Mining 4th Year Research Trip

Chile

February 14-29, 2008

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1.0 INTRODUCTION

In recent history mining engineering students at UBC have been working hard to become better global citizens in all senses of the words. Our program teaches us the value and necessity of communication with local stakeholders in the area that we operate. Learning to understand and respect the ideas and cultures of others is an integral part of being a mining engineer in today's market where there are job opportunities across the world.

The 4th Year Research Trip was borne from this ideology, to allow graduating students the opportunity to experience the industry from an international perspective and to be able to compare and contrast the way that business is done.

This year the class decided that Chile would be the perfect country to visit. Chile is not only one of South America's most stable and developed countries, it is also the world's premier copper producing nation and this trait meant that we would be able to visit world class mining operations that are on a completely different scale than we would find in Canada.

The trip took place between February 13th to March 1st, and took months of planning to organize and raise the money to be able to go. During the fundraising process students gained valuable industry contacts and the class was incredibly pleased with the generosity of all the sponsors and the UBC engineering students through the Professional Activities Fund. Without this support the trip would not have been possible and the students would have lacked a piece of their education that, although not required, is very valuable to their professional careers.

2.0 SANTIAGO

Santiago, located in the central Chile, is an integration of old European world and modern cosmopolitan. Together with the development of suburban, it forms Greater Santiago. Therefore in order to make sense of Santiago, an understanding of its history is recommended.

Santiago was founded by Spanish conquistador Pedro de Valdivia in 1541, yet the city was destroyed 7 months later by the Indian forces led by Chief Michimaloco. The city was resurrected with the help of the native Pincunche Indians. However, couple hundreds year later, it was destroyed again in the War of Independent, 1810 to 1818. Santiago remained as a small town until 1880s, when its fertilizer extraction promoted city development and contributed to Chile's prosperity. Major landmarks were not constructed till 1910, when Chile gained independence from Spanish dominance; for example, the National Library, the Museum of Fine Art and the Mapocho Train Station. Further development had promoted migration from north and south, and then Santiago development had taken off along with problems.

In modern era, Chile had gone through socialist government headed by Allende in the 70s, then dictated by the military figure Pinochet for more than 2 decades; recently, democratic government has the reign. Post Pinochete era, Chile as a whole is developing and growing rapidly.

Santiago is really diversified in architectural aspect. Many landmarks from the past are standing still while new buildings are being constructed. However, there is this district that is nearby an area that is concentrated of colleges and the district becomes student housing. Judging by the visit, the buildings lack maintenance and management. It is rather painful to see the historical landmarks being abandoned by the people and the city. The residences are all old buildings from the 19th century; all the buildings reminisce the wealth of the rising middle class. Most interesting point is that they are all different; one would be French, but the next would be Italian, or English, or other European countries. Their existence allows people to walk through past and to gain an insight to the old community.

Above: Historic area of Santiago

Similarly, Santiago is populated with art centers and museums; and it was a feast to visit them or by looking at the buildings and monuments, especially the ground is where a major event had taken place. For example, it is mind blower to know that the Santa Lucia Hill is where, not only thought as a place closest to God, but also a place where Santiago founding ceremony was held. However, one distracting feature is that there is graffiti art everywhere even on the wall of the landmarks. After seeing no end to them, one could just come to accept that it is just part of the culture.

From left to right: Santa Lucia, Plaza del Armas.

Moreover, due to Santiago’s geography, it is surrounded by wineries. Making a trip or two to the wineries is both stimulating and relaxing at the same time. Drinking wine is a major part of the Chilean life, so it is a cultural experience and why not indulging in luxury when it is ready for one to grab.

Indeed, Santiago offers cultural excitements and relaxing life style. Its integration of the Old and New traces past glories and showcases new advances. It was an eye opening journey for anyone who has not been to South America, and relaxing for those who have.

From left to right: View of Santiago from Cerro San Cristobal, Errazuriz winery.

2.1 Finning

2.1.1 Finning Facility Tours

Three Finning Facilities were visited in Chile: the South American headquarters in Santiago, the Caterpillar mine services and assembly plant, and the Caterpillar Rebuild Plant, both in Antofagasta. The three facilities offered an excellent opportunity to observe the operations of a contractor servicing the mining industry in Chile and throughout South America.

2.1.2 Finning South American Headquarters

Finning is an international distributor of Caterpillar equipment with world headquarters in Vancouver, Canada. The company operates in Western Canada, The United Kingdom, and South America. The South American headquarters is located in Santiago and services Chile, Argentina, Uruguay, and Bolivia.

2.1.3 Caterpillar Mine Services and Assembly Plant

The Caterpillar Mine Services and Assembly Plant services a total of 16 mining operations within the Atacama Desert region. Due to the arid conditions within the region, water for the operation is piped from over 50km away onto site. All sewage is treated onsite and recycled. Due to public pressure and concern about the future of aquifers within the region, businesses including Finning, in the region are in discussion to construct a desalinization plant on the coast to service the areas water needs.

The plant employs 65 people at the plant with an additional 65 people off site servicing equipment. The plant services both underground and surface mining Caterpillar equipment. All Caterpillar equipment purchased by a client in the region is shipped from the US, Germany, or Brazil to the Assembly plant. 8 mines in the region utilize 777 haul trucks and an additional 8 utilize the larger 797B haul trucks. Once the trucks are constructed, they are driven to site (Farthest mine is Escondida 150km away). The plant constructs some of the largest mobile equipment in the world including 994 loader, 854G dozer and 797 haul truck. A large contained painting booth is located on site as well as a supply of Nitrogen gas for filling tires.

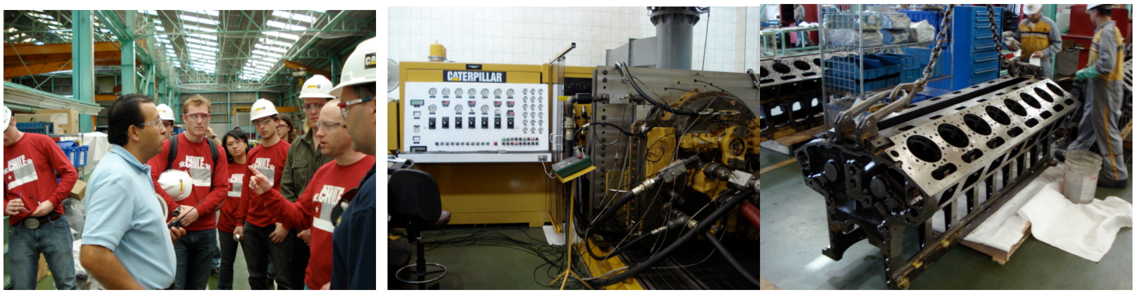
Above: Construction of a Caterpillar 797B Haul Truck. Truck to be delivered to the Escondida Mine Site.

The plant strives to maintain a high level of health, safety, and environmental standards. Safety boards are available for employs to comment on the operation, all oil is recycled, and work places are kept to the highest of standards.

2.1.4 Caterpillar Rebuild Plant

The Caterpillar Rebuild Plant services parts for clients throughout South America. The plant employs 200 people in Antofagasta located in Northern Chile in the Atacama Desert. Rebuilt parts are on average 50% cheaper than the equivalent new parts. The plant's primary focus is on engines, drive trains, and transmissions, and typically requires 35 days to complete an engine rebuild. Sophisticated dynometers are located on site to test the completed motors for proper motor operation, excess vibration, optimal running temperature, and correct power output.

Equipment is also converted to operate at high altitudes on site by increasing the air:fuel mixture ratio.



From left to right: Plant Manager gives a facility tour to UBC students. Catepillar's in house dynometer can test engine and transmission performance. An engine block being refurbished.

Finning also has an SOS Oil Laboratory located on site. 12000 oil samples are processed every year at a cost of $20 per sample. Oil samples are shipped to the laboratory from mine sites within the Antofagasta region. The samples are tested to determine the integrity of the oil composition and for particulate matter greater than six microns. The data from the samples is collected and returned to the client within a 48 hour time period.

All of Finning's operations in South America continue to expand. With a diversified customer base in the mining, forestry, construction, and the power industry, Finning has large potential to continue to grow in South America. The mining industry continues to be a strongly committed to Caterpillar equipment and Finning looks to benefit from the strength of the industry.

2.2 El Teniente

The El Teniente mine is the worlds largest underground copper mine, employing the block caving mining method. The site is immediately adjacent to the abandoned town of Sewell, approximately 120 kilometers south of Santiago, Chile. To date, over 2500 km of tunnels have been mined inside the Andes Mountains. Current mining production rate at the mine is 37,000 tonnes per day, however Codelco is currently developing new areas to force production over 45,000 tonnes per day.

2.2.1 History

Copper production first began in the pre-Hispanic era of South America when natives of the region extracted copper for local use. Once the Conquistadores arrived in Chile, the Spaniards extracted copper to be sent to Peru to make domestic goods such as kettles, pots etc.

In 1822, the property was acquired by Don Juan de God Strap of Saa and Martinez who was a lieutenant in the Patriotic Army and this is how the propertiy gained its name El Teniente, Spanish for The Lieutenant. He acquired the property through marrage to the granddaughter of Mateo de Toro Zambrano, Nicolasa aristocrat de Toro and Dumont.

Industrialization of the mine began in 1903 when the property was sold to the William Braiden and the Braiden copper company. In 1905 a 250 tonne per day processing plant was built and in 1908 production was increased to 3000 tonnes per day. In the mid 1940s Kennecott Corporation implemented the block caving mining method and increased the production rate to 20,000 tonnes per day.

June 19, 1945 a fire started in a forge inside one of the main accesses to the mine. As a result of the smoke and carbon monoxide produce by the fire, 355 miners died. This was and remains today one of the worst non-coal mining related tragedies in the world. The accident represents a landmark in the development of modern occupational health and safety programs in Chile.

In 1967 the government of Chile bought 51% of the shares of then-owner Anaconda copper company and later nationalized the remaining 49% in 1971. Through nationalization, the Chilean government acquired complete ownership of the El Salvador, El Teniente and Chuiquicamata Mines. Today El Teniente is still owned by the state corporation Codelco.

2.2.2 Ore reserves and geology

At the center of the deposit is a carrot-shaped, barren but very hard and competent breccia where the majority of the mine offices and other infrastructure are located. Surrounding the central breccia is the ore zone, forming a cone-like shape. Ore occurs as a chalcopyrite and molybdenite and is hosted in breccia, with average grades of 1.04% Cu and 0.025% Mo. The ore zone currently measures 2km in width, 3.5 km in length and 2km in height. At current production rates and commodity prices, there is an estimated 50 to 75 years of mineable reserves still available. The following schematic shows a rough crossection of the geology:

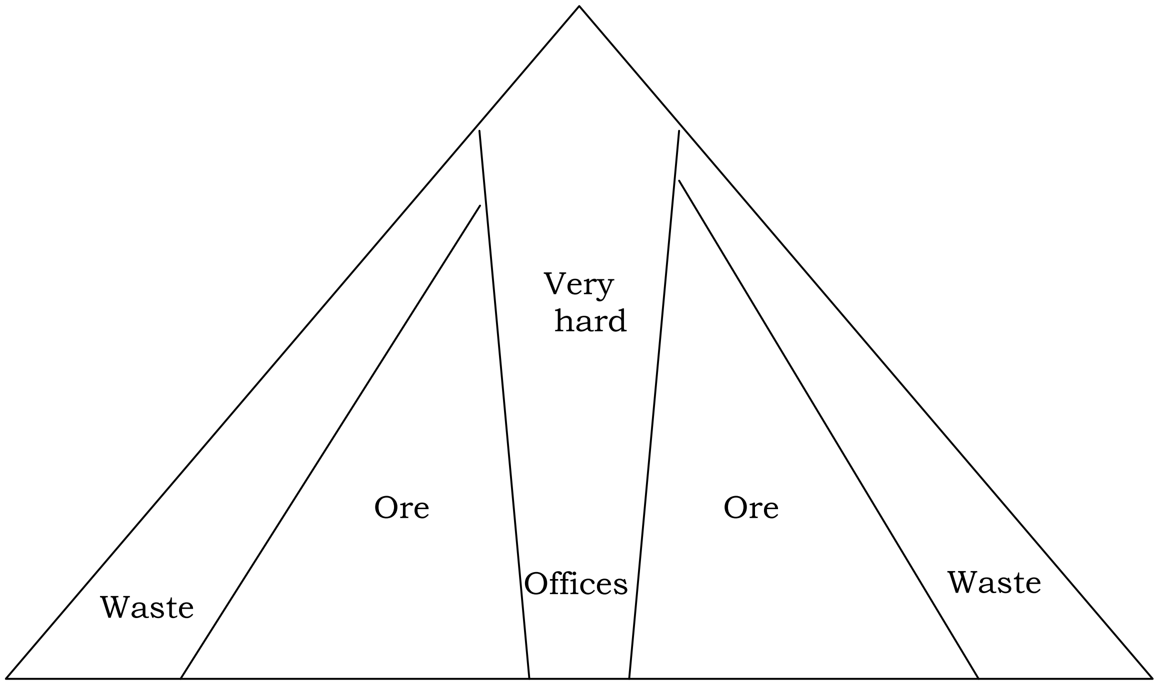


Figure 1. schematic cross section of El Teniente

2.2.3 Mining Method and Layout

As the Ore is hosted inside a very steep mountain and bulk mining began long before the advent of very large open-pit mining equipment, the decision to use block caving was made. The principal behind block caving is that mining starts with drawpoints at the bottom of an ore block, and the weak and fractured nature of the ore allows it to collapse and cave into the drawpoint on its own.

2.2.4 Production Level

On the production level, drawpoints are laid out on a pattern every 15m along the access drives with the access drives being spaced 25m apart. On the production level, LHDs (underground scoops) are used to dig the ore from the base of the drawpoint and transport it to an orepass leading to the level below. In case there is any large boulders that require additional breaking, there are pneumatic hammers at the top of each orepass available to break the ore. In the mine, there are 16 LHDs each with a 7 yd^3 capacity and 32 pneumatic hammers that can be moved to

It was named after the company's first president, Mr Barton Sewell, in 1915.

Our guide Rómolo, a former Codelco employee, described the city as paradise; free rent, water, electricity, and maintenance was provided to the employees. It had a fire department, social club, movie theater, bowling alley, school and hospital. The colourful timber houses were built along the main street, a steep staircase running up from the train station. The city contains no roads due to the steep terrain; it's only connection to the outside world was a train. Due to the triangular shape of the city, built up a mountain, it resembled a Christmas tree at night.

Over 80,000 people were born in Sewell, and the city contained a population of 15000 at its peak. In 1971, the Chilean government purchased 51% of the mine from the owner at the time, Kennecott. Shortly afterwards, the final 49% was nationalized and the mine was given to Codelco. Sewell was closed in 1978 due to lower copper prices and the prohibitively high cost of $32 million per year to maintain. It was made a national monument in 1998, and became a UNESCO World Heritage site in 2006.

We were fortunate to have a visit, as most tourists find it expensive, inconvenient, or otherwise difficult to obtain a tour due to the still operating mine nearby and the remote location of the town. We were extra fortunate to have an amazing tour guide – Rómolo – a gifted public speaker and knowledgeable gentleman.

2.4 Andina

On our last day of mine tours we had the pleasure to visit another large Codelco mine, Minera Andina. Located roughly 60 km directly north east of Santiago (over 100 km by road), it benefits from large deposits of copper as well as low grade molybdenum which is now being extracted at its own surface plant. Most workers are on a camp schedule and during shift time they are housed at the Hilton Camp located at 3,070 meters elevation. Mining is performed both on surface and underground, using a block cave. Copper is sent through bulk sulphide flotation, to get a copper concentrate and molybdenum product.

2.4.1 Mining Process

Andina has two main mining methods; open pit and underground. The open pit is located between 4000 to 4200 meters and is directly south of the concentrator plant. Using conventional truck and shovel methods they output 31,000 tonnes of ore per day. This ore is dropped off at an ore pass which sends it directly to an underground primary crusher. After crushing it is transported via underground conveyors into the milling and concentrator plant.

The underground mine uses typical block caving techniques and manage to output 43,000 tonnes per day of ore. It is located between 3000 to 3600 meters. The ore is taken to the North and South primary crushing plants where it is passed through parallel cone crushers, followed by a gyratory crusher then into a series of tertiary crushing plants before milling. The milling process is all performed underground after an avalanche destroyed their old facilities. It consists of bulk sulphide flotation, processing 74,000 tonnes per day of ore at a grade of 1.074% Cu and 0.019% Mo. Through a series of crushing, grinding and flotation a product of 29.5% Copper and 0.42% Molybdenum comes out of the end of the circuit with an overall recovery of 87.9% of the copper and 71% of the molybdenum. A picture of the flotation flowsheet, including recoveries and grades and several points, can be seen below.
As can be expected with these types of mining methods, the block caving has caused severe subsidence near the highwall shared with the neighbouring mine owned by Anglo American but we are told it is now under control.

Above: Open pit Mina Sur

Above: Flotation Flowsheet

2.5 Wineries

The wine industry was brought to Chile in the 16th century by the Spanish. Under Spanish rule, vineyards had many restrictions placed on them to encourage the Chileans to purchase most of their wine from Spain. Despite these restrictions, the Chileans still bought locally as the imported wine was often oxidized and vinegary. Despite being politically tied to Spain, Chilean wine was heavily influenced by the French. In the mid-19th century there was a outbreak of grape phylloxera, an aphid that destroyed many of the vineyards in Europe. Fortunately due to Chile's isolation from the outbreak, the Chilean wine industry took off and many prominent winemakers made the move, bringing with them their expertise.

Vina Errazuriz was founded in 1870 in the Aconcagua Valley. Don Maximiano Errazuriz, who founded the winery, brought grapes over from France. The winery is now owned by Eduardo Chadwick who is the fifth generation of the Errazuriz family. The winery produces a wide variety of wines and involves the major vine growing styles. We also visited Vina San Esteban, which is a smaller wine producer. There we learned the processes of wine tasting.

3.0 NORTHERN CHILE

Northern Chile is a region of incredible mining activity and was the major centre for our visit to many world class operations. To get to this region of the country we took a 2 hour flight from Santiago to the city of Atofagasta.

Antofagasta is Chile's 4th largest city and it's economy relies heavily upon the region's mining and extraction industries. Visiting Antofagasta was an interesting experience, for much of the city has been constructed at a time when there was less money available. Thus when driving or walking through much of the city we experienced a place that, in contrast to Canadian cities or even Santiago, was much worse off. Although a poorer city, evidence of the new money being infused was found a block away from the hotel where there was a brand new, North American style mall which was a hotbed of community activity and showed promise for the future of Antofagasta and Northern Chile.

3.1 Escondida

On the 2008 research trip to Chile, the UBC Mining Engineering Research Group had the opportunity to visit one of the world's premier open pit mines, Minera Escondida. Located 170km southeast of Antofagasta, Escondida is the world's largest copper producer, accounting for approximately 8% of the global copper production and 23% of the total Chilean copper production. The operation is owned by multiple companies with BHP Billiton owning the largest percentage, 57.5%. The breakdown of the ownership structure can be found in Figure 4.

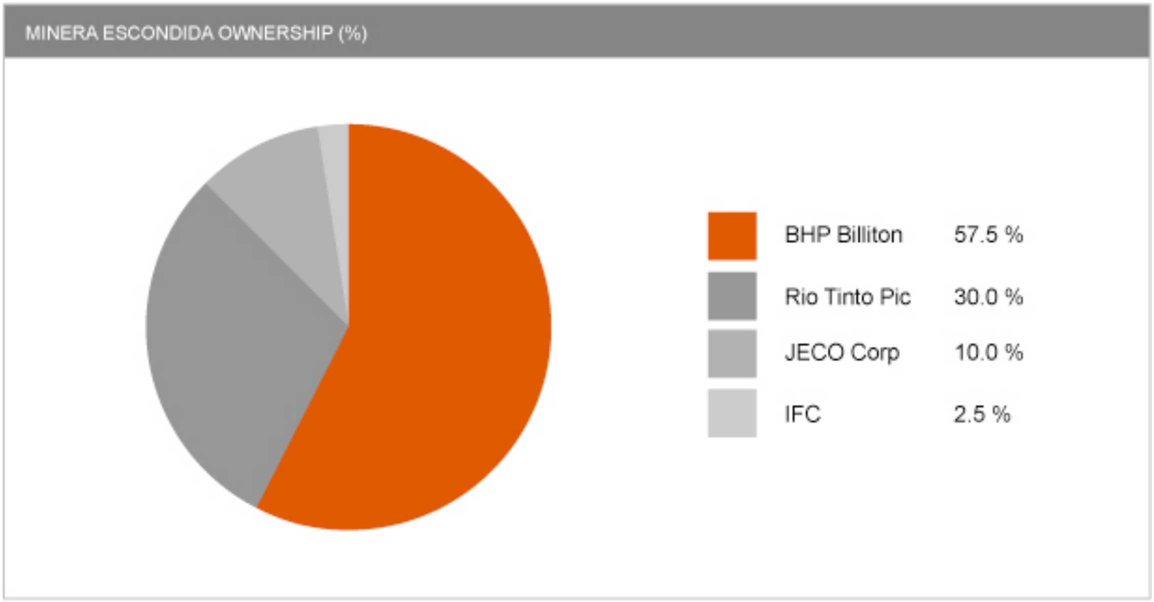


Figure 4: Minera Escondida Ownership (www.escondida.cl Accesed 31 Mar 2008)

Operations at Escondida consist of two conventional open pits producing both sulphide and oxide ores, Escondida (main) and Escondida Norte (located 5km from the main open pit). The Escondida Norte pit began producing ore in 2005. Ore from the Escondida pit is trucked to in-pit primary crushers which is then sent via overland conveyor to the Los Colorados concentrator plant. This plant is capable of milling over 130,000 tonnes per day. Combined with the Laguna Seca concentrator, the total milling capacity of Minera Escondida is over 300,000 tonnes per day. Oxide ore is taken to either a ROM heap leach pad or a recently installed bioleaching process. The impregnated solution is processed with SX-EW processes. The concentrate is sent by two pipelines to a filter plant at a port near Antofagasta and then the dried copper concentrate is shipped to smelters primarily in Asia. In 2006, Minera Escondida produced 1.3M metric tonnes of fine copper.

With a world class deposit comes world class financials. Escondida averages roughly US$35M dollars PER DAY with an average copper recovery of 90%. However this allows Escondida to invest heavily in the community. To date Escondida has invested over US$5 Billion dollars in direct investments in Chile and as a result, the mine enjoys a very good relationship with communities in the surrounding areas. As well, Minera Escondida's 2006 exports made up 10% of Chile's total export revenues.

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

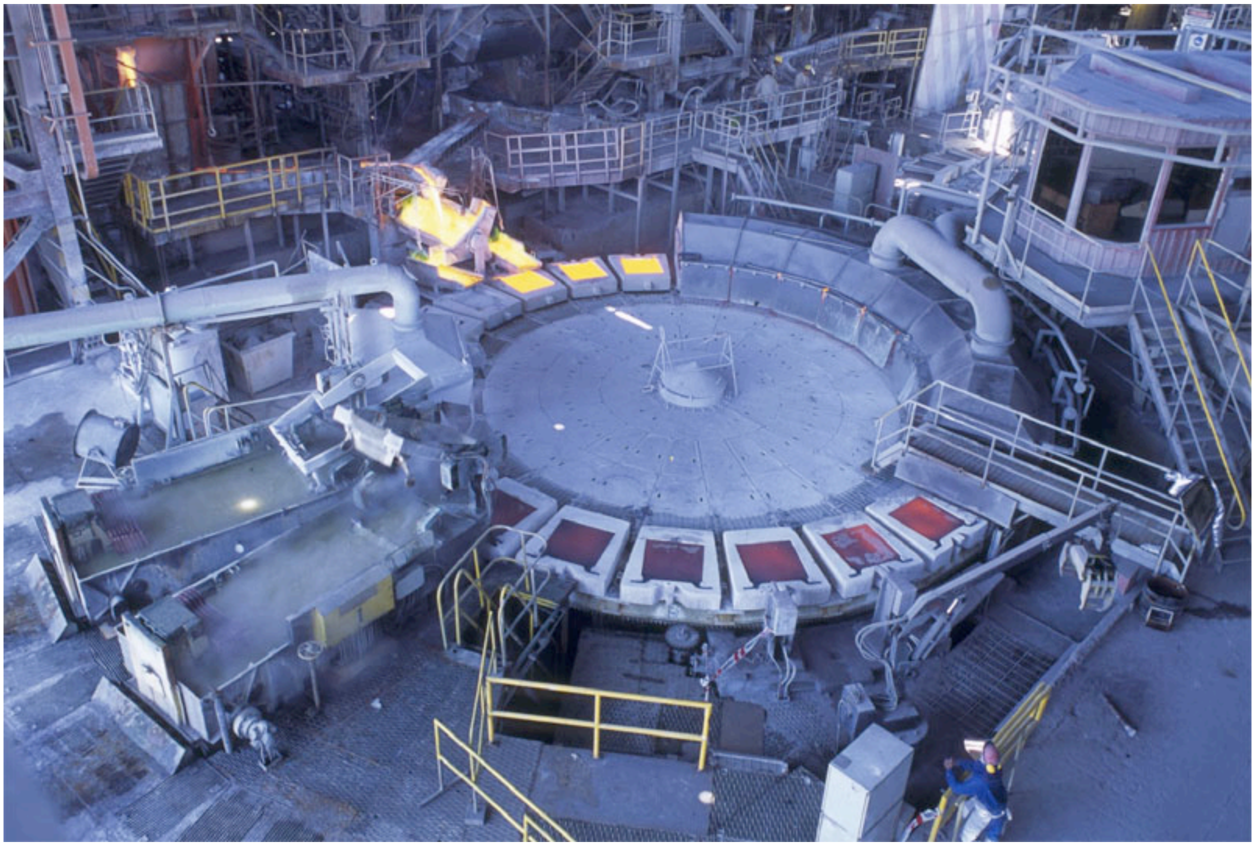
3.3.1 History of Altonorte Operations

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^{o}C near the inlet and decreases to 100^{o}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% O_2) 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 (SO_2). 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 purfication. 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 occured 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.

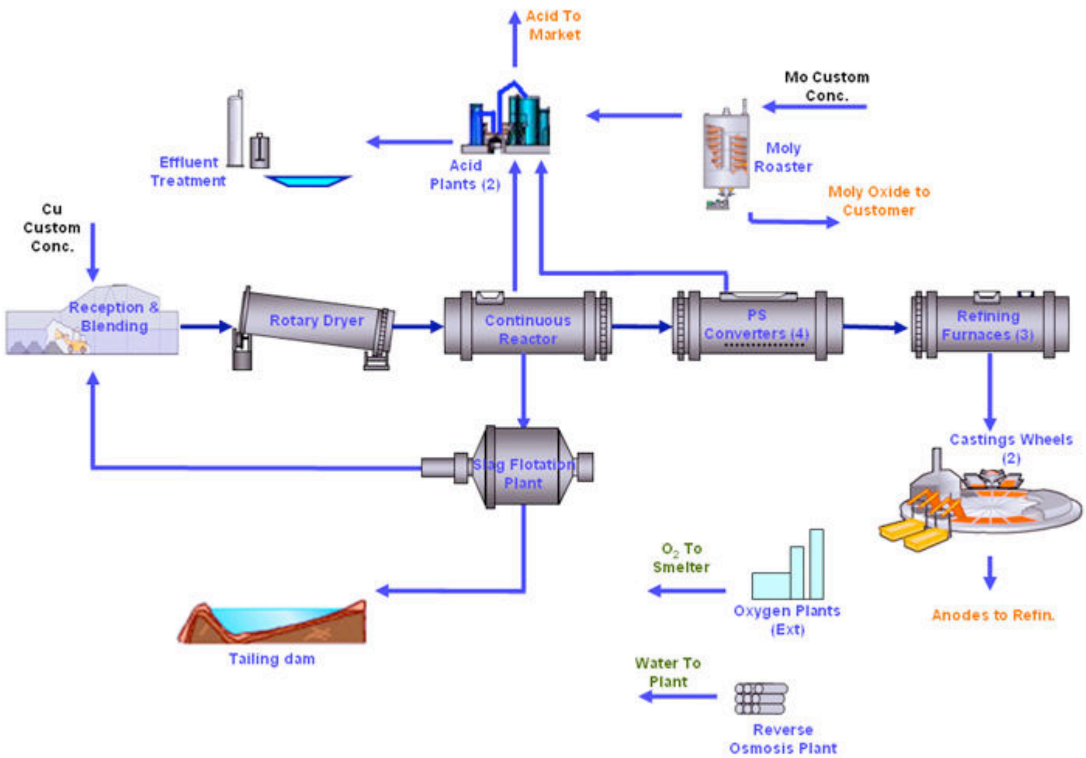


Figure 5: Altonorte Flowsheet

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 metropilitan 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.