Review of the In-Stope Pillar Cutting Support System at Merriespruit 3 Shaft

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SYNOPSIS

Historically the gold mining industry in South Africa has always been regarded as the leader in the implementation of technological advances. However, upon closer investigation it became evident that some of the older proven shallow mining and support strategies have been forgotten. This paper attempts to quantify the effects of a change in the support system implemented at Harmony's Merriespruit 3 Shaft to enhance efficiencies and ensure stability of mining panels, as well as highlight the problems experienced by the introduction of a new mining system.

INTRODUCTION

Merriespruit 3 Shaft is situated in the town of Virginia in the Free State goldfields. The old Harmony mine has been in production since the late 1970's, mining on both the Basal and Leader reef horizons. In the past, mining was mainly done by longwalling, but since the 1990's this has changed to a scattered mining environment due to variable grades and relatively large geological discontinuities.

The relative flat dip of the orebody, ranging from 5° to 10º, allows stoping to be done in any direction and is mostly dependent on the pay trends. Mining at Merriespruit 3 Shaft is conducted at a depth of between 700m and 1 100m below surface, effectively placing mining in the shallow to medium depth environment, where a regional support system is required, as described in rock engineering literature.

BACKGROUND TO GROUND CONTROL PROBLEMS

Since changing from the longwall to a scattered mining method in the early 1990's large collapses have frequently occurred, described by Brentley and Lucas (1999). These large collapses were mainly geological or span-related, or a combination of both. To eliminate these large collapses, Cross (1995) initiated the introduction of in-stope crush pillars on Harmony on the A-reef horizon. The initial resistance to change contributed to the implementation failing, but the low gold price and various rock related difficulties forced the re-introduction of the system in early 1997.

STOPE SUPPORT STRATEGY

Due to fears of a further reduction in efficiencies, the support strategy was to be implemented in phases, starting with the areas where the most benefit could be achieved and where it was most likely to succeed. The new Merriespruit 3 Shaft stope support strategy incorporates mainly a local support system with the regional support system incorporating pillars formed by naturally occurring fault losses and other geological discontinuities, as well as relatively large unpay areas. A strike orientated rib pillar layout was introduced in 1997 to ensure that panel spans do not exceed 35m on dip. The average crush pillar sizes are 3m wide on dip and 8m length on strike with 2m ventilation holings. These dimensions vary, depending on the stope width, span and mining sequences planned for individual mining blocks (refer to Figure 1).

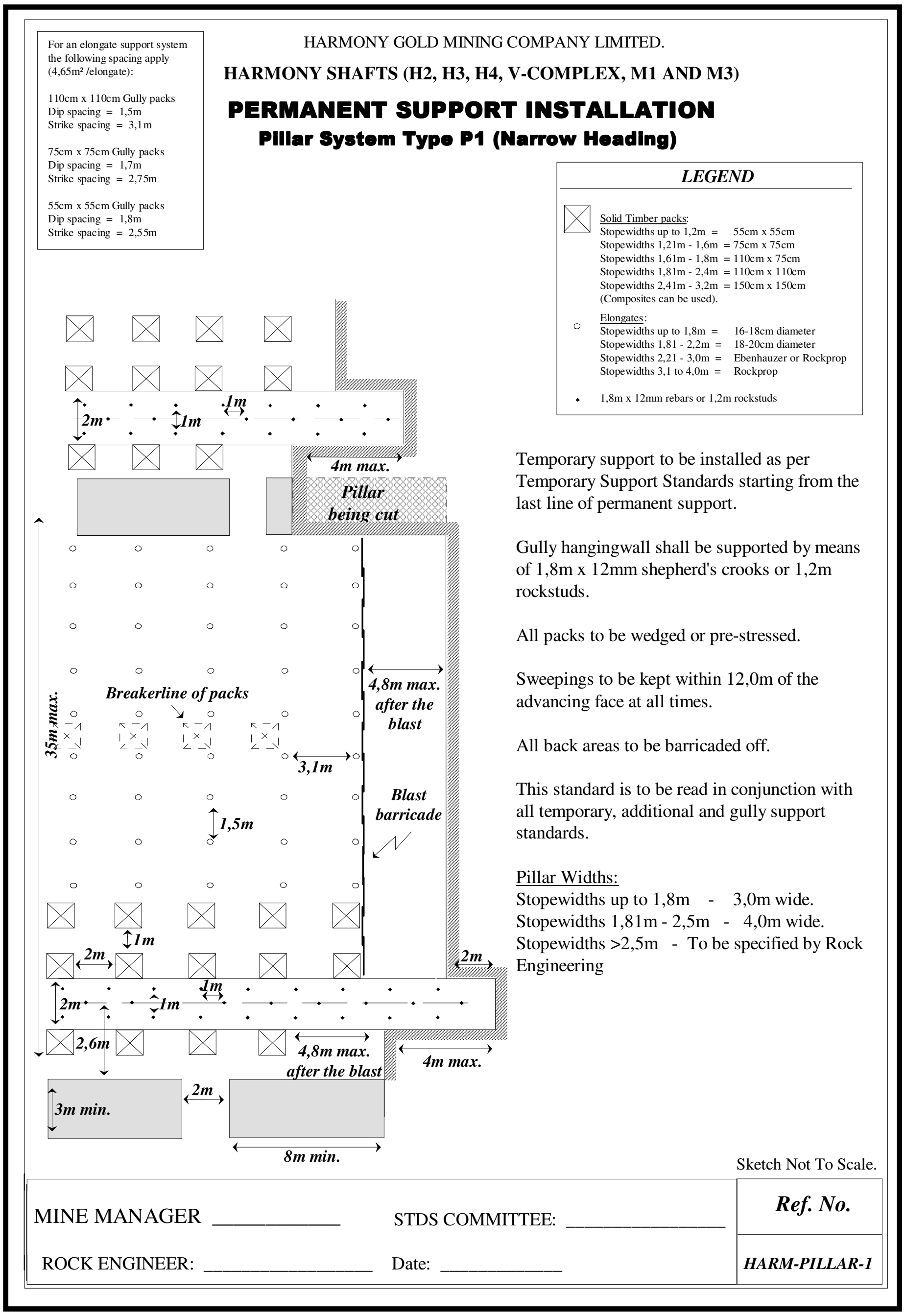

Figure 1
Crush pillar and elongate support system

The accessways and gullies are supported by means of packs with yielding elongates forming the internal support system. In addition, 1,2m rockstuds are installed to stabilize and reinforce the immediate hangingwall beam. This system of support has been used with great success in the platinum industry and was documented by Korf, C W in the Association of Mine Managers Papers and Discussions, 1978 – 1979.

REVIEW OF THE CRUSH PILLAR SYSTEM

As previously mentioned, due to fears of a further reduction in efficiencies during the change, the implementation was done in phases. For practical reasons one mine overseer section was chosen to implement the system. This section was chosen because of the higher stoping width mined (> 2m) as well as the excessive tramming and transport distances.

FACTORS INFLUENCING THE EARLY IMPLEMENTATION OF A CRUSH PILLAR SYSTEM

Management clearly understood the changes required to the support system in order to reduce the number of large collapses which affected production during the early 1990's. The new system also needed to address various factors which inhibited productivity. Following various workshops, some areas were identified as problematic, however during the changeover from one support system to the other, various unexpected problems were experienced. The following areas were identified as problematic during the implementation of the pillar and elongate support system.

Human Behaviour

As there was a clear need for change, it was imperative that the normal resistance to change was addressed. The workforce, as well as line production officials were briefed on the expected changes to the system prior to introduction. Obviously, changes to the mindset where people were used to pack support, required management to ensure that extensive training programmes and communication sessions be introduced. These sessions took the form of underground workshops and feedback opportunities to address problem areas. The visual changes from packs to elongates required some ingenuous thinking and solutions included the painting of elongates for the visual effect as well as the introduction of in-stope roofbolting as additional support.

Changes to the Mining Layout

As Merriespruit 3 shaft consists of a low-grade orebody, where the average belt grades are in the region of 4,5 grams/ton and was earmarked for closure in 1997, development was extensively curtailed. With the increasing of production levels to approximately 60 000 tons and the backlog in development, level-to-level access was not possible. Strike slushers were introduced in some areas to increase production, resulting in large back stopes being created with up- and downdip mining practiced due to ventilation and access constraints.

In addition, the lack of regularly spaced raiselines resulted in some panels being mined on breast in excess of 150m. This placed an additional requirement on the support systems as it became imperative that the back areas remain stable for long periods. For this reason, the back area support had to be designed so as to ensure sustained stability.

Gully Configuration

Blasting of the advance strike gully

In the past, when mining on block values, the normal scattered mining practices normally consisted of an overhand face configuration where the top panels made use of footwall lifted gullies. The new system required an advanced strike gully on every panel. This meant an extra driller per panel and, due to the shortage of qualified development drillers, stope drillers were vigorously trained. It is of utmost importance to focus on drilling control to ensure an effective gully lead, which will ensure that the panel is properly advanced.

Depth and distance of gully siding

Due to the depth of the mining operations and the relative low stress conditions, the advance strike gully heading with a lagging siding is most commonly used. As the dip of the reef is relatively flat, it is of utmost importance that the downdip siding is blasted to the correct dimensions and kept within 4m of the face position to assist with fracture control in the gully. Various problems have been experienced with the gully as the abovementioned factors of depth and distance from the face played an important role to ensure stable gully conditions. The use of shift supervisors and service department officials to report sub-standard gully conditions and configurations greatly improved the initial problems experienced.

Blasting of the Face

As the stope excavation is situated in a tensile zone, the crush pillar / elongate support standard is normally implemented at shallow depths. Minimal horizontal clamping forces are present due to the lack of intense fracturing and dilation. It is therefore important that the hangingwall beam remains intact and that damage to the hangingwall be avoided at all times. In order to achieve this, good drilling control and blasting procedures have to be adhered to.

Hangingwall damage is mainly caused by the gasses, which create cracks and elongation of cracks during blasting. Elongation of cracks are in the direction of the major principle stress. In order to reduce the damage caused by detonating explosives, low density Anfex and ammonium nitrate based explosives were introduced.

It must also be ensured that shotholes have a free breaking face which is not too far away from the shothole. If burdens are too large, the energy released during detonation will be absorbed in the surrounding rock, thereby damaging the hangingwall. Shothole burdens of ≤ 0,6m, drilled at an angle of 70º towards the free-breaking face have a positive effect on hangingwall stability.

The above may seem as a ‘back to basic’ statement, but it is of utmost importance to take cognisance of the hangingwall stability when changing from a high areal coverage support system of packs to an elongate support system.

Changing to an Integrated Support System

Support Lines and Grids

The support system was designed such that an area of ± 4,0m² is supported by a single unit. The grid is dependent on the size of the gully pack as well as breakerline packs, which are, in turn, dependent on the stope width.

Support lines and grids are painted in and used with relevant ease, making use of measuring tapes and / or string. The introduction of a grid line support system greatly assisted in the support installation and the sweeping cycle. The implementation of the grid line support system assisted in the use of blasting and back area barricades as well as the reduction of support re-installed during sweeping operations (see Photo 1).

Photo 1
A line of elongate support and back area barricade ropes installed in a panel.

Breakerlines

Breakerline packs of a correct width-to-height ratio are installed in the middle of the panel on strike. An alternative method would be to install a full line of packs on dip after every 4th line of elongates. The condition of the hangingwall and geological discontinuities dictate which breakerline system will be used and whether it will be on dip or strike.

The breaker pack line with the gully packs and rockstuds are an integral part of the crush pillar elongate support system. Breakerlines are introduced to give areal coverage in areas where people usually travel such as the strike material ways as well as to isolate the face area from the back area to reduce the area affected in the unlikely event of a hangingwall collapse.

Scraping Between Support Units

Even though strike spacing of elongate support units are either 3,1m or 2,75m apart depending on stoping width, damage is still caused during cleaning operations. These support units are replaced.

Problems occur when sweepings are kept more than 9m from the face, support units are pulled out and not replaced. This is problematic as additional load is placed on the remaining support units. This can result in a reduced support resistance, which might lead to support system failure when the load on the system exceeds the resistance. It is for this reason, as well as the presence of local geology, that collapses still occurred in some back areas. It is of utmost importance to install back area barricades to reduce the area of responsibility and the likelihood of workers traveling through the back area.

Negotiating Steeper Dips

In the pillar and elongate support system panels are situated between rib pillars. As the rib pillars are cut from the panel face, the pillar has already been fractured and will crush and scale. This poses the threat of rocks scaling from gully sidewall where no siding is carried or from updip pillar rolling downdip in reefs with relatively steep dips. This threat was eliminated by installing support less than 1m from the top siding on which a plank barricade is erected to protect workers working downdip from the pillar and the cutting of sidings or pinning the gully sidewalls. In Photo 2, scaling of the updip sidewall of the pillar is clearly visible.

Photo 2
Scaling of the updip crush pillar

Tramming and Mining Cycle

Long panels, up to 40m, and high stoping widths of up to 4m generate tonnages which are in excess of orepass capacities and tramming capabilities for the various levels. Most of the constraints were highlighted by the workforce during the feedback sessions and were solved by introducing the following:

- A transfer orepass system allowing for a dedicated tramming haulage.
- The shortening of panels to maximum of 35m in length improving cleaning efficiencies.
- Increased use of elongates in the place of packs, reducing the support installation time and the material handling required from the shaft to the mining areas.
- Introduction of man carriages to increase “on the face” shift time.

EFFICIENCY TRENDS AT MERRIESPRUIT 3 SHAFT

As the pillar system has been operational for the last 5 years, some useful information regarding the effectiveness of the system was available. Since the implementation of the system, the progress has been monitored from various perspectives.

The amount of square meters mined on the pillar and elongate support system has gradually increased to nearly 50% of the total shaft production. This was mainly due to migration of mining to the higher grade and higher stoping width area to the south of the mine.

The progress of the pillar and elongate section was monitored to ensure compliance with the initial objectives. In Figure 3, use was made of the tons per man criterion, as an efficiency indicator, to allow for the variations in stoping width that existed in the area of initial implementation. It is evident from the general trend line that the changes made resulted in an increase from 90 tons/man to approximately 120 tons/man over the 5-year period up to September 2003 - 33% improvement for that mining section.

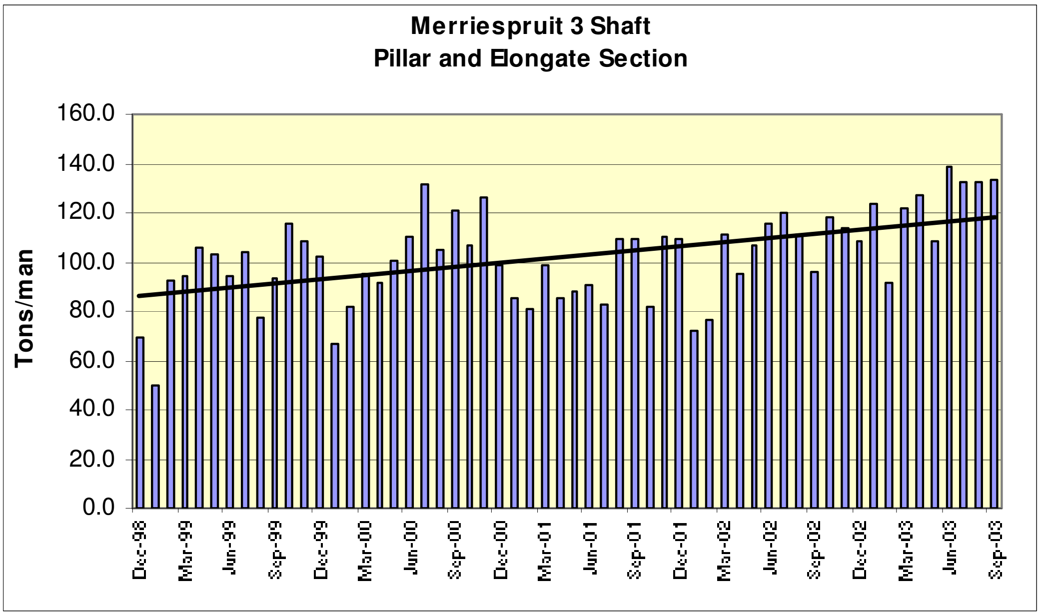

Figure 3

As the average stoping width in the section has remained at 220cm for the last 3 years, the square meters/man criterion was also used as an efficiency indicator (see Figure 4). From the graph, it is evident that the square meters/man have increased from 14 to 20, resulting in 50% increase over the last 5 years to September 2003.

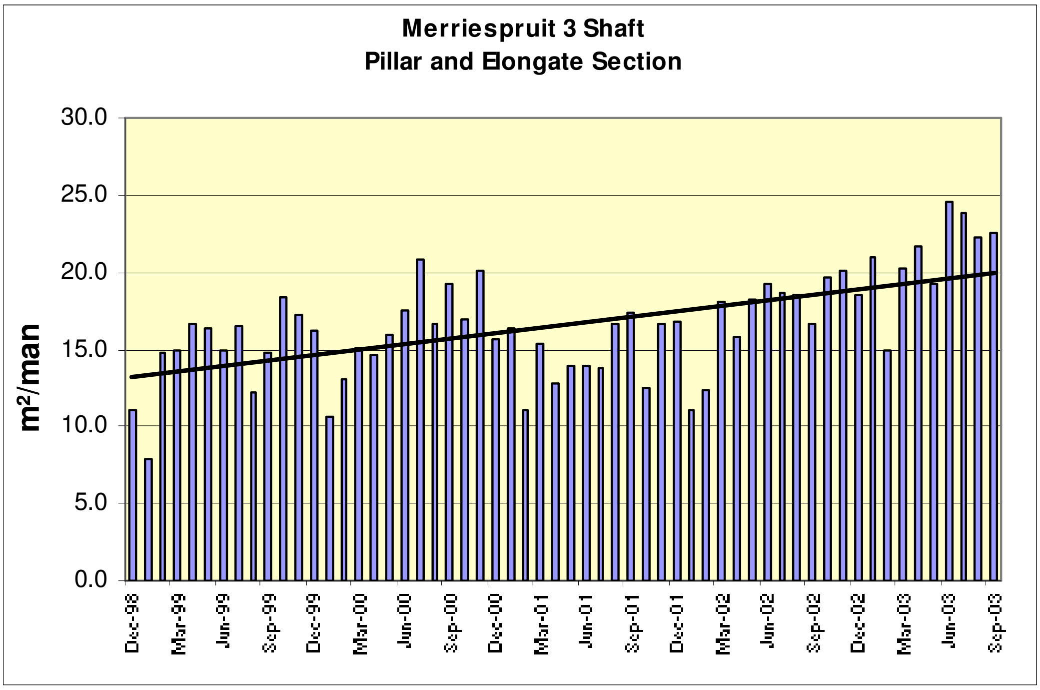

Figure 4

It is thus evident that increased attention given to more efficient mining, has resulted in an increase in efficiencies of 10% per year over the last 5 years. This is approximately the same amount of increase in square meters mined on the pillar and elongate support system per year. In addition, it is also evident from Figures 3 and 4 that a more constant production performance has been achieved during the last 2 years. Even the traditional lower production months over the Christmas period appear to be more productive.

When the pillar and elongate system is compared to the mining sections still mining on a pack support system, it is evident that, although during the initial period of introduction where the system seemed less efficient, it would appear that for the last 2 years the pillar and elongate support system has exceeded the efficiencies of the sections on the pack support system. Due to the large variations in stoping widths of the 2 sections, both the square meters and tons per man are used as efficiency indicators seen in Figures 5 and 6.

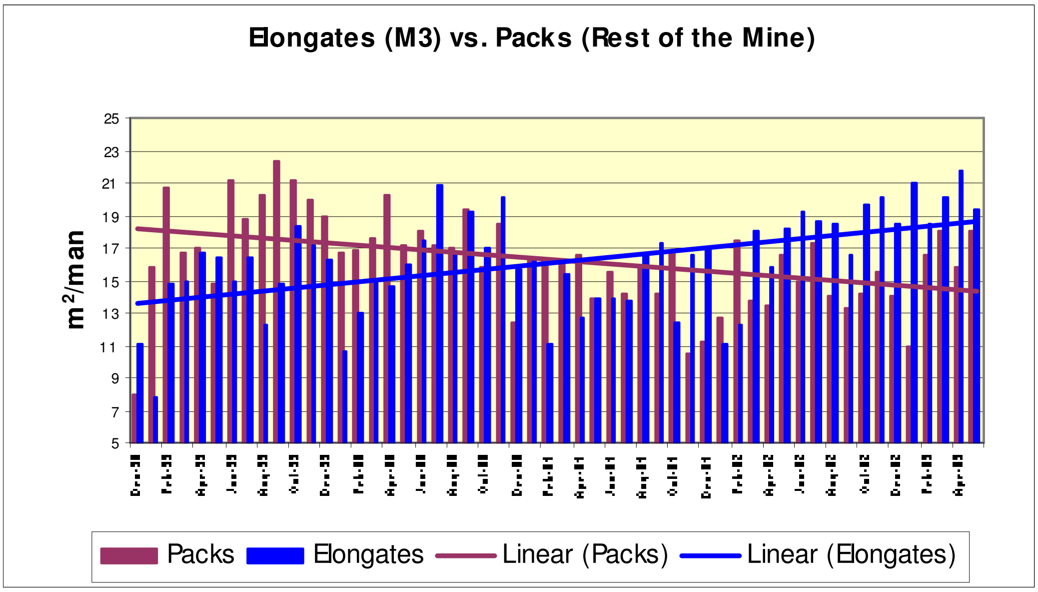

Figure 5
Efficiency trends of the different mining sections measured in m²/man

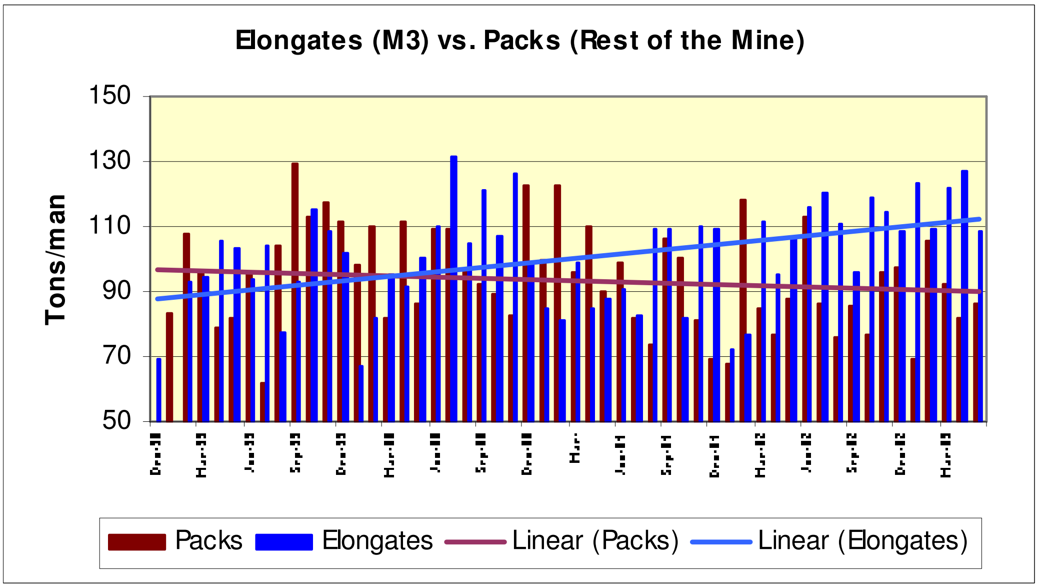

Figure 6
Efficiency trends of the different mining section measured in tons/man

When comparing the two mining systems, it is evident that the higher stoping width, pillar and elongate section compared favourably with the traditional pack sections in March 2000 on tons/man as well as with the m²/man in the early months of 2001. Since then, the pillar and elongate sections have generally been more efficient.

ADVANTAGES

Since the introduction of the system, a number of advantages have been observed which directly affected the mining cycle resulting in increased productivity:

- Reduction of large stope collapses and production delays occurring in panels.
- Substantial saving in the transport labour.
- Standard of sweepings of the back areas increased which improved the grade.
- Improved ventilation conditions as a result of rib pillars acting as natural ventilation seals.
- Increase in productivity due to the reduction of support installation time. The mining cycle has effectively been reduced by a day.
- Only a marginal increase in the support costs has been realized over the last 5 years. The total support cost per ton milled for 2003 was in the region of R12.
- Reduction in the support-to-face distance with the introduction of elongates.

Various other advantages have been observed, but are difficult to quantify and directly attribute to the change to the pillar and elongate system.

DISCUSSION

The introduction of the pillar and elongate system is by no means new and various mines have successfully implemented the system. At Merriespruit 3 Shaft, the introduction of the system has exceeded all expectations. However, the change, which was initially seen as a support system change, can in effect be described as a mining layout change. The problems experienced were foreseeable and could have been minimised if the necessary impact of changes was thoroughly workshopped and analysed prior to the implementation.

The lack of knowledge and skills transfer between mining groups and even between gold and platinum mines is, however, concerning and needs to be addressed.

CONCLUSION

The South African gold mining industry is faced with an enormous challenge to remain profitable and competitive in the future.

As the pressure on mining houses to become more efficient increases, it is imperative that all mines critically analyze their mining systems currently in place. All mines have the potential to implement mining and support systems, which will be less labour intensive and eventually more productive. Rock engineering practitioners must be involved in the conceptual design phase to integrate currently available technologies into workable and practical mining systems.

ACKNOWLEDGEMENTS

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