Considering geology in drill and blast operations to optimise ore body value

S. Osborne[1] and L. Maw[2]

[1]AMS Project Engineer, Orica Mining Services, Macraes Minesite, Macraes, New Zealand

[2]Geology Superintendent, OceanaGold, Macraes Minesite, Macraes, New Zealand

Abstract

New Zealand's largest gold producers' OceanaGold Macraes Mine is characterised by a large tonnage and relatively low grade operation. To survive in diminishing real gold prices, the operation must focus on a culture of continuous improvement. This paper presents the outcome of a supplier sponsored continuous improvement project known as the Orica Advanced Mining Services project.

In March 2004 OceanaGold (then GRD Macraes) entered into an Advanced Mining Services (AMS) project with Orica Mining Services. The motivating factor behind OceanaGold's need to improve bulk waste productivity and SAG mill throughput was the planned increase in production from 5 million to 5.4 million tonnes per annum. A stripping ratio of ten to one meant that optimisation of the drill, blast and production functions was paramount.

The primary focus of the project was to optimise the drill and blast parameters to suit the variable rock conditions throughout the mines main operating pit (Frasers Pit). Fragmentation of the ore for presentation at the SAG mill, and cost reduction on the mining of bulk waste movement, were the primary objectives. A number of additional initiatives complimenting the interface between drill, blast and ore production were also established. These included;

- Reduced ore loss through delineation of ore boundaries to allow for blast movement,
- Established blasting parameters for variable geological conditions, resulting in improved fragmentation
- Improved asset utilisation by establishing a blasting regime that angled grade control holes to be used as blastholes in the stockworks area.

A year into the project, the philosophy of continuous improvement is now in-grained at the Macraes minesite. As the project continues, the focus is on the further refining of those procedures established, to ensure a continued focus on lower unit mining production costs.

Introduction

OceanaGold's Macraes Gold Project (MGP), is situated approximately 60km north west of Dunedin. The mine is located on the Hyde-Macraes Shear Zone (HMSZ), which is a NW-SE striking low angle shear zone in the Otago Schist. The HMSZ can be traced for approximately 30km and although gold mineralisation can be found along most of the known outcrop, economic deposits are at present confined to a 7km interval from Horse Flat (Deepdell) in the north to Golden Ridge in the south. In addition, a small deposit has also been defined at Golden Bar, about 4km south of Golden Ridge.

The Macraes Gold Project is the country's largest gold operation, producing in excess of 184,000 ounces in the year 2004 from over 5 million tonnes of ore, with an average head grade of 1.36 g/t.

The relatively low grade of the deposit requires the mine to be extremely efficient in all aspects of the operation. Over the mine's history as head grade has eroded, milled tonnages and recoveries have increased in order to maintain profitability.

With the desire to further increase productivity and mill throughput, OceanaGold entered into an optimisation project with Orica Mining Services. While the project looked at both bulk waste productivity improvements and ore body optimisation, this paper reviews the gains made only with regards to ore body optimisation.

Geology

The ore-bearing HMSZ is hosted within a sequence of inter-layered pelitic and psammitic schists and has a complex internal structure. It comprises the upper hanging wall (HW) shear, internal sub-parallel concordant shears or lodes, and stockwork vein sets.

The HW is typically a wide structure (2-20m) of strongly deformed graphitic cataclasite with variable amounts of quartz brecciation and veining, and lesser deformed 'lode schists' (mineralised schist displaying intensive micro-shearing and hydrothermal alteration). Concordant lodes are similar to the HW but show more variable dip angles and orientations. Quartz vein stockworks are locally developed between shears. Figure 1 shows the HW ore zone (blue lines), bounded by a zone of massive ore bearing psammites to the immediate left (mine west) which in turn is bounded by the pelitic schists. To the right (mine east) the hanging wall is bounded by waste psammites.

The psammitic zone pinches out to the south, where the ore zone is hosted in a mix of inter-bedded psammitic and pelite schists.

Figure 1: The complex geology of the HMSZ, outlining the hanging wall bounded by massive psammites in the north wall of Frasers 3 Pit.

Optimisation of ore body drill & blast

The host rock sequence is of primary importance in achieving acceptable fragmentation for the SAG mill configuration. The host rock ranges in compressive strength from 25 MPa to 250 MPa, with the dominant massive psammites being at the upper end of the compressive strength range.

The relatively massive psammitic schist can dominate stages of the mines development and detrimentally affect mining productivity and mill throughput by dropping off-bench productivity rates by over 10% and slowing SAG mill throughputs by up to 15%.

The challenge is that the schist lithology is extremely complex and is not modelled at the resource stage. In addition, lithological mapping has typically not occurred during grade control processes as it is thought to have little importance in ore definition. As such, blasting parameters have typically not been tailored to suit the rock strength requirements rather blasthole positioning has been based on ore definition requirements. The constraint of blastholes used as ore sampling holes, has meant that some ares of the mine are over blasted, impacting on drill and blast costs with little further benefit, while others are under-blasted, producing oversize and poorly fragmented rock, especially in the stemming region.

An additional challenge is the grade control and blasting of stockwork ore. As the vein sets are typically steeply dipping, ore definition is markedly improved by sampling angled holes (60 degrees), with vertical holes over-drilled on the assay pattern for blasting. This practices requires double drilling of stockwork areas, and impacts on drill availability and drilling costs.

The optimisation project embarked upon looked to improve current drill, blast and ore body optimisation through applying a holistic approach to all stages of the operation.

The project sought to optimise blasting activities in the identify areas of concern including;

1. Under-blasting of massive psammites to improve overall fragmentation,
2. Over-blasting of low strength shear zones resulting in unnecessary increases in drill and blast costs, and
3. Optimisation of stockwork angle hole blasting.

Throughout the optimisation process, a program of matched pairs was used to ensure only one variable was assessed in any trial. This ensured that variables including geology and operating conditions, as well as mill settings were maintained throughout the trialing period.

Under-blasting of massive psammites

Historically, the massive psammite has posed the area of greatest impact on SAG mill throughput due to the high compressive strength of the rock and relatively poor explosives distribution resulting in poor fragmentation, especially in the stemming region.

A review of ore processing in the psammite areas showed a decrease in SAG mill throughput by up to 50 t/hr when processing ore sourced from this area of the pit. The decrease was directly related to the increase in poor fragmentation and rock competency.

The program of optimisation looked to improve SAG mill throughput by improving fragmentation. By understanding the effect of explosive distribution on fragmentation, particularly in the stemming region, a trial of reduced drill hole diameter (from 102 mm to 89 mm) was conducted. While the overall powder factor changed little (less than 5%), the trial looked to improve explosives distribution through increasing explosives into the stemming region, or top 2.5m flitch.

Stemming height is a function of blasthole diameter. Additionally, stemming height at Macraes was defined by the need to ensure no excessive movement of the ore zone. Therefore, as typical blastholes used for ore blasting were 102mm, required stemming heights were determined to be a nominal 2.5m. In order to improve the explosives distribution in the stemming region, (ie reduce the stemming height) it was necessary to reduce the blasthole diameter, thereby reducing stemming height (to 1.8m) while maintaining explosives confinement and limiting ore movement.

As the blasthole diameter was reduced, an invariable reduction in powder factor resulted if drilled on the same pattern. Therefore, the blast pattern was reduced to 4.5m x 3.5m to maintain the powder factor. The east-west spacing was reduced from 4.5m to 3.5m to increase ore definition in the direction of least continuity of mineralisation.

Calculating the cost benefit

In order to ensure the benefit gained through improved explosives distribution was not out-weighed by the increase in costs due to increased drilling, and sampling requirements, a series of driver tree simulations were run with anticipated results.

A calculated increase in SAG mill throughput of 5% was required to offset the additional increase in drilling and sampling costs. Additional benefits of improved digger productivity, reduced GET wear and secondary breakage were also captured in the driver tree, although as the improvement could not be measured prior to commencing the trail, SAG mill targets were the used as the main key performance indicator.

Results

The aim of the explosives distribution trial was to influence fragmentation such that improved mill throughput was obtained. Orica's Powersieve® software was used in obtaining fragmentation distribution data for the trail and control batches processed. Additionally, campaign crushing through the mill was used to ensure mill settings remained constant for the processing period. Two stockpiles (control and trial), of 20,000 tonnes were used for comparative measures of the success of the trial.

Table 1 shows the resulting fragmentation distribution data obtained from the trial. The table highlights the reduction in oversize between the control and the trial. This was considered to be the area of most impact on the SAG mill throughput.

Table 1: Fragmentation results for the trial of 89mm versus 102mm in comparative rock types.

Trial		Control	
Size (m)	Cumulative(%)	Size (m)	Cumulative(%)
0.1	62.9	0.1	65.7
0.2	80.0	0.2	83.2
0.3	90.9	0.3	90.6
0.4	95.4	0.4	94.6
0.5	97.4	0.5	96.8
0.6	100	0.6	97.9
	0.7	98.6	
	0.8	98.9	
	0.9	100	

The overall results obtained from the improved explosives distribution in massive psammites trial were:

- 8% improvement in SAG mill throughput.
- 6% power draw/ tonne reduction in processing requirements.
- Reduced variability in mill operating parameters.
- An improvement in instantaneous load rates of 100 t/hr.

Over-blasting of low strength shears

In direct contrast to the massive psammites, a large area of highly sheared host rock exists in the northern area of the Fraser's pit. This area is typically over-blasted as the geology has predefined the resulting fragmentation, with blasting merely providing enough movement for diggability. As such, the costs associated with drill and blast were excessive in this area given the direct blast related output.

However, the constraint of needing to provide assay holes for ore definition on a given spacing dictated the blasthole pattern.

In order to optimise drill and blast operations in this area, the main constraint revolved around ore body definition, as opposed to blast outcomes. As such, the initial step was to determine the optimal assay dimensions, such that ore was accurately defined, yet blast patterns were able to be expanded.

Determining optimal ore definition patterns

In order to determine the limitations of pattern expansion, a series of block modelling simulations were run on various pattern configurations. The series of faults and splays associated with the northern reaches of the Fraser's Pit have resulted in greater continuity of ore in a north south direction rather than an east west direction. As such, pattern expansion was not detrimental to ore block definition through an expansion in this direction.

However, the simulations also highlighted that if pattern expansion exceeded 6.0m in the north south direction, the increased expansion reduce ore definition to a level such that the cost benefits associated with expansions would be off-set by the loss in defined resource.

Results

Based on the block model simulation, a pattern of 4.5m x 5.5m was adopted for the highly sheared areas. This provided an increase in blast pattern of 13% without detrimentally effecting ore reserve definition, productivity or SAG mill throughput rates. Further a drill, blast and sampling cost reduction of 20% was realised.

Optimisation of angle hole blasting

The Macraes Gold Mine has over 50% of its ore reserves contained within stockwork. Stockwork (SW) ore is problematic in that nearly all the gold is localized in narrow, discrete, steeply dipping quartz veins. Mineable ore only exists where vein density is high enough to raise the bulk grade above the economic cut-off. The likelihood of intersecting near vertical veins with vertical blastholes is significantly less than intersecting the flat lying, more continuous shears and lodes that comprise the remainder of the deposit.

The typically steeply dipping stockwork veins are defined through angle hole drilling on a 4.5m x 4.5m spacing. The angle holes are drilled at 60 degrees north, with vertical blastholes overdrilled on the same pattern.

In reviewing optimisation initiatives the effect of double drilling an area, and the impact this had on overall mine production as stockwork areas grew, was highlighted. As such, a program of single pass drilling with assay holes doubling as blastholes was embarked upon.

Prior to commencing blasting of angle holes, three major issues needed to be assessed. These included;

1. Ability to load angle holes. Typically the angle of a blasthole is no greater than 70 degrees to enable consistent delivery of quality product. Where the angle of a blasthole extends beyond this, concerns in ensuring quality product delivery as well as manual handling issues increase.

2. Optimal angle for ore definition. Although some work had previously been completed in defining the optimal angle for stockwork definition, the issues around explosives delivery required that the angle be reduced.

3. Increased ore dilution through blasting of angle holes. Although not proven, it was a common belief on site that blasting of angle holes would result in increased ground movement and thus result in increased ore dilution.

Optimal angle for ore definition

Although previous works had begun to investigate the optimal angle for ore definition, it had long been a given that the steeper the angle drilled, the better the ore definition. However, as this would mean that angle holes were unable to be used as blastholes, a program was set-up to determine if a 70-degree hole would impact significantly on ore definition.

The trial program involved the drilling of two sample areas at 60 and 70 degrees. Samples were also taken on the vertical hole to enable a baseline for comparison of the defined ore.

The vertical data from each area was combined and modelled in MP3 software using standard operating procedures. The angled data was also combined and modelled in the same manner. In both cases, surrounding data were excluded from the input data sets. Variogram models were derived from each data set but were similar in both cases, describing a maximum direction of continuity in an ENE direction.

Blocking was done at a 0.7g/t ROM cut-off. Minimum block size is 6 smu (smu is 2.0 x 4.0m, E by N). In some instances smu's coded to be ore at 0.5 g/t were included to maintain a mineable shape or reach the minimum block size. At least 80% of the smu's within any block is coded to be ore at the 0.7g/t cutoff.

Table 2 shows the results of the ore results from each angle hole area, the vertical hole and the variance from the baseline. The results show no statistical improvement between the drilling of 60 degree versus 70 degree angled holes, however shows a marked improvement ore definition with the use of angle holes as opposed to vertical holes.

Based on the trial results the ability to drill angle holes at 70 degrees and thus allow for charging of these holes was proven without a loss of ore definition.

Table 2: Ore definition provided by variable angle drilling in stockwork.

	Angled Drilling			Vertical Baseline			Variance		
60 Degree	Tonnes	Grade	Au	Tonnes	Grade	Au	Tonnes	Grade	Au
485	9,633	0.95	9,154	7,946	0.93	7,357	1.21	1.03	1.24
482.5	7,174	0.94	6,719	6,780	0.97	6,551	1.06	0.97	1.03
480	6,122	0.95	5,816	6,299	0.98	6,172	0.97	0.97	0.94
485-480	22,929	0.95	21,690	21,025	0.96	20,081	**1.09**	**0.99**	**1.08**
70 Degree	Tonnes	Grade	Au	Tonnes	Grade	Au	Tonnes	Grade	Au
485	7,344	1.06	7,810	7,063	0.96	6,748	1.04	1.11	1.16
482.5	8,008	1.02	8,179	6,945	0.94	6,507	1.15	1.09	1.26
480	5,150	0.96	4,945	3,741	0.93	3,489	1.38	1.03	1.42
485-480	20,502	1.02	20,934	17,749	0.94	16,743	**1.16**	**1.08**	**1.25**

Increased ore dilution through blasting of angle holes

The final concern to be addressed prior to implementing blasting of angle holes was the need to ensure that angle blasting did not provide increased ore movement as opposed to vertical blastholes. In order to confirm the ability of angle blastholes to be blasted, a trial of vertical and angle blasthole movement was completed.

The trial involved the monitoring of ground movement with polypipe markers placed on a 15.0m x 15.0m. Polypipe markers were picked-up by survey control on all mining flitches, with data input into Blast Refinery, a software package specifically designed by Karjeni Pty Ltd for analyzing blast movement and using the data to adjust ore outlines.

Figure 2 shows the comparable movement between vertical and angle blastholes. The histograms indicate that angle blastholes do not provide greater movement that vertical blastholes.

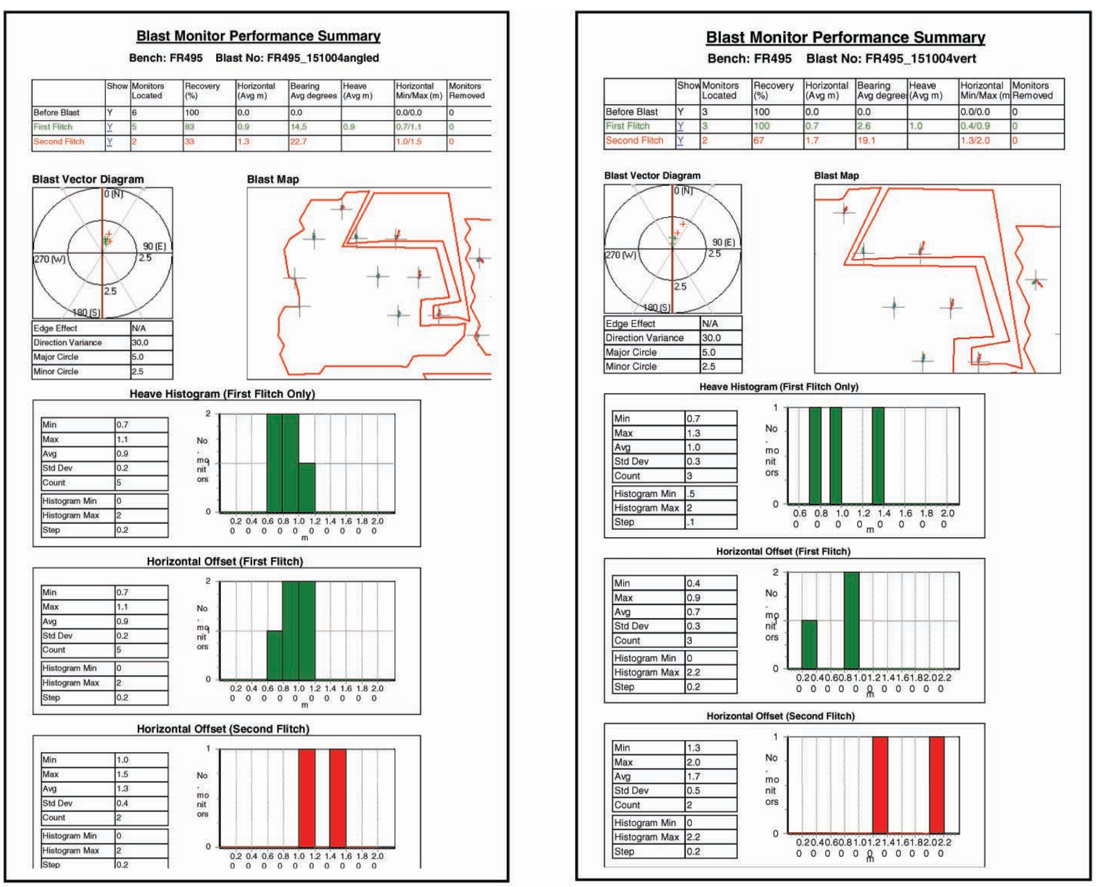

Figure 2: Blast movement monitoring pipes indicate equivalent movement with both angle and vertical blastholes

Results

The trialing phase proved that angle holes could be used for both sampling and blashtoles where the angle of the hole was a nominal 70 degrees. Further, blast monitoring of ore movement showed no detrimental effect with the firing of angle versus vertical holes.

Following these results angle holes were adopted for stockwork ore thus improving drill availability and flexibility for alternative work areas.

Conclusions

The program of process improvement implemented at Macraes Gold Mine, has provided necessary cost reduction and process improvement solutions to the mining of gold reserves.

The application of measurement and successive step-by-step improvements has resulted in the adoption of a number of optimisation initiatives within the ore mining areas. These initiatives have enabled Macraes Gold Mine to work towards the target of increased production.