the single most important factor in ensuring success was the partnership relationship that existed between the mine and the equipment supplier. The net result is that between now and 2011 Lonmin Platinum plans to ramp up production, from mechanized breast mining from the current one million tons to eight million tons per year. Anglo Platinum plan to increase production from hybrid and full trackless mechanized mining from 41% of 33.8 million tons per year of underground production in 2006 to 48% of some 43 million tons of underground production in 2011.

Comment

The change that comes from existing mining systems using existing technology is only incremental and marginal. Water jetting undoubtedly reduced the time taken to clean the stope face. It also resulted in clean back areas as sweeping was carried out concurrently with face cleaning. However, it did not reduce the time for stope cleaning as there was no improvement in strike gully cleaning rates.

The introduction of water hydraulic drilling into conventional stoping, in place of pneumatic drilling, provided a tool that has twice the productivity of the pneumatic rockdrill. Thus the number of rock-drillers exposed to occupational health and safety risk is reduced. It would appear that the need to use hydropower has reduced the acceptability of water hydraulic drilling and the perceived benefits from large-scale implementation are not being achieved.

The example of hybrid mining used at Union Section utilizes a new mining system and existing technology. Union Section proved that mechanized mining methods can be installed in narrow seam environments as an alternative to labour intensive methods without sacrificing operational costs. Productivity was 80% higher than in conventional mining. The downside in the 1980s was dilution of the ore from the large advance strike drives. The profitability of the mining operation was subsequently improved through a reduction in dilution achieved by the introduction of a new technology in the form of low profile mining. The use of low profile equipment has moved Union Section into new mining system and new technology, and the mining method must be considered a success with nearly 10% of Anglo Platinum's underground production coming from this mining method.

The development of the XLP fleet of equipment and mechanized breast mining is a new technology and a new mining system. Trials of both the equipment and the technology have been ongoing for a number of years. The issues that have been addressed by the mining companies involved in these trials can be summed up by *safe, cost-effective production*. The decision to implement XLP mining by both Lonmin and Anglo Platinum to the extent of some 14 million tons per year demonstrates that XLP mining is safe and cost-effective.

The examples quoted all have the defined necessary ingredients for successful change. It would appear from the above that small changes associated with water jets and water hydraulic drilling fall into the category defined by Lazarus Zim as 'More of the same is not going to do the trick'. To make the breakthrough and advances necessary to propel narrow reef hard rock mining into the 21st century requires the development and introduction of new mining systems and new technology.

How is the industry to achieve the substantial change that new mining systems and new technology demand? Past experience indicates that there are two prime drivers in partnerships and leadership. Partnerships occur when two or more organizations share a vision that neither can achieve without the active participation of the other. Leaders create the vision out of which partnerships grow. What are leaders? A definition coming from one of those management gurus is that leaders influence decisions. I think that in my own way I have been a leader, if this definition is used, as have many of those with whom I have worked. However, I have not had to make hard decisions about the implementation of change that could have a substantial impact on the business that I am employed to run. Again a quote from Lazarus Zim on the need for leaders to walk the talk: 'Our focus should change from the behaviour of others to the behaviour of ourselves'.

The following offer some definition of leaders.

- ➤ 'Don't be afraid to take a big step when one is indicated. You can't cross a chasm in two small steps.' David Lloyd George.

- ‘Example is not the main thing in influencing others, it is the only thing.’ Albert Schweitzer.
- ‘People ask the difference between a leader and a boss…The leader works in the open, and the boss in covert. The leader leads, and the boss drives.’ Theodore Roosevelt.

Leaders are instigators of change and by their example drive forward into a new future. Good leaders who look to better the world are people like Mandela and Ghandi. They have real stature and engender respect. Real leaders are those who eat, sleep and live the addition value that comes from change and who understand the value of the benefits that will accrue as a result of change. An MD with good strategic vision, when making company decisions, constantly referred to the vision and determines what impact each decision would have on the vision.

Has the narrow reef hard rock mining industry learnt how to change? Most definitely. It is also clear that change takes time and that there will always be the early adopters at one end of the spectrum and the laggards at the other end. The key requirement is leadership, and our industry has had some truly remarkable leaders. Where are the next major changes required? I believe we need the technology and mining process to improve the steeply dipping hard rock gold mines, plus the ultimate goal of the development of a cost-effective non-explosive continuous mining process for narrow reef mines. Can a partnership of equipment suppliers and mining companies achieve these objectives? In my view—yes; it just takes leadership.

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