3.2 Lomas Bayas

Lomas Bayas is a low-grade copper porphyry deposit hosted within the San Cristobal granodiorite. It is a 54 million tonne per year copper operation located in Northern Chile approximately 120 km from Antafogasta. It was acquired by X-Strata in 2006 and is their second Chilean operation along with their smelting property Alto Norte. Lomas Bayas produced 64,320 tonnes of copper cathodes in 2006 and 61,455 in 2007. With an expansion beginning in three years the mine life of Lomas Bayas has been extended to at least 2020. The operation is run on a 4 day on 4 day off shift rotation with a total of 1000 employees. Their main processing methods are heap leaching with a solvent extraction electro-winning (SX-EW) plant that produces copper cathodes as their final product.

3.2.1 Mining

Currently Lomas Bayas mines approximately 54 million tonnes a year increasing to 63 million tonnes per year once their expansion is complete. They have two 60 ton PH shovels, three 30 ton front end loaders, 24 180 ton haul trucks, and 5 drill rigs. Their shovels and trucks have GPS and are controlled by the dispatch system. The in-pit bench height is 15 meters at a 35 degree wall slope. There is no necessary de-watering in the pit.

3.2.2 Processing

There are three streams of ore coming from the mine. High grade is crushed followed by heap leaching, low grade is sent directly to a dump leach and anything lower than 0.05% copper is classified as waste and sent to waste dumps. Copper is recovered from solution by solvent extraction and electro-plated like high quality cathodes.

3.2.3 Challenges

Currently Lomas Bayas pipes their water in from Calama approximately 150km away at 150 L/sec. They recycle all water on-site however evaporation is a problem. Energy costs are becoming high due as they are dependent on Argentina gas supply which is in high demand as well diesel prices are high. With their upcoming expansion a focus will be on expanding their water supply to satisfy demand.
3.3 Altonorte Smelter

3.3.1 History of Altonorte Operations

Altonorte was originally known as Refimet and commenced operations in 1988 as a concentrate roasting operation. The company was owned 66.6% by Inversiones del Pacifico and 33.4% by Minera Barrick Chile. A copper smelter was built in 1993. In 1998 Refimet was acquired by Noranda and the smelter was renamed to Altonorte.

In 2003 there was a major expansion which included the installation of a new concentrate dryer, the replacement of the reverberatory furnace with a continuous reactor, new converters and acid plant, an additional anode furnace, a second casting wheel, and a slag flotation plant.

Altonorte started to process molybdenum concentrates in 2005.

Altonorte was acquired by Xstrata as part of the Falconbridge assets in August 2006. A new expansion is underway to increase capacity to 1.2 million tonnes per annum of copper concentrate by 2009.
Above: Altonorte Smelter
3.3.2 Description of Altonorte Operations

Altonorte is a custom copper smelting operation located near the port of Antofagasta in northern Chile. The smelter has the capacity to process 900,000 tonnes of copper concentrate per year, yielding 290,000 tonnes of anode copper and 800,000 tonnes of sulphuric acid annually.

The Phase 4 expansion is under way and will increase the capacity to process 1,200,000 tonnes of concentrate per year, yielding 375,000 tonnes of anode copper and 1,100,000 tonnes of sulphuric acid annually once the expansion is completed. The expansion is worth $89 Million capital and has a NPV of $96 Million.

Altonorte takes custom feeds from:
- Antamina
- Collahuasi
- CCR
- Anglo American
- Minera Alumbrera
- Codelco
- Escondida
- CRL Refineries
- Lomas Bayas
- Tintaya

3.3.3 Altonorte Smelting Process

Copper concentrate and other custom feed arrives at Altonorte and undergoes a blending process. This is done to ensure a consistent feed to the downstream smelting unit operations. The copper concentrate comes in between 27% to 35% Cu. During transportation and through blending, the concentrate contains some residual moisture that will interfere with the pyrometallurgical separation process. The concentrate is fed to a rotary dryer where the water in the concentrate is evaporated. The temperature inside the dryer varies down the length of the vessel. It can range from 600°C near the inlet and decreases to 100°C at the outlet.

The bone dry concentrate then enters the continuous reactor, which unlike conventional reactors, is not a batch process and so can be ran continuously. Reactants necessary in the separation of valuable metal from the waste inside the reactor are added. These include coke, flux...
(mainly silica) and reverts. Enriched air (38% O₂) is also added. The combustion process that takes place inside the reactor is self-sustaining as the sulfur contained inside the concentrate minerals acts as a fuel source. Inside the converter, the valuable metals separate by density from the waste material. In this case, the copper (and some left over iron) sink to the bottom of the reactor while most of the iron and sulfur float to the top. The reactor is then tapped and the lighter waste, known as “slag”, is skimmed off and treated (see below). This reaction occurs at a temperature of around 1000°C. Sulfur is also expelled by off-gassing inside the reactor to form sulfur dioxide (SO₂). Dust is also produced inside the reactor. Both dust and sulfur are captured and treated in later processes (see below). The denser, valuable material is then transferred to three Pierce Smith converters for further refining. At this point, the valuable material is called “matte” and it contains around 72% Cu and 3.2% Fe.

The purpose of the converters is to further purify the matte product by removing many of the impurity metals, primarily iron. The converters, which run at 1200°C, heat the matte further to try and remove the impure iron. In a process similar to the reactor, the valuable material sinks while the slag floats. The lighter slag is then poured out the top of the converter as it is rotated. Eventually, a final converter product known as “blister copper” is produced, which is a metallic material of 99% Cu. The sulfur dioxide produced inside the converters is also captured and treated.

The blister copper is then sent through three refining furnaces and then on to two casting wheels where the liquid hot metal (1360°C) is poured into moulds that are part of two rotating casting wheels. Once cooled, the copper casts, called anodes, are removed and stored for shipping to electrowinning plants for further purification. At this final stage, the anodes are 99.6% pure copper.

The slag removed from both the reactor and the converters is poured into a special cooling area where water is sprayed on it for 24 hours. Once cooled, the slag is transported to a special milling area where it is ground in a ball mill and subject to a flotation process. The “concentrate” that floats in the flotation cells is the placed with the incoming concentrate at the start of the process while the tailings are disposed of in a tailings facility some distance away.

The sulfur dioxide produced in the off-gassing that occurred in the reactor and the converters is captured and sent to two sulfuric acid plants where water is added to produce saleable sulfuric acid for market. This by-product has been extremely profitable due to a world wide shortage of
sulfuric acid, needed for leaching and other hydrometallurgical operations in Chile and elsewhere.

Figure 5: Altonorte Flowsheet

Above: Copper Anode Casting
3.4 Radomiro Tomic

Radomiro Tomic was the first mine to have been entirely developed by the Chilean state copper-mining company, Codelco. Located at 3,000m above sea level in the Atacama Desert of northern Chile, the mining and hydrometallurgical operation is 4km from the Chuquicamata mine and smelter. Development was approved in 1995, started in 1996 and was essentially completed in 1997. The initial target capacity was 150,000t/y of copper cathodes but optimization during construction raised the rating to 180,000t/y by the commissioning date.

In 1999 Codelco increased the plant capacity to 250,000t/y of cathode copper at a cost of $220m. This expansion was completed in 2001.

To help achieve economic and environmental sustainability at Codelco Norte as a whole, and to improve workers’ quality of life, Codelco has built over 2,000 new homes at the nearby town of Calama.

The Radimiro Tomic deposit lies beneath approximately 100m of alluvial material and extends over 5km x 1.5km x 200m. During 1993-94, Codelco upgraded the geodata, establishing a resource base for the operation comprising 802Mt of oxide ore grading 0.59% copper, with 1,600Mt of refractory ore.

The conventional open pit strips at a 1.5:1 waste-to-ore ratio using rotary drills, P&H 4100 shovels, a LeTourneau loader, Caterpillar 793B and Komatsu 330st-capacity trucks. RT is currently trialing five automated Komatsu haulers. An FFE Minerals gyratory primary crusher near the pit rim supplies coarse ore, which travels to the main processing area via a 9,615t/h Krupp conveyor. Conveyors take stockpiled ore to pre-treatment and stacking on the racetrack-style heap-leach pads. Leached material is reclaimed by a bucket wheel and is conveyed to the dump area.

Following acid leaching, the copper is separated from the heap-leach solution by four-stage solvent extraction. The solution is fed to the electro-winning tankhouse for recovery as cathodes.

Radomiro Tomic’s total operating costs of $0.44/lb, producing 162,000t of copper in 1998 and 190,100t in 1999. The expansion boosted output to 256,000t/y in 2001 and Codelco hoped to maintain production at around 300,000t/y thereafter. Actual output in 2002 was 297,119t at a cash cost of $0.33/lb.
3.5 San Pedro de Atacama

We arrived in San Pedro de Atacama on Thursday Evening. That night was spent relaxing and taking in the local culture after riding the bus all day and touring the RT mine. On Friday morning we began our tours of the area. The first place we went to was the salt flats. On the way there we passed through a reclamation research project from the 1960’s. There was a section of desert that would not allow anything to grow due to the wind conditions in the area. The wind was caused by the proximity to the Andes Mountains. Much effort was put into finding a species of tree that could withstand the high winds and lack of water. One species was eventually found that grew 3 feet of roots for every 1 foot of height. The trees were planted in a long but narrow barrier. The width was around 300m. On the leeward side wild grasses and shrubberies were growing without assistance almost 50 years after the experiment started. Wild goats and llamas were also seen grazing on the native land. After passing through the forest, the landscape on the other side was barren and desolate. There was nothing growing, or any sign of animal life. Such reclamation techniques were noted by the students to be useful reclamation of tailings impoundments and waste rock dumps.

After what seemed like forever of driving through barren wasteland, we arrived at the salt flats. This area of the desert at one point had large areas covered by sea water. As the water evaporated large areas of the desert were left covered by salts. The salt flats are home to some large salt lagoons. This region of the desert also houses major lithium mining. While the mining is considered small scale to almost all other minerals, Chile is the largest producer of lithium, and all of the lithium produced in Chile comes from this region. The salt water in the area is full of life. Small organisms that have adapted to extremely saline environments flourish here. These small saline organisms are a nutrient rich food source for large numbers of flamingos. There are three different types of flamingos that migrate through the salt flats.

We then proceeded up to a much higher elevation to see the world’s highest lagoons, Miscanti and Miñique. The blue water of these lagoons perfectly reflects the surrounding mountain ranges, providing a stunning backdrop seen no else in the world. This unique ecosystem showcased how successful mining operations can exist in near proximity to a fragile environment.

The following morning, the group awoke at 3am to catch an early bus to El Tatio, the world’s highest geyser field. Because of the low air pressure at the geysers, the affects of the internal geothermal pressure were amplified, providing an impressive show. The early morning departure
allowed us to view the geyser shows at sunrise, making the show even more stunning. Even more impressive was how the Chileans were utilizing this resource to assist them in their energy crisis. They were tapping the heat producing capacity of the ground to build a geothermal plant, capable of providing 250MW to the power grid. This is the equivalent of building three new major hydroelectric dams, and showed the class new and innovated ways of producing "green" energy in a world that is hungry was more power.

The tour returned back to San Pedro for lunch, before going back on the road for a visit the Valley of the Moon. This valley had an untouched sand dune which reached over a hundred meters of elevation. Upon reaching the summit, one was able to look down upon a valley with resembled the surface of the moon. This, coupled along with the moon rise for the evening, provided an almost surreal ending to our time in San Pedro de Atacama, as the tour departed for Antofagasta early the next morning.
4.0 CONCLUSION

This trip has solidified mining as a global industry in the minds of the graduating students. Students have experienced the manner in which mining can be an important and beneficial part of an economy in a developing region of the world. Students were able to see that the mining process in Chile is no different than what we learn in school or see in Canadian mines. In fact, in many cases the scale of mining in Chile was on a different order of magnitude than we have experienced in Canada.

In addition to the mining experience, students had the opportunity to experience the Chilean culture first hand, from the traditional feel of San Pedro de Atacama to the metropolitan streets of Santiago. The Chilean hospitality was incredible as was that of our host sponsors who ensured that we were well educated, well fed and learned as much as possible about mining and life in Chile.