Selective highwall mining at the Dome Open Pit mine

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ABSTRACT: Following completion of planned mining operations at the Goldcorp Dome Open Pit Mine, a high-grade Shaft Pillar located in the pit highwall was recovered. Mining of this Shaft pillar faced numerous rock engineering design and implementation challenges due to its remote position on the highwall and the presence of mine workings within the wall.

The case example presented in this paper discusses the geotechnical investigation performed at the site, novel measures undertaken for installation of ground support required for rockmass reinforcement and for worker protection, as well as operational challenges to successful mining of the Shaft Pillar.

1 INTRODUCTION

The Dome Mine began underground production in 1910. It is the longest continuous operating gold mine in Canada. Over the years, more than 900 underground stopes have been mined and hundreds of miles of drifts, sublevels and raises developed. Underground mining methods included shrinkage, cut and fill (narrow and panel) and longhole.

Open pit operations began in 1988 to supplement underground production, see Figure 1. Upon completion of pit mining in 2005, pit floor was at a depth of 335m from the initial surface. The pit is mined with 9m bench heights with catch benches established at 27m intervals. The ramp is 24m wide and grades 10%. Inter-ramp wall angles vary from to 39 degrees to 54 degrees with average of 49 degrees. Bench face angles vary from 75 degrees to 46 degrees with average of 65 degrees. Catch bench widths range from 7.6m to 12m, with most common being 11m.

Following completion of planned mining operations, a portion of a Dome #3 Shaft Pillar, exposed in the pit highwall at a depth of approximately 865’ (260m) below initial surface was recovered. See Figure 2.

2 GEOTECHNICAL EVALUATION OF SITE

A geotechnical investigation was undertaken at the beginning of the project to examine the rockmass in the vicinity of the #3 Shaft Pillar. The investigation consisted of four tasks: (i) Review of mined geometries from the Dome Underground Mine (DUG) and Dome Open Pit (DOP) in the vicinity of the area of interest; (ii) Compile available structural information from DUG and DOP sources; (iii) Assess structural wedge potential, and (iv) Examine stress influences of proposed #3 Shaft Pillar mining sequences on highwall stability.

Figure 1. Dome Open Pit (circa mid-1980's) showing Shafts and approximate position of pit shell

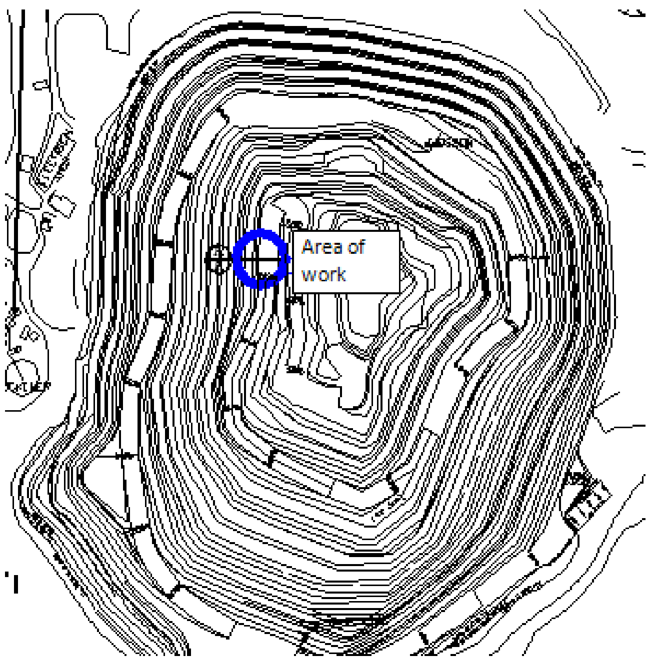

Figure 2. Plan view of pit shell, showing work location

2.1 *Review of mined geometry*

The shaft pillar site was located between the DUG 7L and 8L mine levels, located at 211m and 258m, respectively, below initial ground surface. Much of the underground workings and stopes were excavated previously by the open pit. However, field investigation, and a review of mine records and plans revealed that isolated remnants, including three drifts, access raises, the #3 Shaft, and a small stope (850 Stope) remained in the vicinity of the project site. See Figures 3 and 4. The 850 Stope was mined in 1937 by Cut and Fill methods, meaning that the stope was likely filled with unconsolidated sandfill, with the exception of the uppermost lift – which was likely not filled.

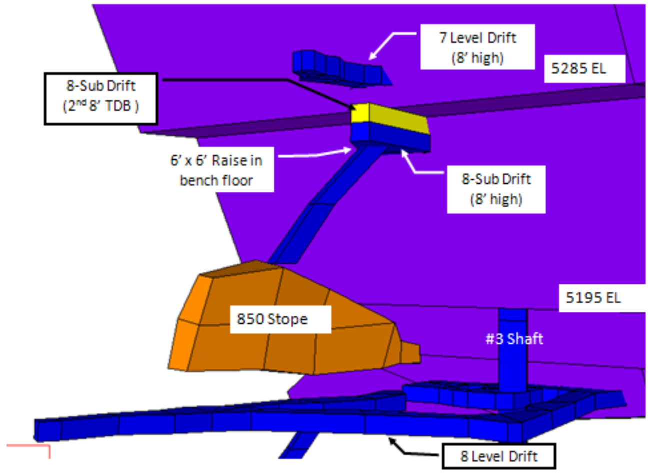

Figure 3. Location of mine workings intersecting pit shell at Shaft Pillar recovery site

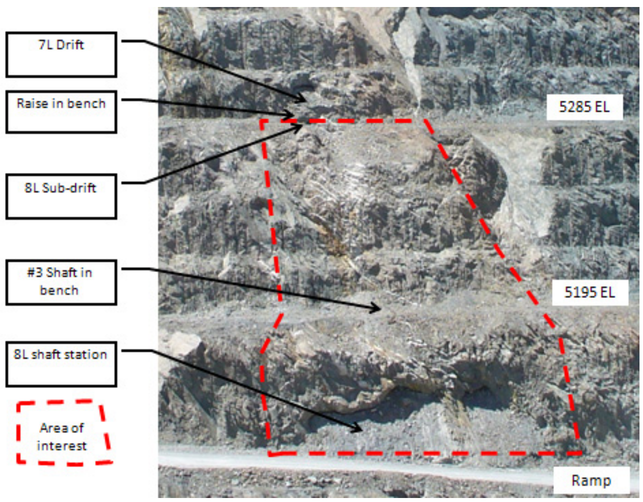

Figure 4. Location of mine workings intersecting pit shell

2.2 *Structural data collection*

Structural information from surface mapping of available rock exposures on the pit wall at the site and from geology plans of underground mine excavations (see Figure 5) was compiled using DIPS software. Attempts at utilizing photogrammetric techniques for additional mapping of the pit wall were unsuccessful, due to the isolated site location. DIPS analysis (Figure 5, insert) identified five clusters of Joint Sets. Results are summarized in Table 1.

2.3 *Structural assessment*

The viability of structural wedge formation in the pit wall, resulting from the intersection of two sets was evaluated with SWedge software. Five joint families, representing ten potential combinations of joint intersections were evaluated. See Table 2. Of these joint combinations, four sets of structural wedges are possible. Three potential wedges had Factors of Safety > 1.0, suggesting stable conditions. However, one wedge intersection, defined by the intersection of Joint Sets J2 and J4 with the pit wall, was identified as being potentially unstable. The J2 and J4 relationship is illustrated in Figure 6.

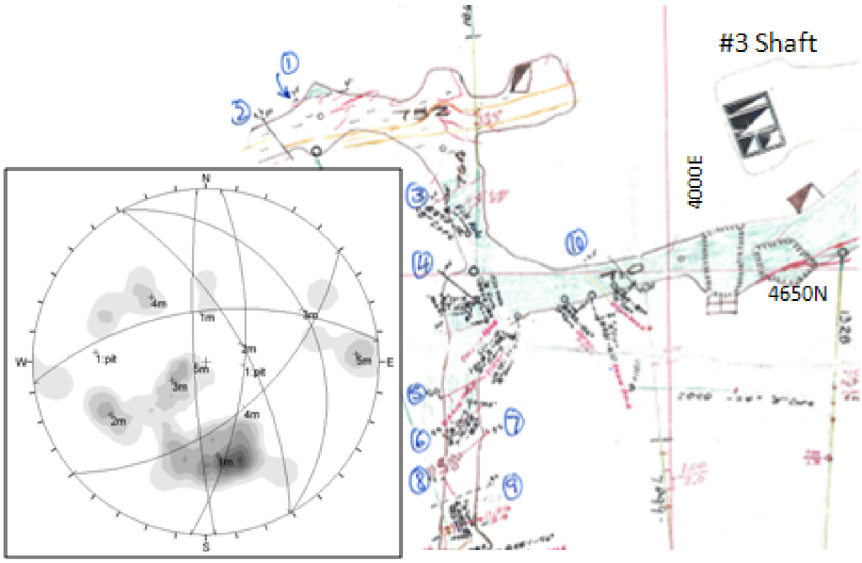

Figure 5. Geology plan, DUG 7 Level. Insert: Pole plot concentration of compiled data

Table 1. Representative joint sets, Shaft Pillar recovery site

Joint Set	Dip	Dip Direction	Comment
J1	57	353	foliation trend common to underground mapping
J2	64	061	
J3	25	061	Shallow dip equivalent to J2
J4	52	140	Set J4 is a persistent joint set, prominent in the pit wall
J5	82	267	Joint set trends sub-parallel to, and dips steeply into the wall

Table 2. Summary of potential structural wedge intersections

Intersecting Joint sets	Wedge Factor of Safety (FS)	Relative weight of wedge (tonnes)	Sliding line of intersection	
			Trend	Plunge
J1, J2	No intercept with pit face			
J1, J3	1.08	360	065	25
J1, J4	1.89	121	068	22
J1, J5	No intercept with pit face			
J2, J3	0	10	Stable block (on bench surface)	
J2, J4	0.46	2777	116	49
J2, J5	No intercept with pit face			
J3, J4	1.06	474	071	25
J3, J5	No intercept with pit face			
J4, J5	No intercept with pit face			

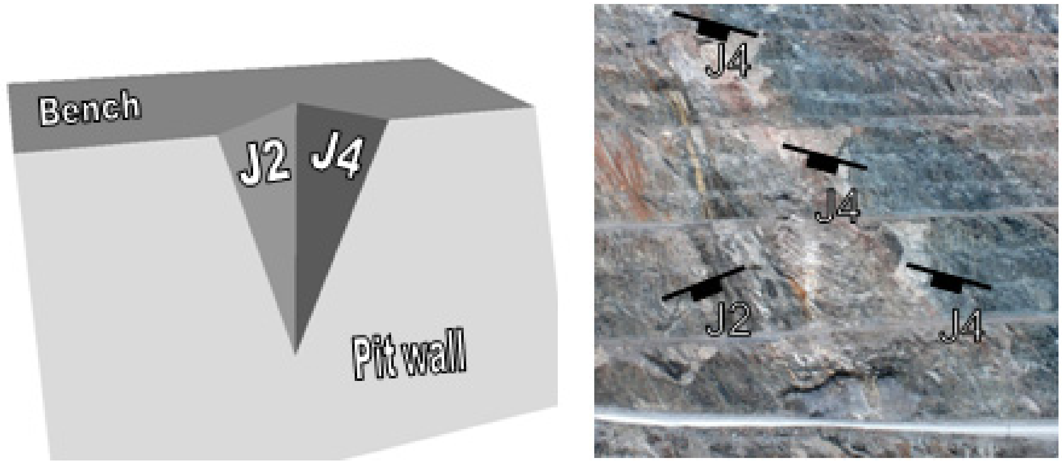

Figure 6. Potential wedge intersections associated with joint families J2 and J4

2.4 *Numerical modelling*

Local stress conditions within the pit wall were simulated using three-dimensional Map3D elastic numerical modelling software. Modelled geometry incorporated local details of the pit shell and underground workings. Shaft pillar mining influences on the pit highwall, both behind and above the wall slash area were examined. Model results indicated that no significant change in stress conditions due to Shaft Pillar mining were evident, provided that the mining does not encroach too close (< 15m) towards the #850 Stope.

3 GROUND SUPPORT AND MINING PLAN

The findings from the geotechnical evaluation were used to develop strategies for ground reinforcement and excavation design and sequencing. Ground support and mining sequence is summarized in Table 3.

Screening was required above Shaft Pillar site to protect workers, as mining would result in the loss of overhead catch benches. The installation of wall reinforcement around the Shaft Pillar site was planned to stabilize anticipated wedge intersections. Wall pre-support consisted of plated, full column grouted cablebolts, of lengths up to 10m, installed on a pattern of approximately 3m x 3m (2 cables per hole). Cablebolting and screening and locations are provided in Figures 7 to 9.

Survey prisms and extensometers were installed into the wall above the Shaft Pillar site for monitoring of highwall stability over the long term. Monitoring cables for the multiple point borehole extensometers were carried 150m up the pit wall to the ramp above.

Excavation of the Shaft Pillar was planned as a multi-stage approach, starting from the top (5285' elevation) and advancing downwards. Planned mining called for the drilling of vertical production boreholes to depths of 9m or 18m prior to blasting. Broken rock was cast down onto the ramp, where it was loaded onto rocktrucks and hauled up to surface. Once the blasted surface was cleaned, a drill was brought back onto the site for drilling of the subsequent horizontal slice.

Table 3. Ground support and mining sequence

Step	Action
A	Install cablebolts around the Target Area (see Figure 7)
B	Install screening between 5285EL to above 5375EL (see Figure 8)
C	Drill and blast Phase 1
D	Extend screening (installed with Step A) downwards (see Figure 9)
E	Drill and blast Phase 2

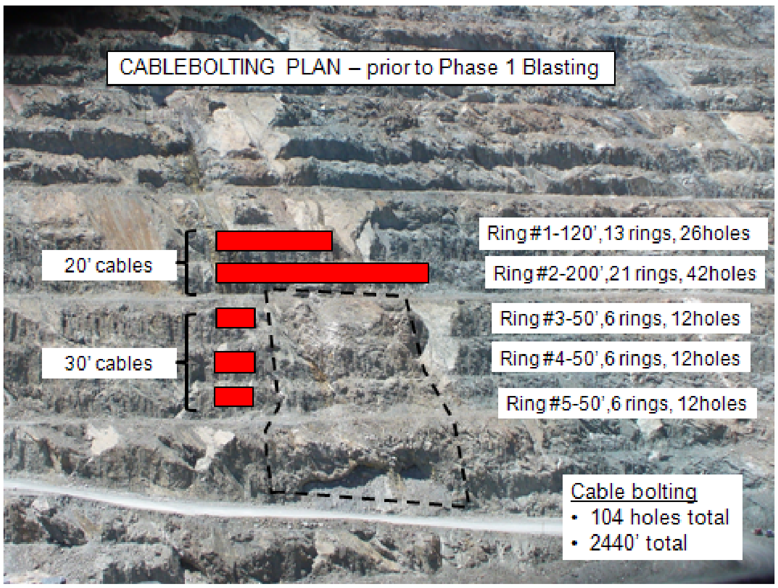

Figure 7. Cablebolt pre-support locations

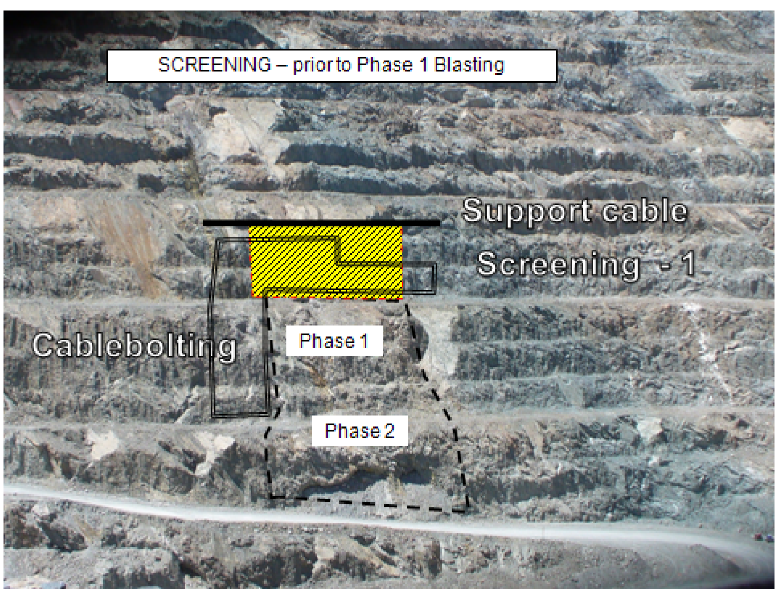

Figure 8. Screening location

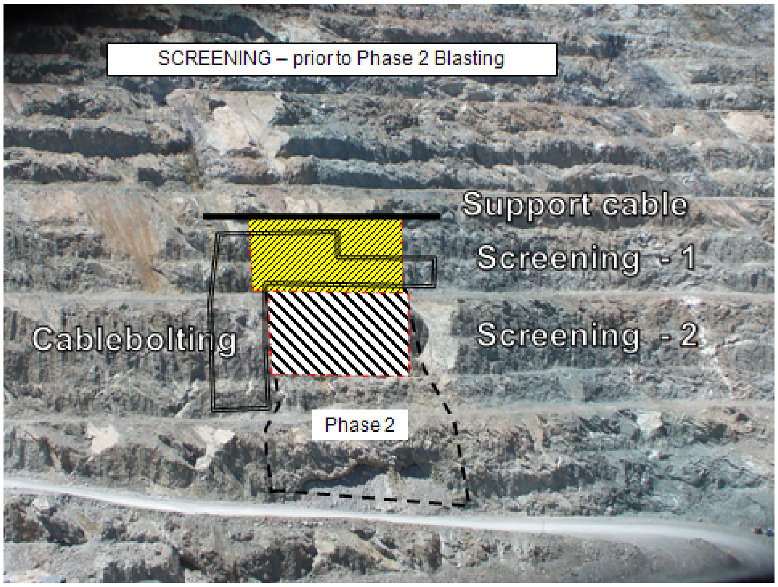

Figure 9. Location of extended screening

4 SUPPORT INSTALLATION AND PRODUCTION DRILLING

Support installation, drilling and blasting was performed by contractors skilled with working on highwalls. Because of the remote access to the site, all heavy or bulky materials were lifted up to the worksite by either long-reach cranes or by helicopter. Daily travel to and from the work-site required rappelling on the highwall face – either 60m down or 27m upwards.

Support installation began after the overhead highwall had been thoroughly checkscaled. Cablebolts were installed first, followed by the screening, which was draped down the wall. Figure 10 illustrates drilling of 50mm diameter boreholes for cablebolt installation. Drilling of production boreholes was performed using a small track mounted drill (Figure 11).

Figure 10. Borehole drilling for cablebolt installation

Figure 11. Drilling blastholes with mini-drill

5 CONCLUSIONS

Figure 12 illustrates the outcome of the selective highwall mining project. Because of the non-standard activities required for mining of the Shaft Pillar, more than fifteen non-routine hazardous task reviews were completed during the project. In all, the project was successfully completed with 15,792 incident free man-hours.

(a) Before (b) After

Figure 12. Before and after comparison of Shaft Pillar recovery

6 ACKNOWLEDGEMENTS

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