PICKERING, R.G.B., DU PLESSIS, A.G., and ANNANDALE, G. Hard-rock room and pillar mining best practice industry workshop. *The 4th International Platinum Conference, Platinum in transition 'Boom or Bust',* The Southern African Institute of Mining and Metallurgy, 2010.

# Hard-rock room and pillar mining best practice industry workshop

R.G.B. PICKERING, A.G. DU PLESSIS, and G. ANNANDALE
*Centre for Mechanised Mining Systems at the University of the Witwatersrand*

The Centre for Mechanised Mining Systems at the University of the Witwatersrand recently organized a Hard Rock Room and Pillar Mining Best Practice Industry Workshop. Eleven different mining companies and mining operations from Southern Africa shared the details of how they organize their individual mining operations and what productivity they obtained from the mechanized equipment. There were also presentations on the history and on the future potential of hard-rock mechanized room and pillar mining in Southern Africa. Four different subjects were then specifically discussed in facilitated breakaway groups, namely equipment selection and utilization, maintenance, shift cycles and staffing; and layout and ore handling.

The outcome of the workshop has been the development of best practice guidelines for narrow reef mechanized room and pillar mining in Southern Africa. This paper describes the input and outcome of the workshop.

## Introduction

The *Encyclopædia Britannica* states that: 'In room-and-pillar mining a series of parallel drifts are driven, with connections made between these drifts at regular intervals. When the distance between connecting drifts is the same as that between the parallel drifts then a checkerboard pattern of rooms and pillars is created. The pillars of ore are left to support the overlying rock, but in some mines, after mining has reached the deposit's boundary, some or all of the pillars may be removed.' On the face of it, quite a simple definition; however, room and pillar mining as practised in the narrow reef hard rock mines in Southern Africa is not so simple.

In recognition of the complexity of hard-rock room and pillar mining, the mining industry sponsors of the Centre for Mechanized Mining Systems at Wits University requested that the Centre design and facilitate a Best practice workshop on the topic. The objective of the workshop was to provide a forum for mine operators and others in the industry that have a direct interest in room and pillar mining to enable them to exchange knowledge, practical experiences, ideas and innovations relevant to room and pillar mining in hard-rock mines. Mining companies were invited to present their experiences, where the major issues that influence mining performance and safety were discussed in facilitated peer-group workshop sessions.

This workshop received presentations from eleven different mining companies, ten of which were chrome and platinum mines, and some of the presentations covered more than one mining operation. It is the information from these ten different companies that will be discussed in this paper.

Overall observations from the presenting companies were as follows:

- The common feature of these mining operations is that virtually all development is on reef with only the occasional mine having a footwall decline for conveyor transport of the ore to surface.
- Rock loading from the face is exclusively with LHDs, typically having a capacity in the range from 3 to 7 tonnes.
- Rock transport from the face area to surface was with conveyors in nine out of the ten cases with only one mine using 30 tonne low profile trucks.
- All the mines use mechanized low profile drill rigs for face drilling but in two cases hand drilling with pneumatic rockdrills is also employed.
- Roof support is typically 1.5 to 1.6 metre resin grouted bolts with 4 to 6 metre long cable anchors used at tips. Four of the operations use low profile mechanized bolters for support installation. Three use Autorock drill units, two employ a combination of hand drilling and Autorock units, and one uses hand drilling only.
- Typical panel length varies between a minimum of 7 metres and a maximum of 12 metres.
- Shift systems are substantially different with some mines having continuous operations and others limiting themselves to an eleven-day fortnight with a blasting frequency of once or twice per day.

What is immediately apparent from the above general observations, is the variety of design and operational approaches to hard-rock room and pillar mining in Southern Africa—one size definitely does not fit all.

## Best practice workshop

The procedure used at the workshop was for the Centre for Mechanized Mining Systems to provide introductory presentations on the Centre's activities and the history of mechanised room and pillar mining in Southern Africa. The various mines then each made a presentation on their operation to a template that had been prepared by the

Centre. Following the presentations from the Centre and from the mining companies, those present at the workshop were polled to see what they regarded as the most important aspects that should be addressed in facilitated working group sessions. The following topics were determined to be the most important and were discussed in breakaway groups:

- Equipment selection and utilization
- Maintenance practices
- Shift cycles and staffing
- Layout and ore handling.

It was recognized that safety was a theme that affected all of the above areas. It was also agreed that rock engineering was a subject that warranted a dedicated workshop in the future, although rock bolting method were addressed in some detail.

The deliberations of the various breakaway groups, and subsequent analysis of the presentations by the authors, are presented below. However, it must be emphasized that the presentations collectively contain an enormous amount of material and any person or organization setting out to implement best practices for hard rock room and pillar mining would be advised to study the material presented in some detail.

## Equipment selection and utilization

The issues identified by this breakaway group, in order of priority, were:

- What is the impact of layout on equipment utilization?
- How is utilization measured?
- How is roof bolting equipment selected? What are realistic bolting rates? How are long anchors installed?
- What is the relationship between OEMs equipment performance figures, those used by mining system designers, and the real practical mine environment?
- Other items raised but not considered in this workshop were: What are fleet selection criteria? What is the spare fleet philosophy?

### Layout

The impact of layout on equipment utilization is governed by a number of variables such as: tramming distances, room sizes, panels per section, numbers of strike conveyors per section, pillar geometry, size and frequency of roof bolt installation, overall face shape, decline development rate relative to production, and build-up rate.

After some discussion the group concluded that with such a large number of variables the only way to address a problem of such complexity was with comparative modelling studies that would also include detailed sensitivity analysis.

Subsequent analysis by the authors indicates that drill performance varies from about 15 000 tonnes/month to 20 000 tonnes/month. There is evidence to indicate that panel length is a critical factor in drill performance. Mines with panel lengths allowing one or two full drill set-ups perform better than mines with panel lengths between 8 m and 14 m. The differences are also influenced by the available shift hours per month.

Loader performance varied between 4 000 and 5 700 tonnes/month. The best performing mine therefore handles 40% more rock than the worst performing mine. Available shift hours utilized and the distance the LHD has to travel to the tip may be factors that impact on loader performance.

In considering the optimal number of rooms per section, the following makes use of some of the presented material and concludes that, when planning how many faces must be available for a single drill rig, it is important that available face is based on the maximum potential production, rather than the average. Figure 1 demonstrates the variability of production over nearly three years on one mine, from drill

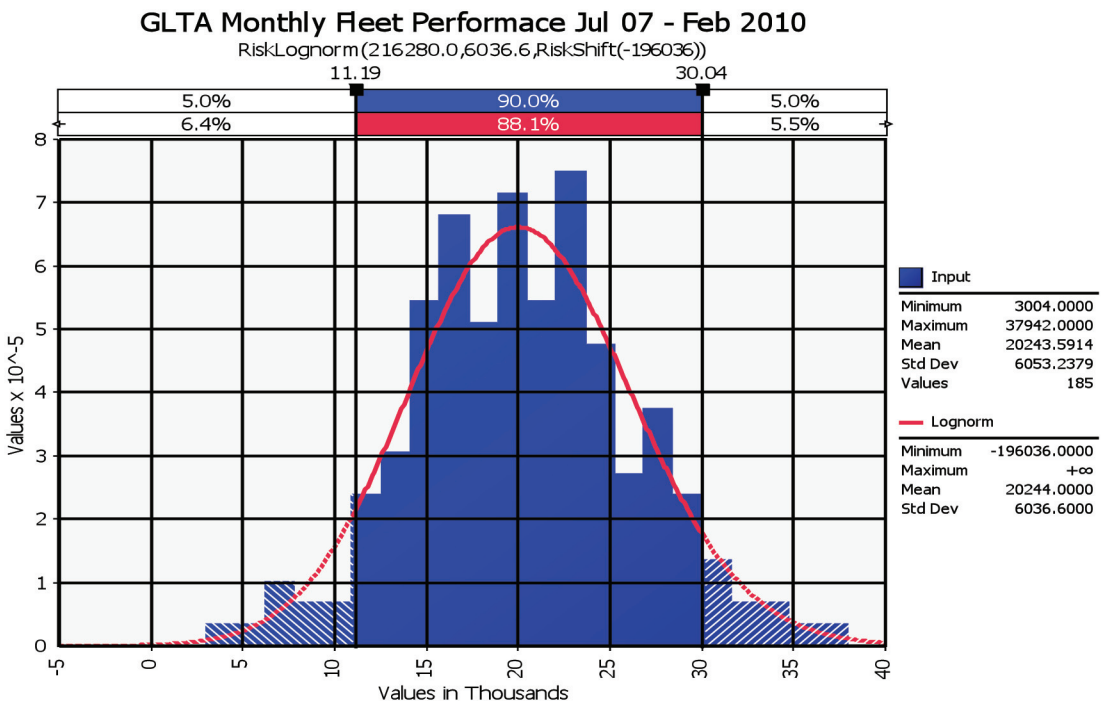


**Figure 1. Accumulated fleet performance over three years**

rig sections with eight rooms, operating two shifts per day of ten hours each, seven days per week and blasting twice per day.

If the number of rooms per section is based on the average production then that becomes the maximum production and it is not possible to exceed the average production. The only way to be able to exceed the average production is to ensure that, on those really good days when everything works well, there is sufficient face length available to exceed the average production. The very high production rates in Figure 1 probably came about because one section was underperforming for some reason such as excessive ground loss, and equipment was moved to supplement production at a section with all eight faces working.

In the above example, the target production is to blast two 12 m rooms every shift. Therefore target production is 12 m × 1.85 m × 2.9 m × 3.8 × 2 × 60 = 29 350 tonnes/month. Reality is different with mean production per section being 20 243 tonnes/month or 69% of target. However, even that is not correct as at least 10% of production is scalped and remains underground.

Figure 2, from a different mine, shows the amount of available face versus what is considered to be the minimum amount required to maintain production.

At the above mine, the average production from a single drill rig section is 16 993 tonnes/month with a maximum production of 23 700 tonnes/month. The mining cycle is three shifts per day for five days per week and one blast per day.

The obvious conclusion of the above analysis corroborates the principle that, in order to achieve optimal production, it is essential that sufficient length is available for mining.

Face required is also directly related to the blasting frequency as with higher blast frequency there is higher face utilization.

**Equipment utilization**

When considering equipment utilization, the issues raised in order of importance were:

- How is utilization measured?
- What is the equipment availability and on what basis is it measured?
- What proportion of 24/7 is used for face activity? What is the mining cycle? What is the shift cycle and hence labour availability? What is the blast frequency?
- Based on the mine design, what is the face availability?
- How does the equipment reach match the room dimensions—especially for drill rigs and bolters?

It was considered that the last three items were the responsibility of the other breakaway groups and that the second item was a subset of the first item.

Discussion clearly identified that there was not a simple answer to how utilization is measured. In the presentations it was clear that different metrics were being applied for LHD utilization and drill rig utilization. For example LHD utilization is based on engine hours and drill rig utilization on percussion hours. The group decided that it was important to measure efficiency of equipment in terms of rate per hour as applied to effective face time, not shift time. However, it was equally important to measure rate per hour based on 24/7 to determine overall system efficiencies. Specific measurements that should be made to enable these calculations to be carried out are:

- For LHDs effective face hours, engine hours, and tonnes handled
- For face rigs and bolters effective face hours, engine hours (for travelling), power pack hours (for operating time), percussion hours (for production activity) and metres drilled or bolts installed.

It seems that the achievement of optimum performance has less to do with the actual design of shift cycles than with managing effectively within the confines of the design.

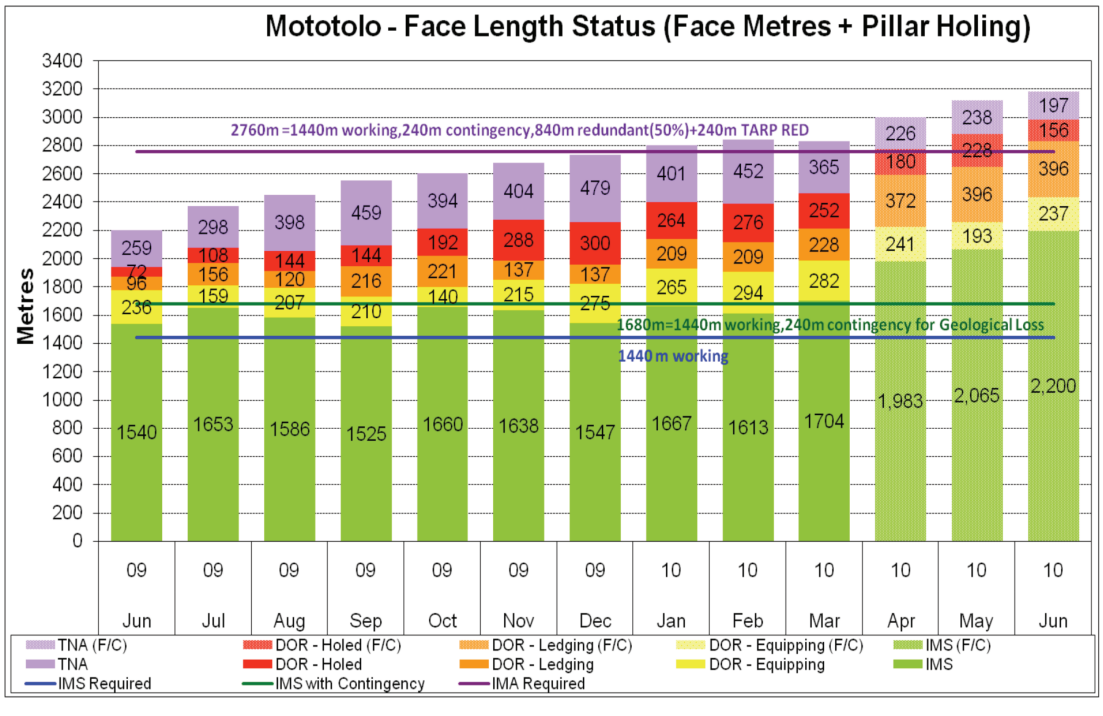


**Figure 2. Available face required to maximize production**

In order to apply control parameters such as face availability and utilization, equipment availability and utilization should be understood and the impact of these on overall performance should be quantified.

A set of metrics should be designed and operating tolerances must be determined. Both operators and supervisors must understand the impact that operating outside of the set parameters has on overall system efficiency.

The factors to be considered to determine the optimal roof bolting strategy were initially thought to be a simple choice between mechanized bolters and the Autorock type of bolting. However, a complicating factor was the increasing need to install long anchors and the ever increasing demand from mine operators to install bolts that are longer than the stoping width. The individual issue identified were:

- Operator exposure
- The variability of the mining height
- Support length and anchorage mechanism
- Required bolting rate to match other mining activities
- Bolting density and bolts required per face advance.

The overall dominating factor was operator safety and it was concluded that the optimal solution was some form of mechanized cable bolter. It was decided that such a solution did not currently exist and that equipment manufacturers should be approached to develop a more efficient mechanized bolter capable of installing longer bolts in narrower stope widths.

Most of the mines employing room and pillar mining are now using systematic bolting patterns and typical bolting patterns are around 1.5 m × 1.5 m with about 1.6 m long, resin grouted bolts, with long anchors being used as required by local conditions. A drill rig section mining 20 000 tonnes/ month or 2 500 m²/month will require approximately 1 100 bolts installed per month. There are fully mechanized bolters available that enable the mine to install bolts without people being exposed to unsupported ground. The alternative of using the Autorock bolting system requires that the operators install safety nets and temporary support before bolting begins.

The relationship between support pattern, panel design and the utilization of predictive tools such as ground penetrating radar or drilling and using a borehole camera, should result in improved bolting support performance. However, there were insufficient data in the presentations to confirm this conclusively. What is clear is that mines with the highest face availability are best able to deal with long bolting cycles.

The equipment performance figures presented by equipment manufacturers, those used by mining system designers and those that are achieved in practice are sometimes substantially different. Performance claims for LHDS, trucks, drill rigs and bolters quoted by manufacturers are derived from first principles and cannot take account of the vagrancies of actual mine operating conditions. To compound this problem, most mine designers use their own performance modifying factors.

The breakaway group concluded that, in order to arrive at best practice, a study should be carried out, possibly as a research project at the University, to consider each item of equipment currently in use and to compare the manufacturer's estimated performance with real on-mine performance.

## Maintenance

The issues identified by this breakaway group, in order of priority, were:

- What is the optimal workshop layout and how should the workshop be integrated with the infrastructure?
- What is the optimal maintenance philosophy? In-house or outsourced maintenance?
- Replacement or refurbishment?
- How can brake testing be conducted when in an underground workshop?
- What are the best and most practical workshop maintenance practices?
- How should spares and logistic support be optimized?
- Other items raised but not considered in the workshop included:
  - An understanding of realistic metrics for availability, utilization, equipment life, equipment operating cost and component life
  - Maintenance shift changeover practices and integration with production shifts
  - Roadway conditions and the impact on maintenance
  - Overall fleet asset management
  - Equipment ergonomics.
  - Best manning practices.

In a mine with a vertical shaft, an underground workshop has to be operational before mechanized mining can begin. The workshop should be located next to the shaft and fitted with a discrete workshop, refuelling bay and wash bay. Water from the wash bay must go to an oil separation unit. Spare part stores, hoses and a tyre bay should be adjacent to the workshop with space for a tyre-handling facility. Care should be taken in siting the workshop to ensure that any risk associated with the flammable components and commodities stored in the workshop is mitigated. There were no specific workshop designs considered other than it should be fit for purpose.

Satellite workshops should never be more than 500 m from the face and preferably at the miners' waiting place. They should be equipped with a concrete slab, a single ramp, good lighting, minimal lifting gear and a small store. Activity in the satellite workshop is limited to refuelling, daily examinations and lubrication. The machine parking bay should be adjacent to the satellite workshop to facilitate shift changeover.

For decline shafts, the initial workshop would be on surface and, as mining progresses, this would be replaced with an underground workshop and satellite workshops. The decision as to when the surface workshop is replaced by an underground workshop should be based on a business case investigation.

Given the reality that workshop infrastructure is invariably late it is essential that an exercise be carried out to determine a realistic workshop construction time.

Since maintenance and time spent travelling to and from the workshop has a major impact on the performance and life of equipment, more attention should be paid to the requirement and design of workshops. Available data indicate the effect of positioning and design of workshops on performance. Although consensus is that workshops impact on quality of maintenance and equipment availability, there are no clear best practices in this regard. Establishing best practice should be relatively easy and a 'design model' or guideline can easily be established. Such a model should indicate facilities, layout, size, design, the maximum area to be served and the intervals at which

satellite workshops should be established. A study to this end will serve the industry well. In addition, consideration should be given to convening a best practice workshop to focus on the issue of maintenance only.

The authors are aware of operations where it can take up to three hours for drill rigs to travel from the work place to the workshop and this is a loss of productive time. Drill rigs travelling in confined spaces are subject to excessive boom and feed damage. If workshops are not constructed timeously, it is recommended that mobile servicing units are used to service rigs daily, and that rigs and LHDs are refuelled at, or close to, the mining areas. Consideration must be given to the risk associated with having diesel tankers transiting the mine.

The group identified the following aspects as important in determining maintenance philosophy and, in particular, whether maintenance should be in- or outsourced.

- Is the maintenance of mining equipment core business and does the mine have the requisite skills and experience? Whichever choice is made, the mine and the OEM must work closely together. When the mine carries out maintenance it makes it easier to split equipment purchases amongst more than one supplier. For a greenfields operation it is easier to get an OEM to initiate maintenance and this can be seen as similar to using a mining contractor to complete the capital footprint of the mine.
- From the supplied information it was not possible to determine if the quality of maintenance varied when outsourced or in-sourced. Factors such as workshop quality, artisan skill and motivation, supervision and management probably have a more significant impact on maintenance quality, than does the choice between in- and outsourcing.
- Most, if not all, the participating mines have a maintenance plan in place. The plans vary in complexity and have varying degrees of success. More work will need to be done to determine which is best and this issue could be examined during a best practice workshop focused on maintenance specifically.

It was interesting to note that, when maintenance is outsourced, the OEMs try to operate on a strict hour-based maintenance schedule; whereas in-sourced mines schedule equipment maintenance to specify days closest to the OEM's recommended hourly basis. Which system is best depends on operating conditions, operating hours per day or week, footwall conditions and the working environment. In other words, service intervals should take cognizance of OEM recommendations and mine operating conditions.

Whereas available data presented at the workshop do not indicate whether there is a relationship between performance and machine life, and service intervals, it is accepted that regular maintenance prolongs machine operating life, improves machine availability and minimizes operating cost. In the case of extreme operating conditions such as an excessively hot environment or very poor roadways, experience has indicated that maintenance intervals should be shortened. Ideally, machines should be fitted with on-board monitoring of components and lubricants in order to indicate when components and lubricants require attention.

The question as to whether it is more cost-effective to replace or refurbish equipment was difficult to address. It would appear that the considered opinion is that the best practice is to monitor equipment maintenance, determine refurbishing cost by asking the OEMs to quote and then to conduct a business case to identify the best approach. There was no proposed measurement of reducing productivity and using that as the key performance indicator to determine replacement or refurbishment. The issue of which party (mines or manufacturers) has the requisite skills to refurbish equipment generated significant discussion.

From the presentations, it appears that the decision to rebuild will generally be determined by the quality of operation of the machine during its lifetime. To determine the viability of rebuilding, a study will have to be undertaken to establish the relationship between the structural condition of the equipment at the end of its first life and the roadway conditions it operated in. Machines operating in good footwall conditions have been known to be rebuilt successfully a number of times, whereas there are known cases where machines had their structural integrity destroyed early during their life, rendering rebuilds uneconomical. Best practice would be a code or procedure that rated operating conditions and prescribed the condition of a machine prior to rebuild.

The requirements for brake testing were considered important. Brake tests as per OEM recommendation should be conducted once per shift. The test environment should simulate the equipment fully loaded and operating at mine dip. Consideration should be given to the use of electronic accelerometers.

Spares should be sourced from the OEM wherever this is possible and cost-effective. There is no clear indication, from the information supplied, as to whether the supply of parts has a marked influence on the performance of equipment or not. Best practice is this regard is, however, unclear.

## Shift cycles and staffing

The issues identified in order of priority for this breakaway group were:

- What is the ideal shift structure based on shifts per day, shift duration and shift cycle?
- What is the ideal team composition and how should engineering and production interrelate?
- What end of shift hand over procedures should be employed?
- What recruitment, training and retention strategies constitute best practice?

This was the most difficult of the workshops to arrive at concrete recommendations, and because of the large amount of information and different practices it was not possible to define best practice. It is recommended that more time be found to debate and evaluate the various options. However, analysis of the presentations enables the following to be concluded.

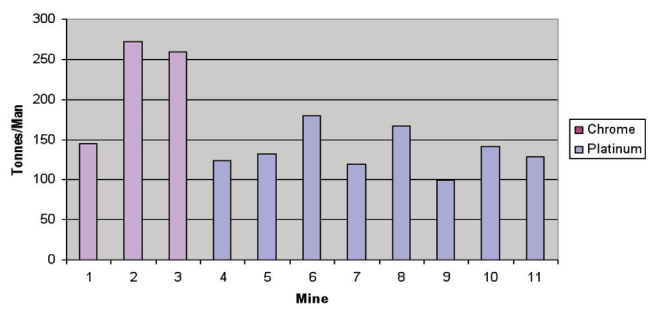


**Figure 3. Labour productivity by mine**

**Table I**
**Drilling requirements for different mines**

| Mine | Board width (m) | Board height (m) | Number holes | Holes/m² face |
|---|---|---|---|---|
| Dwarsrivier chrome | 8 | 2 | 51 | 3.19 |
| Xstrata chrome | 8 | 2 | 48 | 3.00 |
| Xstrata chrome | 10 | 2 | 60 | 3.00 |
| Mototolo platinum | 10 | 2,2 | 76 | 3.45 |
| Bathopele platinum | 9 | 2 | 63 | 3.50 |
| Two Rivers platinum | 12 | 1,85 | 74 | 3.33 |
| Zimplats | 7 | 2,5 | 57 | 3.25 |

Labour is the biggest single contributor to total mine operating cost. Analysis of labour productivity from various mining operations, measured in tonnes/man/month, is shown in Figure 3. There is some uncertainty attached to these figures as it is not always possible to ensure that the different mines are supplying equivalent labour statistics.

Chrome mines are more labour efficient than are platinum mines. The data shown below in Table I compare the various drilling requirements for chrome mines and platinum mines and clearly show that platinum mines require approximately 10% more holes/metre of face compared with chrome mines.

A second differentiator is that chrome mines have substantially better footwall conditions as they generally break to a pronounced reef/footwall contact. By contrast, platinum mines always break into the footwall, partially because of the unevenness of the UG2/footwall contact but also to ensure that the high grade footwall contact portion of the reef is mined. The better footwall condition has a major impact on equipment operating costs.

Thirdly, the platinum mines have substantial ground loss associated with the occurrence of potholes.

Table II considers shift hours and relates tonnage per section to shift hours as a measure of efficiency. It is thought that the figure at Xstrata Chrome may be a maximum and not an average—whereas all the other figures are based on mine averages. As can be seen there is a wide variance. A more accurate representation would have been to base this efficiency measure on effective hours per shift.

The factor that has the most impact on effective shift time is blast frequency. All the mines operating two ten-hour shifts blast at the end of every shift and have a two-hour re-entry period. The major advantage is that this cycle maximizes face utilization. The disadvantage is that there is no face-to-face shift handover. These mines all work seven days per week and hence loose production from sections undergoing infrastructure extension.

The Xstrata mines blast once per day and operate for an effective 21 hours per day and allow a three-hour re-entry. This cycle requires more available face length to be effective and has the major benefit of hot seat changeovers. It is apparent that good inter shift communication is very important and a variety of communication tools are used, but the most effective is probably face-to-face. In both these operations the mine has moved the shift boss and foreman offices underground to ensure better communication. The other variable at these mines is that they work only for five days per week, thereby making the weekend available for infrastructure maintenance.

Bathopele is in a category of its own and states that, although the shift duration is a little over eight hours, the effective shift time is 5.5 hours.

## Layout and ore handling

The issues identified in order of priority for this breakaway group were:

- How many rooms per section assuming that a section is the face drilled by one drill rig?
- How to optimize ore handling? Important aspects of this are LHD tramming distances, tip spacing, ore sizing at the tip and conveyor design.
- What is the maximum dip where room and pillar mining can operate?
- How much of an issue is room ventilation?

Room size is determined by geology and maximum pillar spacing. Given the size of the rooms and the pillars, the optimal number of rooms per section is governed by the number of shifts, duration of shifts and blast frequency. If no spare face is provided then the minimum number of rooms per section should be 7 or 8. However, making a 50% allowance for ground loss would increase the rooms per section to 11 or 12. Blast frequency has a major impact on the required number of rooms per section.

An important factor, borne out by some of the data, is the panel length in relation to the drill rig's effective reach. Drill set-up, even with an experienced operator, takes a considerable time and therefore the need to set up the drill twice during the drilling cycle should be avoided if possible, unless the panel width is equivalent to two or three times the drill rig's reach.

Important aspects of ore handling are LHD tramming distances, tip spacing, ore sizing at the tip and conveyor design. The most efficient tramming distance was considered to be loading the LHD within a 75 m radius of the tip. Given that the tip will advance every 60 m to 100 m, the realistic tramming distance will become 150 m to 175 m. Thus tips and conveyors should be spaced 70 m to 80 m apart on dip. As room and pillar size vary with depth

**Table II**
**Mine productivity measured in tonnes per shift hour**

| Mine | No shifts h/shift | Blasts per day | Shifts per month | H per month | Tonnes per section per month | Tonnes per shift hour |
|---|---|---|---|---|---|---|
| Dwarsrivier Cr | 2 × 10 | 2 | 60 | 600 | 16 500 | 27.5 |
| Xstrata Cr | 3 × 8 | 1 | 64 | 512 | 22 500 | 44 |
| Mototolo Pt | 3 × 8 | 1 | 64 | 521 | 16 993 | 32.6 |
| Bathopele Pt | 3 × 8.16 | 2 | 71 | 579 | 14 536 | 25.1 |
| Two Rivers Pt | 2 × 10 | 2 | 60 | 600 | 20 243 | 33.7 |
| Zimplats Pt | 2 × 10 | 2 | 60 | 600 | 20 000 | 33.3 |

and ground conditions the metric should not be rooms per tip but rather that conveyors are spaced every 70 m to 80 m apart on dip irrespective of number of rooms per drill rig.

The question of tip design is more complex and direction rather than solutions were provided. Tip design depends on rock size produced by the blast and whether or not scalping or rock sizing is required. A strong recommendation was that tip sites should be identified early so that preparatory work can be undertaken. The real requirement is for simpler tip design dealing with lower tonnages that are easy to advance.

One aspect of tip design not raised at the workshop but subsequently identified to the authors is the issue of scalping. The chrome mines frequently have waste bands which are mined concurrently with the chrome ore, especially in cases such as mining the LG6 and LG6a. These waste bands are usually drilled with a coarser drilling pattern than the reef to ensure that the waste is not as finely broken as the reef. At the tip grizzly, the coarser waste product is separated from the reef and usually dumped behind the tip. This waste material is then transported by LHDs and tipped in the back area. In the platinum mines the following has occurred:

- At one of the Zimbabwean mines using conveyor belts, the back area of the mine is full of blocks of reef that would not go through the grizzly.
- At other platinum mines the waste is often contaminated with high grade reef and there is evidence to suggest that all the 'waste' has a grade in excess of 2 g/t. Typically scalping separates about 10% of the reef mined. In a platinum mine this would represent many thousands of ounces of PGM over the life of the mine.

This would suggest that in platinum mines all the material mined on reef should be treated as reef and sent to surface for treatment—separation of waste and reef could be carried out with dense medium separation processes. Thus, the entire volume of reef loaded in the face has to be sized to fit onto the belt as even one oversize rock could seriously damage the belt. Perhaps rock sizers should be considered for every tip? An alternative approach used at Mototolo is to fit a hydraulic hammer type impact breaker on every second tip. The oversize from the one tip is then transported by LHD to the second tip for sizing.

The work load of LHDs in a section depends on the tonnage blasted and the travelling distance to the tip. Travelling distance is a function of tip spacing on dip and proximity of the tip to the face. Mines that have longer dip spacing between strike conveyors usually have more LHDs to compensate for the higher work duty requirement.

At Mototolo mine, a drill rig section consists of 15 × 8 m boards (i.e. 120 m of face) and two LHDs are used to feed onto strike belts spaced every six boards. At Two Rivers mine, where a drill rig section is 8 × 12 m boards (i.e. 96 m of face), three LHDs are used per section to feed onto the strike conveyor and these conveyors are spaced approximately 160 m apart. At Zimplats, 30 tonne low profile trucks are used in roadways positioned 110 m apart on dip and service 70 m of face. The trucks are loaded with a single 10 tonne LHD per section.

Information from the workshop suggests that despite the fact that the importance of minimizing tramming distances is appreciated, the enforcement of standards is lacking. In reality, the spacing of conveyors on dip is less important than the frequency of tip moves. Most mines have design parameters specifying the tip to face distance but few adhere to this specification.

Many aspects of mine design and operation, including choice of equipment, increased dilution, maintenance cost and rock handling rate, are influenced by dip. The team considered that standard room and pillar mining should take place at dips of less than 11°. The layout becomes more complex with acute split angles, reverse bays, longer tramming distances and dedicated roadways at greater dips, although room and pillar mining can be used at dips of up to 20°. The authors view is that room and pilar mining cannot operate at these steep dips and that the realistic limit is only marginally above 11°.

Room ventilation was not considered to be an issue. However, poor ventilation negatively affects the performance of equipment and workers. Statutory ventilation requirements in terms of air volume, temperature and emissions can be considered best practice.

## Conclusion

The information contained in the presentations from those mines that participated in the Hard-Rock Room and Pillar Mining Best Practice Workshop, and this summarizing document, contains a wealth of information. Various mining circumstances require various solutions but some solutions are definitely better than others. All engineering consists of arriving at an optimum compromise between often conflicting demands. It is the hope of the authors that these collected works will provide the guidance to assist mine operators in selecting best practice for their specific application.

The team studying maintenance requirements were conscious that they had scratched only the surface of best practice and recommended that another similar workshop should be convened to study problem in more depth.

It was a conscious decision of the organizers not to address rock mechanics as an issue at this workshop. It was recognized that the design of pillars and support practices would need to be addressed in a similar workshop.

## Acknowledgements

Without the support from the various mines, mining companies, mining contractors, suppliers and consultants listed below this workshop would not have been a success. On behalf of the Centre for Mechanised Mining Systems at the University of the Witwatersrand, the authors would like to thank all who contributed to the success of this workshop.

Presentations were made by the following individuals and organizations:

- Introduction. Alex du Plessis
- History of Room and Pillar Mining. Rod Pickering.
- Two Rivers Platinum. Mike Cowell.
- Unki. Sam Jena.
- Bathopele. Carlo van Rensburg.
- Eland Platinum. Rodney O'Reilly.
- Dwarsrivier. Walter Molapisi.
- Mototolo Platinum. Johan van Tonder.
- Zimplats. Gift Zhou.

- Kroondal and Marikana. Lawrence Schultz.
- Xstrata Eastern Chrome Mines. Caide Barlow.
- Everest Platinum. Gus Simbanegavi.
- Nkomati Nickel. Lazarus Motshwaiwa.
- Future of Room and Pillar Mining. Rod Pickering.

Contributions to the workshop came from the following groups and organizations.

- Consultants: RSV, Ukwazi Mining Solutions, Turgis Consulting, DRA Mining, LQS Group, TWP Projects and Spencer Rock Mechanics.
- Supliers: Sasol Nitro, Sandvik Mining and Construction, Minova, AEL, Joy Mining Machinery and Atlas Copco.
- Other mining companies; Anglo American, Kamoto Copper, Impala, Northam, Zimasco, South Deep and Bafokeng Rasimone.
- Contractors: Murray and Roberts Cementation and Grinaker LTA.

## Rod Pickering

*Consultant, Sandvik Mining and Construction*

Rod grew up in Yorkshire and was educated in Dorset. He started work in 1960 when he joined Shell Tankers as an engineering apprentice. There he completed a training programme for merchant navy engineering officers. He had nearly three years of general maintenance in marine and steam raising plant. He learnt the basics of engineering from the ground up and today he is still a competent fitter and welder. In 1965 he enrolled at Brighton College of Technology where he obtained a BSc Honours in Mechanical Engineering. He arrived in South Africa in 1969 and started work on the mines as a Junior Engineer with Union Corporation. There he obtained his Mechanical Engineers Certificate of Competency. He moved from the mines and worked in maintenance, sales and construction for a period of six years. His last position was that of contracts manager on the Pelindaba uranium enrichment site. He joined the Chamber of Mines Research Organization in 1977 and the highlight of his time with COMRO was being appointed director of the Stoping Technology Laboratory with the responsibility to develop ways of mechanizing the narrow reef hard rock gold mines. It was while at the Chamber that he gained a good understanding of the opportunities and the barriers inhibiting change in the mining industry. In late 1996 he started his own business combining his knowledge of mechanisation and mining. His first task was to investigate the practicality of using a Tunnel Boring Machine in a deep level gold mine. Since 1998 his major client has been Sandvik Mining and Construction
where his role is that of Manager of Strategic Projects with special responsibility for narrow reef and narrow vein mining throughout the world. His objective is to develop new mining processes in collaboration with customers. These new mining processes will use existing technology, or new technology that has to be specially developed. The ultimate objective is safer more cost-effective mining. The last few years have resulted in Low Profile and Xtra Low Profile mining equipment as well as a novel rock cutting machine. Rod is passionate about working within the mining industry to introduce change. His dream is to be part of that change that will transform the narrow reef hard rock mining industry and South Africa. He has been a Fellow of the SAIMM since 1985 and believes that it is important to give back to the mining industry