



The ongoing evolution of stope panel support at Impala Platinum Limited

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Synopsis

Labour-intensive narrow reef stoping, as traditionally practised in South African gold and platinum mines, is almost unique in the modern first-world mechanized mining environment. Shortcomings of the system include the ever increasing cost of labour, a cap on achievable productivity and a poor safety record, particularly in the field of rock-related accidents.

In the absence of sustainable alternative technologies, the South African mining industry has spent millions of rands improving the present system, focusing on improving workplace safety. This paper details the changes to stope support at Impala Platinum's Rustenburg operations, and the impact on rock-related safety performance.

Keywords

Stope panel support, narrow reef stoping, improving workplace safety.

Introduction

Labour-intensive narrow reef stoping, as traditionally practised in South African gold and platinum mines, is almost unique in the modern first-world mechanized mining environment. The process involves a 7–15 person team excavating stopes averaging 1.0 m wide, using hand-held drilling and charging up holes with explosives prior to blasting. Blasted rock is removed by means of scraper winches and artificial timber support is manually installed to maintain the stability of the excavated area.

Historically based on a plentiful supply of cheap unskilled labour, some would argue that the system has outlived its sell-by date. Present-day shortcomings include the ever increasing cost of labour, a cap on achievable productivity and a poor safety record, particularly in the field of rock-related accidents.

Given the present shortage of sustainable alternative technologies, the South African mining industry has spent millions of rands researching, improving and refining the present system. Much of this research has been focused on improving workplace safety and reducing the incidence of rock-related accidents.

Whereas some improvements have been brought about as a result of industrywide research programmes, most have been introduced by the mining companies themselves in the interests of safety, cost-effectiveness and user friendliness. This paper details the changes to the stope support system at Impala Platinum's Rustenburg operations, and the impact on rock-related safety performance.

Locality and background information

Impala Platinum Limited is the world's second largest Platinum Group Metal (PGM) producer. The company's main mining lease area (Rustenburg operations) is situated some 30 km north of Rustenburg in the North West Province, along the western lobe of the Bushveld Complex (see Figure 1). The lease area measures some 12 000 hectares.

The geological sequence in the lease area dips at approximately 9 degrees to the north-east. Two PGM-rich horizons are exploited; the Merensky economic horizon and UG2 chromitite seam. These two horizons are separated by an 80 to 100 metre middling. Aside from opencast operations, thirteen shaft systems are currently used for access and mining purposes, at depth of 30 to 1 200 metres below surface (see Figure 2).

Underground mining operations generally follow traditional tabular mining practice. The orebody is accessed by means of travelling ways emanating from footwall haulages and extracted using narrow reef stoping techniques, as detailed above. More than 20 000 people are employed underground on the lease area to extract approximately

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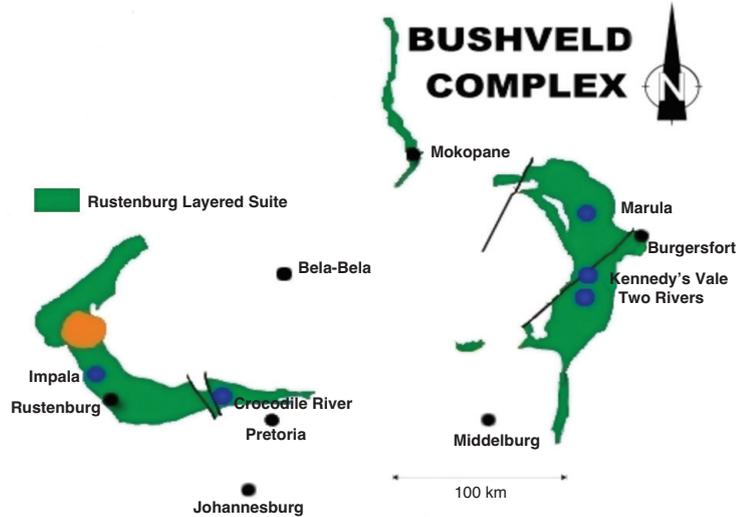


Figure 1—Geological map of the Bushveld complex

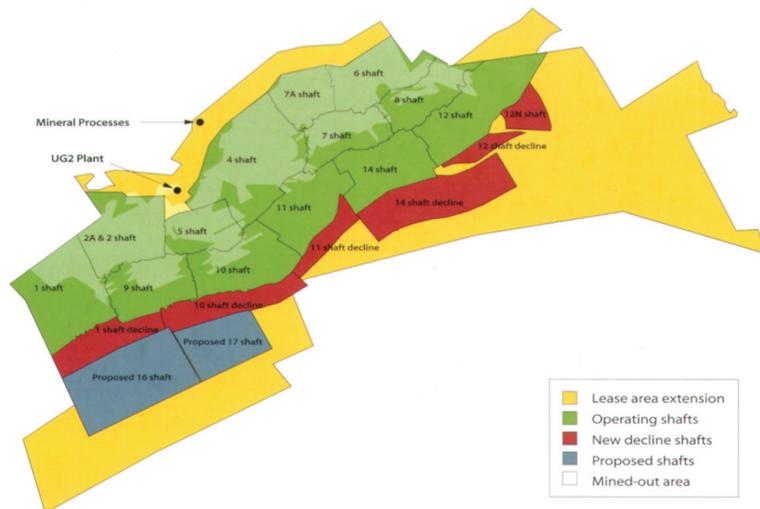


Figure 2—Shafts and workings on the Rustenburg lease area

17 million tons of ore per annum. This yields some 1.2 million ounces of platinum, plus additional quantities of other associated platinum group metals.

Sequence of events

In the beginning...

In the early 1990s, Impala's in-stope support system (like most platinum mines) comprised a combination of temporary jacks, hydraulic props and mine poles. Two rows of temporary jacks were installed in the face area during the drilling shift. The main face area support was provided by two or three rows of hydraulic props, used on a 'rolling' basis, with the first row as much as 6 metres from the face after the blast. Rows of 130 mm–150 mm diameter sticks were installed as permanent support in the back area as the hydraulic props were 'rolled' forward.

The first row of hydraulic props was used to carry a blasting barricade—not only did this contain the blasted within the face area, it also reduced blast damage to the installed support units. Although considered state-of-the-art at the time, the system was not without its faults—temporary support was installed only during the drilling shaft, hydraulic prop control was a logistical nightmare and the hydraulic prop seals were susceptible to damage from the abrasive chromitite ore.

Prestressing units for elongates

By the mid-1990s, the logistical and practical problems associated with hydraulic props prompted mines and support system suppliers to investigate alternative systems. The hydraulic prestressing unit for elongates was conceptualized, invented, evaluated and tested—and has not looked back since. Testing of prestressing units on Impala began in 1997, while full-scale implementation followed in May 1998.

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Introduction of ground control districts

An updated guideline for compiling a Mandatory Code of Practice to combat Rockfall and Rockburst Accidents was issued by the Department of Minerals and Energy in January 2002. This guideline required the identification of different ground control districts (GCDs) and classification of the mine into these GCDs, to assist in drawing up a ground control district plan.

For the purpose of this exercise, the following definitions were applied:

- Ground control means the ability to predict and influence the behaviour of rock in a mining environment, having due regard for the safety of the workforce and the required serviceability and design life of the mine.
- Ground control district means a portion of a mine where similar geological conditions exist, which give rise to a unique set of identifiable rock-related hazards for which a common set of strategies can be employed to minimize the risk resulting from mining.
- Ground control district plan means a plan of good quality transparent draughting material of a thickness not less than 0.08 mm, indicating to a scale of 1 in 2 500 all applicable ground control district of the mine.

Drawing up an effective GCD plan required various contributions, including:

- Input provided by mining, geology and rock engineering personnel
- Rock mass-related information applicable to different areas
- Geological features and related information recorded on mine plans
- A formal method of gathering and investigating rock-related incidents
- A detailed rock-related incident database that is continuously updated, containing information of all reported rock-related incidents, not only those resulting in serious or fatal accidents and/or production disruptions
- Regular analysis of information contained in the rock-related incident database.

For Impala's Rustenburg operations, with its mainly geologically dominated mining environment, GCDs were defined based on:

- The presence of dominant or persistent geological features
- Potential fall-out height for the face and area
- Potential fall-out height for the back area
- The risk factor associated with different areas or phenomena.

The various GCDs are listed in Table I.

A copy of the ground control plan for the Merensky reef workings on a particular shaft (not to scale) is shown in Figure 3. Following the development of the ground control plan, support strategies were prescribed for each identified GCD and the mine's support standards were revised. This process resulted in a drastic drop in the number of stope panel support standards—the original 32 different standards were reduced to 6 new standards. Due to complex geology in the Bushveldt there are exceptions when conditions are addressed differently.

Elongate diameter and specification changes

While the ground control district plan was being developed, several large falls of ground accidents occurred on the mine, resulting in fatalities. On investigation it became apparent that the falls had exceeded the capacity of the support system. Although this not should have happened, observations and tests showed that an earlier management decision to do away with blasting barricades in stopes had resulted in the sticks being exposed to blast damage, reducing their capability.

After some debate, backed up by laboratory testing and underground observation, in November 2002 it was decided to increase the specified diameter for elongates from 130 mm–170 mm to 180 mm–200 mm. This increase in diameter represented an increase in laboratory test (not derated) strength from 326 kN to 714 kN, or a 119% difference.

The change increased the mine's support budget by an additional R20 million, but reduced the number of falls of ground larger than 4 square metres from more than 50 incidents per month to approximately 10 per month—a drastic reduction.

Areal support—nets

Within a few months of implementing the larger diameter elongates, statistics showed that whereas the larger falls of

Table I

Showing different ground control districts

| GCD code | Ground control district description | Major generic hazard description |
|----------|--|--|
| A | Normal ground | Low risk from geological features |
| B | Surface protection | 0–30 m No mining, 30–100 m Shallow mining restrictions |
| C | Curved joints | Wedge-type failure |
| D | Coarse pyroxenite, spotted anorthosite | Large flat failures, extension fractures |
| E | Rolling reef | Associated with curved joints, domes and various reef types on same panel: A, B and C |
| F | Blocky ground | Associated with extensive jointing, faulting, shear zones, etc. on the various reef horizons |
| G | Triplets or ICL < 0.3 m above UG2 Reef contact | Narrow beam can result in falls of ground between support units. |
| H | Low angle joints on UG2 | Series of domes that intersect into the triplets and results in major falls of ground |
| S | Seismicity | Seismic risk associated mostly with crush type events (pillar or strain bursts) and less with slip type events (geological features) |

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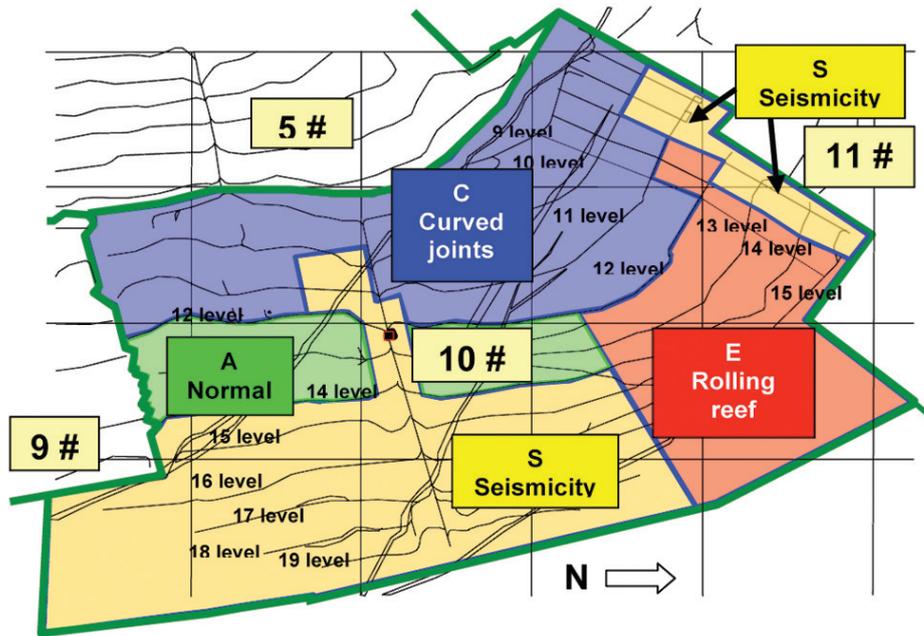


Figure 3—Ground control districts for a particular shaft

ground and panel had been greatly reduced, smaller falls were still happening in the stope face area. Analysis of the falls showed that they were mostly small (less than 0.25 cubic metres) and thin (less than 30 cm), and that the falls were occurring between the installed temporary support units.

Given that the temporary support units were spaced 1.5 m apart in the face area, and equipped with load-spreading headboards, a need for better areal support was identified. Investigation of available alternatives showed that the only viable option was strapping or netting, which could be installed on a daily basis with the temporary support and removed again prior to blasting.

Experimentation resulted in the adoption of a 15 m long x 30 cm wide 'rock stop strap' for use in conjunction with the temporary jacks. The extruded plastic strapping could allegedly hold up to 750 kg, rolled up quickly for easy storage and was expected to last approximately 3 months in a working stope. Photographs of the 'rock stop strap' are shown below in Figures 4 and 5.

The implementation of the 'rock stop strap', which began in January 2004, definitely proved beneficial. In the months after their introduction several cases were reported where the straps had either stopped a falling rock, or slowed its momentum sufficiently to allow personnel to get out of its way.

Support tendon changes

Three fatal fall of ground accidents occurred in development ends on different shafts during the first quarter of 2004 (an example is shown in Figure 6). The subsequent investigation revealed a need for a more user-friendly tendon support system, with simplified means of installation and pre-tensioning and ideally fitted with some form of load indicator for supervision and quality control purposes.



Figure 4—Rock stop strap installation



Figure 5—Rock stop strap holding potential fall

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Figure 6—Fall of ground in development end



Figure 7—Hydraulically-prestressed tendon when installed

The resulting testing and evaluation process resulted in the introduction of hydraulically-prestressed tendons, supplied by a leading local manufacturer (Figure 7). These made use of the same prestressing equipment as the elongate prestressing units, that was by now well accepted and understood by the mine's workforce. Initially introduced in development ends, these hydraulically-prestressed tendons were also implemented in the stoping panels' advanced strike gullies.

The impact of introducing a different tendon support system was not immediately observed in the safety statistics, as falls of ground in development ends were a minor contribution. Nevertheless, the change represented a deliberate move away from the cheapest support system towards one that presented greater user-friendliness and reduced risk.

Coping with extra depth—yielding elongates

With more shafts mining deeper areas, a gradual increase in panel collapses was recorded during 2003, particularly in these deeper areas. Investigation of these events, combined with results from closure measurements, concluded that the

levels of closure being experienced in deeper stopes were exceeding the deformation range of the elongate support units, rendering them ineffective.

Experimentation with different types of yielding elongate followed, culminating in the selection of two types of yielding elongates sourced from different suppliers (Figures 8 and 9). Implementation of these yielding elongates began in July 2004, and has continued to the date of writing, as more stoping takes place on deeper levels. The effect of introducing the yielding units, despite the additional cost, was to again drop the number of panel collapses recorded monthly to single figures (for a mine with some 650 stoping panels).

Full-time face area support—in-stope bolting

Despite the decreases in large collapses and falls in back areas, the changes in elongate support were having very little effect on falls of ground in the stope face area. Although falls in the stope face area were normally smaller than 1.0 cubic metre and less than then 80 cm thick, they were (and are still) the most common cause of rock-related accidents and fatalities.



Figure 8—Yielding elongate unit in operation



Figure 9—Alternative yielding elongate unit in operation

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The improvement in face-area safety that could be brought about by the 'rock stop straps' was limited, mainly because they were mounted on the temporary jacks. These temporary support units were installed only for the drilling shaft, some 6.5 hours of the working day. In addition, the actual act of installing and removing temporary support units was rated as one of the most hazardous activities, as it could lead to rock being dislodged and falling.

Our research indicated that the need for a practical solution that provided full-time, on-the-face coverage in stoping panels could only be met by one system—in-stope bolting. This concept involved eliminating the temporary support units, replacing them with a systematic pattern of tendons installed in the stope hangingwall, right up to the face. It had been trialled and implemented on several other similar mines in the industry, the most successful being the intermediate-depth gold mines in the Goldfields group, and the platinum mines in the Thabazimbi area.

Trials with suitable installation equipment and different tendon types were carried out during the second half of 2004 (Figures 10 and 11). Based on fall of ground statistics, the focus for implementing in-stope bolting was placed on Merensky stopes. Implementation began in January 2005, but



Figure 10—In-stope bolting testing in progress



Figure 11—In-stope bolting in operation

it took until December that year to convert 80% of Merensky stoping panels onto the new system.

Due to poor communication about the project there was large-scale resistance from the majority labour union, which threatened to halt the implementation. This resistance was overcome by visits to mines using the system, a detailed awareness programme, and the promise of additional financial remuneration for production crews using the system.

Initial project planning aimed to absorb some of the additional cost of in-stope bolting by moving the elongate support further back from the face, thus reducing blast damage and eliminating the need for prestressing units on the elongates. However, it soon became apparent from fall of ground statistics that this goal could not be achieved—larger falls, which exceeded the tendons' capacity, began occurring in the face area. The decision was reversed, and elongates were brought closer to the face again and integrated with the in-stope bolting, immediately cutting down on the larger falls.

The benefits of in-stope bolting were soon apparent—the number of serious and fatal fall of ground accidents in the stope face area began to steadily decline, and continued this trend over the period 2005 and 2006. An excellent example of this phenomenon was No. 10 shaft, which had previously experienced the most rock-related fatalities. Since the introduction of in-stope bolting, No. 10 shaft has gone on to achieve 2 million fatality-free shifts for the first time in its 20-year history. Impala ended 2006 having recorded its best ever safety performance, with just two rockfall fatalities in conventional stopes.

Improving the gully support

In contrast to the excellent safety performance of 2006, seven lives were lost to rockfalls in 2007. Four of these accidents occurred in conventional stopes, but only one occurred in a stope panel—the other three (and one accident the previous year) had occurred in the gully area. It seemed that no sooner had we got the stope panel support under control, than the problem surfaced elsewhere.

Another round of observation, measurement and analysis followed. We concluded that the main problem was the removal of the elongate support units closest to the face/gully 'corner', either by blasting or cleaning operations. This resulted in a loss of support resistance in this critical area until the support could be reinstalled, usually only during the following dayshift.

To provide additional support resistance in this area, a recommendation was put forward to increase the density of tendon support in all on-reef development ends and stope panel gullies. Despite the additional cost, management immediately agreed, and the tendon support pattern was changed in November 2007. Although it is still too early to analyse the impact of this change, we are convinced that it, to will bring about results—not only a reduction in rockfalls, but also an improvement in gully stability.

The results of the changes

The effects of the various events listed above are shown in the graphs below. Figure 12 shows the total number of rock-related fatalities recorded per financial year (July–June) for

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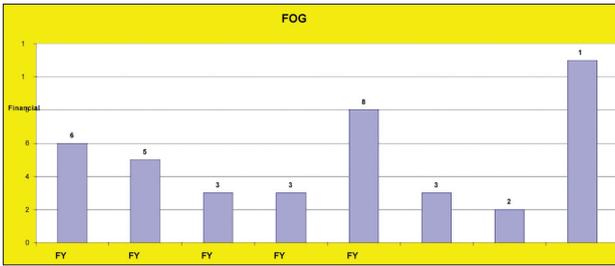


Figure 12—Total rock-related fatalities recorded since 2001

the period 2001 to the present. The general trend is obviously downwards, despite the spike in 2007 (the majority of which were in mechanized sections).

Figure 13 below shows the number of fall of ground incidents recorded in conventional stopes on a monthly basis since just prior to the introduction of ground control districts. Again, the general downward trend is noticeable. During FY2010 a mechanized bord collapsed resulting in 9 fatalities.

Figure 14 presents the history of large falls (greater than 4 square metres) since before the introduction of ground control districts, and points out the dates when different

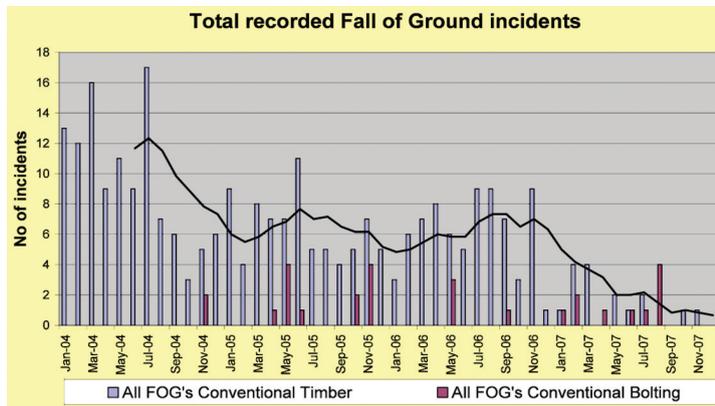


Figure 13—Recorded fall of ground incidents since January 2004

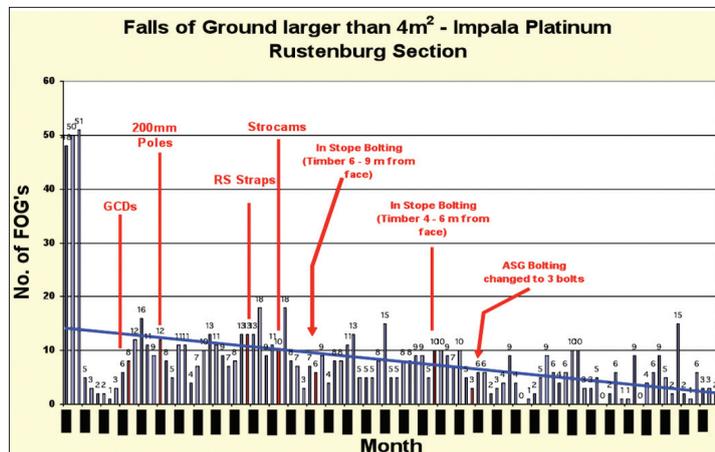


Figure 14—History of large falls since August 2001

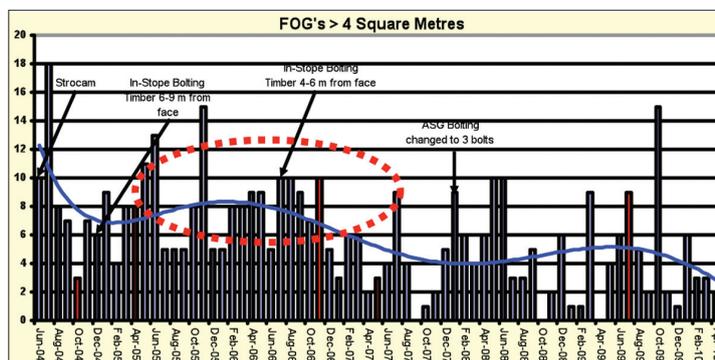


Figure 15—History of large falls since January 2004

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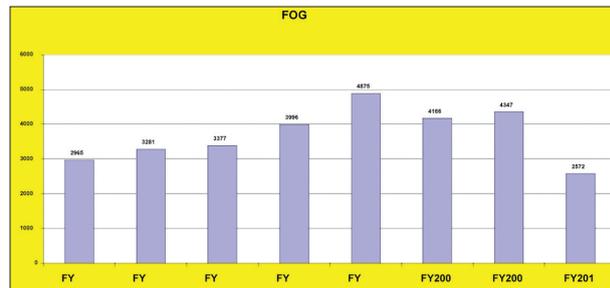


Figure 16—Square metres mined per fall of ground injury

initiatives were implemented. It should be noted here that the data include both conventional and mechanized stoping areas.

Figure 15 again shows the history of falls greater than 4 square metres, but focuses on the period January 2004 to December 2007. Of particular note here is the period highlighted by the oval, which shows the increase in large falls when elongates were moved further back from the face with the introduction of in-stope bolting. When the elongate spacing reverted to the original distance, the large falls were reduced.

Figure 16, the last of the series of graphs, shows the number of square metres mined per lost time injury for the last 5 financial years. The number of square metres mined relates directly to the amount of hangingwall exposed, which in turn must be worked under and supported. This is, in reality, a measure of the fall of ground risk in stope panels.

The graph clearly shows that the number of metres mined for each fall of ground-related lost time injury is increased over the period measured—again an indication of the success of the measures implemented. It can also be seen as an indication of how productivity has improved—over the period in question, Impala increased production from 15 million tons to 17 million tons, while still maintaining a downward trend in rock-related accidents and incidents.

A glimpse into the future

How will an Impala stope panel be supported in 2015? Assuming that there will still be people working in stopes by then, and barring any sudden technological breakthroughs, platinum mine stope support will probably follow the route set by the gold mines, with a few exceptions.

If this is the case, then we can probably look forward to some variation of:

- Backfill to provide regional support
- Yielding elongates as the primary support
- In-stope bolting as the face area support, with tendons in the gully
- Netting suspended from the tendons, or some form of sprayed material, to provide full areal coverage to the production crew.

Examples of this system are shown in Figures 17 and 18.

Concluding remarks

Rather than presenting technical detail, this paper attempts to tell the story of how Impala has continually updated,



Figure 17—Face area support combination of bolting and netting



Figure 18—Use of yielding elongates and backfill in back area

upgraded and improved its stope support system. Although this story is by no means unique, it provides an example of how such changes should be ongoing, and the resulting improvements that can be brought about in both safety and productivity.

Acknowledgement

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