Freeport's New Barmac Delivers High-Quality Shotcrete Sand

by Stacy Goldsworthy and Samuel Hewitt

In November 1936, during a climbing expedition to the glacier-capped peaks of central New Guinea, Dutch Petroleum Geologist Jean Jaques Dozy discovered a massive copper mineralized outcrop that would later become one of the world's largest copper deposits and the single largest gold deposit.

Located in what was then the Netherlands New Guinea and close to the 16,020 ft (4883 m) Carstenz Pyramid, the highest mountain in Oceania, he named the mountain Ertsberg or "Ore Mountain." Dozy stated that the location was so remote, that it may as well have been "on the moon."

It wasn't until 1960 that Freeport Minerals followed up on Dozy's report by undertaking an initial exploration of the area. Drilling finally began in 1967 with positive results, followed by site construction, and, by 1972, a 6800 tpd open-pit mine was working the Ertsberg orebody.

The world class Grasberg orebody of over 200 million tonnes was discovered in 1988 adjacent to the Ertsberg. This major find, along with the underground workings, have driven continuous expansion to today's production rate of 220,000+ tpd of copper and gold ore in an extreme environment of rugged mountains and high rainfall.

An overview of PT Freeport's NW7100 at Milepost 72

PT Freeport Indonesia

PT Freeport Indonesia (PTFI) operates the Ertsberg District mines and is one of the largest and lowest cost copper-gold producers in the world. The PTFI project site is located approximately 4°-6' south latitude, 137°-7' east longitude in the Sudirman Mountain range of Papua, the easternmost province of Indonesia, which occupies the western half of the island of New Guinea (see map).

The company is an affiliate of the New Orleans-based Freeport McMoRan Copper & Gold Company. The operation is serviced by the company towns Ridge Camp, Tembagapura, and Hidden Valley in the highlands between the elevations of 6230 and 8200 ft (1900 and 2500 m), and the administrative center of Kuala Kencana in the lowlands. The local town of Timika serves as home for the families of many of the local work force, which, combining direct employees and contractors, totals in excess of 18,000 people.

Ore is mined from the Grasberg open pit, located 12,795 to 13,780 ft (3900 to 4200 m) above sea level, and the deep ore zone (DOZ) underground block cave mine. The ore is primary crushed and delivered via ore passes to the concentrator at Milepost 74 at 9680 ft (2950 m) above sea level.

After further crushing, grinding, and flotation, a 30% copper concentrate is gravity fed downhill more than 62 mi (100 km) to the dedicated Amanapare Port Site for dewatering and shipment to various refineries. Metso Minerals plays a role in the processing by supporting the secondary and tertiary crushers and screens, nineteen grinding and regrind mills, pumps, and dewatering filters.

The open pit ore reserves will be depleted in 2016, after which the underground reserves will become the primary ore supply with a planned combined capacity of over 220,000 tpd. The Grasberg block cave mine alone is planned to be mined at 115,000 tpd, which will make it the largest single underground mine in the world.

The first step in this transition from open pit to underground is the commencement of the Common Infrastructure Tunnels. These are twin tunnels extending from Ridge Camp to the Grasberg block cave and other underground deposits and will function primarily as man and materials access, utilizing high-speed rail infrastructure. Total planned development is over 11 mi (18 km).

Along with the main processing facilities, Metso Minerals has supplied three quarry plants. One of these is located adjacent to the Ridge Camp and Common Infrastructure Tunnel Adits at Milepost 72 (MP72), 71 mi (115 km) from port site. This contains a 30-year-old Nordberg-supplied two-stage, closed-circuit crushing plant, comprising a dump hopper, Hewitt Robins feeder, Bergeaud VB1008 jaw crusher, wet 6 x 16 ft (1.8 x 4.9 m) DD screen, Symons 4-1/4 ft (1.3 m) standard cone crusher, and a DEA dewatering wheel.

This plant traditionally processed about 100 tph of glacial till, free dug from the adjacent mountains. The products were mainly a natural washed sand and one or two sizes of coarse chips that were then used for road maintenance and as a coarse aggregate for concrete.

Shotcrete

Shotcrete is the term used for concrete that has been sprayed into place with compressed air (90 to 120 psi [62 to 83 kPa]) rather than the traditional method of forming and pouring. A concrete pump transports the mixture from the receiving hopper to the shotcrete machine's nozzle, which is fixed to a robotic arm. It is here the compressed air and a set accelerator are added. The compressed air provides the spraying force and the accelerator provides early strength development. Typically, a strength of 145 psi (1 MPa) is achieved in 1 to 2 hours.

Shotcrete has a wide variety of applications from supporting underground excavations and slope stabilization to swimming pool linings. In mining applications, shotcrete is predominantly used as an effective and reliable method for ground supporting tunnels, shafts, and mines and is far safer, less expensive, and quicker to apply than formed concrete support.

Case Study

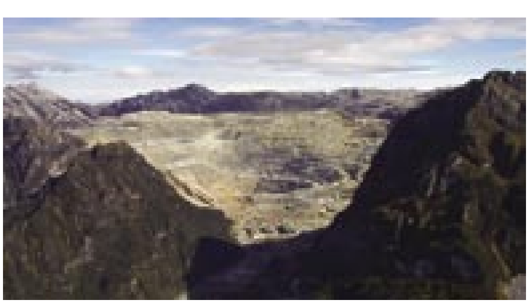
In 2002 Samuel Hewitt, then part of the Underground Engineering Department, was charged with improving the quality of concrete and shotcrete being used for the DOZ Underground mine development, which was fast approaching 6540 yd^3 (5000 m^3) per month.

One of the major shortcomings identified was the poor quality of the stone aggregates, which were flakey and elongated in shape, poorly graded, and lacking in fines. It was thus envisaged that improving the quality of the stone aggregates would improve the concrete and shotcrete properties of workability, long-term strength, and durability with a reduction in the high cement ratios being used. Metso Minerals was approached to investigate how the aggregate plant and general process could be improved.

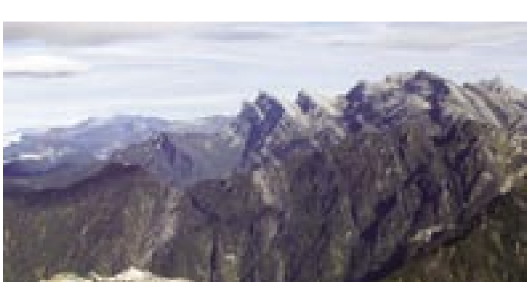
A number of opportunities for improvement were identified. The glacial till was deficient in suitable fines, much of which were lost in the dewatering wheel. There were no other suitable natural sand deposits in this mountainous country and the existing crushing circuit allowed badly shaped chips to enter the sand product.

The Common Infrastructure Tunnels were soon to commence and a possibility to use this ready supply of development muck for aggregate feed would provide substantial operational saving over digging and transporting the glacial till.

A Barmac VSI was proposed to provide a specification minus 1/4 in. (6 mm) manufactured sand. Material was sent to Barmac headquarters in Matamata, New Zealand, for testing. The existing capacity was considered adequate for current and future demands, so a proposal for a Barmac B7100, rated at up to 100 tph, was provided to Freeport, together with anticipated product gradations and wear costs.



The Grasberg open pit mine



The Sudirman mountain range

Ertsberg District location

The initial machine proposal was then refined to include the mounting of the Barmac onto a Nordwheeler trailer with all the necessary infrastructure of feed hopper, VS feeder conveyors, and screen. This produced a dedicated stand-alone beneficiation plant to process the existing crushing plant coarse chips and to produce a specification shotcrete sand, as well as a quality shape coarse aggregate for other concrete work.

After going to a general tender process in 2003, Metso was awarded the order to provide the NW7100 trailer plant and associated conveyors. As part of this tender process, Samuel Hewitt and colleague Ridwan Wibiksana toured the Matamata Barmac factory and actual operating Barmac quarry sites both in New Zealand and Australia.

Barmac Specifications

The Barmac B7100 VSI operates with a tip speed of 148 ft/s (45 m/s) with no cascade. The drive motor is 185 kW fixed speed. Feed is controlled by the loading hopper's variable speed feeder and is conveyed direct to the Barmac, with product taken back to the Nordwheeler-mounted CVB1845 III screen. Oversize is then recirculated to the Barmac by screen chute.

Feed is highly variable from glacial till, comprising differing types of rock, or underground spoil, which has also varied from friable siltsone to abrasive sandstone and diorite. Throughput is largely material-dependant, but averages 90 to 100 tph based on a feed of between 0.2 and 1.18 in. (5 and 30 mm) tunnel sandstone.

The Solution

The existing crushing plant makes a washed –0.2 in. (5 mm) "natural" non-specification sand, as well as –0.79 in. (20 mm) up to –1.73 in. (40 mm) crushed rock dependant upon screen mesh selection. These products are ground stockpiled for general road making use and as feed for the Barmac plant.

Material from the old crushing plant is taken from the ground stockpile by wheel loader and fed to the new 11.7 yd^3 (9 m^3) dump hopper on the Barmac plant. This hopper is fitted with a TK8-32 (31.5 in. wide x 10.5 in. long (800 x 3200 mm) variable speed vibrating feeder, discharging to an H6.5-15, 26 in. x 49 ft long (650 mm x 15 m) conveyor.

The conveyor feeds the Barmac and its product is transferred by two scissor conveyors back to the Nordwheeler-mounted CVB1845 III (5.9 x 14.8 ft [1.8 x 4.5 m]) long, triple deck inclined screen. Oversize from the screen passes back to the Barmac in closed circuit and the other screen products, being 0.79, 0.47, and –0.28 in. (20, 12, and 7 mm), are ground stockpiled.

The Barmac's role in the new plant is pivotal.

The shotcrete sprayer in its natural environment

It is interesting to note that the Nordwheeler design and portability of the plant allowed it to be erected and commissioned on prepared concrete pads in under a week, and it gives the added benefit of future relocation when required.

As the plant is currently adjacent to the tunnel entrances, it will require relocation within the next 2 years. Also, as there is limited power available at the crushing plant, the old existing plant operates for 50% of the time and then power is switched to the Barmac plant, hence the need to double handle the old plant product/new plant feed.

Using the Barmac

Since commissioning in August 2004, the performance of the Barmac plant has met or exceeded all of Freeport's expectations in providing a specification shotcrete sand for tunnel lining. Additionally, it provides superior shaped coarse aggregate for general concrete.

"Since the installation of the NW Barmac plant," says Scott Peterson, the Metso Freeport site manager, "it has provided superior product benefits. It has saved water and cement in Freeport's underground tunnel-lining shotcrete mix by ensuring the aggregates and crushed sand achieve the specified grading and particle shape configurations to more than exceed the desired specifications. This has been accomplished notwithstanding a feed of highly variable rock characteristics and high moisture content derived from the tunnel drive spoil."

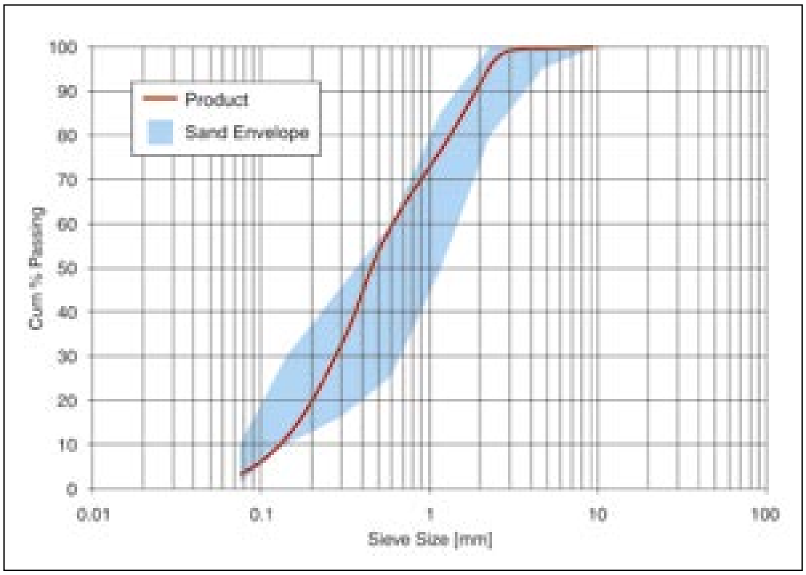
Once in operation, the abundant steel debris present in the underground blasted rock required a scalping magnet be installed on the feed conveyor. Additionally, secondary belt scrapers were fixed to better clean and manage belt spillage.

The plant processes diorite and sandstone very efficiently with minimal attention; however, a period of shale/siltstone feed produced inferior shape and poor sand gradings leading to shotcrete pumping blockages. It was found that the siltstone was very cohesive and, especially when moist, would blind over the screens. This period was managed by ensuring the feed material was as dry as possible and by conducting regular screen inspections and cleaning.

Beyond the final product quality improvements, the Barmac has achieved substantial cost savings for the quarry operation because the equipment once required to dig and transport the glacial till is no longer necessary as blasted muck from the Common Infrastructure Tunnels provides feed.

Difficulty in maintaining the tight shotcrete specification is carefully monitored with weekly grading checks. Since using the purely manufactured sand, and no longer adding or mixing the natural washed sand, concrete strengths have increased from an average of 7250 psi (50 MPa) to over 8700 psi (60 MPa), even though cement addition has been dropped from 978 lb/yd³ (580 kg/m³) down to 840 to 910 lb/yd³ (500 to 540 kg/m³). A 5800 psi (40 MPa) minimum compressive strength at 28 days is required.

The NW7100 gets the job done



Sieve analysis of fine aggregate/sand

Conclusions

The Barmac installation has satisfied all of Freeport's criteria in a difficult situation with variable feed conditions and tough operating conditions, due to excessive altitude and rainfall. The Barmac is considered easy to operate and work on by the labor force. Predicted tip wear of 50 hours per set has been exceeded with an average set obtaining 60 hours life on the hard abrasive sandstone.

The plant has met all capacity and product criteria. The use of Metso Superflex rubber screen media on the lower decks was vital to the screen efficiency of the plant and the cleanliness of the final products in a dry plant operation, notwithstanding the high average daily rainfall.

This operation is currently tunnelling through Diorite. This is producing a very well graded product with particle shape in the coarse product significantly improved from the cone crusher output. As a result, shotcrete and concrete workability has increased significantly without increasing water and high-range water-reducing admixture.

Operationally, the plant is producing 70% sand and 30% coarse aggregate on the first pass. This is a complete reversal from the old system and the correct proportions with high sand demand for shotcrete, approximately 3920 to 4580 yd^3 (3000 to 3500 m^3), concrete 2620 to 3270 yd^3 (2000 to 2500 m^3) per month.

Two bulldozers, an excavator, and a couple of haul trucks have been reallocated to other jobs, meaning a large savings in the use of mobile equipment is achieved. Also, being a dry system as opposed to a wet system, there will be fewer interruptions from the sensitive water source during the "mini-droughts" that take place every 4 to 6 months.

The wear life of the Barmac tips in the Diorite is now 90 hours with the plant working two 8-hour shifts, 5-1/2 days a week.

Further Business

Metso has recently submitted a study for Freeport on the future relocation of both the original and Barmac plants. This could include the demobilization of the existing crushing plant and commissioning of a new plant. In this case the Barmac plant would be fully integrated into the new circuit.

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The Barmac B-Series Vertical Shaft Impact (VSI) crusher is a proven producer of top quality aggregate products for concrete aggregates, asphalt paving, and specification sand. It crushes a wide range of materials and will process hard, highly abrasive rocks as a matter of course.

The autogenous crushing process, as performed by the Barmac, produces the best-shaped aggregate on the market today. The high-velocity impact crushing achieved in a Barmac improves the soundness and shape of stone, reducing product moisture, and easing the screening task while producing superior products at a minimum cost.

Stacy Goldsworthy *is the Barmac team's manufactured sand technical specialist for Metso Minerals Limited in Matamata, New Zealand. Goldsworthy previously worked for the Barmac System team in other roles in both New Zealand and the UK before moving into his present position in early 2004. His primary focus is on developing BarmacSAND. He has presented technical seminars to a wide variety of audiences, highlighting the advantages of using manufactured sand and high fines, and the importance of aggregate shape in concrete.*

Samuel Hewitt *received his bachelor's in mining engineering from the University of South Australia in 1995 and began working for civil tunnelling companies in Australia, Malaysia, and Hong Kong until starting his job with PT Freeport Indonesia in 2000. Here, he supervised the concrete and shotcrete mixing and delivery operations in the underground engineering and underground construction departments. Currently, he is a project engineer for Freeport-McMoRan Copper & Gold, Inc.'s New Orleans headquarters working with the strategic planning group involved in the preparation of feasibility studies for PT Freeport Indonesia's future underground mines.*