Longwalling at great depth in a geologically disturbed environment—the way forward

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Synopsis

TauTona Mine (the renamed Western Deep Levels East) is using a longwall mining method with stability pillars to extract the Carbon Leader Reef at a depth ranging from 2097 metres to 3456 metres below surface. Seismic activity and the complexity and hazards associated with negotiating geological features at great depth pose the most severe hazard to deep level gold mining in South Africa. It impacts negatively on safety and the profitability of the mining.

The critical success factors in longwalling at depth are:

➤ Sound mining strategies and face shape control
➤ Ensuring follow behind development infrastructure is kept up to date
➤ Support system design as a strategy to effectively limit the serious effects of damaging seismicity.

This paper describes the following:

➤ Implementation of the required mining strategies
➤ The evolution of a new stope support system and problems associated with its development and implementation. How this support system was adapted for the successful negotiation of major geological features with known seismic potential and problems encountered
➤ Current initiatives to optimize follow behind development infrastructure
➤ Current initiatives in designing a new gully support system and problems experienced with its development and implementation.

Finally, this paper will deal with the way forward, briefly covering areas like the above-mentioned gully support system, the proposed phased introduction of technology, and the use of alternative mining layouts.

Introduction

TauTona Mine is an Anglogold mine in the Carletonville district, situated approximately seventy kilometers southwest of Johannesburg. A longwall mining method with stability pillars is used to extract the Carbon Leader Reef at a depth ranging from 2097 metres to 3456 metres below surface. The reef has an overall dip of 21 degrees to the southeast.

Associated with this depth of mining are high levels of seismic activity and an increased incidence of rockbursts which has a negative impact on safety and production. This consideration influenced the choice of the mining method.

When the mining method was initially decided upon, the longwall mining system was chosen as it was felt that this method was superior to the alternative method of scattered mining.

There are a number of advantages and disadvantages of the longwall mining method when compared to the scattered mining method.

Advantages

➤ No remnants are formed
➤ Development is protected against high stresses associated with stoping faces and the effects of seismicity as it is positioned in overstopped ground
➤ It is a continuous stoping operation unlike scattered mining which typically consists of three phases, namely the ledging and equipping of a stope, mining at full production in a stope and finally the remnant mining stage
➤ Faster access to reef
➤ It is a concentrated operation that makes for easier management and for more efficient ventilation control, which is always a problem in the scattered mining method.

Disadvantages

➤ Inadequate information on geological structures as there is no leading off reef development
➤ The majority of the geological structures are mined through. This has a big impact on the amount of off-reef mining that is done and increases the risk of seismicity whilst negotiating these structures
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- Geological structures with major throws that cannot be negotiated require additional development and infrastructure like service inclines to re-establish interlevels in order to re-establish the longwall. This carries a high cost implication
- Development intensive.

With a number of alternative methods for mining at depth such as Sequential Grid Mining and Downdip Pillar Mining finding increased acceptance in the industry, we have to ask the question: is Longwall Mining, with its shortcomings, still the method of choice for mining at depth? For TauTona Mine the answer remains YES.

To convert the mining layout to sequential grid would require extensive development which is costly and time consuming and therefore not justifiable in the light of the limited life span of the operation. However, a part of the operation has been converted to the sequential grid mining method, namely the west side of the Lower Carbon Leader section. The sequential grid layout was chosen for this area as an alternative to reestablishing the longwalls on the other side of a major geological structure, the Serpent Dyke (see Figure 1).

Longwall mining remains the method of choice as it has been quite successful during the life of the operation. There are three critical success factors in longwall mining at depth:
- Correct layout design and strictly controlled mining strategy
- Ensuring that you maintain adequate and up to date follow behind development infrastructure
- Support system design as a strategy to effectively limit the serious effects of damaging seismicity. A critical factor here is that your support system MUST include backfill.

TauTona Mine has been fairly successful with the implementation of these strategies and they will be covered in some detail in the ensuing sections.

Mining layout

In this mining system, the original longwalls were established from a central position related to the shaft area. A large shaft pillar was left behind. From this central position mining took place towards the east and the west. Replacement haulages were mined out from the shaft stations towards the east and the west and outside the shaft pillar area crosscuts were developed south to the breakaway position of the footwall follow behind haulages. Raises were developed between these levels and mining was initiated from these. Also from this position service inclines were established between main levels and interlevels in predetermined positions were established from these inclines. Footwall follow behind haulages were started from these interlevels. The main characteristics of the layout of the longwall mining system used at TauTona are as follows:

Forty (40) metre wide strike stabilizing pillars are left between mini longwalls. As far as possible major geological discontinuities are incorporated into these strike stabilizing pillars. Strike stabilizing pillars were initially introduced in 1980. At this stage these pillars were 20 metres wide. In 1985 a decision was taken to increase the dimension of these pillars to 40 metres.

There are six 40 metre panels per mini longwall, i.e. a total back of 240 metres between strike stabilizing pillars, giving an extraction ratio of 85%.

Overall configuration of the stop faces in the mini longwall is overhand. However, the general configuration for the total longwall system is underhand with the top mini longwalls leading.

Follow behind haulages are placed ideally at between 20 and 25 metres in the footwall. Crosscuts to reef are developed from the follow behind at 69 metre intervals in order to develop boxholes and travellingways to reef. These follow behind haulages are positioned as per the ‘45 degree’ rule so that they are not in the high stress zone.

Each panel has its own individual boxhole. A system of on-reef dip-gullies is established every 69 metres to coincide with the travellingway position for on-reef access.

Replacement haulages are carried between 70 and 90 metres in the footwall. These provide the main access for men, material and rock transport back to the shaft.

Every 750 metres a connecting crosscut is developed to the follow behind haulage to replace that infrastructure and the portion of the follow behind towards the back is abandoned. This ensures that these haulages never deteriorate to the point that they start affecting the horizontal transport operations. Because the area covered by a longwall is extensive and the stoping of the longwall continues for the life of the longwall, travelling distances become considerable and in the lower levels can extend for 4 to 5 kilometres. For that reason a very high quality of track work construction and maintenance is done in these replacement haulages as they will service a longwall for its entire life.

The stoping to development ratio is typically 28 square metres per metre.

Service inclines and pipe raises for replacement of access and services to the interlevels are also established every 750 metres from these connecting crosscuts as well as a new ore transfer system between main levels.

In order to de-stress the service incline and the connecting crosscut, a 40 metre wide slot is mined in the stabilizing pillar every 750 metres.

Air is brought in on the bottom level via a bulk air cooler to supply ventilation to the bottom four panels. It is then recooled in an intermediate cooler in the level above to supply ventilation to the top two panels and is then returned to this level through exhaust fans at the bottom of a ventilation boxhole.
The back lengths of the individual mini longwalls are dictated by the vertical spacing of the main levels, therefore it is not always possible to implement the ideal layouts in practice. These are the main characteristics of the longwall mining system as is practiced at TauTona.

Mining strategy

Strike stabilizing pillars

These stabilizing pillars form one of the main components of our strategy to reduce E.R.R. and the number of rockbursts. Rockbursts are mainly associated with the mining faces and the presence of geological structures ahead of the advancing longwall. It is thought that the two main attributes of strike stabilizing pillars are to reduce the longwall span, effectively reducing closure, and their role in ‘clamping’ the surface of a potential slip at intervals along its length. These attributes should prevent the occurrence of a large seismic event, although smaller events cannot be eliminated.

The other component is a support system that incorporates backfill. The role of backfill is twofold, i.e. regional support and strata control. Effectively, backfill assists with regional support and minimizes the effects of any rockbursts that still occur. TauTona Mine has been very successful with its backfill programme and currently our backfill placement is running at an average of 70% of area mined. This was made possible by the introduction of a new support system which will be discussed in detail later.

Mining strategy

In order for the longwall mining system to be used successfully at depth it is imperative that sound mining strategies are maintained and that strict controls are applied over adherence to face-shape configurations.

In May 1996 this fact was made all the more evident as we had a magnitude 4.0 seismic event when two adjacent longwalls effectively ‘breasted’ onto a fault which resulted in significant damage occurring in both these longwalls. This event was a direct result of face shapes not being adhered to, particularly when the optimum overall angle of approach to a geological feature. Another factor which contributed to face shapes not being maintained is the ‘easier’ practice of rather mining the panels in good ground with the panels negotiating the geological feature having a slower advance due to deteriorating ground conditions, the effects of seismicity and increased density of support installation.

There is no doubt that the manner in which geological features are approached and mined through has a significant bearing on seismic activity. It must be ensured that all mining options are thoroughly evaluated and the best sequence used to negotiate the feature.

A major thrust was instituted to reassess the current mining sequence and the validity of all the longwall mining strategies at TauTona Mine. In addition, an important commitment was made by management to rectify all non-adherence to the required mining strategies and face-shape configurations. Greater emphasis has been placed on the mine design/mine planning process using seismic data coupled with rock engineering expertise. In order to maintain this emphasis continuously, a monthly internal rock engineering meeting is held where each and every longwall mining strategy is reassessed using the updated plans, geological information and normalized seismic data. Written minutes are taken during this meeting which are submitted to line management prior to the start of the planning process.

The newly instituted rock engineering meeting is held prior to the planning process. The normal pre-planning meeting is held where the minutes from the internal rock engineering meeting are used to ensure that the next month’s planned mining sequences adhere to the required mining strategy for that area. Support by line management is constantly required to ensure that corrective action is taken where necessary. All these meetings are attended by qualified rock engineering personnel.

In addition to these formal meetings, close contact is maintained between the rock engineering personnel, the mining department and other service departments throughout the day-to-day management of the mine. It is felt that by having instituted the above, a more stringent control on adherence to the required face configurations is being exercised. This is substantiated by the dramatic decrease in the mine face-shape index since 1996 as shown in Figure 3.

This index is obtained by comparing the ideal face shape with the current face shape and calculating an index. With this method the lower the index the better the adherence to the ideal face shapes.
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Support strategy
This is described in detail in the section: Discussion.

General considerations
As far as possible, incorporate strike pillars along major geological discontinuities.
Ideally the orientation of the overall longwall system should be underhand with the top mini-longwalls leading the bottom ones. The face shape in a specific mini-longwall to be overhand but this must be flexible to allow for the negotiation of geological features.
Maintain follow behind development such that boxholes are never further away from the stope face than 90 metres.
Geological structures with up-throws up to 20 metres can be mined through, above that, stope is to be re-established.
Geological structures with down-throws up to 2 metres can be mined through, above that, stope is to be re-established.

Development infrastructure
Maintaining adequate and up to date follow behind development infrastructure is a critical issue for longwall mining as previously mentioned. Follow behind haulages are initially laid out at between 20 and 25 metres in the footwall.
However, stoping operations are usually carried out at approximately 5 degrees above the strike of the reef. The cumulative effect of this as you mine away from the shaft is that follow behind haulages become progressively deeper in the footwall. They have to be turned north to maintain the 45 degree rule in relation to the pillar abutment and a considerable amount of face length is ultimately lost.
If follow behind haulages become any deeper than 40 metres in the footwall then it becomes impossible to maintain boxholes a maximum of 90 metres from the advancing stope face which results in serious productivity losses.
The ideal solution to this problem is for the strike stabilizing pillars to be planned and established at 5 degrees above strike to coincide with the mining orientation. The consequence of this is that the mini-longwalls have to be periodically ‘stepped-down’ and the pillar positions moved. This is clearly seen in Figure 4, which shows a plan of the Lower Carbon Leader section at TauTona Mine indicating the ‘step-down’ positions of a number of mini-longwalls.

These ‘step-downs’ are done by taking a follow behind haulage south at an orientation of 90 degrees under the abutment until it intersects the reef. Then a reef drive is developed ahead of the mini-longwall up to a position where a reef raise is developed to hole in the bottom strike gully of the mini-longwall. This raise is then ledged and the faces reestablished in the correct position. The follow behind haulages can then be turned south to the correct elevation below reef.
A number of other initiatives are also in place to address the excessive depth in the footwall of the follow behind development where the pillar cannot be moved down as in a couple of isolated cases where the bottom mini-longwall is leading.
One of the most promising ones is a slusher system situated approximately 8 to 10 metres in the footwall of the reef from which short boxholes are developed to the strike gullies of the stope faces. With this method it is possible to have boxholes as close as 20 metres from the face.
Boxholes in excess of 40 metres like the exhaust ventilation boxhole to the top strike gully are in many instances developed by mechanical means using a blindbore hole borer drilling from the footwall elevation.
The last issue as far as the development infrastructure is concerned is that of replacement haulages which must be kept up to date with the longwall. These haulages continue for the life of the longwall and constitute a high-speed access to the shaft. Therefore it is extremely important that a high quality of trackwork be maintained.

Effective support system

Old support strategy
The old support system consisted of Rapid Yielding Hydraulic Props, yielding elongates and backfill with pack support along the gullies as shown in Figure 5. The following problems were encountered with this support system:
➤ When geological features were being negotiated, sympathetic minor faulting and jointing associated with the geological feature in most of the cases caused a major deterioration in the hangingwall condition. In this scenario, the removal of RYH Props became a hazardous operation that at times resulted in hangingwall failure and unraveling of the hangingwall. Worker resistance has resulted in these panels being supported with pack support where the installation of backfill was either stopped or only placed between the rows of packs. The permanent support distance to the face was also compromised with the pack support system, which due to spatial constraints was increased to 3.7 m maximum distance from the face
➤ The RYH Props were susceptible to maintenance problems and due to this the blast out rate of these props was high. This compromised the support system and worker acceptance of the RYH Props system became extremely poor
➤ Removal of the hydraulic prop results in a reduction of horizontal clamping forces in the hangingwall beam in the area where the prop has been removed (confirmed by modeling). Due to this key block failure occurs

Figure 4. Plan of Lower Carbon Leader section showing ‘step-down’ positions
The backfill to face distance was a maximum of 5.8 m, which was not always maintained, increasing the risk of hangingwall failure between the face and the backfill.

Current support system

Initially a prestressed elongate (PSE) support system, as shown in Figure 6, was introduced in the panels where geological features were being encountered. The prestressed elongate system proved to be extremely successful in these areas due to the following:

- Stiff permanent support was maintained closer to the face
- Where falls of ground increased the stoping width, longer elongates are installed rather than packs
- Backfill was used and the backfill to face distance was reduced

Production delays due to rockfalls and support installation in these areas were reduced.

Due to this, the success of the PSE support system was expanded to all panels on the carbon leader horizon. It has been found that this support system has improved the integrity of the stope-hangingwall in all panels on the carbon leader reef horizon due to the following factors. The prestressed elongates are not removed, and there is no tendency of a horizontal stress decrease in the hangingwall behind the face. This has been confirmed by FLAC modeling. (Leach1997). The maximum distance from the face to the backfill was reduced from 5.8 m (RY H Prop system) to 4.5 m effectively reducing the unsupported hangingwall beam. A fill-to-face distance of 3 m is common on the mine. When these elongates are enclosed in backfill, it’s load carrying abilities increase and the yieldability of the elongate is enhanced. The hangingwall area where the

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**Figure 5. RYHP support system**

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**WESTERN DEEP LEVELS EAST**

**SUPPORT TYPE SC1**

**BACKFILL WITH STRESSED ELONGATES**

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**TENDON SUPPORT IN ALL GULLIES 1:2:1 PATTERN**

- **1.5 X 0.75 m PACKS**
- **0.75 X 0.75 m PACKS**

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**INSTALL PRE-STRESSED ELONGATES IN THE TOP OF PANEL AS PER MINE STANDARD SUPPORT TYPE H1**

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**SPECIAL NOTES**

1. ALL PACKS TO BE PRE-STRESSED
2. IF TENDON SUPPORT CANNOT BE INSTALLED THEN INSTALL SETS TO PROVIDEAREAL COVERAGE

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**BACKFILL MAX 4.5 m FROM THE FACE AFTER THE BLAST**

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**SPACE PACKS 1.8M APART AS MINE STANDARD H1**

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**2.0 m MAX BEFORE BLAST**

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**TENDON SUPPORT IN ALL GULLIES 1:2:1 PATTERN**

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**LEGEND**

- **TENDON SUPPORT**
- **PRE-STRESSED ELONGATES**

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**SC1**

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Figure 6. PSE support system
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backfill support resistance is still too low is supported with these prestressed elongates. The stiffness of the prestressed elongates combines well with the low initial stiffness of backfill.

The relatively high support resistance provided by the prestressed elongates in the face area and in the backfill, in addition to the high percentage of backfill installed, increases the stability of the hangingwall beam. This in conjunction with the fact that the length of the effective hangingwall beam (backfill to face) is maintained at a minimum provides an extremely effective protection against seismic damage. This is borne out by the fact that during the past two years several large seismic events have occurred in close proximity to the mining faces and minimal damage has occurred in the panels. However, gully stability is still a problem.

**PSE support system problems**

The effectiveness of this support system is entirely dependent on maintaining the backfill as close to the face as possible. If the distance from the face is exceeded, the energy absorption capacity of the row of prestressed elongates closest to the backfill is reduced by closure, to below the designed energy absorption requirements in this extended face area. This problem was overcome as follows.

Considering the resistance of mining personnel to the use of hydraulic props the following motivations were used to ensure that backfill was maintained as close to the face as possible.

In order to use the PSE support system the maximum distance of the backfill from the face of 4.5 m must be maintained at all times otherwise the RYH Prop system will have to be used.

If a pack system is used, PSEs or RYH Props must be installed as per the required standard and the packs installed between the elongates. In addition backfill must be installed between the rows of packs.

These points are continuously pointed out to production personnel, and backfill to face distances are regularly monitored. This has resulted in the PSEs support system being implemented successfully and the backfill continuously being maintained at a maximum distance of 4.5 m from the face. In addition the percentage of the mined area backfilled has increased significantly since the introduction of this support system. Today, the majority of the workforce will resist working in any area where backfill is not used.

With the backfill being closer to the face (effectively reducing the face area) cleaning operations using a scraper between the backfill and the last row of support becomes time consuming and problematic. In order to speed up the cleaning/sweepings in this area (to ensure that the next backfill bag is installed timeously) the use of a water jet is a necessity.

One problem is the possibility of gold loss occurring due to inefficient sweeping prior to the installation of the backfill. This has been overcome by ensuring that backfill is not installed unless the area has been inspected by a member of the grade department.

The use of water jets in certain instances has traditionally been blamed for gold loss. However, in this scenario, the blasted rock is confined in the area between the face and the backfill and must be removed as soon as possible to provide access to the panel and to clear the area where backfill is to be installed. This implies that the broken rock is effectively only wet once and not several times as would occur in non-backfilled panels where sweepings are left, usually for an extended time period. The MCF has actually increased with the backfill placement as shown in Figure 7.

**Negotiation of geological structures**

The country rock surrounding geological features (especially dykes) in the vicinity of the reef plane is intersected with sympathetic jointing, running parallel to the feature, which increases in frequency in close proximity to the feature. In addition, if the feature is a dyke, numerous joint sets usually occur within the dyke. As the breast mining operation approaches the geological features blockly and friable hangingwall conditions usually occur.

In the past when major geological features were approached on breast the usual practice was to change the support system from the normal Rapid Yield Hydraulic Prop and backfill system to a pack support system. This changeover was undertaken for these reasons.

➤ Keyblock failure with resultant hangingwall beam failure was a common occurrence when the R Y H Props were removed
➤ Worker resistance to the use of R Y H Props where friable ground conditions exist.

The consequence of this changeover to a relatively soft support system was an increase in the inelastic closure rate with an amplification of the hangingwall beam failure resulting in major falls of ground and/or seismic shakedown. These hangingwall problems were either overcome by continuing mining on breast, or in severe cases of hangingwall failure, the breast faces were re-established either by using updip mining panels or a sequence of updip panels, to re-establish on breast. All of the above methods cause a major slowing down of the mining operation in a potentially hazardous area with the following results:

➤ longwall face shapes are jeopardized
➤ deterioration of ground conditions
➤ lowering of morale.

Mine call factor 1993-1998 vs Backfill % of area mined

![Figure 7. MCF vs backfill](image-url)
Considering the failure of the above attempts to negotiate potentially hazardous, geological features successfully and timeously, it was decided that a specially designed support system for breast mining in these areas is required. This support system should be stiff enough to provide significant horizontal stresses that will assist in retaining the integrity of the hangingwall in this geologically disturbed area.

This was done by reducing the strike spacing of the prestressed elongates on strike from 1.6 m to 1 m and reducing the maximum distance to face before the blast to 1.3 m. In addition, the face advance per blast was reduced from 0.9 m to 0.5 m by using shorter drillsteel. The maximum distance to face of the backfill, after the blast is reduced from 4.5 m to 3.0 m.

The relatively higher static support resistance provided by the prestressed elongates and the decreased backfill to face distance, has greatly reduced the propensity for falls of ground due to unstable keyblocks. This, in conjunction with the fact that the length of the unsupported hangingwall beam has been further reduced, provides additional protection against seismic activity.

The above support system has proved to be successful in dramatically improving the stope hangingwall conditions in the panels mining in major geological features where hangingwall control problems exist. In addition to this the time taken for a panel to negotiate these problematic geological features, has been greatly reduced. Several large seismic events have occurred in these areas and minimal damage has occurred in these stope panels.

Another consideration when mining through geological structures is the protection of bottom and top strike gullies in the mini-longwall as they are particularly vulnerable. These constitute, respectively, the intake and return airway in the stope.

Enhancements to the on-reef support system consist of pre-conditioning, either by itself or with the addition of void fill. Pre-conditioning is a term that is given to the drilling and blasting of 3.0 metre-long holes which have been drilled into the north or south side of stability pillars. The pre-conditioning holes are normally charged for 50% of their hole length, using emulsion-based explosives, with the remainder of the hole obviously being tamped. This is done to try and keep as much of the explosive energy in the hole as possible, as blow outs will not serve the purpose as follows. The purpose of these pre-conditioning holes is an attempt to extend the fracturing zone into the stability pillar, thus providing a ‘cushion’ to reduce the amount of damage that can be generated by seismic events. These holes are usually spaced at intervals of 3.0 metres, as measured in the direction of mining.

The pre-conditioning holes are not drilled as a matter of course in our normal stoping operations, but are planned for when the leading or trailing panel in a longwall will be negotiating a seismically active geological feature. This proactive rockburst damage control can be further enhanced by the installation of air-rated cement, which is cement that if prepared correctly, has a very low Young’s modulus, thus giving the cement very good energy absorption characteristics, which provide an additional ‘cushion’. To date, very good results have been achieved by the implementation of both pre-conditioning, and pre-conditioning combined with the installation of void fill, on the pillar side of the gully.

Falls of ground in strike gullies, are usually associated with seismicity or geological features or both. The standard support system for gullies includes gully packs as well as the installation of support tendons (usually friction stabilizers). In areas where seismically active geological features are to be negotiated, then the support tendons are enhanced by the injection of resin, either into the existing support tendons or into newly drilled holes using the contractor’s purposely designed rock stud. The injection of the resin, if done under the correct pressure, will then bond the layers of hangingwall rock into a competent beam. To date mixed results have been achieved, as some sites have seen the hangingwall looking ‘like a sosatie’, while some areas have seen the hangingwall remaining intact, despite repeated seismic activity in the area.

Discussion

TauTona has to date achieved a fair measure of success in the management of seismicity using these strategies. As can be seen in Figure 9 there definitely is an overall downward trend in the reportable accidents related to seismicity.
It can also be seen in Figure 9 and Figure 10 that there appears to have been a reduction in large seismic events as production and the percentage of backfill increased. These are, however, preliminary results and a more in-depth investigation is still to be done. The support system has proved to be extremely effective in combating rockburst damage. With the old RYH Prop support system seismic damage typically affected a large area with panels often almost completely closed up, usually due to footwall heave and hangingwall beam failure. A large amount of production time was lost in such circumstances as a result of opening up operations (at times up to 6 weeks and more). With the introduction of the PSE support system the damage due to footwall heave has become more localized. This has lead to rockburst damage in the panels becoming significantly reduced, resulting in very few cases where lost production time exceeded two days.

Fall of ground accidents have not been reduced by the increased use of backfill, however, this appears to be more of a behavioural issue and needs to be resolved by an increased focus on discipline concerning timeous installation of temporary and permanent support, good barring practice, etc.

Figure 11 shows the number of seismic-related fatalities over the period between 1995 and 1999. It can be seen that 1996 was a disastrous year in terms of safety and seismicity and was the main cause of fatalities at TauTona during that year. From 1996 when the new support system was introduced and strict controls were placed on face shape management, a dramatic reduction in seismic-related fatalities can be seen.

In Figure 12 it can be seen that 1998 was a disastrous year in terms of fall of ground fatalities. A major safety drive was initiated in December 1998, which was named the ‘Seven Deadly Sins’ campaign and focused on seven critical safety issues of which numbers 1 and 2 were Entry Examination and Support Installation. Severe disciplinary action followed from the onset of the campaign and it focused primarily on supervisor level. A dramatic turnaround was achieved in a very short time period as can be seen from the graph.

The way forward

Gully support

The above strategies have contributed significantly in the drive to increase safety and improve production at TauTona Mine. However, gully hangingwall failure during seismic activity is still a common occurrence. The type of gully hangingwall failure observed underground can be attributed to high differential movement taking place along the gullies of the backfilled panels owing to differences in closures between points inside and outside the backfill. These differential movements induce tensile strains in the hangingwall across the gully, resulting in the loosening of the fractured rock, creating the potential for rockfall.

The strategy to address this problem is to reduced the size of the hangingwall ‘tensile zone’ across the gully by replacing the timber packs along the gullies with backfill as shown in Figure 13. However, to do this, a high yield prestressed elongate must be installed along the gullies. This...
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is due to the fact that these elongates will be exposed to a higher magnitude of closure before they are enclosed in the backfill. In addition, the elongate installed along the gully edge will not be enclosed in backfill and will fail as the mining faces are advanced, marginally increasing the span not supported by backfill across the gully. In order to strengthen the ‘beam’ across the gully, in addition to the splitsets being installed, the use of superskin/fibrecrete and resin grouting are being investigated.

Technology implementation

TauTona Mine will continue to look into ways of improving work practices, safety and productivity. The next step is the phased introduction of technology into the workplace. At this stage we are planning to introduce instope drill rigs, electronic delay detonators (EDDs) and pumpable emulsions.

Introduction of drill will certainly have a positive impact on safety mainly due to its remote mode of operating. A combination of drill rigs, electronic detonators and pumpable emulsions will result in improved blasting techniques and hence a reduction in fall of ground accidents.

Faster inclined development methods

Boxholes and travellingways distances to the stoping face remains a critical issue in longwall mining. If this distance is longer than 90 metres it starts having a huge impact on face advance and productivity. As previously mentioned this is partly being addressed through mechanical drilling in the form of blindboring and the introduction of footwall slusher layouts in some longwalls. However this remains an area of further research for the future.

Conclusions

Longwall mining is generally viewed by the mining industry as being inflexible, however, experience at TauTona mine has shown that with the right attitude and approach by management, changes in mining direction and the handiness of the mining faces, can be adapted to suit the given conditions. This remains a viable method of mining at great depth in a geologically disturbed environment as long as a few critical factors are observed.

The critical success factors in longwalling at depth are:

➤ Sound mining strategies and face-shape control
➤ Ensuring follow behind development infrastructure is kept up to date
➤ Support system design is extremely important as a strategy to effectively limit the serious effects of damaging seismicity.

Sequential grid (sequential longwalling) is now being implemented on the western side of the Lower Carbon Leader section between 3370 and 3456 metres below surface. It is in the initial stages but to date it appears to be working quite successfully.

From our experience we believe that the ideal layout for mining at great depth would be a combination of longwalling and sequential longwalling where major geological features are bracketed.

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References
