Ground Support 2023 – J Wesseloo (ed.)
© 2023 Australian Centre for Geomechanics, Perth, ISBN 978-0-6450938-5-8
doi:10.36487/ACG_repo/2325_45

Stabilising drawpoints for breccia stopes

CG Reola *OceanaGold Philippines Inc, Philippines*

PB Lourence *PB Lourence & Associates, Australia*

JM Bermas *OceanaGold Philippines Inc, Philippines*

DA Dumangeng *OceanaGold Philippines Inc, Philippines*

Abstract

Production stopes at Didipio porphyry gold–copper mine, Philippines, are primarily comprised of two distinct types of rock mass: monzonite and breccia. The monzonite ground conditions are blocky and moderately strong. The breccia ground conditions are a classical, weak rock mass. Opening and stabilising the stope drawpoints in breccia presented challenges that require brow ground support revisions using a trial-and-error approach. A combination of factors including span/geometry, lithological contacts, geological structures, and blast-induced damage all contribute to the overall brow and drawpoint performance.

This paper discusses the types of drawpoint support for breccia stopes using twin-strand, bulbed cable bolts and/or shotcrete-reinforced arches using Osro straps, pinned with friction bolts. Back analyses of recently mined-out stopes demonstrate improvements in brow stability when using shotcrete arches instead of relying entirely on cable bolts.

Keywords: *ground support, brow support, drawpoint support, Osro straps, shotcrete arches, cable bolt*

1 Introduction

Didipio gold–copper mine is an alkalic gold–copper porphyry deposit with sub-vertical, pipe-like geometry and an elliptical shape at the surface. Open pit mine production started in April 2013 and was completed in April 2017. Underground mine development began April 2015, but actual large-scale production started with the commissioning stope in December 2017.

The mining method is longhole open stoping with paste backfill. The stope sequence is top–down, north–south, and primary–secondary. Geotechnically, there are two types of rock mass observed for production stopes: monzonite and breccia. Monzonite rock mass holds the bulk of mineralisation and it is a competent rock mass that allows successful mining of dual-lift stopes (60 m high). The breccia rock mass hosts high-grade, gold–copper mineralisation but is highly susceptible to caving and drawpoint failures requiring more conservative stope geometry and drill and blast techniques.

The challenges and risks encountered during opening and stabilising drawpoints in a breccia rock mass have led to the continuous improvement of brow support standards which have evolved through trial-and-error. This paper compiles the historical drawpoint or brow support combinations applied for breccia stopes in Didipio mine and their relative effectiveness in stabilising drawpoints.

2 Didipio breccia rock mass

The formation of breccia in Didipio is a combination of physical disruption and hydrothermal brecciation of a massive quartz-rich zone. Breccia contains angular quartz clasts (<8 cm in size, >70% by volume) hosted in calcite–illite ± chlorite-altered matrix. Other clasts include actinolite and potassium feldspar minerals, and rock fragments of monzonite, monzosyenite porphyry, and syenite. The clasts and matrix contain high gold–copper grade mineralisation (Wolfe & Cooke 2011).

The breccia orebody occupies the central part of the porphyry deposit, intruding the monzonite orebody. It is spatially located within the western portion of the underground mine from 2535 until 2280 RL. The underground mine operates on a local mine grid rotated 44° east from true north to better align the underground geology and mine designs in a north–south operation direction.

Figure 1 displays the spatial location of the breccia body and Figure 2 shows a drillcore photo of breccia.

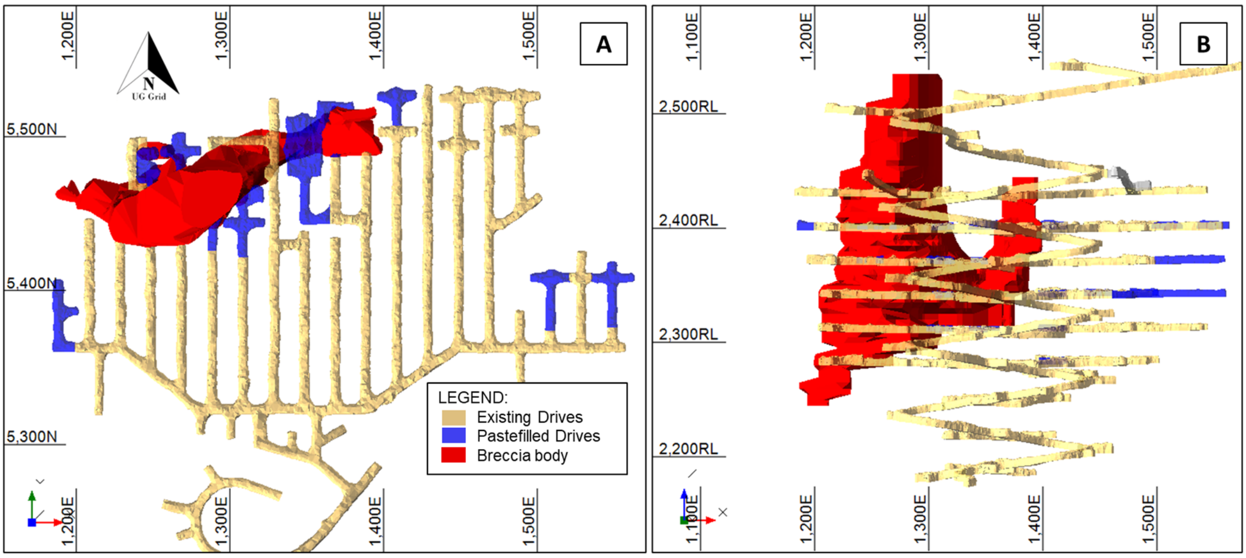

Figure 1 Location map of breccia body in underground mine grid

Figure 2 Drillcore photo of breccia

Rock mass classification in Didipio utilises Barton's Q-System (Norwegian Geotechnical Institute 2022). Figure 3 shows the Q-values observed for all types of rock mass and ranges from 0.01 to 40. This is locally reclassified into three general types of ground conditions: Type 1 (competent) ground, Type 2 (poor) ground, and Type 3 (very poor) ground.

Breccia rock mass has Q-values ranging from 0.01 to 1 and substantially plots within the very poor to extremely poor divisions of the Q-System and corresponds to the Type 2 to 3 ground conditions of Didipio. Type 2 breccia (0.1 < Q < 1.0) shows higher rock quality designation and is more cemented in nature compared to a crumbly Type 3 breccia (0.01 < Q < 0.1) with prominent quartz clast crystals and gouge-like texture.

Uniaxial compressive strength (UCS) of an intact Type 2 breccia has first quartile and median values of 19 MPa and 30 MPa, respectively. Type 3 breccia, when disturbed or mixed with water, has less than 500 kPa UCS and is like a soil. Table 1 shows the general Q rating of Type 2 and 3 breccia.

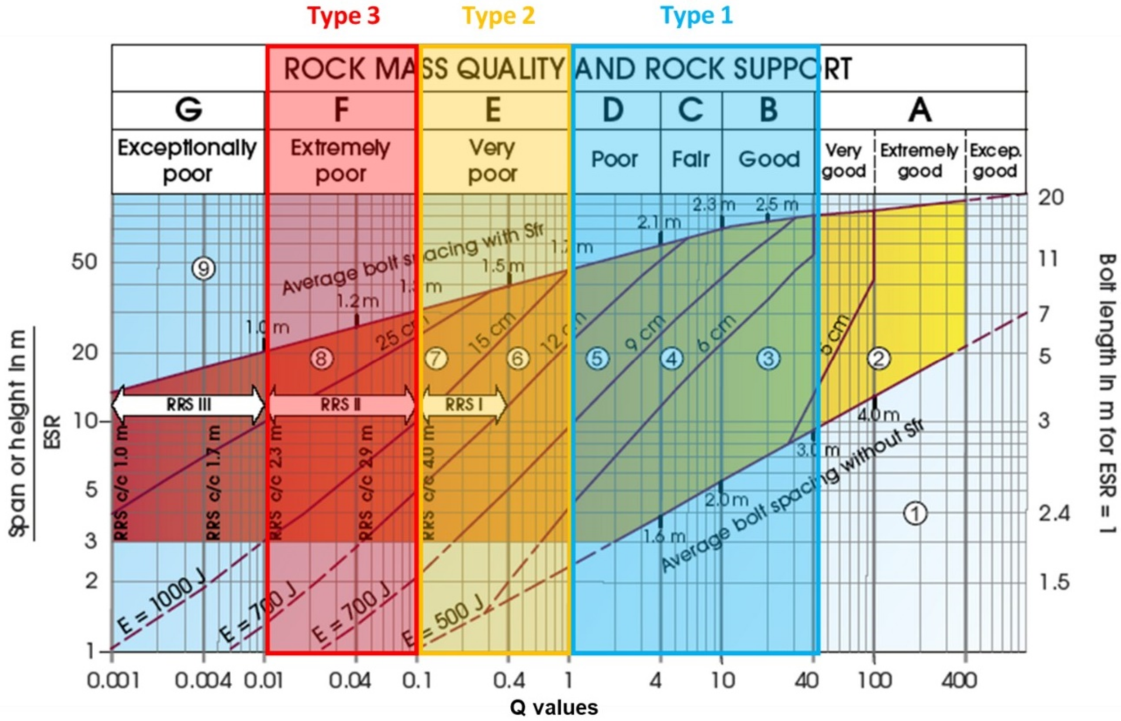

Figure 3 Barton's rock support chart showing common rock conditions in Didipio

Table 1 Rock mass classification of Breccia rock mass using Barton's Q-System

Type of breccia	RQD	Jn	Jr	Ja	Jw	SRF	Q'	Q
Breccia Type 2	60	12	1.5	6	1	2.5	1.25	0.50
Breccia Type 3	10	20	1	8	1	5	0.06	0.01

3 Drawpoint support for stopes

Stopes in Didipio are primarily uphole stopes and taken in sequential firing where drawpoint stability is critical. To date, there are four types of ground support combinations applied in all breccia stope drawpoints.

Earlier drawpoint support for breccia stopes used Categories A and B and employed brow rock mass reinforcement with 6 m cable bolts. Category B has additional surface straps compared to Category A to improve surface retention of small breccia fragments. Initial shotcrete support applied during the drive development encounters cracking and slabbing and requires frequent rehabilitation. These surface straps are exposed and prone to equipment damage during bogging. Categories C and D use shotcrete arches or the shotcrete spraying of a 200 mm-thick layer on surface straps. Category C excludes cable bolt reinforcement and Category D includes cable bolt reinforcement. Table 2 describes each drawpoint support category.

Table 2 Ground support combination for drawpoints

Drawpoint support category	Description
A	75–100 mm-thick shotcrete, 2.4 m split sets, and 6 m twin-strand cable bolts
B	75–100 mm-thick shotcrete, 2.4 m split sets, 6 m twin-strand cable bolts, and surface straps (W or Osro straps)
C	100 mm-thick shotcrete, 2.4 m split sets, and shotcrete arches (surface straps sprayed with 200 mm-thick shotcrete)
D	100 mm-thick shotcrete, 2.4 m split sets, shotcrete arches (surface straps sprayed with 200 mm-thick shotcrete), and 6 m twin-strand cable bolts

Figure 4 summarises the Breccia stope classification (Type 2 and Type 3 ground) versus the number of stope drawpoint in the historical database. Figures 5, 6, 7, and 8 show samples of the installed drawpoint support per category.

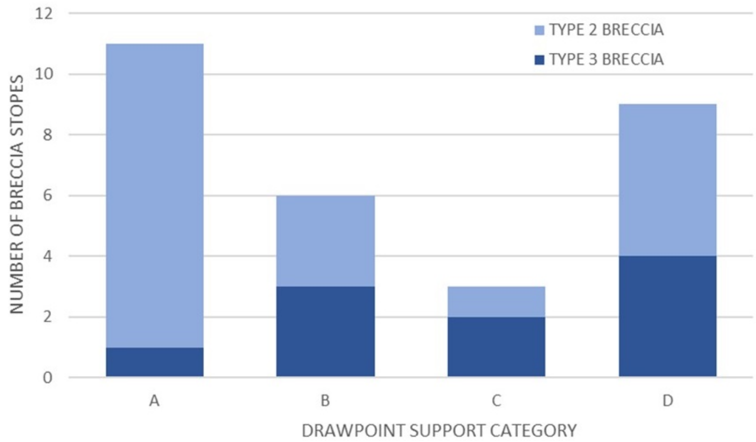

Figure 4 Statistics of Type 2 breccia and Type 3 breccia stopes supported per category

Figure 5 Category A drawpoint support

(a)

(b)

Figure 6 Category B drawpoint support using (a) Osro straps and (b) W-straps

Figure 7 Category C drawpoint support

Figure 8 Category D drawpoint support

4 Drawpoint support performance

Maintaining a stable drawpoint in a breccia rock mass is challenging due to variable ground conditions, the presence of major structures, blast damage, and equipment damage. Figure 9 plots the failed, damaged, and stable drawpoints (tally and percentage) per support category. Out of 29 drawpoints, three were classified as failed and three were classified as damaged. A 'stable' drawpoint means that no rehabilitation was required during the entire stope cycle. A 'damaged' drawpoint means that bogging and/or charge-up was stopped until rehabilitation was completed. A 'failed' drawpoint means that major rehabilitation is required, or the stope is abandoned.

The three 'failed' drawpoints are all within the proximity of major structures and within the Type 2 breccia. Two of them used Category B and the other used Category C support. Two of the 'damaged' drawpoints are also in proximity to major structures and Type 2 breccia. One of the 'damaged' drawpoints was not in proximity to a major structure but situated in Type 3 breccia. Figure 10 shows the major structures close to the breccia orebody and the 'failed' and 'damaged' drawpoints.

All the 'failed' and 'damaged' drawpoints were installed in oredrive excavations with a width close to the 5.5 m design, all with vertical brow angles, and the closest uncharged collars averaging 3 m in length.

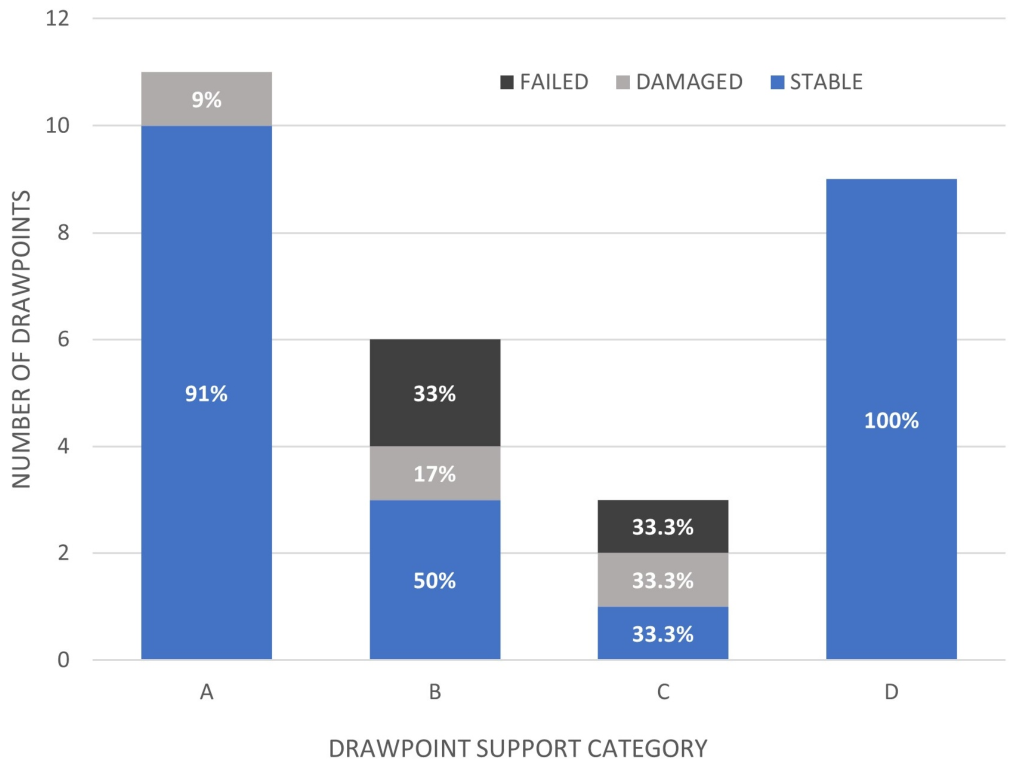

Figure 9 Statistics of Didipio stopes drawpoint support and performance

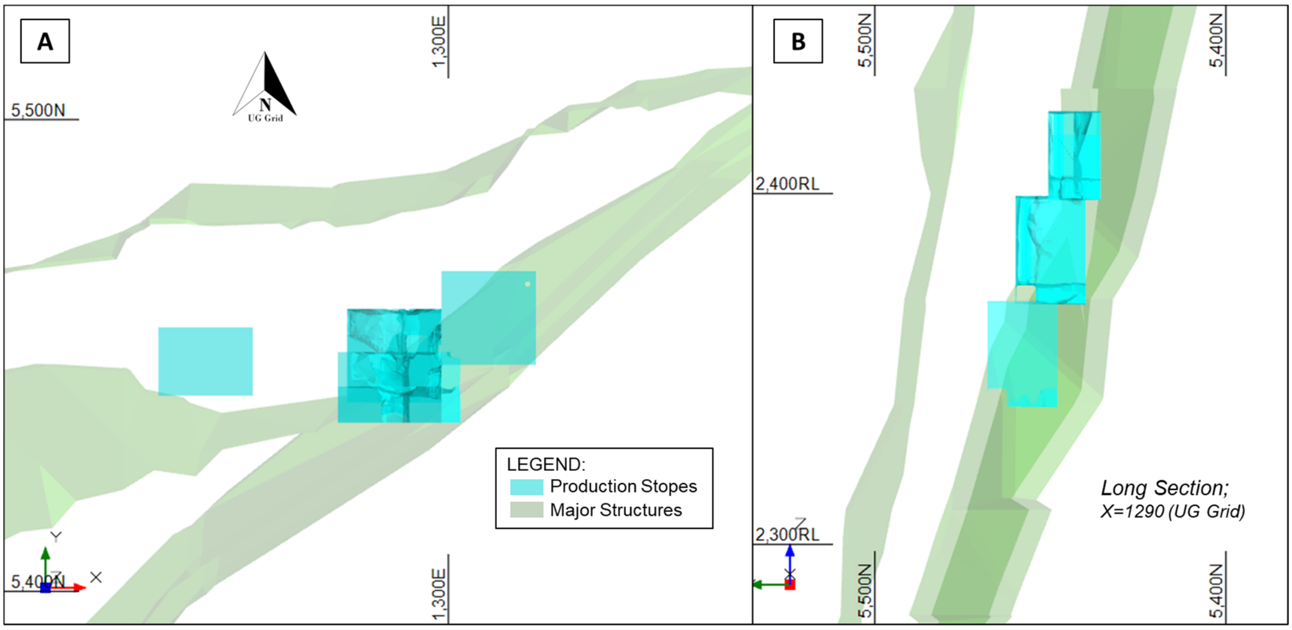

Figure 10 Location of major structures and stopes with failed and damaged drawpoints

5 Conclusion

Didipio's mined-out breccia stope drawpoint support performance is influenced by a combination of factors including the following: (1) proximity to major structures, (2) rock mass rating, (3) brow width, (4) length of uncharged collars, (5) dump angle of the brow, and (6) equipment damage. Proximity to major structures and rock mass rating are the most critical factors at Didipio. Brow width is likely to be another critical factor, but it is not tested beyond 6.5 m width.

Category A drawpoint support has a 91% stable record for Type 2 breccia that is not affected by major structures. Category D drawpoint support has a 100% stable record for all types of ground conditions.

Future work will investigate the influences of brow width, uncharged collars, and brow dump angle. Cable bolt performance will be quantified with extensometers and load cells.

Acknowledgement

The work of the geotechnical team at Didipio mine over several breccia stopes allowed the review and analysis of brow support performance.

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