Using Geometallurgy during Process Optimisation Activities at the Southern Middleback Ranges Magnetite Concentrator

J Gerber[1], C Stanton[2] and D Olwagen[3]

ABSTRACT

From December 2013 to February 2014 the Southern Middleback Ranges magnetite concentrator went through a successful optimisation process that included the installation of extra grinding power to treat a wider range of ore types. After the initial improvements, sampling surveys were conducted to identify the mineral deportment through the concentrator. Samples collected during the survey were analysed using X-ray fluorescence, quantitative X-ray diffraction and QEMSCAN™ to cross-validate the analysis. Certain streams were also put through a laboratory-scale Davis Tube Recovery washing process to produce clean concentrates for analysis. The QEMSCAN™ analysis identified various metallurgical characteristics (mineral association, particle sizes, grain sizes, particle densities, etc) and these were evaluated for each separation and comminution stage to both understand the processes involved and identify opportunities for improvement. Key findings from the investigation indicated the importance of understanding the elemental deportment of target elements throughout the various minerals. The standard practice of tracking iron deportment through assay provided misleading results on losses to tail through the plant. The investigation provided insight into both wanted and unwanted minerals and the efficiency of each separation stage. The efficiencies of separation are critical due to their impact on downstream capacity, and the investigation provided insight into where opportunities exist to extract more benefit. The findings of the geometallurgical analysis have been implemented on the concentrator, and improvements in the rejection of non-magnetic minerals have been seen.

INTRODUCTION

The Southern Middleback Ranges (SMR) magnetite concentrator was commissioned in 2007 to produce feed for the OneSteel blast furnace in Whyalla, South Australia. The concentrator went through an optimisation project in December 2013, which included the installation of a M10000 IsaMill™ and Derrick Stack Sizer™ screens to give it the ability to treat ore with higher silica content.

Magnetite ore is mined from the Iron Magnet pit and then crushed and stockpiled for feed to the concentrator. The stockpiled feed is fed to the high-pressure grinding rolls circuit that produces a coarse grind feed for the first magnetic cobbing stage. The magnetic concentrate then reports to the ball mill for another stage of grinding. The ball mill product goes through a classification stage before reporting to the second stage of magnetic separation. The magnetic concentrate from the second stage reports to the newly installed IsaMill™. The finely ground product is passed through the newly installed Derrick Stack Sizer™ screen system before reporting to the final magnetic cleaning stage. This stage produces the final concentrate that is thickened and pumped down a 63 km pipeline to the filter and pellet plant located in Whyalla.

During the optimisation process, it was identified that the concentrator had increased levels of unwanted elements (predominantly silica) in the final concentrate. While metallurgical characterisation of the ore indicated that marginal increases in the concentration of silica could be expected, the levels seen in the concentrator were significantly higher.

Initial investigations started with a snapshot survey of the major processing streams during stable operation. The analysis of the snapshot surveys included X-ray fluorescence (XRF), quantitative X-ray diffraction (QXRD), QEMSCAN™ and Davis Tube Recovery (DTR) washing.

The findings from the snapshot survey indicated high levels of entrainment of non-magnetic minerals in the magnetic concentrates. Discussions with subject-matter experts confirmed that the efficiencies around the magnetic separation stages were lower than expected. The snapshot

1. MAusIMM, Principal Process Engineer, Arrium Mining, PO Box 21, Whyalla SA 5600. Email: johan.gerber@arrium.com

2. GAusIMM, Process Engineer, Arrium Mining, PO Box 21, Whyalla SA 5600. Email: chris.stanton@arrium.com

3. Metallurgy Team Leader, Arrium Mining, PO Box 21, Whyalla SA 5600. Email: dian.olwagen@arrium.com

survey also found that a significant quantity of non-magnetic iron was being rejected at the first stage magnetic cobbing.

The surveys indicated that the IsaMill™ improved the liberation of the silicates from the magnetite. This led to a more than 30 per cent reduction in the magnesium oxide (MgO) levels in the final concentrate.

These findings led to more detailed focus points around:

- first stage magnetic cobbing, with an emphasis on both the magnetic concentrate and non-magnetic rejects
- the IsaMill™ feed and discharge streams, with an emphasis on silicates liberation.

MINERALOGY

Mineralogical analysis helps to identify and understand the mineral deportment through a minerals processing plant. Understanding which minerals are reporting to the product stream and the reject stream can assist with optimising the efficiency of separation. It also provides understanding of quality constraints on the product stream and the losses of valuable metals to the reject/tail stream.

The current analysis method employed by Arrium Mining's Geometallurgy department uses a combination of measuring techniques to validate results across analysis methods. The analysis techniques that are currently employed are:

- XRF
- QXRD
- QEMSCAN™
- optical microscopy.

It was found that the combination of XRF, QXRD and QEMSCAN™ works well for samples that have a top particle size of 1–3 mm. Samples that contain particles larger than 3 mm are analysed with XRF, QXRD and optical microscopy. As discussed by Donskoi *et al* (2011), the QEMSCAN™ has trouble differentiating between minerals with similar chemical composition (such as hematite and magnetite). The use of other techniques improves the mineralogists' ability to differentiate these minerals when setting up the species identification profile.

Arrium has a good working relationship with the mineralogists at the Bureau Veritas laboratory in Adelaide. This has led to Arrium using the QEMSCAN™ iExplorer viewing software on-site to comprehensively investigate the analysis results. The use of the software has assisted greatly in reviewing metallurgical characteristics such as:

- grade-density profiles
- grade-particle size profiles
- particle shape analysis
- elemental deportment.

The biggest benefit associated with using the iExplorer software on-site is the ability to modify graphs as the investigation progresses and new avenues of investigation are pursued.

MAGNETIC SEPARATORS

Process improvement

Discussions held with Wennen (April 2014, personal communication) indicated that the weight per cent solids of the feed slurry to the magnetic separators was too high. Plant trials were completed and the feed slurry density was decreased in multiple stages to identify any improvements in the entrainment levels of non-magnetic minerals. The lowest density achievable was limited by the capacity of the water supply system. The samples taken during the trial were washed using a DTR method. The amount of non-magnetic material measured by this test was assumed to be the entrained material that should have been rejected. The results were reported as mass per cent magnetic recovery. Figure 1 shows the magnetic recoveries for the various trials. A lower magnetic recovery indicates a higher level of entrainment. The test work confirmed that at lower slurry densities, the entrainment decreases. The concept of lower feed density was embraced by the production personnel, who immediately reduced the density to the lowest possible level with the current infrastructure. A review is currently underway to optimise the water distribution system to allow more flexibility in controlling the slurry densities to the magnetic separation stages.

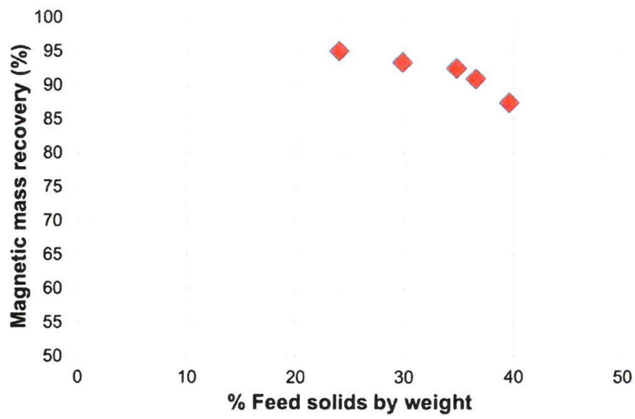

FIG 1 – The magnetic mass recovery for various per cent feed solids by weight for the first magnetic cobbing stage.

Mineral deportment

The samples taken during the trials were sent for mineralogical analysis to understand which minerals were being entrained, recovered or rejected at the magnetic separation stages. The feed to the various magnetic separation stages showed that the main mineral groups contributing to iron content were:

- iron oxides (magnetite, hematite) – 78 per cent
- iron silicates (chlorite, minnesotaite) – 14 per cent
- carbonates (siderite, ankerite) – seven per cent
- iron sulfides (pyrite, pyrrhotite) – one per cent.

The magnetic separation recovers any particle that contains magnetic minerals as long as the magnetic force is larger than any of the other forces being applied to the particle (drag force, gravity, particle interaction forces etc). Depending on the size and weight of a particle, only a small amount of magnetic material is needed for the particle to be recovered (Figure 2). From the minerals listed, it was found that only magnetite and pyrrhotite responded positively in the presence of the magnetic field strength used in the concentrator. This limited the iron recovered to those magnetic minerals plus any of the other minerals being entrained during the separation stage.

The magnetite-hematite association is such that a large portion of the hematite is recovered in the concentrate. The QXRD analysis (Table 1) showed hematite and magnetite levels as high as nine per cent and 61 per cent respectively. Other main minerals identified were quartz, talc (in the form of minnesotaite), dolomite/ankerite, siderite and chlorite.

Analysis of the tails indicated that the hematite lost was not associated with the magnetite but rather with iron silicates or as liberated hematite particles. The pyrrhotite was present

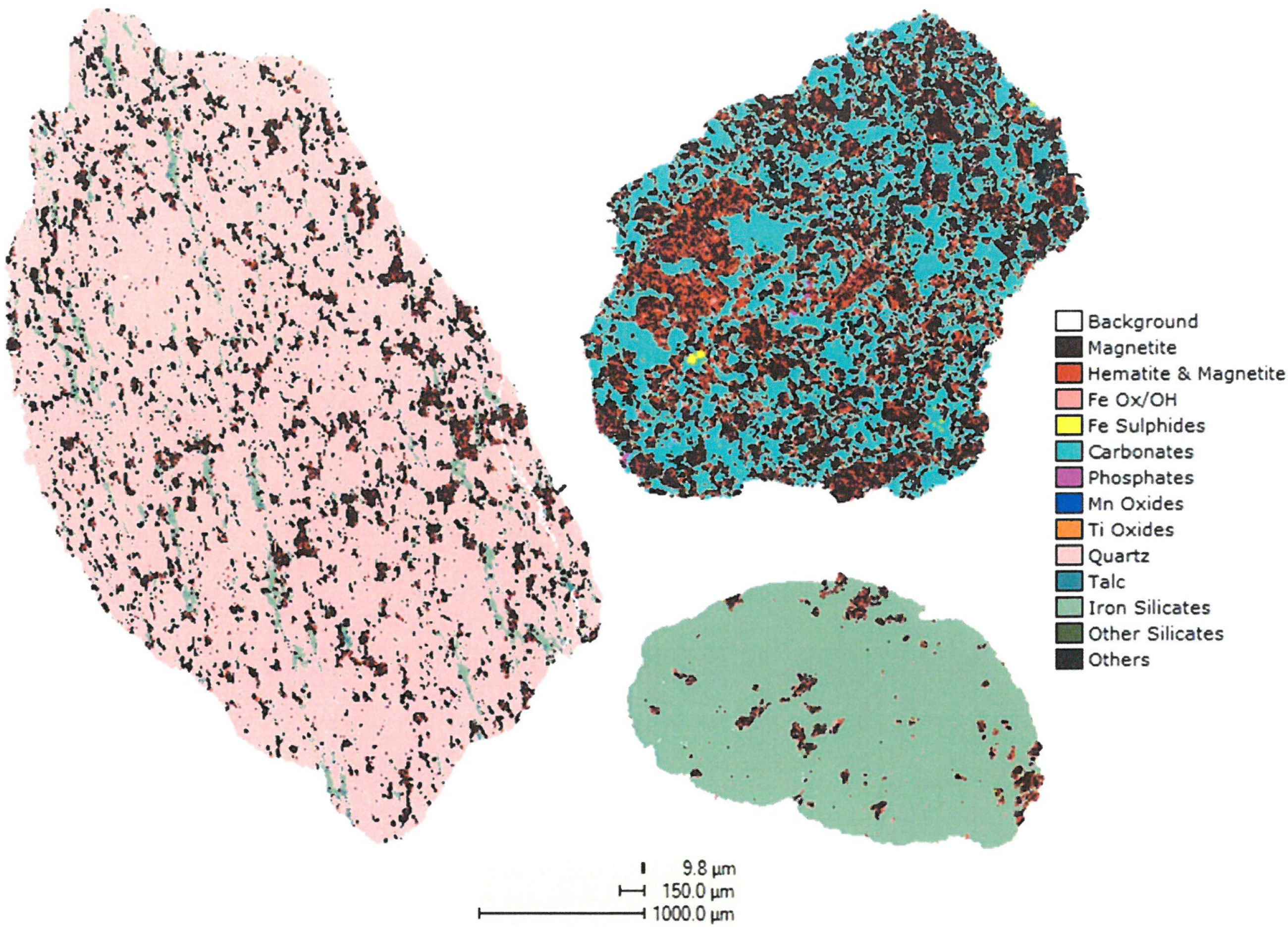

FIG 2 – Three magnetite concentrate particles from the first magnetic cobbing stage, each containing the three dominant non-magnetic minerals (quartz, carbonates and iron silicates) together with magnetite.

TABLE 1

Quantitative X-ray diffraction results from the surveys for the concentrate from the first magnetic cobbing stage.

Mineral	Composition	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5
Quartz	SiO_2	10	16	11	11	12
Magnetite	Fe_3O_4	61	53	56	60	59
Hematite	Fe_2O_3	9	9	7	7	7
Chlorite	$(X_5Al)(AlSi_3)O_{10}(OH)_8$	5	5	4	3	2
Talc (minnesotaite)	$(Fe^{2+}, Mg)_3Si_4O_{10}(OH)_2$	4	3	10	8	11
Dolomite/ankerite	$Ca(Fe^{2+}, Mg, Mn)(CO_3)_2$	5	8	7	7	6
Siderite	$FeCO_3$	5	4	5	4	4
Sepiolite	$Mg_4Si_6O_{15}(OH)_2(H_2O)_6$	2	2	-	-	-
Total		100	100	100	100	100

Chlorite where X = Mg, Fe, Ni and Mn.

in very small quantities and, from the QEMSCAN™ particle view data, was typically rejected due to the particle sizes it was found in. The particle density and particle size for hematite present in the rejects from the magnetic cobbing stage is shown in Figure 3. Sixty-four per cent of the particles in the cobbing rejects were larger than 45 µm. These particles were rejected due to low magnetic content, but still contained significant amounts of iron (12 per cent by mass) at grades of around 60 per cent. Recovery of these particles with a gravity-based concentration stage is possible.

ISAMILL™

Process improvement

The original Project Magnet concentrator flow sheet consisted of two stages of grinding to produce 1.8 Mt/a of slurry concentrate at a grind of 38 µm (P80). This grind was necessary to ensure that the concentrate quality was within the blast furnace requirements; however, to meet ongoing throughput and grind requirements and increase the range of feed materials that can be processed, the optimisation study concluded that the plant required a third grinding stage to ensure ongoing compliance with concentrate specification. For the upgraded concentrator flow sheet, the installed M10000 IsaMill™ sits downstream of the existing 7.5 MW ball mill. With the installation of the IsaMill™, the throughput capability of the concentrator was increased by 20–30 per cent while maintaining the final grind and quality specification.

Mineral deportment

The IsaMill™ was installed as an energy-efficient tertiary grind stage to improve the liberation of magnetite from

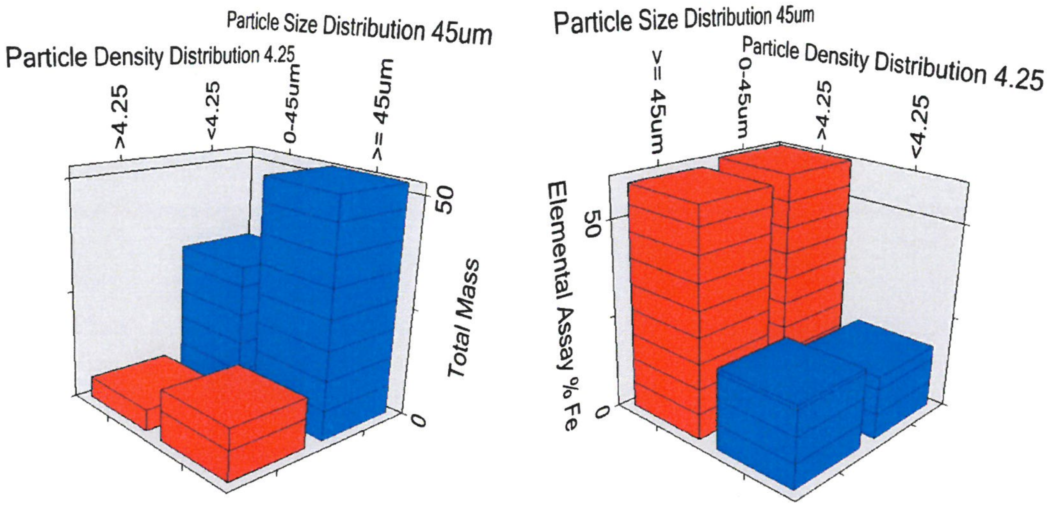

FIG 3 – Three-dimensional figures showing the relationships between particle density, particle size and both the mass distribution and iron assays for each grouping of the magnetic cobbing rejects.

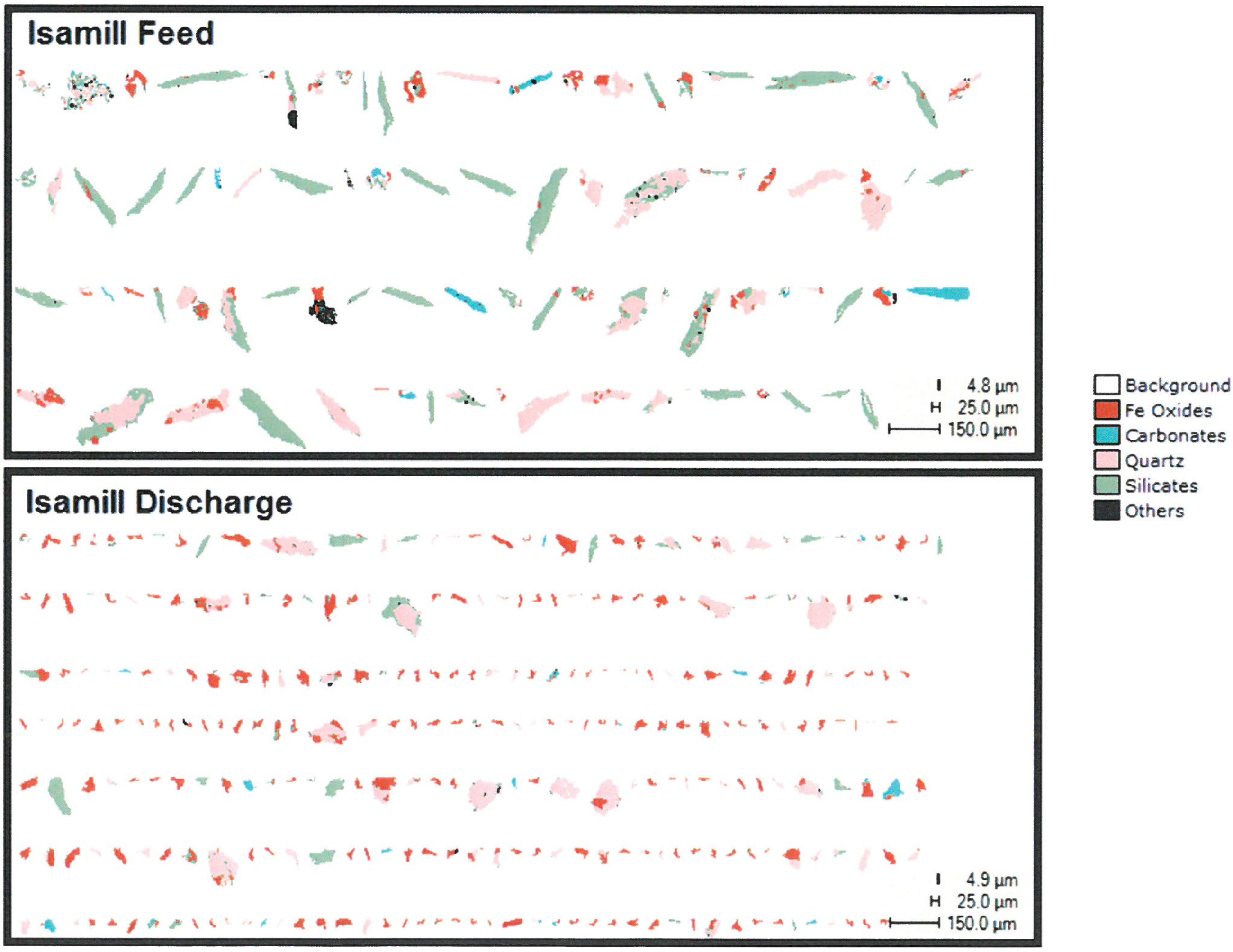

FIG 4 – Particle view report for the IsaMill™ feed and discharge streams arranged by the shape factor of the particles using the QEMSCAN™ iDiscover software package.

the other non-magnetic minerals, predominantly quartz, ankerite and talc. The samples analysed to identify the improved liberation from the tertiary grinding stage were the IsaMill™ feed and discharge. A DTR wash was completed on both samples as well as mineralogical analysis with the QEMSCAN™. The DTR wash in the feed showed a magnetic recovery of 84 per cent and the discharge was 78 per cent. The drop of 6 per cent in magnetic recovery indicates that more non-magnetic material was liberated from the magnetic particles in the IsaMill™ discharge.

The grade of the concentrate between the feed and discharge showed an improvement from 7.2 per cent to 4.9 per cent for silica and 0.9 per cent to 0.07 per cent for MgO. The improvement in MgO liberation is a significant improvement when compared to historical performance. Figure 4 shows how the elongated shapes of the IsaMill™ feed particles have been ground smaller and the amount of elongated particles present in the material reduced. The majority of the elongated particles are dominated by the 'silicates' mineral grouping

The improvement has led to adjustments in the fluxing philosophy at the pellet plant, which is delivering cost benefits by using cheaper dolomite, rather than limestone, to achieve the required flux levels.

CONCLUSIONS

Mineralogical investigations have proven quite useful for Arrium Mining. The use of analysis tools is expanding towards not just fault finding, but also to optimisation exercises and opportunity investigations. It is important to use multiple techniques to ensure that measurements and interpretations are representative. Mineral deportment analysis on the concentrator has identified potential iron recovery gains. These gains are currently being investigated for feasibility.

ACKNOWLEDGEMENTS

The authors would like to thank Mike Bannear for allowing this paper to be submitted and the groups involved during the optimisation process. A special thank you to Wade Hodgson and Barry Whittington from Bureau Veritas for taking the time to train one of the authors in using iExplorer.

REFERENCES

Donskoi, E, Manuel, J R, Austin, P, Poliakov, A, Peterson, M J and Hapugoda, S, 2011. Comparative study of iron ore characterisation by optical image analysis and QEMSCAN™, in *Proceedings Iron Ore 2011,* pp 213–222 (The Australasian Institute of Mining and Metallurgy: Melbourne).