4th Year Mine Engineering Graduation Field Trip 2011

Brazil
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1.0 Introduction

In the past decade Mine Engineering as a discipline has experienced drastic changes. Today, new graduates are expected not only to be highly experienced with technical knowledge needed to develop and operate world class operations but to conduct these actions in a sustainable and environmentally friendly manner. In addition cultural awareness and intelligence is becoming a fundamental skill for mining engineers. Unfortunately, it is very hard to teach cultural awareness in school and it is for this reason that we decided to organize the 2011 UBC Mine Engineering field trip to Brazil.

It is inevitable for a mining engineer to interact with people from different cultures around the world. By having the opportunity to travel to different countries and become immersed in their history and culture; mining students are able to learn firsthand what kind of attitudes people have towards mining and how to successfully interact with other cultures. This experience enables students to use such knowledge in their future careers.

More specifically, we chose to travel to Brazil because of its importance to the mining industry. Brazil has 182 mining and mining related companies that operate within its borders producing and exporting minerals, some of which are different to those mined in Canada. By travelling to Brazil it allowed us to gain a broader perspective of the mining industry as a whole and at the same time experience its unique culture.

Brazil’s culture has many similarities with Portugal’s. This is because Brazil was a Portuguese colony from 1500 to about 1822 when Brazil achieved independence. The declaration of independence from Portugal on September 7th 1822 created a national holiday every September 7th. Since then, Brazil has gone though many government changes. The most recent one was in 1985 (to present) when civilian rule has once again come into place, with President Lula being re-elected in 2006. Since Brazil’s was a Portuguese colony for a long time most of the holidays are catholic’s holidays such as Our Lady of Aparecida, Day of the dead, and Christmas. Our lady of Aparecida is Brazil’s patron saint and Day of the dead is referred to All Soul’s day from the old Catholic Church.

In terms of contemporary culture, citizens in Brazil are more people and family oriented with emphasis on the interactions between people. Food wise, Coxinha is a common snack with minced chicken, shaped like a drumstick, and deep fried in batter. Feijoada is considered a national dish of Brazil, which comprise of a thick stew of black beans with pieces of beef and pork added to it. It is traditionally prepared in a clay pot. Some desserts are: Arroz doce, a simple rice pudding made with cinnamon, Cuscuz branco, a tapioca pudding cooked in coconut milk with sugar, and Brigadeiro, truffles-like balls made with condensed milk, butter, and chocolate powder.

Such an experience opens students to new cultures and ways of life. The more students are exposed to different kinds of cultures the more capable they will be in interacting with
people from all over the world. The more students are immersed in different cultures, the less likely for them to develop culture shock, as they will be more equipped to handle the differences. Opportunities such as these are not only beneficial at an engineering level, but also on a cultural level as well. This experience will play an integral part in our development as mining engineers and is unique to UBC Mine Engineering program. We are proud to be apart of this opportunity. The following report provides a brief overview of our trip with specific emphasis on the mines we visited.

2.0 Belo Horizonte

Belo Horizonte is Brazil's third largest city and capital of the state of Minas Gerais. With a population of approximately 2.5 million, the city is a thriving cultural center, with numerous Universities, historical museums, libraries and sports stadiums. The city was our first stop from May 4th to the 8th, and did not disappoint!

During the four short days we spent in Belo Horizonte, we had the opportunity to visit the Universidade Federal de Minas Gerais and a number of Vale operations. Vale was extremely hospitable, as they provided us with tours of their Complexo Varagem Grande the Aguas Claras iron ore mine as well as their Nova Lima Research Centre. During these tours, we had the valuable opportunity to experience iron ore mining and processing, one of Brazil's main mineral export industries. In addition to the research work completed, we enjoyed the unique nightlife and culture the city had to offer by visiting the local food markets and countless patio bars with live music.

2.1 Universidade Federal de Minas Gerais

On May 5th, we visited the Universidade Federal de Minas Gerais (UFGM). It is one of two Federal Universities in the state of Minas Gerais that offer Mine Engineering programs. The University’s main campus is located 30 minutes from downtown Belo Horizonte but there are several satellite campuses located around the city. The Mine Engineering Department is located on the Pampulha campus, which was first establish in the 1940s. The University was federalized in 1965 after which a number of faculties were integrated to form the one school.
Today, UFMG offers 48 different degree programs and is among the most prestigious Universities in Brazil.

Our tour of the University began with presentations from UBC and UFMG professors as well as students. Following the presentations, we were given a tour of the department’s facilities including the processing and rock mechanics laboratories. From the laboratory equipment to the undergraduate curriculum, it was surprising to see how similar the UFMG mining program was to UBC’s. However, after speaking to a number of UFMG students over a lunchtime mixer, it was interesting to see how different the work experience programs are. Unlike UBC, UFMG does not have a co-op program. Instead, each student is responsible for completing a certain amount of work experience while at school. It is very common for a UFMG student to have class in the morning and then work in the afternoon throughout their 5-year degree. This is very interesting as it presents the opportunity to apply the knowledge learned in class with actual industry experience. It also ensures that every student graduates with at least some work experience, which is not the case at UBC.

Overall, it was an invaluable opportunity to see the similarities and differences between the program at UBC and UFMG and to network with students outside of Canada.

2.2 Vale’s Complexo Vargem Grande

Vale’s Complexo Vargem Grande is located in the Iron Quadrangle on the outer edge of Belo Horizonte. The complex is the main processing facility for a number of the mines in the Iron Quadrangle including the Paraopeba mining complex owned and operated by Vale. The processing of the Iron Ore at Vargem is both a wet and dry process. The process starts with a jaw crusher followed by size classification, separating the iron ore into lump, fines, and ultra fines. The lump, large pieces of iron ore, is taken out of the feed and stored in the Lump Ore stockpiles for later transportation. The fines and ultra-fines are also stockpiled before being sent through hydrocyclones to separate the Large Sinter Feed and the Fine Sinter Feed. Each sinter feed goes through its own concentration loop and then gets combined with the other to create the Final Sinter Feed. The Large Sinter Feed goes through more hydrocyclones and a Spiral Rake Classifier, while the Fine Sinter Feed is fed through
hydrocyclones and magnetic separators before being combined into the Sinter Feed. The Sinter Feed is then passed through more hydrocyclones. The underflow is dewatered and stored as the Sinter feed, while the overflow is feed through a flotation and thickening circuit. The tailings are sent to the old open pits and the concentrate is filtered to obtain the Pellet Feed Fines. The products created at the processing facility are, Lump Ore, Sinter Feed, and Pellet Feed.

Material is continually stockpiled at strategic locations of the processing process to ensure a smooth and steady flow of material. The dispatch system used on site is ‘Smartmine’. It is used to optimize the feed and ore movements on, off, and around site. Ore is continually being trucked in from the mines and dumped into the crusher. The products from the processing are transported to a railway storage facility a few kilometers away by conveyor belt. The products are then loaded onto trains and taken to the port to be shipped to Vale's customers.

The water obtained from pit de-watering is recycled and used for the processing of the iron ore and as drinking water. Vale is able to do this because of the lack of chemicals and reagents used in the processing process.

2.3 Aguas Claras

Aguas Claras is one of the mines that are apart of the Paraopeba mining complex. The mine is located a few kilometers from Vargem and right next to a major highway and town. Mining is carried out using drill and blast followed by excavation and truck haulage. The mine employs excavators to load an army of 40 tonne trucks, which transport the ore to Vargem to be processed.
Due to the close proximity of a town to the mine site there are a few problems. The town’s people complained about the noise of blasting and the ugliness of the mine. Therefore, Vale was limited to blasting during certain hours of the day and having to reduce the size of the blasts. Vale also, could not expand the mine any closer to the town and had to create reclaimed berms to hide the mine from the town’s view. Vale is currently looking at expanding the mine away from the highway and town.

This property also has a fertilizer grade phosphate vein that runs through it. Vale brings in an outside contractor to remove the sections of phosphate from the pit. Vale does this because they do not have the means to process the phosphate ore readily. It is cheaper for them to contract out the work, but more profitable than treating the phosphate as waste rock.

![Figure 3- Aguas Claras pit with the city in the background](image)

2.4 Vale’s Nova Lima Research Centre

The Nova Lima Research Centre was initially created in 1965. The centre has been through three main stages since it opened. The first stage was Process Development, the second stage was Product Development, and the third stage is Integrated Burden Solutions. The first stage focused on developing new and efficient processes for the beneficiation of iron ores. The second stage was centered around creating new products and better ways to transport the products to the customer. In the third stage of Nova Lima the researchers are focused on developing integrated solutions to maximize the asset value and value to the client. This means that the researchers are defining the characteristics of each individual ore and understanding their behaviour under different conditions, such as size, temperature, and composition to name a few.
Nova Lima has its own small scale testing plant, furnace, and pelletizer. The facility also had XRD, SEM, and radiation testing equipment on site. With this equipment the researchers are able to determine which of the iron ore deposits is best suited for a certain product or what blend of ores will give them their largest profit.

![Figure 4- Pelletizer (left), Final pellets pellet product (right)](image)

**Figure 4- Pelletizer (left), Final pellets pellet product (right)**

![Figure 5- Nova Lima Pilot test facility](image)

**Figure 5- Nova Lima Pilot test facility**

### 3.0 Paracatu

On the morning of May 8th we left Belo Horizonte for Paracatu. We stayed in Paracatu from the 8th to the 10th and visited Kinross’s Paracatu Mine on May 9th. That evening Kinross hosted a traditional Brazilian barbeque where the UBC students were able to meet some of the mine personnel.

#### 3.1 Kinross Paracatu Mine/Mill Tour

Morro do Ouro (Paracatu Mine) is the largest producer of gold in Brazil. The mine is located a couple of kilometers north of the town of Paracatu and 230 kilometers southeast of the
Brazilian capital Brasilia. Mining has occurred in this region since the discovery of placer gold in 1722. Artisanal miners primarily mined the area until Rio Tinto began exploration in the early 1980’s. Rio Tinto created the Rio Paracatu Mineracao (RPM) with Autram Mineracao and began production of the Paracatu Mine in 1987. Kinross then acquired the Paracatu Mine in two stages. First they merged with TVX, which was Autram Mineracao, in January 2003 acquiring a 49% ownership of Paracatu Mine in the process. Two years later in December of 2004 Kinross bought the remaining 51% of the Paracatu Mine from Rio Tinto.

The Paracatu Mine consists of an open pit, processing facility, tailings management facility, and surface infrastructure such as offices and maintenance buildings. In 2006 Kinross expanded the plant to a capacity of 61 million tonnes per year. The life of the mine is now predicted to be 2040. The price of gold used for the long term planning is $900/ounce and the current cost to mine is $600/tonne. The average grade of the ore is 0.4 g/t with the cut-off being 0.2 g/t.

The open pit operation used to be carried out using dozers, loaders, and haul trucks. This unique method of mining is due to the sedimentary characteristics of the deposit. The ore is soft enough that it does not need to be blasted. Cat D10 dozers are able to cut into the ore and pile it up where Cat 992 loaders scoop up the ore and load it into Cat 777 haul trucks. However, they are encountering some areas of harder rock where blasting is required. In these situations they use a 6 and ¾ inch tricone drill bit to drill 13.5 meter holes. They use 30 kg of explosives over 200 holes per blast, which is a powder factor of 0.2. Kinross only loads and detonates explosives during the daytime on weekdays. Four meters of limestone stemming is used to absorb energy and noise from the blast. Kinross uses a P&H 2800 cable shovel and a fleet of larger Cat 793 haul trucks to move the blasted material. The stripping ratio over the entire mine is 5:1.

![Figure 6- Kinross Open pit](image-url)
The processing of this ore is quite complex due to the low grade, small gold particle size, minerals associated with the gold, and the two types of ore. 80% of the gold is free gold and 20% is associated with sulphides, such as Arsenopyrite, Pyrite, Chalcopryite, Sphalerite, and Galena. 40% of the gold is below 45 microns making it very difficult to liberate and recover. Kinross uses a jig, Knelson, flotation, and luxivation techniques to recover the gold. The jig is used to recover the gold associated with the Arsenopyrite, because of the high oxidation rate of Arsenopyrite. The jig feed is the cyclone underflow, while the cyclone overflow goes to the flotation circuit. This process takes place in the sulphides plant, or Plant 2, while the oxidized ore is treated in Plant 1. Both plants use SAG and Ball Mills to grind the run-of-mine ore before the beneficiation process can begin. The grinding circuits of both plants use about 100 MWatts/hour of energy and account for 35% of the total cost of the operation.

From the Gold concentrate, Kinross creates their own Dore Bars on site. Each bar weighs approximately 20 kg. Each week about 10 bars are produced and shipped via private helicopter to Brasilia and then on to Sao Paulo, where the bars will be refined even further to 99.99% pure gold bricks. Last year the Kinross Paracatu Mine’s revenue was $500 million.

Figure 7- Kinross Info session (top), Students at mill (left), Kinross leach facility (right)
4.0 Araxá

May 10th and 12th were spent in Araxá, a small town of roughly 85,000 people located 360km west of Belo Horizonte. During our two-day stay we visited two mines, Vale Fertilizante and CBMM Niobium mine.

4.1 Vale Fertilizante

Vale is a leader in both the Brazilian and international fertilizer markets. They own phosphate mines throughout Brazil, including one mine in Araxá, which they recently purchased from Bunge and Fosfertil in early 2010. We were fortunate to experience both the production operations as well as the processing facilities at this large open pit mine.

The production equipment at the Araxá mine were surprising despite the relatively large production rate. The mine uses a fleet of 85 -40 tonne trucks and small excavators to produce 100,000 tonne/day. Problems with consistent tire supply in the past forced Vale to switch from large trucks to smaller ones for which tires are more readily available. In addition to the concentrates, waste ore containing high grades of titanium is being stockpiled for future use. Mining of the working face is done in 10m benches with a cut of grade of 5% and feed grade to the mill of 8%.

The milling facility processes material at a rate of 65,000 tonnes/day using a standard phosphate floatation circuit. Both oil and starch are used to depress the excess clay minerals. Water consumption for the entire plant is 12,000 m³/hr of which 82% is recycled. Due to the calcium and magnesium in the flotation wastewater, the amount of recycled water from this stage of the circuit is restricted. Currently, the mine produces both coarse and fine P2O5 concentrates at a final grade of 35.8%. The annual production rates for the standard and fine concentrates are 2 million tonnes and 165 thousand tonnes respectively. After processing, both the coarse and fine concentrates are transported off site for further refining. The coarse product is transported via pipeline whereas the fines are trucked. The total cost to produce the final concentrate including mining costs is approximately CDN $80/tonne.

Figure 8- Pit (left), Process facility (right)
4.2 CBMM Niobium Mine/Mill Tour

Niobium (Nb) is an element obtained from the minerals pyrochlore (most common source) or columbite. It is mixed with steel to produce high strength, low weight, steel alloys that have high temperature resistance. Today, niobium is used in the aerospace, automobile and medical industries.

Companhia Brasileira de Metalurgia e Mineração’s (CBMM) Niobium mine in Araxá is the world’s largest Niobium mine. It supplies 80% of the world’s Niobium demand and has the resources to continue for at least another 200 years (460 million tonnes). For this reason, we were extremely lucky to have had the opportunity to visit this mine.

The mine itself produces a number of products from which niobium can be derived. These products include, pure niobium, nickel-niobium, ferro-niobium, niobium oxide, niobium-aluminium and pyrochlore concentrate among many others. Currently the total production capacity of all niobium products is 60,000 tonnes per year. The majority of the products utilize either chemical process techniques or flotation as a means of separation however an electron beam furnace is used to produce pure niobium at a capacity of 210 tonnes per year. Interestingly enough, the total world consumption of pure niobium is only 500 tonnes per year.

From an operations perspective, the mine is about as close to perfect as you can get. The ore is soft enough that it does not require any blasting and there are no water inflow or geotechnical issues. In addition, the difference in color between the waste material and the ore make it easy to visually differentiate the two. The residual ore (weathered ore) has a mean grade of 2.5 % and max grade of 9.5%. It is yellow in color and stands out compared to the Fe₂O₃ rich red-orange waste material. The primary ore (unweathered ore) starts several hundred meters deep with a mean and max grade of 2.5% and 9.5% respectively. Currently, only the residual ore is being mined. The mineralogical makeup of the ores consists mainly of limonite, goethite, barite and magnetite.

CBMM plays an active role in building a sustainable environment both in and around the mine site. They fund the development of local rehab centers as well as housing developments for the mines employees. In addition, they have built a zoo on the mine property itself to help show their effort to make mining a sustainable industry.

The visit to CBMM’s niobium mine was an invaluable experience as it may be both the first and last time many of us get to see a niobium mine. The cleanliness and meticulous care of the mine site also surprised many people.
5.0 Ouro Preto

Ouro Preto is a cool little town. It is built in a very similar way to towns in the Alps. We walked the cobbled streets of Ouro Preto from the 12th to the 14th. While in Ouro Preto we visited the Universidade Federal de Ouro Preto and an Artisanal Topaz mine.
5.1 Universidade Federal de Ouro Preto

The visit to Universidade Federal de Ouro Preto (UFOP) was not as extensive as the visit to UFMG. As with the visit to UFMG, presentations were given by Dr. Bern Klein and Kyle Foster of UBC and by one of the professors from UFOP. The presentations described the programs offered at both UBC and UFOP. They outlined the courses and activities the students partake-in for graduation from their respective programs. As with the presentations from UFMG the similarities between the UBC and UFOP curriculums are very similar. The students from both universities take almost identical classes, but the way work experience is gained is quite different. The students at UFOP start their work experience in their third year. They go and work for companies, normally in head office not on site, while they are still in school. The UFOP students are not only working on their school projects throughout the year, they are also working on projects from their jobs. This is in stark contrast with the way UBC operates its work programs. The students at UBC have their work and schooling separated. This means that they are working while they are not in school. Another difference between the two programs is that the UBC students normally work onsite and not in head offices.

5.2 Artisanal Topaz Mine

After our visit to UFOP the students and professors from UFOP suggested we take a trip to an Artisanal Topaz mine just outside of Ouro Preto. That afternoon some of the UBC and UFOP students and professors went to visit the artisanal mine while others stayed behind in Ouro Preto to explore the town and visit an old underground gold mine in the middle of town.

For the students who went to the Artisanal Topaz mine the UFOP students and professors gave us the history and an overall description of the site. Many of the UBC students took this opportunity to explore the site and try to decipher what the artisanal miners are doing and how they are going about it. On the stepper slopes miners employed a benching system. They created benches that are 1 to 2 metres high and deep. On flatter terrain the miners seemed to employ two types of methods. The first method the miners systematically dug away at the earth to create a large, flat working face. The other method the miners employed was to dig out a pocket or hole at the bottom of a slope. From the tool marks visible on the work faces, the miners are using small square spades, picks, and trowels. The miners used wheelbarrows and buckets to move material from the working face to a dirt walled area. It was determined that this dirt walled structure was some sort of wash area to separate the dirt from the stones.

While we were exploring the property some of the miners came across the road from their homes to try and sell us some of the stones they had extracted from the mine. With the help of the UFOP students many UBC students were able to negotiate good deals for precious stones, some cut and some uncut. Other students explored the site and got their own hands dirty looking for whatever they could find. Many of those students found amazing samples of quartz and some weathered hematite.
For many UBC students the experience of coming to the Artisanal Topaz mine was a highlight of the trip. As many students had only been to full scale company owned operations.

![Figure 11- Artisanal Topaz Mine outside of Ouro Preto](image)

### 6.0 Rio de Janeiro

May 14th – 18th was spent in Rio de Janeiro. Located on the Atlantic Ocean the city is the 2nd largest in Brazil with a population of over 14 million people. As past capital of Brazil, Rio has many historic sites. In the near future the city will be hosting both the final match of the 2014 FIFA World Cup and the 2016 Summer Olympics.

### 6.1 Sugarloaf Mountain

Resembling a traditional sugarloaf this 396m tall mountain stands at the mouth of Guanabara Bay. Known for its spectacular views from the summit, which can be reached by either rock climbing or cable car.
6.2 Copacabana and Ipanema Beaches

Two of the most iconic beaches in the world are located amongst the 80km of beaches in Rio. Many students took time to enjoy playing soccer and volleyball along with surfing and snorkeling.
6.3 Christ the Redeemer

On May 16\textsuperscript{th} the group went to go see the statue of Christ the Redeemer. Completed in 1931 the 130ft tall concrete and soapstone statue is considered an icon of Rio. Located at the peak of Corcovado Mountain, the statue and surrounding Tijuca Forest National Park looks over the city and is a must see for any visitor. The statue is one of the New Seven Wonders of the World and was enjoyed by all.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{christ_redemer.jpg}
\caption{Christ the Redeemer overlooking Rio de Janeiro}
\end{figure}