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**Summary of 4<sup>th</sup> Year Research Trip to China**

**March 27, 2007**

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## 1.0 Introduction

This report represents a culmination of the impressions and learning experiences that were gained on an extraordinary 4th year undergraduate research trip to China. These impressions, good and bad, are from the perspective of four members of the UBC Mining Engineering class of 2007. All students present on the trip regard the experiences and knowledge that was gained as invaluable and many now see the Chinese mining industry in a completely different light.

The trip lasted a total of fifteen days, six of which were spent in the mining district of the Shandong province. In the six days of mine visits, the students had the opportunity to see four different mining and mineral processing sites as well as one bio-oxidation plant. These visits provided a unique opportunity for students to see a side of China that many people will never get to see. The town of Laizou, home to the group for the first week, was well off the beaten track for tourists. We were informed that many of the people there had never seen westerners prior to seeing our group. Exploring the markets, drinking in tea parlours, eating bugs in the village markets (grubs, scorpions, centipedes and pupas), or even simply finding some lunch was an adventure and a learning experience. We soon learned that being skilled in charades was simply not enough to communicate effectively; subsequently, our translators became critical to our Chinese experience. We would like to once again recognize James Hui of AMEC and our own Gordon Chen for dealing with our incessant requests for help. It was a wake up call for all of us to the importance of language.

Although language was an issue, it did not stop us from appreciating the remarkable hospitality that was offered to us by the Chinese mining operations that we were fortunate enough to visit. All the mines went out of their way to make sure that we were well taken care of and most importantly, well fed. In the first mine that we went into, we were amazed at how orderly and well put together everything was. Even some of the simplest tasks were performed differently than what would be found in Western nations. The visit dispelled many of the negative preconceptions that we had about the Chinese mining industry. This theme continued throughout all of the site visits with only a few exceptions.

## 2.0 Mining in China

Many of the students had preconceived ideas of how a Chinese mine would look, primarily due to the media influence in our lives. Most of these misconceptions stemmed from negative publicity about the frequent coal mine accidents in China. The four mines we visited were underground gold operations in Shandong province. The following mines were visited over the duration of our stay in China: Yingezhuag Gold Mine, Sanshandao Gold Mine, Jiaojia Gold Mine, and the Tarzan Gold Mine. This region of China outputs 30% of China's gold, making it the gold capital of China, and one of the wealthiest regions in the country.

Many common themes prevailed between all four mines. The underground environment at all four operations was significantly different than those found in North America in many respects. The most readily apparent difference was the utilization of underground lighting throughout all main and production drifts.

The most important realization that we came to in the Chinese mining environment was the lack of a codified or structured rock classification method. This came as a shock to most of the group because this is an integral part of modern underground mine design that we have become accustomed to throughout our experiences and education. We found that any rock mechanics work performed was based solely on the experience of the engineers and geologists working onsite. This shows how valuable a rock mechanics engineer or geologist is to a particular mine as well as the region. This experienced-based ground control methodology highlights an opportunity for improvement. Currently, frequent regional conferences allow for exchange of technical information between different operations. The mining method of choice was primarily modified cut and fill with alterations being made to accommodate ground support issues as they appear.

The first three mines that the group visited had a very similar geology, classified as mild hydrothermal altered rock. All four mines were located along the Jiaojia fault, which is host to a series of lenticular gold ore bodies and is 300km in length, with thickness varying 20m to 300m. Mineralization occurs at intersections between this major fault and secondary faults. The close proximity of all the mines to the ocean was clearly evident by the vast amount of seawater present underground as well as the salt deposits visible throughout the workings.

Even with low tonnages maintained at all four operations, the mines maintained high employment, which is portrayed by Yingezhuag mine that has approximately 780 employees for 3,200tpd (this was the largest of the mines visited) and Jiaojia mine with approximately 3,000 employees for only 2,800tpd.

## 2.1 Yingezhaug Gold Mine

The Yingezhaug Gold mine is classified as a low grade ore deposit with an average grade of 2.5g/t that is uniform throughout the ore body with a current reserve of 20 million tons. The only access to the underground workings is a single shaft that currently extends to 630m below surface. The head frame is 76m in height, and can be seen in Figure 1 below.



**Figure 1 - Yingezhaug Headframe**

The majority of mining activity occurs around the 500m level and the current drilling program has prompted the operation to plan for a shaft extension to 1000m below surface. There is no stockpiling of ore so the mine production rate is matched to the milling rate of 3200tpd. The timing of our visit did not permit us to go underground because the mine operations were shut down due to the Spring Festival, a weeklong event prior to Chinese New Year. The average annual salary for the mine's employees is approximately 30,000rmb, equivalent to approximately \$4,500 Canadian. The operating cost for the mine was an extremely low cost at 120rmb/t, equating to \$18CAN/t.

## 2.2 Sanshandao Gold Mine

Sanshandao's greatest claim to fame in the Chinese gold mining industry is their fleet of three electric 35 ton haul trucks purchased from Sweden nine years ago. The mine has had great success in the maintenance of these trucks with no unplanned maintenance since purchase. This mine consists of four shafts that

produce 3800tpd combined. In addition to the four shafts, the mine also employs ramp access via a portal. The underground workings of the mine are located underneath an ocean ridge, resulting in massive water influx. The system of water removal consists of gutters constructed on the sides of the primary drifts to allow water to drain freely. Sanshandao has to pump 15,000 cubic meters of water daily in order to prevent the mine from flooding; this was accomplished by an array of pumps. Average grade of the deposit was 2.5g/t with approximately 3,000 kg of gold being produced annually. Mild ground support was present in the form of 1.8m plated split sets in a 1.5m by 1.5m pattern.

### **2.3 Jiaojia Gold Mine**

The Jiaojia Gold Mine was the first operation to exploit the Jiaojia fault. The mine has already removed 12 million tons of ore, and has indicated mineral reserves of 20 million tons. The total mine throughput is 2800tpd produced from two shafts. This operation is fully mechanized using LHDs to deliver blasted ore to ore bins. The ore bins then dump into railcars which deliver the ore to one of the two shafts where ore is transferred into skips and taken to surface. Ground support is employed at this mine in the form of shotcrete containing 10% cement. Split sets 2m in length on a 1m by 1m pattern are also used sporadically. The water issues at this mine aren't as severe as at Sanshandao, only having to pump out 2,800 cubic meters of water on a daily basis. The Jiaojia mineral deposit has a gold grade ranging from 3.1 to 3.5g/t Au. Currently the target depth of the mine is 600m with potential for expansion into another ore body below the current one. A drilling program has been employed to determine the feasibility of doing this.

### **2.4 Tarzan Gold Mine**

The Tarzan Gold mine is a relatively small operation producing 1000tpd from four separate shafts with the largest one producing 500tpd. The measured reserves are 2.5 million tonne with a mine life of 10 to 15 years. Gold grades in this ore body vary widely from 1g/t to 30g/t. An average mill feed grade of 7g/t is fed through the mill by blending stockpiles. The host rock is highly fractured granite. No ground support was used in the working areas other than some strategically placed timbers. The maximum stable back span is 3m. The fault that produced the mineralization generates a significant amount of water that requires the mine to pump out 4,100 cubic meters per day in total from all four shafts. There are 1,200 employees at the mine with 800 working underground. This mine was more manual than any of the other three that were visited; using jacklegs for drilling, dynamite for blasting and slushers for moving blasted muck. An electric rail system is used to deliver ore to the shaft, where ore cars are taken to surface. Most of the tailings are used as a non-cemented back fill for the overhand cut and fill operation. The mine appeared to use a modified shrinkage/cut and fill method. Mining direction was chosen by 'following the gold'.

### **3.0 Mineral Processing in China**

The mineral processing technology that we were exposed to was fairly similar in all of the processing operations that the group visited with the exception of the bio-oxidation plant. The actual methods implemented in the mines, as pointed out by Dr. Bern Klein, are "1950's technology" that is for the most part being utilized effectively. In order to keep this report concise, only the plant at the Jiaojia gold mine and the MIC BIO-OX plant will be described in detail. Unique attributes of the other milling operations will be also be contrasted to the Jiaojia milling operation.

#### **3.1 Jiajia Milling Operation**

At the Jiaojia milling operation, after being skipped to the surface, the ore is delivered to a coarse ore bin. From there, ore is conveyed to a three stage closed crushing circuit consisting of a primary jaw crusher followed by secondary and tertiary cone crushers. After passing through each stage of crushing, the ore passes through a set of inclined vibrating screens. The coarse material is re-circulated and the portion that passes through carries on to the next stage of crushing.

Once the ore has passed through the entire crushing circuit, it moves on to one of two parallel ball mills for grinding. The discharge slurry from the ball mill is sent through a cyclopack, with the overflow reporting to the rougher floatation circuit while the underflow is sent back to the ball mill for further comminution. Roughly one quarter of the underflow is separated and sent to a centrifugal gravity concentrator in attempt to recover any free gold that may be trapped in the grinding circuit.

The rougher floatation circuit consisted of two parallel banks of float cells that were an older style but remarkably clean. As a side note, the performance observed in these cells varied significantly from one operation to the next but the recoveries that the mines reported did not correspond to this observation. A picture of these cells can be seen in Figure 2:





**Figure 2 - Rougher Flotation Cells at Jiajia Milling Operation**

The concentrate from the rougher circuit was then sent to the regrind cyclopack where the overflow would report to the cleaner flotation circuit and the underflow would go to the regrind mill in attempt to liberate the pyrite from the gangue particles. The regrind discharge would then be sent back to the regrind cyclones to undergo size classification once more before proceeding to the cleaner circuit.

The cleaner circuit utilized the same type of cells that were used in the rougher flotation circuit except there was only one bank of cells instead of two. The concentrate from the cleaners went directly on to cyanide leach tanks where the gold was leached into solution. The impregnated solution is then sent through to various stages of solid liquid separation. Once the solution has been separated it is then subjected to the Merrill-Crowe process, (zinc is added and the gold is precipitated out) and then the mixture is filtered again so that the barren liquor may be removed and the precipitate can be taken for smelting.

### **3.2 MIC Biogold**

The Biological (Bacteria) Oxidation plant was a very interesting experience for the students since none of the students had ever seen one before. The UBC undergraduate program does not delve very far into the refining process after it leaves a milling operation so it ended up being a good learning experience.

MIC Biogold is a joint venture that was set up by Michelago of Australia and they hold 99.5% of the shares after a merger that occurred in December 2006. The facility currently purchases gold concentrates from all over China and the rest of the world and then sells their product on the Shanghai gold exchange at a very low risk.

The markets for non-refractory gold ores are competitive but there is relatively little competition for refractory gold ores containing arsenic.

The facility has three main parts: a BACOX circuit, a cyanide leach circuit, and a lead/zinc floatation circuit. The operation has a zero cyanide discharge policy and therefore all of the cyanide in the process is recycled repeatedly. There is also a gold refinery on site where gold bars and bullion are produced. Our group was fortunate enough to see the facility, including the gold refinery where all the members of our group were allowed to hold one kilogram of gold under close observation of the guards.

Flowsheets for the BACOX plant, cyanide leach plant, float plant and the gold refinery can be seen in Figure 3 on the following page:

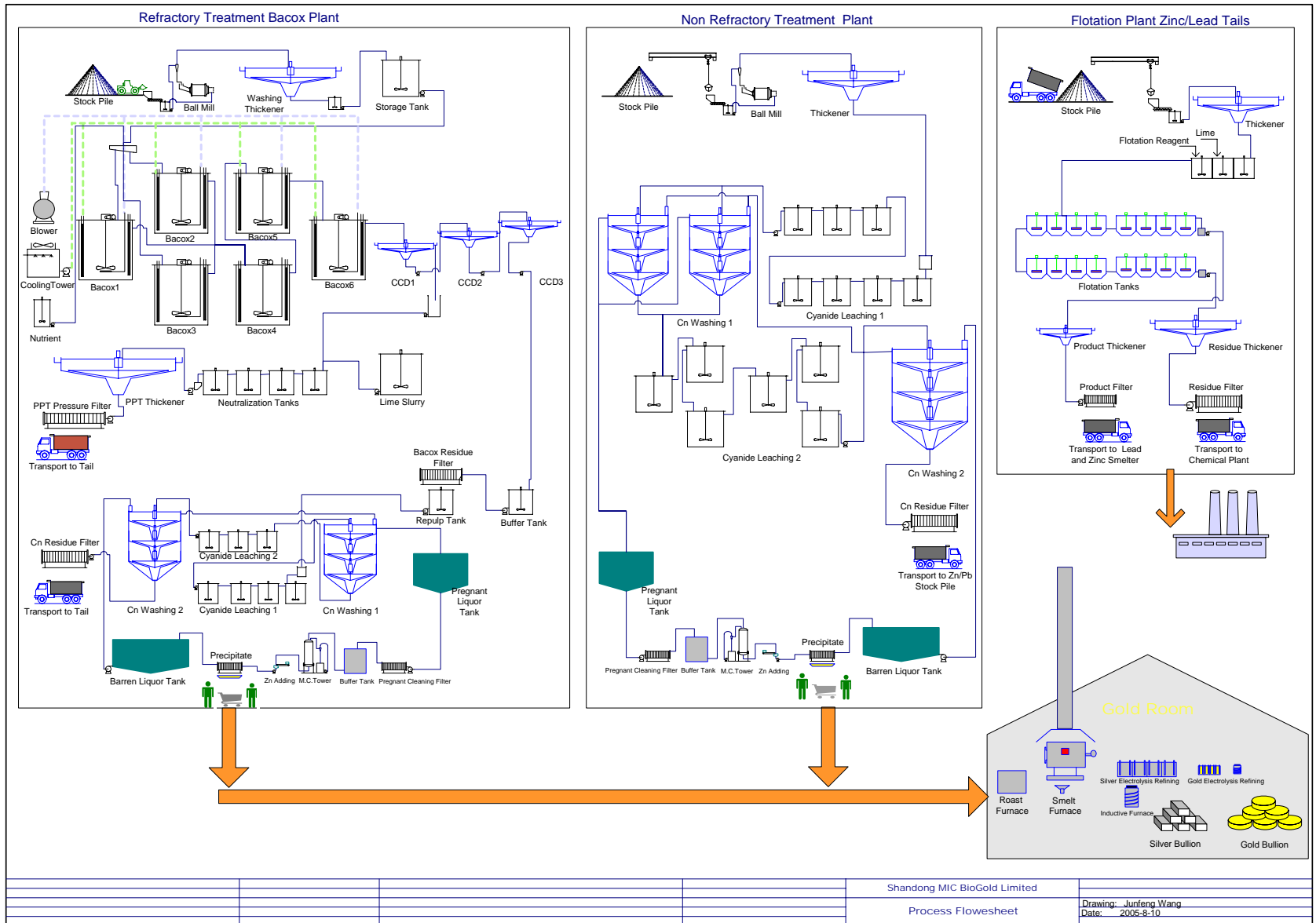
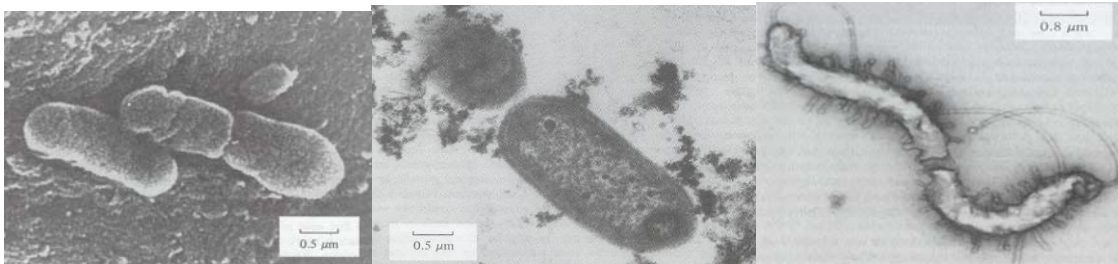


Figure 3 - MIC Biogold bio-leaching process

The bacteria that are utilized in this particular facility are of the mesophile strain which can only survive at temperatures between 25-42 degrees Celsius. The three types of mesophile bacteria that are used are Thiobacillus Ferrooxidans, Thiobacillus Thiooxidans and Leptospirillum Ferrooxidans. The bacteria, which can be seen in the figure below, need air, food and warmth to survive. The role of the bacteria is to attach to the mineral surface, convert ferrous portions to ferric in solution for ferric leaching and to produce acid that will aid the leaching process. There was apparently some concern amongst the workers at MIC BIOGOLD that the bacteria would make them sick but they were reassured that the bacteria cannot process complex organic food and are therefore benign to humans.



**Figure 4 - Mesophile Bacteria**

Bacterial oxidation is the only real option for processing gold ores in China because roasting is not permitted and Autoclaves are too expensive. There are some challenges that they face with respect to power outages and the loss of their bacteria but they seem to be dealing with them well and are planning an expansion that will take place in the next six months. The current throughput is 100tpd and after the expansion they will have the capacity to process 200tpd of refractory ore which will make them the largest facility of this type in all of Asia.

## 4.0 Health and Safety

The safety record of China's mining industry is well known to be less than satisfactory. While a vast majority of the negative press is given to coal mines in other parts of the country, the statistics still indicate that as a whole, mine safety in China is far behind that of western nations. As a result, having a firsthand look at the safety policies of the Chinese mines we visited was one of the most anticipated and dreaded parts of our trip.



**Figure 5 - Impressions of Underground Workings at the Tarzan Gold Mine**

While we were unable to go underground at the Yingezhuag Gold Mine, we were told that due to the highly-mechanized mining method, the mine possesses a good safety record. The mine staff also told us that scheduled Government inspections occur twice a year with the possibility of intermittent surprise visits. New employees are given a one week safety orientation, with job-specific safety issues learned through onsite training.

At the Sanshandao Gold Mine, the high amounts of seawater present in the underground workings meant that corrosion was a major issue. Ground support in the form of splitsets and 'spotcrete' was sporadic and without any discernible pattern. The high temperatures and stale air at depth brought up ventilation concerns. Vent tubing was minimal, consisting mostly of short sections to pump air into active headings. Two wing raises and the main ramp were used for ventilation, but it was unclear if the mine was working as a forcing or exhausting system.

At the Tarzan Gold mine, back support was minimal, with no rock bolts or screens used, but some were stulls present in working headings. The placement of these stulls, however, was completely random and did not show any interpretation of the faults and wedges in the back. The tight working spaces and lack of safety equipment, egress, or ground support made this the most uncomfortable mine visit for most members of the trip. The incident rate at the Tarzan mine was admittedly higher than average, but

officials also commented that they did have a dedicated mine rescue team on site, and that safety training was conducted twice a year for all employees.

Overall, the safety policies of the four operations we visited were of very high standards. As with many government policies in China, the actual enforcement and practice of these standards is suspect. The mines' commitment to safety was most questionable when it came to the implementation of personal protective equipment. Safety glasses and steel-toed boots were rarely seen, with most employees wearing thin rubber boots while working underground. Mine workers also did not wear self-rescuer equipment, most likely due to cost issues. All employees did, however, wear hardhats while in the mill or underground.

With the exception of the Jiaojia Gold Mine, safety bays and paths of egress were non-existent underground. In addition to this, the high-voltage line used to power the locomotives at the Tarzan and Jiaojia mines ran along the back about six feet above the floor with no electrical shielding. For some of the taller members of our group, this meant walking along the sides of the drift to avoid touching the line.

In Canadian mines, it is very typical to see statistics boards showing the days passed since the last first aid or lost time injury. These statistics are shown for two reasons – to celebrate safety successes and to promote safety as the number one priority. At the four mines we visited, these statistics weren't immediately available. While not an immediate safety concern, the presence of this data would go a long way towards showing that the mines are committed towards the highest safety practices.

One of the most surprising aspects of all four mine visits was the cleanliness of both the mine and mill sites. Pathways and accesses on the surface were impeccably clean, far beyond what would be seen in a Canadian mine. The environment underground showed even a starker contrast, with cemented ditches for runoff and clean equipment.

It is important to note that while the four mines we visited had varying degrees of safety equipment and policies, at no time during the visits did any members of the group feel unsafe or in harm's way.

## 5.0 Environment

The initial impressions of Chinese environmental practices confirmed many students' preconceptions. Smog-filled skies, garbage ridden ditches and abandoned buildings plague the landscape in all directions. The word "environment" appeared as a fuzzy concept of the land, air, water and minerals that are available to the people, with little thought of the people's effect on their surroundings by their actions.

The mines visited in the Shandong province, however, were like an alternate reality. Both underground and on surface, the cleanliness and housekeeping was surprising. During the question and answer sessions at all the mines, there appeared to be a connection between the operations and environmental responsibility. All mines expressed that the government's environmental policies were strong in the region with annual, biannual and surprise site visits. However, the claims of environmental stewardship by these operations were not necessarily backed up by any evidence or explained in any detail.

There were two major commonalities between both mines, the first of which was pyrite being the dominant sulfide mineral in the ore. Strangely enough, only one mine (Jiaojia Gold Mine) admitted to having a "slight acid rock drainage problem" but quickly closed the topic by saying "the rock is naturally alkaline". There was no mention of any acid rock drainage management programs at any mines.

Water in the underground workings was the other major commonality between the mines. The mines pump up to 15,000 cubic meters of water per day and claimed to recycle the water in the "process". It was not explained where all this water went after the process, and whether or not it was treated. The impact of salt water flowing into the local groundwater could have serious implications on local drinking sources and agricultural irrigation practices.

In all of the mines visited, the coarse tailings were sent underground to be used as fill material, decreasing the environmental footprint of the tailings ponds. In addition, the Jiaojia mine also showed some sustainable practices by utilizing 10-15% of the total tailings material to manufacture cinder blocks. There was also some reclamation evident in the Yingezhuag Gold Mine tailings pond that was following the upstream dam construction. In terms of the other mines, no visits to the tailings ponds took place.



**Figure 6 - View from Tailings Dam of Reclaimed Area, Mine and Village**

The MIC Biogold plant was the best display of advanced technologies and sciences seen during the China tours. The presentations and tours given were thorough in all explanations of the process and the environmental awareness; it was more than just claims. There was a zero discharge policy on site, due to government regulations regarding cyanide discharge. To avoid the use of expensive equipment to remove any cyanide from discharge water, the plant reuses the solution. Nonetheless, the plant was admittedly worried about thiocyanate and some other metals. During the process, sulphuric acid is created when the bacteria eat the sulphur. To neutralize this, the plant introduces lime to bring up the pH. By neutralizing this material, the plant ensures that there is minimal environmental hazard potential.



## 6.0 Impressions and Conclusion

Before coming to China, the students as a whole were apprehensive about visiting mining operations, especially underground ones. Throughout the trip, we realized that our impressions were false in many cases, but by no means were the standards at the level they need to be for China to be a world class metals producer.

The language barrier between the students and mine officials made it extremely difficult to carry out technical conversations. As a result, it was unclear what the exact environmental and social policies of each operation were. Based on the limited responses we were given to questions, we inferred a lack of environmental concern. In addition, the barrier also made it difficult to ascertain exact details about the safety statistics of each operation.

The general employment strategy in China as a whole runs contrary to the western ideologies of mechanization and the technocentric viewpoint. A typical operation in China employed many people at a lower wage as opposed to few highly skilled people at a higher wage. This approach was carried across many industries that were observed throughout the trip.

Outside of the mining operations, the conditions of the environment were a shock for most of the students on the trip. Garbage and waste disposal has a whole different meaning in China. While driving from Quindao to Laizou, we saw excavators in peoples' back yards digging out pits for garbage which they would re-cover once they had finished. This, if anything, made the Chinese public much more aware of the amount of waste that was being created in their day-to-day lives. This awareness was demonstrated at each of the mine sites through the mention of their environmental impacts.

The major operational issues that the group felt really needed to be addressed were:

- Ventilation of the workplace
- Personal Protective equipment
- Ground support
- Safety guards and trips
- Ways of egress and safety bays

There is contemplation as to whether or not there is a will to change/improve some of the issues that have been mentioned in this report; we believe there is. It is because they are already dealing with the consequences of the air, water, and soil pollution that they will be required to mitigate the problems that have been created. Even in our brief whirlwind tour we saw significant steps in the right direction such as reclamation on the tailing dam, or the production of cinder blocks from coarse tailings. These examples of ingenuity are only the beginning of what will be realized in years to come.

As a nation with an emerging international economy, it is imperative that China strives to operate at acceptable standards that will attract foreign investment and maintain a global profile. Current Government regulations appear to be focused on some of the environmental concerns such as water quality and hazardous chemicals, but do not extend into all facets of mining operations. The implementation of a strict mines act covering health, safety, environmental and operating practices through the province or country would codify the high standard to which all mines must adhere to maintain their license to operate. The enforcement of this act would be critical to the creation of a safe and sustainable working environment in China.