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Ellie Hawkins  
*CMOC Northparkes, ellie.hawkins@au.cmoc.com*

Scott Sheldon  
*Orica*

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**Recommended Citation**  
Ellie Hawkins and Scott Sheldon, Evaluation of the recovery of block cave underbreak by sub level caving, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 2020 Coal Operators’ Conference, Mining Engineering, University of Wollongong, 18-20 February 2019  
EVALUATION OF THE RECOVERY OF BLOCK CAVE UNDERBREAK BY SUB LEVEL CAVING

Ellie Hawkins¹ and Scott Sheldon²

ABSTRACT: Northparkes Mines (NPM) is located 27 kilometres north of the township of Parkes in central New South Wales, Australia. The operations consist of underground block cave mines and an ore processing plant which produces high grade copper and gold concentrate. Production is currently sourced from the E48 Lift 1 block cave mine, E26 Sublevel Cave (SLC) and open cut stockpiles. Mining at Northparkes has been underway for over 20 years in various forms. Beginning with open pit mining and later progressing to block cave and sub-level cave mining methods, operations haven’t been without their technical challenges.

During mining of E26 Lift 2 block cave, a wedge of high grade material failed to cave, even with the assistance of preconditioning. The unrecovered wedge created the E26 SLC, which commenced mining in 2015, with production following in 2016. The SLC provides 1Mt/a to supplement the lowering grade of the current block cave feed.

The poor ground conditions in close proximity to the cave have proved a challenge. This was particularly noticeable on the first level, 9740L, with half of the firings including more than one ring. The loss of the brow encountered when blasting in ground that had been initially preconditioned for block cave mining created a heavy reliance on redrills in the operation causing poor drawpoint turnovers. Precharging was researched to improve the flow, however due to prevalence of brow loss; concerns were raised over the inability to hook up the charged ring. In 2018, a wireless initiation trial was completed in the E26 SLC over 24 rings. The trial showed that precharging was achievable in this environment and greatly improved the safety of charge up personnel.

INTRODUCTION

The CMOC Northparkes (NPM) mine is located 27 kilometres north of the township of Parkes in central New South Wales, Australia. NPM is currently operating in production with E48 block cave and E26 Sublevel Cave (SLC), with commencement of development E26 Lift 1 North block cave. NPM is currently producing 6 Mt/a with an expansion project currently in construction to ramp up by 2021 to 7.5 Mt/a. The E26 orebody which is the topic of this paper, shown in Figure 1, is a steeply plunging orebody to the NNE at approximately 80° in a generally upright, pipe-like geometry. It is centred around a tight cluster of quartz monzonite porphyry fingers and an underlying pre-mineral Biotite Quartz Monzonite (BQM).

The E26 orebody hosted the first block cave in Australia, Lift 1, which mined the orebody at a depth of 480 metres below surface. Following its completion, production commenced in E26 Lift 2, 350 metres below Lift 1. During the mining of Lift 2, a wedge of high grade material failed to cave as shown in Figure 2. As a means to recovering the wedge, preconditioning was conducted through a hydro-fracturing program, a Vertical Crater Retreat (VCR) style blasting program with boundary weakening blasts was arranged with the goal to liberate as much ore as possible. From the preconditioning, there were signs of success with finely fragmented ore

¹ Ellie Hawkins: Mining Engineer, CMOC Northparkes, Parkes, NSW 2870, Email: ellie.hawkins@au.cmoc.com
² Scott Sheldon: Senior Specialist Engineer, Orica, Kurri Kurri, NSW 2327, Tel: 0402506891 Email: scott.sheldon@orica.com
presenting to drawpoints in Lift 2, however the possibility of recovering through Lift 2 became unfeasible due to the inundation of clay.

Figure 1: E26 mining activities

Figure 2: Lift 2 southern wedge (outlined in yellow)

RECOVERY OF THE SOUTHERN WEDGE METHODOLOGY

As a result of the underbreak of the Lift 2 cave approximately 9 million tonnes of the original Lift 2 reserve were left behind in what is known as the Lift 2 South Wedge between the
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9650mRL and the 9800mRL. Table 2 shows the options investigated and the use through the recovery of the wedge. Between 2005 - 2007, a combination of the hydraulic fracturing, blasting operations and extraction level extension to the North of Lift 2 took place, however with the presence of clay and fines migration in Lift 2, full recovery of the resources was not feasible. The migration of clay also made the option of the Undercut extension or an extension to the East of Lift 2 unfeasible.

From all the options, SLC was the preferred option due to the high likelihood of success, stemming from the reliance of drill and blast mining methods, rather than natural caving for primary rock breakage. The SLC option also provided greater control over the infiltration and control of clay and fines to draw points through retreat blasting where required, and a crown pillar between the depleted block cave and the SLC. The greatest advantage, stemming from the method being similar to undercutting for block caving, which the operational and technical teams had previous experience.

<table>
<thead>
<tr>
<th>Option</th>
<th>Time to complete</th>
<th>Likelihood of Success</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Fracturing</td>
<td>3-12 Months</td>
<td>Low/Uncertain</td>
<td>Used</td>
</tr>
<tr>
<td>Blasting Options</td>
<td>6 weeks</td>
<td>Low/Moderate</td>
<td>Used</td>
</tr>
<tr>
<td>North Extension to Lift 2</td>
<td>12 months</td>
<td>Low/Moderate</td>
<td>Used</td>
</tr>
<tr>
<td>East Extension to Lift 2</td>
<td>12 months</td>
<td>Low/Moderate</td>
<td>Not Considered</td>
</tr>
<tr>
<td>Panel Cave</td>
<td>2 years</td>
<td>60%</td>
<td>Not Considered</td>
</tr>
<tr>
<td>Sublevel Cave</td>
<td>2 years</td>
<td>90%</td>
<td>Final Solution</td>
</tr>
</tbody>
</table>

The recovery of the Southern wedge was postponed due to the development and early production of the E48 block cave. Then, almost a decade later, the lowering head grade of the producing block cave required a supplementary grade enhancer. The Southern Wedge was identified as a potential source of grade, creating the E26 SLC. As shown in Figure 3, the wedge created a four level transversal SLC with complex geometries with the occurrence of as-built in the footprint and unknown ground conditions presented from the preconditioning.

Figure 3: E26 SLC
Sublevel Cave Performance

The preconditioned ground and cave stresses which the mining area had undergone from Lift 2 caving proved complex with the following drill and blast challenges:

- Backbreak of the drawpoint as far as the next ring collars;
- Reluctant material flow to a drawpoint (hang ups);
- Frozen ground, forming sides to the stope that limits material flow to a drawpoint,
- Collar bridging and requirement to re-charge collars,
- Hole dislocations in the next ring to be charged and;
- Firing against clay and fines, causing compaction.

The initial level, 9740 level (Figure 4), exhibited poor outcomes in terms of blasting outcomes when commencing the cave front in the East and Western ore drives. As the cave front was retreating back along the cave front, there were 15 events with full loss of brow within the first six month of production. These events, in addition to the high reliance on redrills from short holes, heighten the risk of traditional wired precharge and the SLC remained to operate under a single ring, charge and fire cycle.

![Figure 4: Failure modes of 9740 Level](image)

The initial DB design for the SLC was based off best practises, however were reviewed for the blasting outcomes to ensure more optimal results. The changes included:

- Burden between each ring was increased from 2.6 m to 3 m
- Ring pattern – reduction from 10 to 9 hole rings
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- Hole spacing – increased to 3.1 metres with the decrease in holes per ring
- Reduction in powder factor from 0.6 to 0.45

Due to the cave front, these changes were trialled in 9740 OD6, OD7 and OD8. These changes produced 81% of rings fired to plan in the trial drives, compared to 49% for the remaining ore drives, see Figure 5. Due to the improvement shown in the trial drives, the changes were applied to the next level, 9720. The changes did have an impact in terms of reducing entire loss of the brow, from 42 events total on the 9740 to a total of 24 events on the 9720 Level. This result is related directly to the increase in burden between the production rings. The improvement of brow damage and the occurrence of short holes

![Figure 5: Failure modes of 9720 Level](image)

delivered a reduction in the multiple ring firings, improving primary draw. However this was offset by a deterioration in ground conditions and hence an increase in the number of rings requiring re-drill, shown in Table 2.
To overcome the less than optimal outcomes, high level of remediation was required to ensure cave propagation. The re-work process can include the stand-up of drawpoint rill, application of shotcrete for reinforcement and the drilling of recovery or slasher rings. This caused production delays and also impacted on the ability to maintain an optimum cave front with operational drives advancing ahead of drives requiring remediation. Particularly where recovery or slashing rings were drilled in an attempt to recover multiple production rings to be fired in a drawpoint in one blast event.

Previous studies completed by the Ridgeway SLC found that the influence zone for depth of draw of LHD mucking a production ring is generally less than 2.6 m (Power 2004). With the current burden at 3 m for the 9720 level, the firing of multiple rings caused early dilution into the draw cones, as the production mucking attempted to draw the tonnes from the whole blast.

<table>
<thead>
<tr>
<th>Measure</th>
<th>9740 Level</th>
<th>9720 Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of rings requiring re-drill</td>
<td>23.3%</td>
<td>26.4%</td>
</tr>
<tr>
<td>% Re-drills (% of total m drilled)</td>
<td>11.0%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Short holes per ring</td>
<td>15.0%</td>
<td>20.0%</td>
</tr>
<tr>
<td>Shotcrete usage m3/ring fired</td>
<td>1.42</td>
<td>1.13</td>
</tr>
<tr>
<td>% of double ring firings</td>
<td>45.5%</td>
<td>32.0%</td>
</tr>
<tr>
<td>% of rings fired to plan</td>
<td>55.8%</td>
<td>66.2%</td>
</tr>
</tbody>
</table>

Across the SLC, due to the complexities of geometries, no production rings are the same length, from the 9740 Level with 30 m high production rings to 20 m high production rings on the 9720 Level. There was no constants in the trialling in terms of the mine design, making a DB best practice across the cave difficult to develop, rather it relies on geological contacts, previously problematic areas of the cave and daily inspections of the drawpoint. The exposure of underground personnel in close proximity to the rill was a concern with the hours shown in Table 3. The aim was to reduce the exposures of personnel in close proximity to the brow, which was achievable with precharging on the lower levels with WebGen100.
TABLE 3: Labour demand of rework process on 9740 and 9720 levels

<table>
<thead>
<tr>
<th>Measure</th>
<th>9740 Level</th>
<th>9720 Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-drill events</td>
<td>98</td>
<td>90</td>
</tr>
<tr>
<td>Re-drill man hours</td>
<td>420</td>
<td>491</td>
</tr>
<tr>
<td>Rework shotcrete events</td>
<td>173</td>
<td>120</td>
</tr>
<tr>
<td>Rework shotcrete man hours</td>
<td>519</td>
<td>360</td>
</tr>
<tr>
<td>Average exposure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man-hours per blast event</td>
<td>5.94</td>
<td>6.22</td>
</tr>
<tr>
<td>(including charge and fire)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total exposure man hours</td>
<td>1935</td>
<td>1710</td>
</tr>
<tr>
<td>(rework, charge and fire)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Application of pre-charging

The majority of SLC operations in Australia and internationally conduct precharging to take advantage of the improvement in safety performance, working conditions and production flexibility compared to traditional SLC charging practices. One of the major threats to the introduction of precharging in the E26 SLC was managing brow condition to allow for access to the collar of the blast holes. To abandon a production ring due to the inability to hook-up precharge would impact on the ability to recover caving conditions, as well as impede on the safety of personnel with undetonated primers reporting to the draw on future levels.

Precharging presents opportunity for the business in terms of production flexibility and mine efficiency as the dependency on charge up activities is somewhat reduced with the reduction in rework processes. Ridgeway stated that the implementation of precharging provided a ‘realised’ direct cost savings in excess of A$1 million per annum (Wiggin 2002). NPM re-opened the investigation of precharging in the E26 SLC. The steps taken in this investigation were:

- Reviewed the outcomes of a trial conducted by EHM using Orica’s WebGen™ 100 wireless initiation system (te Kloot et al. 2017)
- Reviewed the original SLC risk assessment that excluded precharging with context of it could use wireless initiation
- Engaged with Orica to conduct a 24 ring trial using the WebGen™ 100 wireless initiation system.

It was expected that a wireless initiation system would allow precharging to take place in the preconditioned ground of the E26 SLC. If access to the collars of a precharged ring were lost the ring could still be fired off if the initiation system in the precharged hole was wireless. A wireless system would also remove the need to recover lost brows thereby removing the charge crew from having to access damaged brows.

Wireless initiation trial

Before a precharging trial could be commenced the following capabilities needed to be established:

- Extending explosive bulk product sleep times from seven days to at least 28 days
- Confirming the wireless initiation primer could sustain blast induced pressures
- Confirming the strength, range and reliability of the wireless initiation system signal in the E26 SLC ore body
Extended sleep times

The NPM E26 ore body had previously returned positive samples when testing for reactivity of the ground with Ammonium Nitrate (AN). As a result of the past results, NPM was operating on a maximum 7 day sleep time for any charged hole. With up to 25 drives across two levels in the SLC, the cycle time between ring firings in a single drive was nominally 24 days. In order, to implement a precharging operation across the full SLC, a minimum 28 day sleep time would be required.

Ideally NPM required two precharged rings per drive but it was conservatively estimated that a minimum 40 day sleep time would be required to manage this. So, the plan that was agreed to with Orica was to progressively test and implement extended sleep times until 28 days was reached such that, if the precharging trial was successful, then single ring precharging could be implemented. Once implemented then a program would be put in place to investigate extending sleep times further to a nominal target of 40 days.

Rock samples across the 9720 and 9700 levels were collected focussing on geology that had previously shown to be reactive. These samples were then tested by Orica for reactivity following the guidelines of 2017 AEISG Code of Practice Elevated Temperature and Reactive Ground. Of the 17 samples collected, four tested positive to AN. As a result, the four samples were tested in Ammonium Nitrate Emulsion (ANE) at an elevated temperature of 55°C for a period of 116 days in the lab as per the code of practice. These four samples showed no reactivity with ANE and passed the assessment.

To validate the successful lab results, in situ testing commenced with a program involving three holes were drilled in an area that was defined as being high risk to reactivity (pyrite-anhydrite hydrothermal breccia unit). These holes were loaded with Subtek™ ANE, WebGen™ 100 wireless primers and a thermocouple wire. The thermocouple gauge was located beside the WebGen™ primer to measure the temperature of the emulsion at this point. The holes were inspected daily for indications of reactivity and the temperature reading from the thermocouple was recorded. The procedure in place dictated the frequency of temperature measurement and if a temperature increase beyond 2°C was observed, then shift readings were to be taken. If the temperature reading increased by more than 5°C from ambient ground temperature, the procedure involved E26 blast area excavation and the test holes being fired immediately.

Figure 7 shows the results of the temperature monitoring of these three extended sleep time test holes. The three test holes were successfully slept for the 35 day test period. They showed no indication of reactivity. All three holes were successfully fired at the end of the period via the WebGen™ 100 wireless initiation system.

![Figure 7: In situ extended sleep time results](image)
Before the full integration into production blasting with the WebGen100 system, there was a requirement to investigate the effect of blast induced pressure on a precharged ring when firing the production ring in front. The test needed to validate that the wireless unit could withstand the blasting pressure and not be made inoperable when exposed to close field blasting.

The testing was completed in two slashing rings on 9720 OD6 R102A-R102B (shown in Figure 9) after the initial testing area failed at capturing data. The use of the slashing rings provided a higher blast pressure for the wireless units to withstand with a burden of 1.5 m compared to a typical precharged ring fired on a 3.0 m burden. Each hole was charged as per the plan with the only difference being the addition of a Carbon Resistor Gauge (CRG) attached to each of the wireless units as shown in Figure 8. At firing time, the four CRG cables were then connected to a DataTrap™ II monitor to record the pressure gauge readings when the preceding ring in front was fired. Results from this test recorded blast pressures well below the rating for the WebGen™ receiving unit used in the wireless primer.

With the successful results from the pre-work testing, a 24-ring trial using the WebGen™ 100 wireless initiation system was undertaken. The trial commenced in the 9720 level where production on the level was well underway, using a wired initiation system with no precharge. The concept was to phase out the single ring wired initiation charging and introduce precharged rings with wireless initiation across a section of the cave front.

This strategy was proven to be not suitable with the combination of wireless precharged blasting systems with wired blasting systems in non-precharge conditions. It was noted that this combination was unworkable unless it could be immediately adopted across the entire level. The primary reason behind this conclusion was that precharging was not occurring in neighbouring drives and the failures of brow loss and short hole were occurring, requiring remediation. If redrilling was required in remediation, the neighbouring precharged drives would need to be fired off, due to the 20 m exclusion zone applied to charged solids at NPM as shown in Figure 10. No consistency in drives nor across the level was achievable across the 5 rings fired with WebGen100 on the 9720 Level, and hence the trial was moved to the 9700 Level.
Figure 9: Slashing ring design for the pressure hole testing

Figure 10: Exclusion zone
The 9700 level was in the initial stages of production and the cave front was yet to be established on the Western portion. The commencement of the level meant that precharging could be rolled sequentially into adjacent drives with the breakthrough to the cave. Of the 24 trial rings, 19 were implemented on the 9700 level. This method when utilised allowed for the first set of slot rings and the final development cut to be initiated with a wired blasting system with the next set of slot rings precharged. The method over the first three drives of the 9700 Level provided the correct conditions for the ability to consistently precharge across the entire cave front with no remediation interruptions.

The main risk involved with the traditional wired detonator and its use in precharging is the loss of access to the collars for firing. Across the trial, a total of four entire brow losses were experienced. Figure 11 shows the backbreak of R59 after firing. The brow damage passed the precharged ring collars (R61) which is evidenced by reflective tag on the left side of the rill. This showed the immediate benefit of wireless initiation, as this loss of brow would require no remediation for access and allow for recovery. Once bogging was completed, the precharge process was applied to the next ring with no further issues.

The wireless initiation system allowed precharging to be undertaken successfully in this preconditioned ground. The result was a complete removal of all the issues faced on the 9740 and 9720 levels by the uninterrupted application of precharging. Precharging, as shown in Table 4, removed all requirements for redrilling and reduced the requirement of rill reinforcement with shotcrete. Over the trial, all rings were fired to plan, with no multiple ring firings in all precharged rings.

![Figure 11: 9700 OD01 R59 bogging with precharged R61 not visible](image-url)
TABLE 4: Labour demand of rework process on 9740 and 9720 levels

<table>
<thead>
<tr>
<th>Measure</th>
<th>9740 Level Wired</th>
<th>9720 Level Wired</th>
<th>9700 Level Wireless</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of rings requiring re-drill</td>
<td>23.3%</td>
<td>26.4%</td>
<td>0%</td>
</tr>
<tr>
<td>% Re-drills (% of total m drilled)</td>
<td>11.0%</td>
<td>16.4%</td>
<td>0%</td>
</tr>
<tr>
<td>Short holes per ring</td>
<td>15.0%</td>
<td>20.0%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Shotcrete usage m3/ring fired</td>
<td>1.42</td>
<td>1.13</td>
<td>0.32</td>
</tr>
<tr>
<td>% of double ring firings</td>
<td>45.5%</td>
<td>32.0%</td>
<td>0%</td>
</tr>
<tr>
<td>% of rings fired to plan</td>
<td>55.8%</td>
<td>66.2%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Moreover, the main aim of the trial was to reduce the exposures of personnel in close proximity to the brow when on foot. Table 5 shows the reduction in exposures from over 6 man hours per blast event, reduced to 2.5 man hours per WebGen100 blast.

TABLE 5: Exposure hours in close proximity to the brow on foot

<table>
<thead>
<tr>
<th>Measure</th>
<th>9740 Level Wired</th>
<th>9720 Level Wired</th>
<th>9700 Level Wireless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-drill events</td>
<td>98</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>Rework shotcrete events</td>
<td>173</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td>Average exposure man-hours per blast event(including charge and fire)</td>
<td>5.94</td>
<td>6.22</td>
<td>2.53</td>
</tr>
</tbody>
</table>

Following the successful completion of the trial, NPM assessed the impact on safety for the production crews and the overall improvement in the performance of the cave when precharging. Being first generation technology, the cost per blast is higher, however, this is offset by the remediation works and the primary recovery improvement. Consequently, NPM became the first operation in Australia and the second operation globally to convert to a wireless initiation system for use in production blasting.

Observations to date

As of date of this paper:

- 105 production rings have been fired with the wireless initiation system. The wireless initiation system has 100% success rate in firing of rings.
- 25 production rings have been slept for 28 days without any sign of reactivity. Embarking on a program to collect more data on in hole performance and to further extend sleep time.
- A second extended sleep time trial was conducted underground in a production ring for 35 day, with no reactivity presented and minimal change in the VOD from 28 day firing data.
- Product ejection has led to changing from red caps to gas bags for stemming. Undertaking a program to assess performance of different stemming modes.

The conversion to the wireless system is an on-going strategy with daily changes in draw points impeding on precharged stocks. Currently, 40% of all blasts in 2019 were initiated utilising WebGen100, with the goal to increase to 90% in 2020.
CONCLUSIONS

The E26 Sub level cave has enabled the recovery of the Lift 2 Southern Wedge. The complex geometries and poor ground conditions have created challenges in recovery and optimal drill and blast outcomes. The poor outcomes in blasting increased the exposure risk for the production crews, with particular attention to working in close proximity to the rill on foot during remediation. The wireless technology has enabled the near elimination of working in close proximity on foot.

The proved application of WebGen on site has enabled a trial of high lift drawbells in the blasting in the new block cave, E26 L1N. The major challenge has now shifted from the creation of a wireless detonation system to allow for sequential blasting of decked up holes, to a reliable stemming mechanism to deck the up holes and prevent connections. The intent of this trial is to create a functional methodology for all future block caves to remove the need to develop an undercut level.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the Northparkes management team throughout the wireless initiation program. The long history of innovation at Northparkes has been shown to continue over the 25 years of operation on-site.

Acknowledgement to Orica support personnel and the Northparkes charge-up operators throughout the trial, who provided practical method changes and were receptive to the change.

REFERENCES

AEISG Code of Practice Elevated Temperature and Reactive Ground Edition 4 March 2017


