Reducing Dilution with Technology
A twist on the AVOCA mining method is made possible at Goldcorp's Musselwhite Mine utilizing Orica's wireless, through the earth initiation system

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Abstract

Musselwhite Mine is located on the southern shore of Opapimiskan Lake, approximately 480 km north of Thunder Bay, Ontario, Canada. Musselwhite Mine (Musselwhite) is 100% owned and operated by Goldcorp Inc. (Goldcorp) and has been in commercial production since 1997. The 2017 proven and probable reserves at Musselwhite total 8.84 million tonnes containing 1.85 million ounces of gold. In 2016 Goldcorp entered in a partnership with Orica to provide blasting products and technical support at its Canadian operations.

Through the partnership, Orica identified an opportunity at Musselwhite to utilize their WebGen™ 100 wireless, through the earth initiation system technology to help reduce dilution in longhole stopeing. Musselwhite uses a modified AVOCA mining method. With increasing depth, blast sizes have had to be reduced to control unplanned dilution. A project was initiated in late 2016 to leave temporary rib pillars (TRP's) that could be recovered using the WebGen™ 100 wireless initiation system. Initial results from the project have been very positive and refinements to the TRP mining method are ongoing. The project utilized a collaborative approach between Musselwhite's Engineering and Operations departments, Orica's Technical Services and Technology teams to develop and deliver the project's outcomes.

This paper chronicles the process by which this project was undertaken, provides a description of the challenges that lead up to the project commencement, introduces the WebGen™ 100 initiation system and the TRP Mining Method, details case studies from two stopes, and introduces future wireless blasting applications being investigated by the Musselwhite and Orica teams.

Introduction

Musselwhite Mine is located on the southern shore of Opapimiskan Lake, approximately 480 km north of Thunder Bay, Ontario, Canada. Musselwhite Mine (Musselwhite) is 100% owned and operated by Goldcorp Inc. (Goldcorp) and has been in commercial production since 1997. The 2017 proven and probable reserves at Musselwhite total 8.84 million tonnes containing 1.85 million ounces of gold.

The majority of the mining at Musselwhite is completed using a modified AVOCA mining method. With the modified AVOCA method each blast is backfilled, then waste is removed from the backfilled stope to create a void for the next blast.

As Musselwhite follows the ore body down plunge challenges have been encountered regarding stope dilution. Increasing depth, strike length, and number of lifts are all contributing to high levels of dilution. Generally, some of this dilution is separable during the mucking cycle, but the net effect of this dilution is a reduction in productivity and profit.

In 2016 Goldcorp entered in a partnership with Orica to provide blasting products and technical support at its Canadian operations. Through the partnership, Orica identified an opportunity at Musselwhite to use the WebGen™ 100 wireless through the earth initiation system technology (WebGen™) to help reduce the dilution being seen in modified AVOCA stopeing. A project was initiated in late 2016 to leave temporary rib pillars (TRP's) that could be recovered using the WebGen™ technology.

WebGen™ 100 System

Orica's Wireless Electronic Blasting System, WebGen™ 100 is the first commercially available fully wireless blast initiation system.

The system consists of a consumable detonator/primer assembly, a secure data integrity system and a secured firing transmission system. The firing system operates on a low frequency (through rock), Magnetic Inductance that communicates with specific individual groups of detonators, while all other groups return to a sleep mode. (Wicks and Lovitt, 2017)

Wireless blasting can enable improvements in safety and productivity by eliminating the requirement to physically hook-up the initiation system to a surface network of wires or signal tube. Modifications to existing mining methods and new mining methods are being developed to take advantage of fully wireless communications to the individual blast holes. The WebGen™ 100 system communicates through rock, water and air via low frequency magnetic induction waves.

The WebGen™ 100 primers are encoded with their Group ID (GID) and delay time just prior to loading into the blast-holes. This data is stored in the disposable receiver (DRX) and the i-kon™ plugin detonator respectively. The GID consists of 3 unique codes, the wake-up code, the arm code and the fire code. All three codes are required to initiate the blast.

The DRX switches to standby mode soon after the hole is loaded and then it alternates between sleep mode and listening mode until it receives its wake-up code. Once woken up, the primers can receive the arming code, which will synchronize the units to be blasted and switch them into "armed mode". The firing command, the third unique code, is transmitted when the fire button is pressed, following the mine's blasting protocol.

Temporary Rib Pillar AVOCA

The Temporary Rib Pillar (TRP) mining method was developed by Orica to take advantage of fully wireless blast initiation.

Musselwhite utilizes both conventional and modified Avoca mining methods depending on the access available for that retreat. Retreats without a secondary access are mined utilizing modified Avoca. With modified Avoca, all activities are completed from the retreat drive. The fill is placed from the retreat end and therefore, once the panel has been filled there is a requirement to remove some fill (void pull) to 1. Provide void space for the next blasting cycle and 2. Prevent fill from mixing with the ore causing dilution (Figure 1).

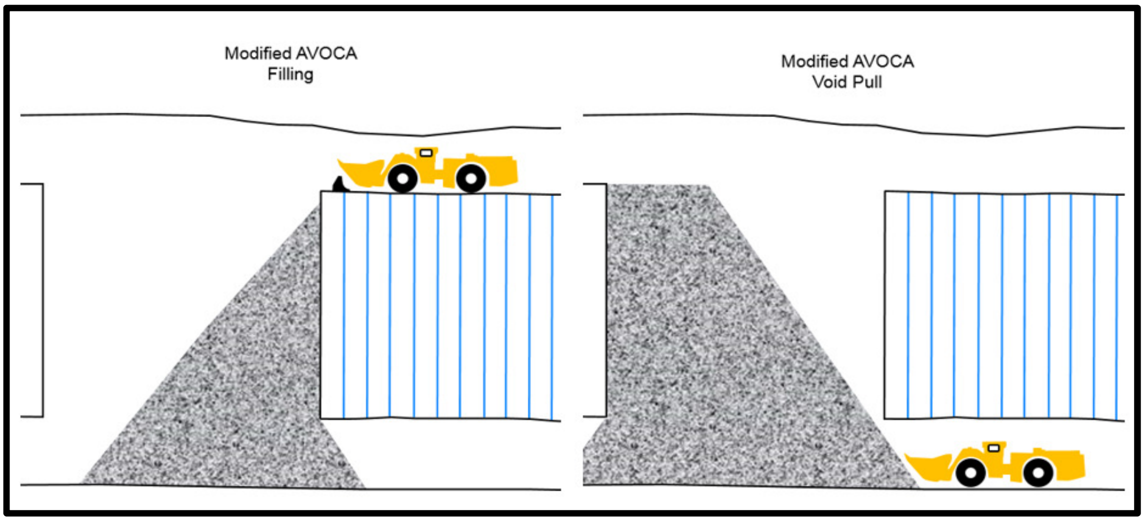

Figure 1. Schematic of Modified AVOCA filling and void pull activities

With the TRP method, a temporary pillar, located at the backfill/ore interface, as well as a slot are drilled in the next panel to be mined (Figure 2). The entire panel is loaded in one loading operation, the TRP is primed with WebGen^{TM} 100 and the Mass Blast is primed with i-kon^{TM}.

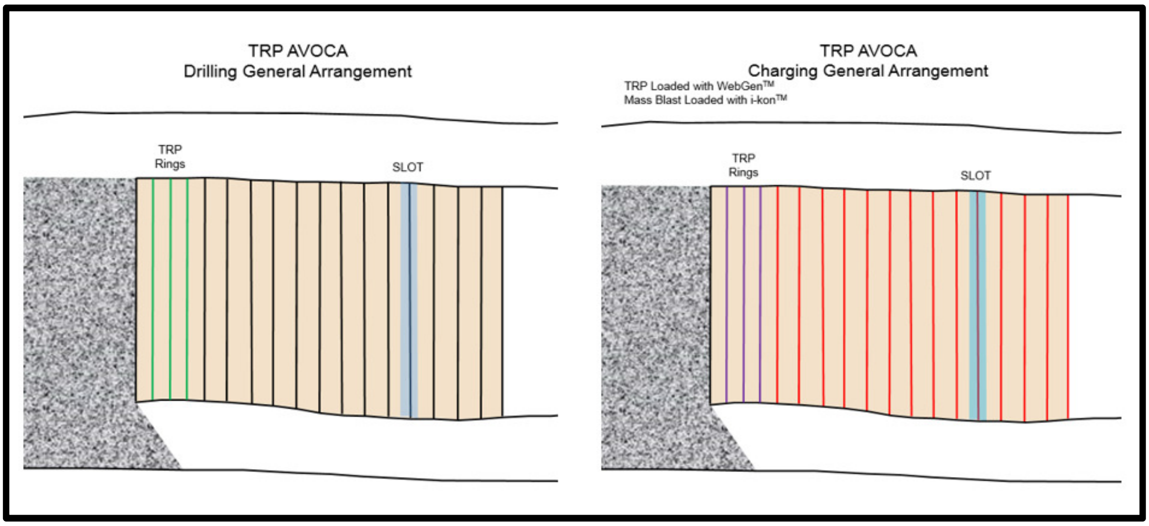

Figure 2. Schematic of typical drilling and charging arrangement of TRP AVOCA

The Mass Blast is fired and mucked out leaving the TRP to hold back the fill (Figure 3).

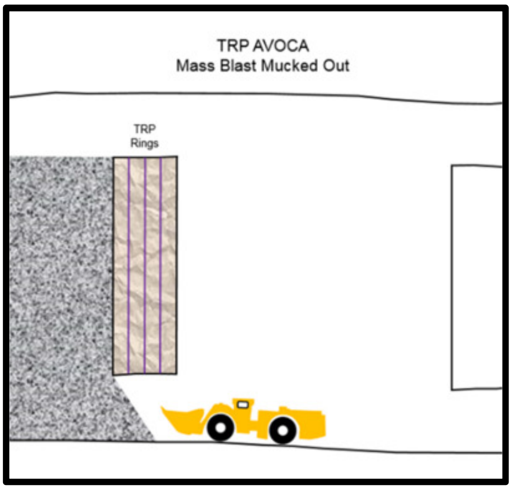

Figure 3. Schematic of mucked out mass blast of TRP AVOCA

The TRP is fired in two distinct blasting sequences within the same blasting event. Blast 2A removes the front ring and the bottom half of the of the pillar. The muck is thrown towards the draw point. The blast is then paused for a period of time in order to let the backfill rill to its natural angle of repose. Blast 2B fires the top portion of the pillar in both directions. The muck that is thrown towards the fill lands on the top of the rill and flows down to the ore/fill interface as shown in Figure 4.

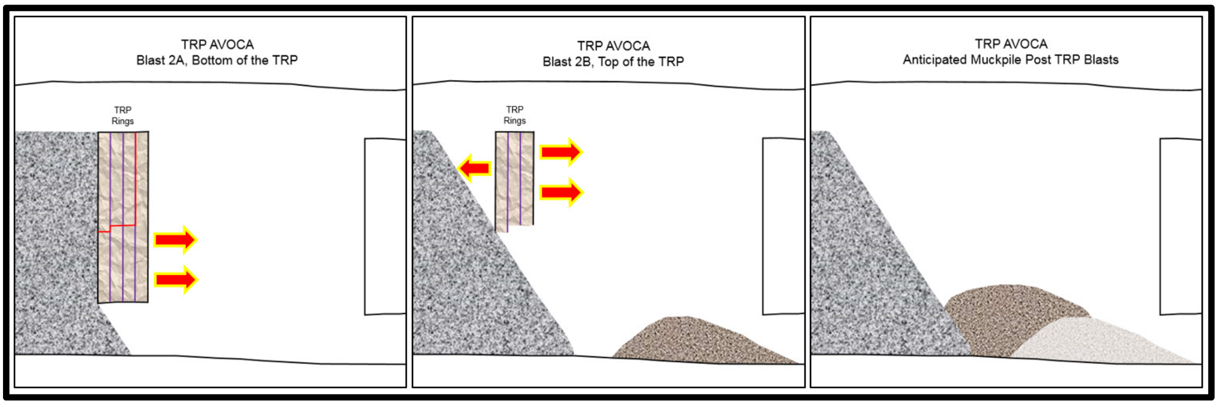

Figure 4. Schematic illustrating firing sequence of the TRP rings

The TRP concept aims to improve two key aspects of the business; safety and productivity. From a safety and asset protection perspective the benefits of the TRP method are:

- Reduced exposure to working adjacent to open holes
- In-Stope exposure time to equipment is reduced during the mucking cycle
- Lowered risk of wall sloughage damaging equipment in-stope

The productivity improvements that are projected for the TRP mining method include:

- Reduced drill and blast cycle times
- Improved fragmentation and mucking rates
- Reduced distances for remote mucking

- Reduced dilution by providing a temporary span pillar
- Reduced fill placement because of dilution reduction
- Eliminating void pulls (material re-handling)

Musselwhite Case Study

The conventional modified Avoca blast discussed below was not typical for Musselwhite. It was a trial attempting to open a larger hydraulic radius (HR) stope with the modified Avoca method. This resulted in excessive dilution, well above historical averages for Musselwhite. Figure 5 shows a sketch of the previously blasted longitudinal stope, the TRP mass blast, the TRP blast, and the mined-out stopes in the area.

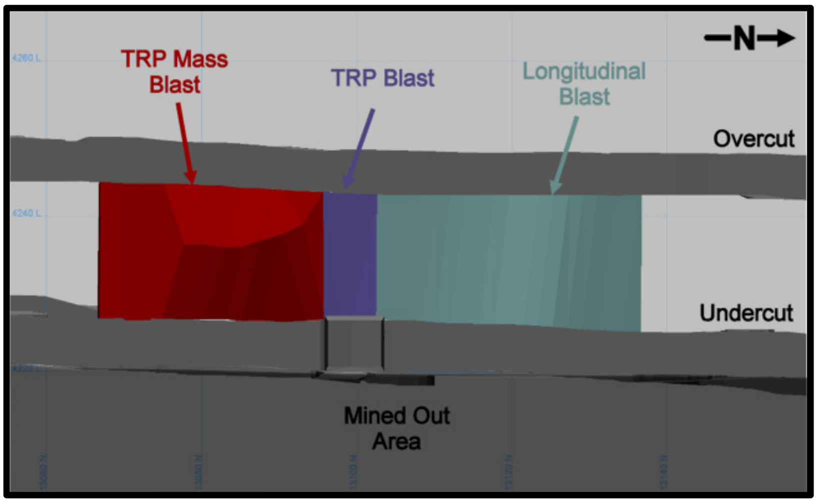

Figure 5. Longsection view of case study stope

The longitudinal stope showed excessive dilution from the hanging wall shortly after the blast was taken due to the strike length exposed, hanging wall hydraulic radius, and lack of confinement at the north end of the stope. Cavity Monitoring Survey (CMS) data showed progression of this dilution during the mucking cycle (Figure 6).

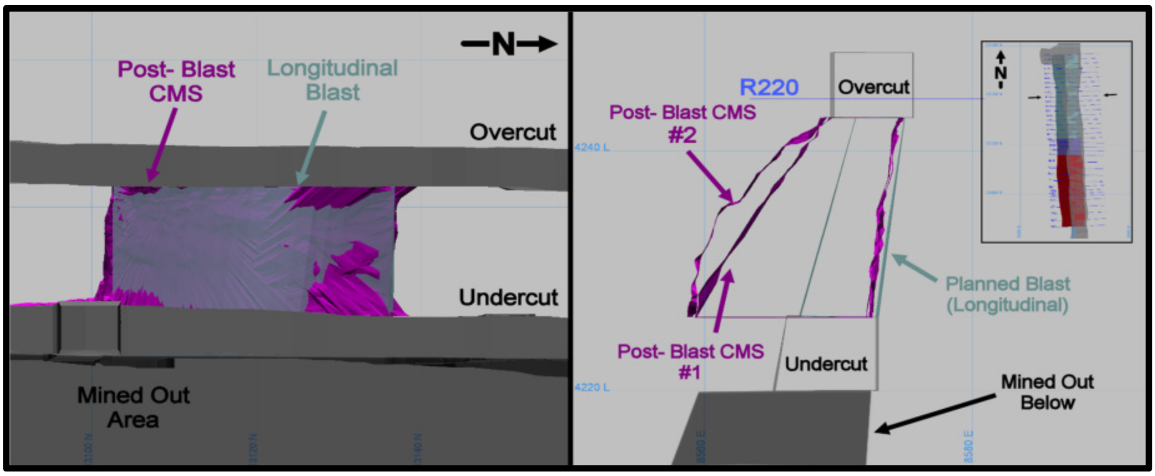

Figure 6. Longsection (left) and cross section (right) views of longitudinal stope blast CMS

The TRP method was being introduced during the same period and the subject stope was selected for a trial due to this excessive dilution. Leaving a permanent span pillar in this location was not favorable due to the local geotechnical and economic conditions.

With the TRP concept a temporary rib pillar is left loaded with WebGen™ 100 and a conventional mass blast is taken. The mass blast is sized based on sound rock mechanics principles and evaluations of the stope development. Ore recovery is maximized for the strike length of the mass blast while dilution is minimized (Figure 7). The TRP provides confinement at the north end of the retreat blast until the mass blast portion of the stope is completely mucked out.

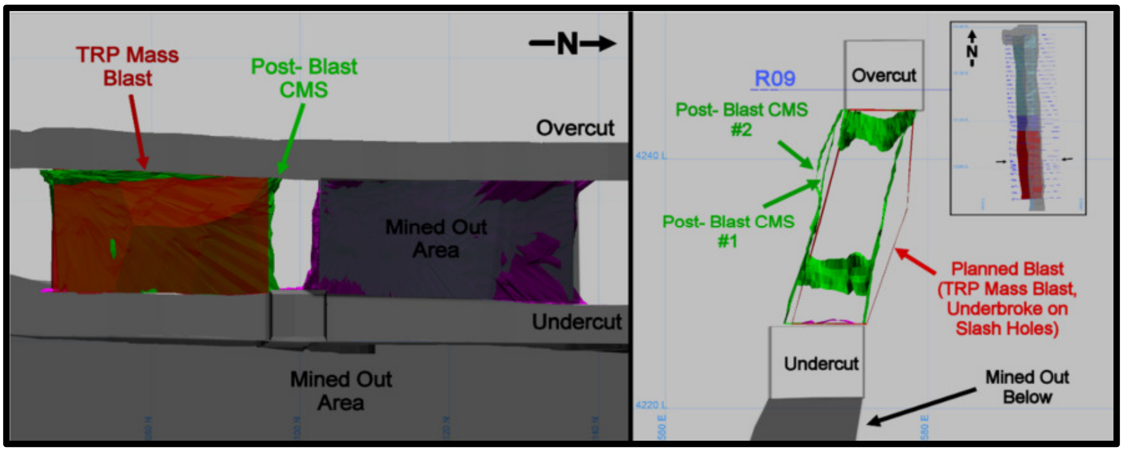

Figure 7- Longsection (left) and cross section (right) views of TRP stope mass blast CMS's

The TRP contains approximately 15% of the total tonnage for the stope. A lower recovery is expected for the TRP since there will be marginal mixing of the waste from the backfilled stope, and once the span pillar has been removed, hanging wall dilution can begin to propagate from the north to the abutment at the south end of the stope.

Figure 8 shows a CMS of the TRP blast immediately after firing. The dilution seen at the midpoint of the TRP shows a large reduction from the previous blast due to passive support provided by the rilling backfill during the stepped TRP blast.

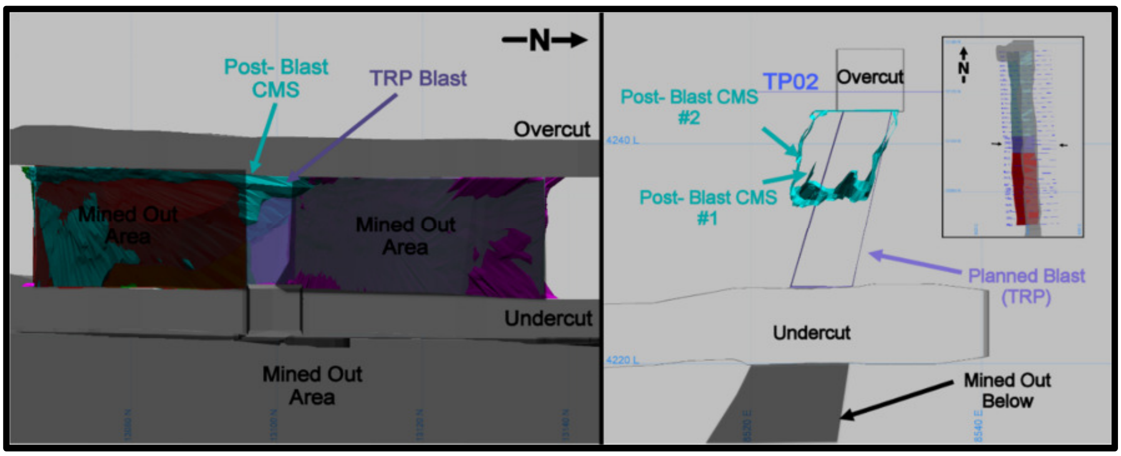

Figure 8. Longsection (left) and cross section (right) views of TRP WebGen™ blast CMS

The post TRP blast CMS also confirmed the theoretical muck movement anticipated for the TRP blast design (Figure 9). The majority of thrown muck was recovered before the stope was called.

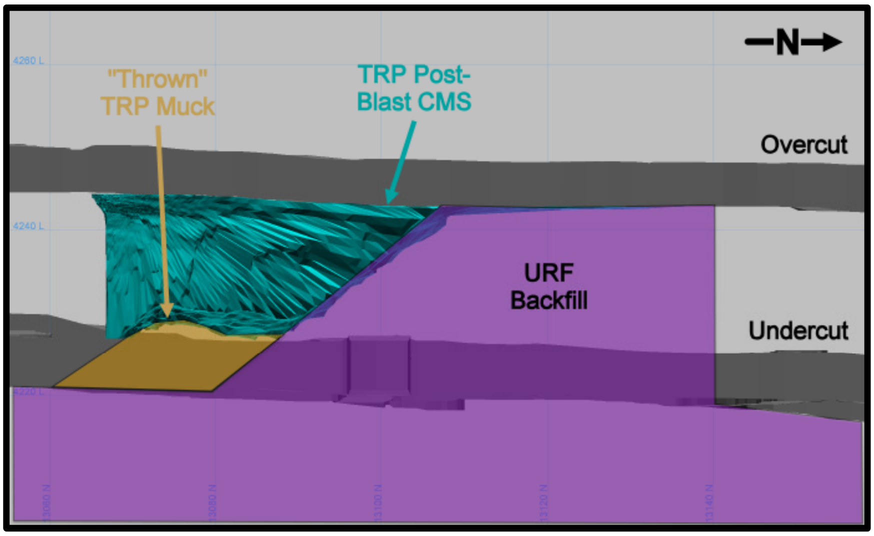

Figure 9. Longsection view of post-WebGen™ blast CMS

For the typical Musselwhite modified AVOCA method, this same strike length would require approximately two blast/muck/fill/void pull sequences. Historical trends at Musselwhite also indicate that as mined out strike length increases, dilution also increases in a progressive manner. With the TRP method the baseline dilution for each blast sequence is reset.

Table 1 summarizes key production metrics for the case study blast discussed above. The metrics selected were the overall stope cycle time in days, the daily scoop productivity in tonnes per day (TPD), and the overall stope dilution. The case study blast showed significant improvements in all metrics selected.

Table 1 - Summary of key production metrics for the case study blast

TRP Case Study Blast	
Days mucked	33% Reduction
Avg. TPD	27% Improvement
Dilution	93% Reduction

The increased mucking rate was verified by analyzing the truck loads hauled from the stope and comparing them to the average truck loads for the same time period from conventional stopes. Musselwhite is fortunate to have a truck scale located on the haul route to the underground rock breaker for daily truck load tracking. On average, trucks loaded from the TRP Mass Blast hauled 15% more tonnage than trucks loaded at conventional stopes.

In conclusion, the case study TRP showed a 93% reduction in dilution in a highly challenging mining front, with the added benefit of a 27% increase in the daily mucking rate. This was a highly successful trial of the TRP method.

Updated TRP Results

Since the case study blast, Musselwhite has implemented the TRP method in several areas of the mine where excessive dilution is being experienced. On average a 34% reduction in dilution has been observed in these TRP mining fronts.

Table 2 summarizes the average improvements in the key production metrics observed after seven TRP blasts. It is important to note that all of these TRP blasts were taken in areas of the mine with higher than average dilution.

Table 2. Summary of key production metrics for TRP blasts after and including case study

Overall TRP Summary	
Blasts	7
Days Mucked	20% Reduction
Avg. TPD	14% Improvement
Dilution	34% Reduction

On several levels, two successive TRP blasts have been designed. The average dilution for each blast in these successive TRP stopes has dropped as the strike distance from the last conventional blast has increased. It is anticipated that the TRP method could be utilized to stabilize the overall average dilution of an entire level to 10-15%. Currently a mining area with four successive TRP stopes has been designed to test this theory.

Future Applications

The continued success of the TRP panels has led to additional opportunities being identified for the WebGen™ 100 technology at Musselwhite. The TRP concept has been extended to uphole stopes, as illustrated in Figure 10, to help improve recovery along the upper plunge of the Musselwhite ore zones. Pillars can be recovered that previously may have been left in place for local stability.

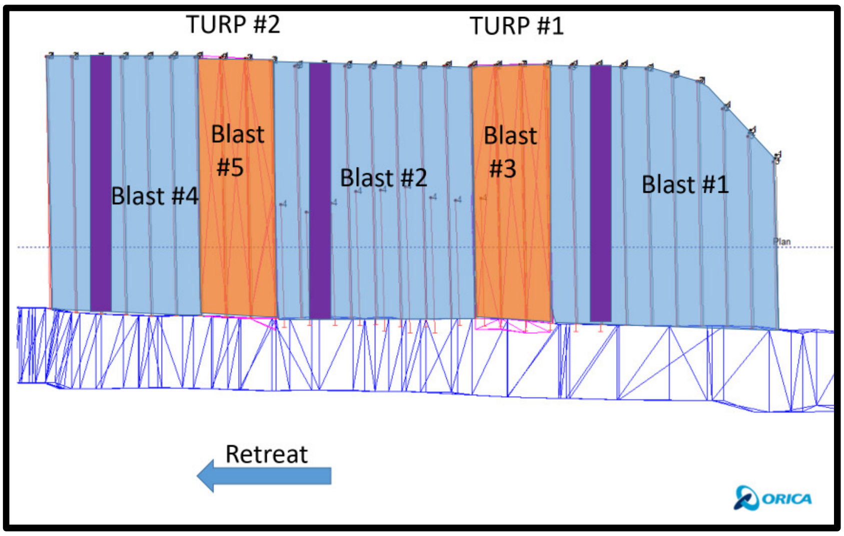

Figure 10. Longsection view of Temporary Uphole Rib Pillar (TURP) mining concept

More recently a bottom plunge blast has been designed with WebGen™ 100 technology. In this concept, sequential blasts allow muck to be thrown to the drawpoint, extending the strike length of non-breakthrough plunge blasts, as shown in Figure 11.

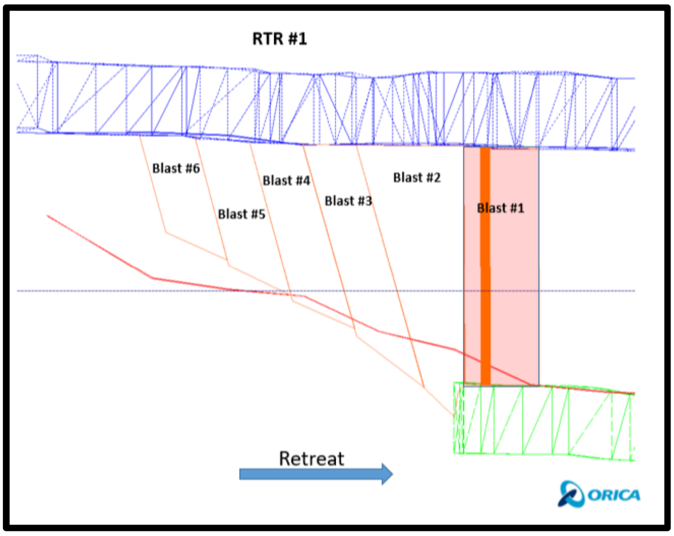

Figure 11. Longsection view of Reverse Throw Retreat (RTR) mining concept

Summary

The WebGen™ system has proven itself as an enabler to modify an existing mining method utilized at Musselwhite and provide substantial improvements in safety, productivity and cost reduction. Based on the success of the TRP method two other mining method twists have already been successfully evaluated. Enhancements to other drill and blast geometries and mining methods utilized at Musselwhite are currently being explored.

References

WICKS, B., and LOVITT, M., 2017. A new era of blast initiation systems reducing safety risks, costs and enabling automation. In proceeding of EFEE 9th World Conference on Explosive and Blasting, Stockholm, Sweden.