Construction of deep emergency access and ventilation shafts at Waihi gold mine

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ABSTRACT

As part of the Newmont Waihi Gold development of the Favona Mine two 2.5m diameter shafts were required to facilitate ventilation and emergency egress from the mining operations 100m below ground level. The geological sequence comprised Volcanic Ash, Ignimbrite, Hydrothermal Tuff Breccias & Vent Breccias and Andesitic Lavas. Major faulting, quartz veining and mineralisation were present. The strength of the prevailing rock covered the full range from “Extremely Weak” to “Extremely Strong” with no trend for increasing strength with depth. The quality of the rock was equally as variable.

The conditions made conventional raise boring methods impractical so construction from the ground surface using heavy duty piling equipment and full length permanent casing was adopted. The paper will provide a general description of the project and cover the following key aspects:

- Coring and rock characterisation
- Assessment of drilling methodologies
- Construction challenges overcome
- Comparison of drilling rates with rock strength and quality

With rock strengths from less than 1MPa to measured strengths of over 300MPa in places a variety of tools and methodologies was essential to progress the shaft excavation and successfully complete the shafts.

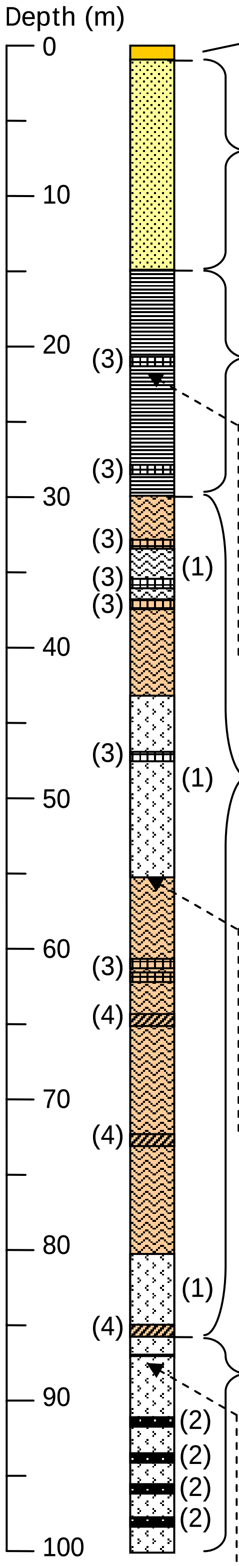
1 INTRODUCTION

Emergency access and ventilation was required to the mine workings 120m below ground level. Consideration was given to a single 4.5m diameter shaft.

A review of the borehole information (Sinclair Knight Merz -2006) revealed that the site was underlain by 15m of surficial soils represented by Volcanic Ash and weathered Ignimbrites of extremely to very weak consistency. Below this Hydrothermal Tuff, Breccia, Andesite and Quartz are present. With the exception of the very strong closely jointed Quartz veins, these deposits were in the strength range of weak to strong. The generalised stratigraphy and engineering geological units are briefly described in Figure 1.

In addition to the variable layers of Porphyric Andesite and Quartz veins a number of crushed and shear zones were identified throughout the depth of the borehole. The mine workings were expected to act as under-drains and thus groundwater would not significantly influence shaft construction options.

Traditionally in stable ground these would have been formed using raise boring techniques, however, the fracture zones and general variability made this impractical. Shaft sinking using small excavation equipment and labour down the shaft was an option. The excavation and construction of the shaft lining would have been such that the unsupported shaft rock face / wall height was minimised. However, safety issues surrounding working at depth in a small diameter shaft were considered unacceptable. Furthermore, the excavation of potentially hard rock with small tools could also be problematic.



Volcanic Ash

The youngest pyroclastic deposits are represented by soft, orange brown, friable silt with minor sand.

Ignimbrite

At the site the post mineralisation surficial deposits are generally completely weathered and represented by sandy silt with some clay and fragments of gravel size weathered rock. The silt is stiff to hard, pink, grey and orangey grey. Highly to moderately weathered, very weak to extremely weak rock was also encountered.

Hydrothermal Tuff

These occur adjacent to the main shear zone of the Favona area. It is hydrothermally altered. The rock is massive and contains clasts of andesite and quartz. It is completely to moderately weathered, strongly to moderately clay altered, and weakly to moderately silicified. It is closely to very closely jointed, extremely weak to moderately strong. The rock quality designation is typically 40%.

Hydrothermal Vent Breccia

Hydrothermal breccia also occurs adjacent to the main shear zone of the Favona area. It is hydrothermally altered. The breccia is clast supported and generally contains medium to coarse gravel size monomict andesite clasts. The clasts are polymict in places. The breccia is highly weathered to moderately weathered, very weak to moderately strong, and closely to very closely jointed. It is slightly to strongly clay altered and slightly to moderately silicified. The rock quality designation varies between 10% and 100%, but typically is between 30% and 70%.

Porphyric Andesite — Hydrothermal Vent Breccia

Porphyric Andesite

Andesite is moderately weathered to unweathered. It is finely to coarsely porphyritic with feldspar phenocrysts up to 7mm in size. The rock is slightly to strongly clay altered and slightly to moderately silicified, closely to very closely jointed and moderately strong to strong. It was found at various depths. The rock quality designation varies between 20% and 100% but typically is between 40% and 70%.

Key:

- Volcanic Ash
- Ignimbrite
- Hydrothermal Tuff
- Hydrothermal Vent Breccia
- (1) - Porphyric Andesite
- (2) - Quartz Vein
- (3) - Crush/Shear Zones
- (4) - Fault Breccia

Figure 1: Site stratigraphy and engineering geological unit description

The use of two 2.5m shafts constructed with rotary piling equipment and permanently cased was a viable solution that would minimise the need for man access of the shaft during construction. The layout of the shafts is given in Figure 2. Excavation of the shaft below 87m in competent stable rock could be carried out from the mine workings below.

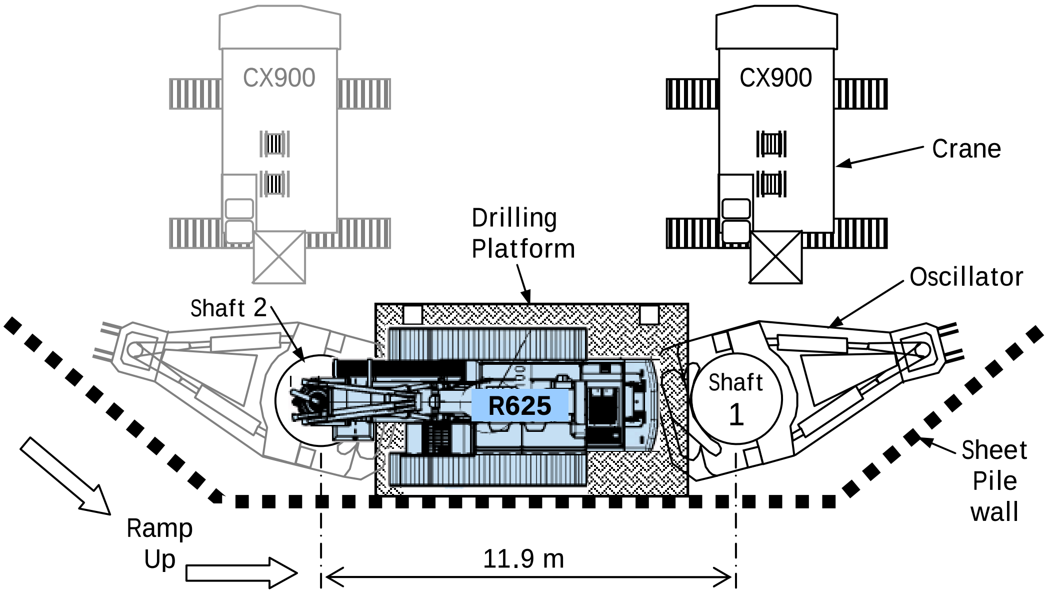


Figure 2: Site and shaft layout with major plant

2 DRILLING METHODOLOGY

Construction of 2.5m to 3.0m shafts to depths approaching 100m using piling techniques has not been done in New Zealand. There is wide experience in Hong Kong and South East Asia but generally using reverse circulatory methods with drilling fluids and casing oscillators / rotators. With the Soilmec R625 drilling rig and 2.5m oscillator Brian Perry Civil had the basic equipment to excavate the shafts. Using their knowledge and experience they developed tooling to progressively enlarge the shaft diameter and optimise the use of the available 25tm torque available from the rig.

2.1 Drilling

The need for 2.5m internal diameter 20mm wall thickness full depth permanent casing and the potential for such a long casing to jam due to excessive friction resulted in the decision to use telescopic casing or larger diameter slip casings over the upper portion to minimise friction on the permanent casing. The 2.8m and 2.6m diameter casings extended to depth of up to 24m; essentially supporting the weak upper soils.

2.2 Casing

Given the configuration of the R625 drilling rig the maximum drilling diameter is 2.5m and where casing is used this is limited to 2.0m. Tools were developed that enabled excavation to up to 2.8m diameter and the rig was located on a platform so that the rig could work over the casing and the number of additional casing lengths site welded were reduced. A sheet piled wall was used to form a ramp for the rig to get up onto the platform; this was incorporated into the permanent works. Commonly the oscillator is connected to the drilling rig, however, the casing oscillator was located below the platform and piles were required to provide the necessary lateral resistance during operation.

2.3 Sequencing

With the oscillator independent from the drilling rig and sufficient cranage to handle the casings and move the oscillator it was possible for the drilling and casing operations to be carried out concurrently by working on both shafts. Due to the particularly hard rock zone found in Shaft 1 and the groundwater encountered this was difficult to achieve and the following general sequence was adopted:

- 400mm diameter pilot holes by Boart Longyear using a reverse circulation drilling with a tricone bit. This provided:
    i. A guide hole to the base of the shaft
    ii. Drainage in the shaft bore down to the mine workings
    iii. Guidance on the strength / drillability of the rock
- 2.8m diameter slip casing and drill out
- 2.6m diameter slip casing in sections and drilled / reamed out
- 2.5m diameter casings in sections then drilled and reamed out
- Remove slip casings
- Provide permanent support to 2.5m diameter casing / shaft liner

Figure 3: Photograph of Site

3 CONSTRUCTION ISSUES RESOLVED

The scope of the project and the fact that, even with the most powerful rig in New Zealand, the drilling boundaries were being significantly extended meant there was always going to be numerous challenges for the project team to overcome. A couple of major issues are discussed briefly below:

3.1 Groundwater

It was anticipated that the mining works would under-drain the site area and hence the shafts would be dry during excavation. When excavation commenced on Shaft 1 it soon became evident that connectivity with the mining operations below was very limited as the shaft bores readily filled with water. The project team decided to sink a 400mm diameter pilot hole facilitated drainage of the shaft bore together with other benefits as noted above. Maintaining the flow pathway during drilling required care and tool development but overall the pilot holes worked well.

3.2 Rock Strength

The boreholes encountered variable rock strengths in the range of very weak to strong (1 – 100MPa) with no discernable trend for increasing strength with depth. Furthermore, whilst the general geological sequence was the same in the two shaft boreholes, the strength at the same level varied considerably. Excavation started on Shaft 1 and progressed well to 40m when the drilling was effectively halted by some very hard massive rock. At this time the central 400mm diameter pilot hole had not been progressed so it was not clear what the nature and extent of the deposit was.

Intact samples of excavated material were tested which revealed strength of up to 330MPa and 180MPa at the locations of Shaft 1and 2 respectively. The strength test results for Shaft 2 are plotted in Figure 5. In addition to halting drilling progress on Shaft 1, the partial intrusion of very hard material on one side of the shaft caused the comparatively thin walled permanent casing to locally deform.

The use of reamer tools, coring tools or a 10t chisel was not sufficient to break through such a hard zone and the project team decided that the use of explosives was the only way forward. Rigorous plans were put in place to ensure safe access / egress, with back up, and to minimise the exposed face whilst people were in the shaft. The casing was repaired and explosives successfully used to penetrate through the very hard zone.

Figure 4: R625 rig on the platform, oscillator and Chisel

4 COMPARISON OF BOREHOLE LOGGING DATA AND DRILLING RATE

From the site investigation cores extracted, rigorous logging was carried out and rock mass characterisation performed using both the Rock Quality Designation (RQD) and extending this to evaluate the Rock Mass Rating, RMR (Bieniawski 1987) and Rock Tunnelling Quality Index, Q (Grimstad & Barton 1993). These approaches have been developed primarily for assessing bulk rock excavation methodology and support requirements in tunnelling respectively. However, combining this with strength test data provided some insight in to the drillability of the rock. In Figure 5 the borehole data is presented graphically alongside a graph of the 400mm diameter tricone drilling rate evaluated from the daily hours and drilling progress made.

From the data presented in Figure 5, the RMR data indicates excavation of the rock by digging or ripping should be possible and hence piling augers / buckets with teeth should be effective. There is a qualitative correlation between strength and the drilling rate achieved using reverse circulatory drilling with a tricone bit. However, the RMR or Q values do not appear to provide any trend with regard to the 400mm diameter drilling rate plotted. This may be due to the small size of the hole when compared to the discontinuity spacing as anecdotal evidence from the site team would suggest that excavation of the 2.5m diameter was influenced by both the strength and discontinuities. For example, the calculated RMR is in excess of 70 in Shaft 1 at 40m hence the inability to progress using “ripping”.

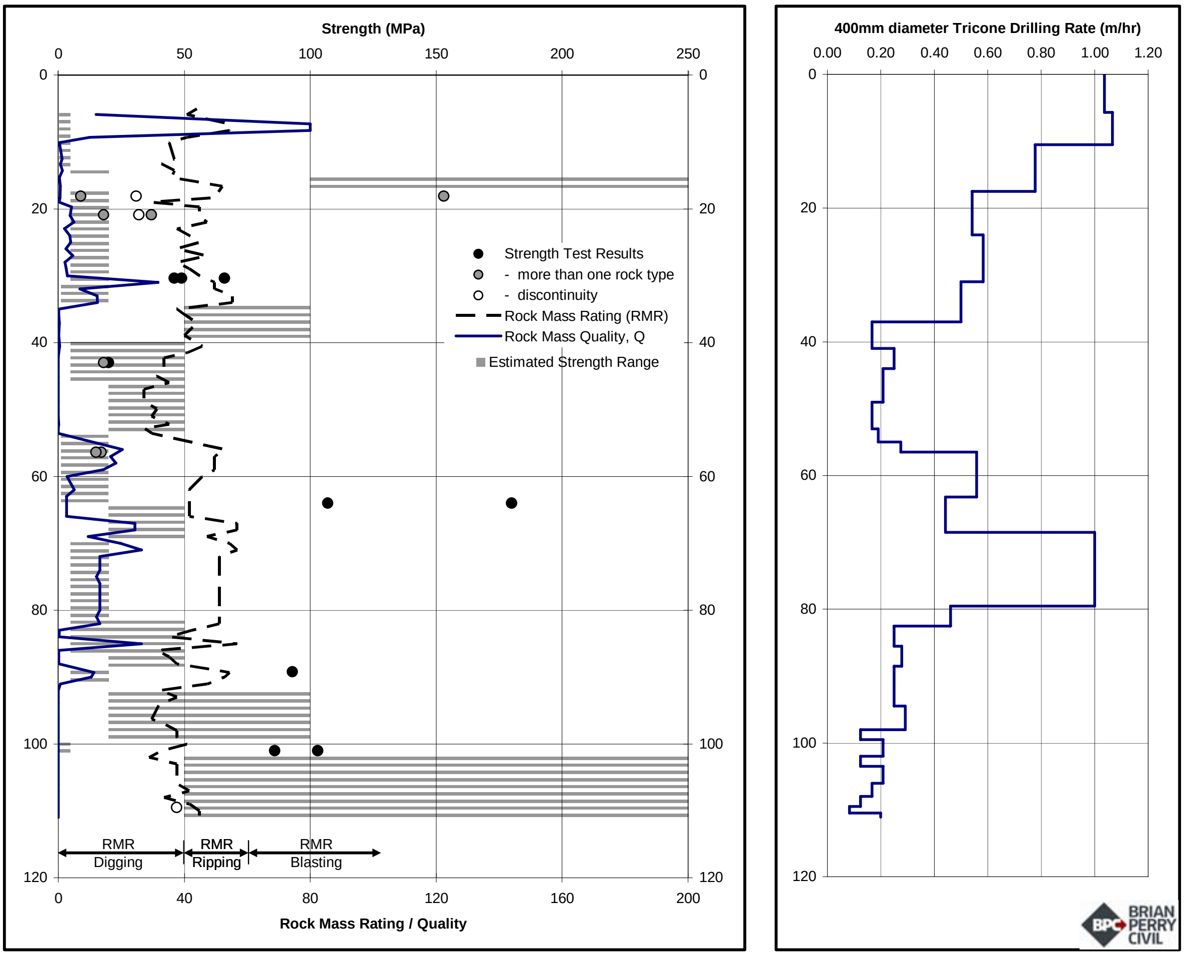


Figure 5: Core logging, strength test and tricone drilling speed data for Shaft 2

5 CONCLUSION

The deposits in the vicinity of the construction ventilation and emergency access shafts are highly variable. The sinking of a borehole at each location coupled with rigorous core logging and strength testing enabled the use of the RMR and Q-method for qualitative assessment of drillability. Even with the core log data, one of the shafts contained a localised very hard zone across part of the cross section area which required man access to remove; safe methods were developed and successfully implemented to progress the shaft. During the 19 week total construction period the 2.5m diameter permanently lined shafts extending to depths approaching 100m were successfully constructed by the project team using rotary piling equipment.

6 ACKNOWLEDGEMENTS

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REFERENCES

Sinclair Knight Mertz (2006). *Favona decline Project factual geotechnical report*

Bieniawski Z T (1987). *Updating the rock mass rating (RMR) system, ASTM STP 984, Philadelphia*

Grimstad, E and Barton, N (1993). *Updating of the Q-system for NMT Concrete for underground support, Proceedings of the international symposium on sprayed concrete, Fagernes, Oslo*