SRDM 2009 — P. Dight (ed)

https://papers.acg.uwa.edu.au/p/902_20_Parrott/

Development rates in poor ground conditions

T.T. Parrott *Newmont Asia Pacific, Australia*

S. Price *Newmont Waihi Gold Mine, New Zealand*

P.C. Keall *Newmont Waihi Gold Mine, New Zealand*

Abstract

Mechanised metalliferous mining occurs all over the world in many varied ground conditions. The Favona underground gold mine in Waihi, New Zealand is no exception with underground development and stoping occurring in ground conditions ranging from exceptionally poor to good. The poorer ground conditions present the greatest challenges from a ground support perspective, a development advancement rate and production perspective. This paper focuses on the challenges experienced and the solutions developed to ensure that acceptable development rates are maintained when poor ground conditions are experienced.

1 Introduction

The Favona underground gold (Favona) deposit at Newmont Waihi Gold Operations (NWG) is located approximately 2 km to the east of the Martha Mine, in the township of Waihi, 150 km southeast of Auckland (on the north island of New Zealand, see Figure 1).

The Favona orebody is structurally complex and is comprised of two main orebodies termed the “Northern” and “Southern Orebodies”, hosted within moderately to strongly altered and weathered andesite, which are separated by a major E–W striking fault. The Northern Orebody consists of two main convergent zones of steeply dipping N–NNE trending epithermal quartz veining, termed the “hangingwall” and “footwall” lodes. These lodes are separated by a band of altered andesitic rock.

The Southern Orebody also consists of a hangingwall and footwall lode within an overall massive epithermal vein complex which is up to 30 m wide. These lodes form along the hangingwall and footwall contacts and are distinguished by gold grade.

Challenging ground conditions are encountered throughout the underground mine including the ‘Main Fault’ which is a subvertical 10–15 m thick zone of ground rock, smectite and illite clays. The Southern Orebody which is predominantly an epithermal vein but appears as crushed rock, or earth-like and highly clay-altered and weathered andesitic rock masses. Other challenging conditions include close proximity to surface and poor ground conditions leading to unravelling and caving; and water-bearing structures with high inflow rates that wash out and create fissures and voids.

This variety of poor ground conditions is encountered frequently within development drives and has presented many challenges to the mine and development crews. Through experience the mine has developed and adopted many practices to ensure acceptable development rates are maintained.

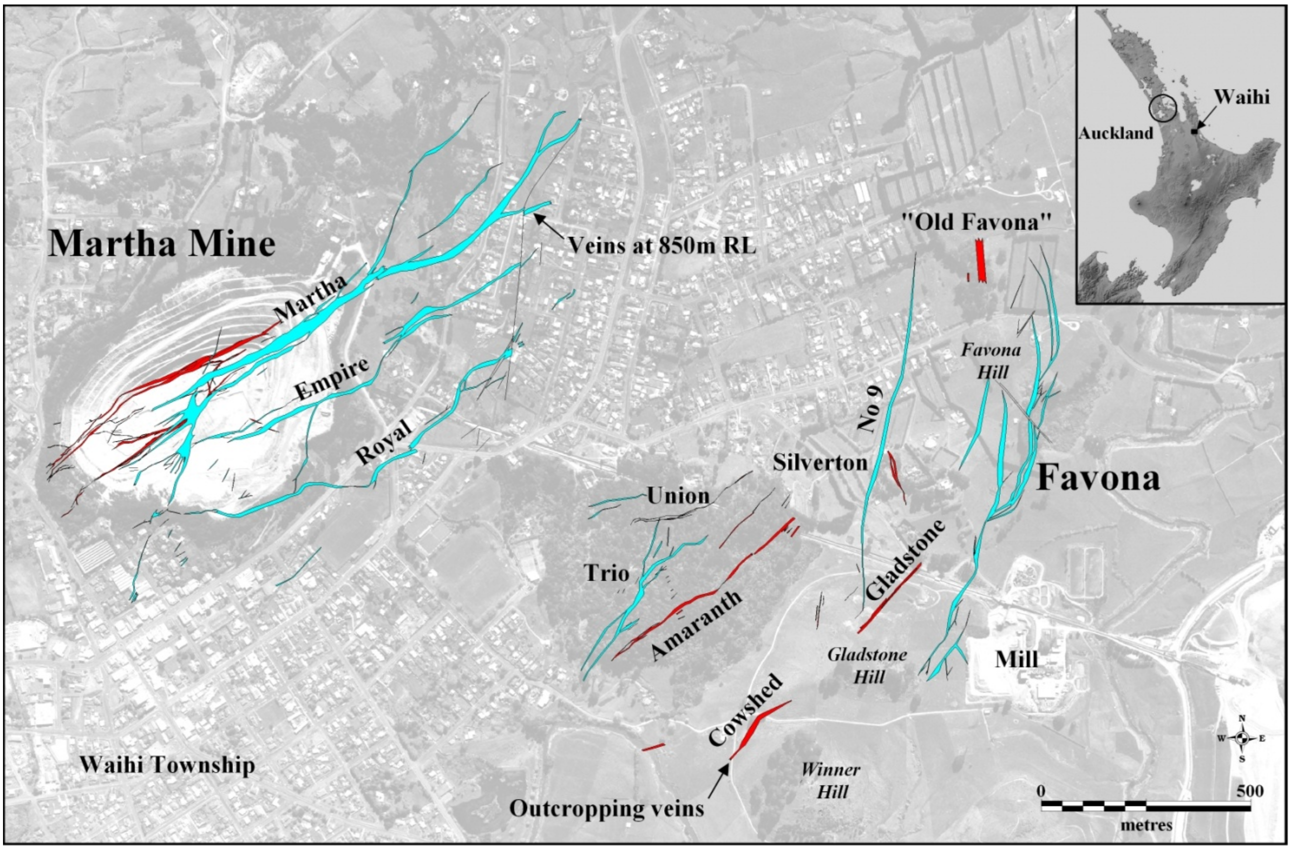

Figure 1 **Map of the north island of New Zealand showing location of Waihi on the east coast and the location of mineralised structures within the district**

2 Rock mass conditions

Rock mass conditions vary greatly at Favona. Significant work was undertaken to characterise the rock mass from diamond drill holes prior to underground development commencing, and later from underground geotechnical mapping.

Typical rock types encountered through decline and access development includes andesite and altered andesite. Typical ground conditions when using the Q-Classification scheme by Barton et al. (1974) yield the following within the majority of development:

- Q = 4–20 (fair to good) typical or majority of ground conditions (Figure 2).
- Q = 0.001 – 1 (exceptionally poor to poor) worst case — mainly limited to the intersection of faults (Figure 3).

Figure 2 Decline excavation face during the ground support installation phase showing good ground conditions

Figure 3 815 level access at Favona — showing exceptionally poor ground conditions at the excavation face following intersection with the Main Fault. Large accumulation of water with two 37 kW pumps for dewatering

3 Management of development rates in poor ground conditions

The first line of defence when developing through poor ground conditions is the use of appropriate ground support and reinforcement methods. There have been instances where the ground conditions behaved unexpectedly resulting in the need to adapt or change the approach. This is a reactive approach, rather than a proactive method for controlling the ground. Several lines of management have been developed in order to maintain safe and effective development rates when encountering poor ground at Favona.

3.1 Development practices

Development at Favona occurs primarily through standard drill and blast techniques using electric-hydraulic development jumbos. Development rounds are three metres in length, with a variety of ground support methods using a combination of 2.4 m Split Sets, welded galvanised steel mesh and plain or fibre reinforced shotcrete as ground conditions dictate.

Several techniques have been adopted to ensure development rates are consistent and achievable, avoiding costly lost time due to loss of availability of development headings.

3.1.1 Development blasting practices and blast vibration limitations

Favona has stringent blast vibration limits of 5 mm/sec between the hours of 7.00 am to 9.00 pm, and 1 mm/sec between the hours of 9.00 pm to 7.00 am, this coupled with over pressure (noise on surface due to blasting) in the early stages of development hindered advance rates.

A vibration monitoring system was installed and later upgraded to include a predictive vibration software package. This software dictated headings that could be fired during the lower (1 mm/sec) vibration limit periods.

The main issues faced during development were timing sequences for blasts, powder factors and structural ground conditions. In areas of elevated vibration, development rounds were reduced to 1.5 – 2 m of advance per round. To date Favona has maintained 98.5% compliance against a consent limit of 95%.

3.1.2 Short development rounds

In very poor ground conditions, typically when developing through highly weathered material near the surface (<80 m deep) or through clay gouge filled faults such as the Main Fault, short development rounds of one metre advance per blast are used. The short rounds control the length of the exposure, hence controlling the stability of the drive back. This allows sufficient time for fibre reinforced shotcrete (fibrecrete) to be applied to the excavation surface, providing an immediate layer of surface support to the excavation prior to bolting and meshing occurring.

Experience showed that when attempts to take full length rounds of 2.4 m in such ground conditions, the excavation stand-up time was insufficient to allow for the application of fibrecrete. This occasionally resulted in significant fall-off occurring in the excavation back, making the ground support cycle slower and more difficult.

In extreme cases, a full length development round resulted in loss of control of the excavation, with caving of the drive back commencing. Caving of up to 15–20 m above the designed excavation has been experienced, resulting in costly rehabilitation to regain control, and a redesign of drive alignment to avoid the caved drive back.

3.1.3 Use of an excavator with a cutting head for development

A cutting head was trialled on a limited basis in the early stages of development at Favona. The trial occurred in the upper levels of the mine where poor ground conditions were encountered more frequently. Following earlier experiences with excavation over break, a development technique was being sought that was less damaging to the ground mass than standard drill and blast practices.

The trials met with limited success in the upper levels of the mine. The road header consisted of a rotating drum head covered in abrasive teeth. A good excavation profile was achieved, however due to practical limitations the trial was discontinued. These limitations included the method being costly and time consuming as a pile of cuttings would pile up at the face, requiring the excavator to frequently pull out of the face to allow removal of the cuttings.

3.2 Ground support practices

Ground support is an important line of defence when managing poor ground conditions. Several factors were key when selecting the design ground support and reinforcement for Favona, including availability of materials, excavation life span, suitability to conditions and ease and speed of installation (familiarity for mine operators).

3.2.1 Ground support regimes

Ground support regimes have been developed with a number of factors in mind including equipment selection, availability of ground support materials, speed of development and the possibility of encountering poor ground conditions. The level of ground support required depends upon the ground conditions encountered.

In poor ground conditions ground support termed 'Regime 1' is applied (see Table 1 for descriptions). Excavations through faults are typical of this application. This includes an initial application of fibrecrete to a 50 mm thickness, followed by meshing with 3 m Split Set bolts to within 1 m of the excavation floor, followed by a subsequent shotcrete (no fibres) application over the top of the mesh and bolts.

As better ground conditions are encountered, the subsequent ground support regimes apply where less ground support is required to support and reinforce the excavation. Four ground support regimes in all are utilised at Favona, with the addition of pattern and spot cable bolting applied where deemed appropriate. By limiting the number of ground support regimes, this ensures the operators know what is required.

Table 1 Description of ground support regimes

Regime	Description
1	Fibrecrete 50 mm, 3/2.4 m Split Sets, mesh, second pass shotcrete 40 mm over mesh, 2 m rounds
2	Mesh, shotcrete 50 mm, Split Sets 2.4 m, 3 m rounds
3	Mesh, Split Sets 2.4 m, 3 m rounds
4	Fibrecrete, Split Sets, 3 m rounds
5	Standard intersection cable bolt pattern

3.2.2 In-cycle fibre reinforced shotcrete

In-cycle fibrecrete has been a key success in providing an early surface support to excavations in poor ground conditions where stand-up times have been experienced as short as a few hours. In-cycle fibrecrete had an initial high use in the early stages of development, but as development progressed it was used more on an as-needs basis. In some cases, the use of fibrecrete allowed the use of longer development rounds, as a batch of fibrecrete could be mobilised to site, prior to the development blast being taken. The fibrecrete would then be applied to the back without any bogging occurring.

Fibrecrete and shotcrete are readily available from a local supplier a few kilometres from the mine site. As part of the supply contract several agi-trucks are made available on day shift in the event the mine requires fibrecrete to be supplied to site.

Generally, the mine can provide enough notice to the supplier so that fibrecrete can be batched and delivered to site in readiness for application. In the event that development headings are not available in time, then the use of a sleeping agent can be used to delay set-times of the fibrecrete so application can occur when the excavation is available.

One drawback is that fibrecrete is not available on a continuous 24 hour period. It is only available during dayshift hours and at limited times on weekends. This requires mine site personnel to plan development in known areas of poor ground conditions around the availability of fibrecrete.

3.3 Dewatering of water-bearing structures

Several major geologic structures transect the orebody at Favona. Two main structures frequently encountered within development are the Main Fault and the 'West Dipping Fault' (Figure 4). These structures are within close proximity to the orebody, and in many cases development could not avoid intersecting these structures.

Both of these structures are major water-bearing structures, locally producing up to 20 L/sec for a short period of time when encountered by development. After several development intersections with these structures where development was successful, albeit very slow and severely hampered by water inflow, two different methods of dewatering these structures was developed.

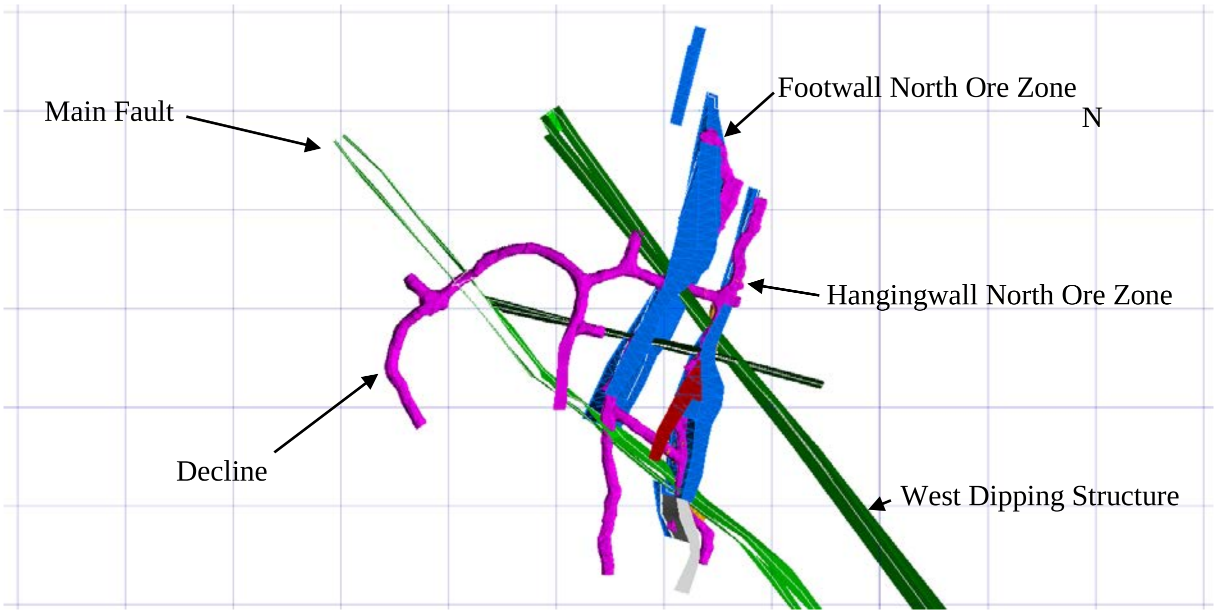

Figure 4 Plan view of Favona underground workings on 980 level showing the interaction of major structures with the Footwall and Hangingwall North Ore Zones; grid spacing is 50 m

3.3.1 Internal dewatering bore

In an effort to dewater major water-bearing structures ahead of development, a large diameter water bore was sunk from within mine workings, with the intention of intersecting the structures at depth. The dewatering hole was bored from the 935 level access to a depth of 76 m, or approximately the 860 level. The intention of the dewatering hole was to intersect the Main Fault, a major water-bearing structure with several planned decline intersections, and dewater this ahead of development.

The hole was bored using a raise-bore drilling rig, with a hole diameter of 25 cm. The dewatering hole was fitted with a compressed air powered lift pump, with pumping occurring from the bottom of the hole. When the hole was first drilled, the water level in the hole was measured at five metres from the collar. After two months pumping a reduction of eight metres of water head was observed.

Success in dewatering advancing development headings through water-bearing structures was limited. It is difficult to gauge the amount of success achieved, but typically the Main Fault took less time to dewater once development intersected it.

This application of a dewatering bore achieved limited success. Ultimately, the bore became too deep, and the pump was of an insufficient size to pump the required volume of water. To repeatedly bore dewatering holes became cost-inhibitive, especially when mobilisation of specialised drilling equipment is a consideration.

3.3.2 Dewatering holes ahead of development faces

During the early stages of development, on several occasions development was advanced into the Main Fault and Western Structure without any dewatering activities occurring prior to the intersection. This more often than not led to long delays to development as several things occurred:

- When first intersected, water would enter the excavation under flow rates as high as 50 L/sec hence flooding the excavation for 20–30 m back from the face.
- Pumping via two electric flyght pumps would take at least ten days and possibly up to two weeks as water pumping dewatered the structure to the current level of excavation. High water inflows could be experienced for up to several days before a gradual decline was observed.
- Due to the poor ground conditions, and the presence of weak infilling material such as clays, calcite and sand material, such high water inflows would often cause significant wash-out of the material. This resulted in large cavities in the excavation wall and backs developing. Significant rehabilitation would then be required to allow development to continue.

In an effort to reduce the amount of lost time due to pumping water and rehabilitation, the use of probe holes was used in advance of intersecting major geologic structures. The purpose of the probe holes was to ascertain the exact location of the structures. Three dimensional geologic models were used to estimate the location, the use of probe drilling could be used when within ~10 m of intersecting the structures.

The probe holes also acted as dewatering holes. Probe holes were typically 10–15 m in length, and were drilled with every development round until water was intersected. The rate of inflow could be controlled by drilling more holes until a manageable flow rate was achieved from the holes.

Once water had been intersected, water was allowed to flow into the mine workings for removal with electric pumps. Pumping would continue until the structure was sufficiently dewatered to enable development to continue.

3.4 Planning and scheduling realistic development rates

Experience gained in developing in poor ground conditions is the best tool for estimating realistic development rates. A great deal of experience has been gained at Favona where the unexpected occurred, leading to effective solutions to be developed and trialled.

The knowledge of how long it takes to develop in particular ground conditions is key to planning and scheduling of the development. Planning unachievable rates sets oneself up for continuous failure. Through experience gained at Favona, mine personnel have detailed knowledge of development rates in different types of ground conditions. Knowledge has also been gained on how to effectively manage and control the wide and varying conditions experienced in order to maintain realistic and safe development rates.

4 Conclusion

Developing in poor ground conditions has many challenges including maintaining acceptable development rates in the safest possible manner. Poor ground conditions are a real threat to mining projects and can cause cost overruns and force projects to run behind time.

Effective management techniques have been developed and adopted at Favona to ensure the mining project is a safe and economic success. Tools used to manage development encountering poor ground conditions at Favona included the use of appropriate ground support and reinforcement materials, shorter development rounds, dewatering major structures before intersection, and effective planning of rates and anticipation of intersections with major structures well in advance.

Acknowledgements

The authors would like to thank the management at Favona underground gold mine for allowing the publishing of this paper. The authors would also like to thank mine personnel for their contributions to this

paper, and their innovative solutions in sometimes challenging conditions which have been the subject of this paper.

References

Barton, N., Lien, R. and Lunde, J. (1974) Engineering classification of rock masses for the design of tunnel support, Rock Mechanics, May, pp. 189–236.