MINE 493
CHINA TECHNICAL REPORT

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TABLE OF CONTENTS

1.0 INTRODUCTION

China currently plays a major role in the global resources industry. Since 2000 China’s total mining output value has doubled, totalling 221.7 billion dollars Canadian in 2005. For 2005 the nation’s total mineral production totalled almost seven billion tonnes of ore with production in coal, steel, copper, aluminium, and cement ranking first in the world [China Mining]. Not unlike Canada, China is a vastly rich nation in terms of mineral resources. Its resources include coal, iron ore, mercury, tin, tungsten, antimony, manganese, molybdenum, vanadium, magnetite, aluminium, lead, zinc, gold, and uranium [Infomine]. As this nation emerges as an economic power the need for resource development will only grow.

Over the past ten years the Chinese Gold industry has undergone an internal revolution. Government control has started to subside and foreign investment and exploration is now encouraged. The result has been an incredible amount of foreign investment, development and expertise flooding into the country. The Shandong Province is a critical region for gold production as it accounts for over a quarter of China’s total production. The University of British Columbia’s graduating mining engineering students visited four mine sites and one bio-oxidation plant in the Shandong Province: Yingezhuag Gold Mine, Sanshandao Gold Mine, Jiaojia Gold Mine, Tarzan Gold Mine, and the MIC BioGold Plant.

2.0 YINGEZHUAG GOLD MINE

The Yingezhuag Gold Mine is located 18 km south of Zhaoyuang city, and owned by the Zhaojin Gold Group. It was the first operation visited by the group. The group had the opportunity to tour the processing and tailings damn facilities, but was unable to see the underground mining operation because it had been shut down for the Chinese Lunar New Year Holiday.

2.1 MINING OPERATIONS

The Yingezhuag gold mine was constructed in 1984 with a designed production rate of 2,000 tonnes per day. In 2000, the mine upgraded the plant and the mine production was increased to 3,200 tonnes per day. The orebody was formed in a mild hydrothermally altered zone, and had an average grade of approximately 2.5g/t of gold. The mine uses an overhand cut and fill mining method. Mining had reached a depth of 500m, and the mine had future plans to extend production to 1000 m below surface. The mining fleet consists of Tamrock drills and approximately 30 ten ton capacity underground haul trucks.

2.2 PROCESSING OPERATIONS

The processing plant was a typical flotation flowsheet, achieving a 97% recovery of gold. Flotation concentrates had a grade of 50-80 g/t gold. To recover free gold, a gravity concentration circuit was included, consisting of a Knelson and a Gemini table. The gravity product had a grade of 50-60% gold. The facility also produced a silver concentrate of 200 g/t which was sold to another part of the company. Concentrates were shipped to another part of the company for smelting. Coarse tailings were separated and used as backfill underground. Fine tails were pumped to the tailings damn nearby (See Figure 1 in Appendix A). The damn had capacity for another 20 years of mining. Since the site geology was very simple, there was little danger of environmental contaminants. The government had a very strict environmental policy in the region that was enforced through regular inspections.

2.3 IMPRESSIONS

In our interview, the senior mine engineer indicated that the mine was large scale, technologically advanced, and had a good safety record though based on the information given, the mine appeared to be very inefficient. With a fleet of 30 ten ton trucks, greater productivity would be expected from the mine. Given the low feed grades, it was impressive that the mine could still operate profitably. Low labour and electricity costs helped make a large difference in the production costs.

The processing plant was very similar to the plants in Canada. A typical gravity and flotation process was used to recover the gold. One of the most significant advantages of the Chinese mining industry was the cheap labour force. This was clear almost immediately at this first mine. Three or four employees were often used for a job where one person would be sufficient in Canada. For example, a manual pressure filter was used in all the plants that were visited in China. The filters required two employees, who were constantly removing the cake from the filters, to operate. This seemed very inefficient and labour intensive. Another seemingly inefficient practice was how this mine transported their concentrate. To the naked eye the concentrate being loaded off these filters did not appear to meet the moisture specifications specified by the Senior Process Engineer. The moisture content seemed too high. This would not commonly be seen in Canada because it results in high transportation costs. The wet materials were very difficult to handle and as a result, trucks needed to be lined in plastic to prevent loss.

According to the Mine Manager, the Chinese government had a strict policy regarding waste disposal. Similar to Canada, the Chinese Government conducted inspections of the property twice a year, as well as unplanned visits, to ensure that environmental standards were being met. The mine did not seem to have the proper technical staff to monitor and manage the tailings facility. In Canada, this job would be designated to one or several employees, but this mine had nobody. Despite their mine waste management system not being as advanced as Canadian mines it still exceeded our expectations. In addition to a basic mine waste management plan, the mine's safety record was very impressive. Chinese mines are stereotyped as being very dangerous; however, the Yingezhuag Mine had a strong focus towards safety. Warning signs were placed throughout the mines outlining proper personal protective equipment use and safe working procedures, and this resulted in their outstanding safety record.

3.0 SANSHANDAO GOLD MINE

The Sanshandao Gold Mine was located in close proximity to the ocean in the small town of Tsang-shang. The mine is owned by the Shandong Gold Mining Corporation. The group had the opportunity to tour the underground mine and processing plant.

3.1 MINING OPERATIONS

The Sanshandao gold mine was a North American style mine with equipment imported from different western countries, most notably three electric underground haul trucks from Sweden (see Figure 2 in Appendix A) boasting an outstanding maintenance record. There were a total of 2,400 employees at the operation with an average salary of approximately $450 Canadian per month. The mild hydrothermal ore body had an average grade of 2.5 g/t of gold and 12 g/t of silver. The mining method used was overhand cut and fill, with a mining capacity of 3,800 tonnes per day. The mine produced 3,000 kg of gold annually. The work schedule was the typical schedule employed throughout the mines in this province; it consisted of three 8 hours shifts per day, with employees working five days on and two days off. The mine operates seven days a week. One of the primary challenges this mine faces is underground water. Being located in close proximity to the ocean the mine is required to pump 15,000 cubic meters of salt water from underground daily. This water was then used in the processing circuit.

3.2 PROCESSING OPERATIONS

After mining, the ore passed through three stages of crushing and grinding. The crushing product then was processed through two rougher flotation banks, and the concentration was sent to the regrind mill (See Figure 3 in Appendix A) and then to cleaner flotation. The cleaner concentrate continued to cyanidation and finally to the Merrill-Crowe process where the gold was extracted. There were several different routes for tailings. Sixty percent of the tailings were used as backfill, 10-15% to make cinder blocks, with the remaining fraction being sent to the tailings pond. The tailings pond had a capacity of 1.8 million cubic meters, and had no significant ARD issues.

3.3 IMPRESSIONS

The Sanshandao gold mine was very similar to western gold mines in many ways. The mine used very advanced equipment and their maintenance program was very well organized. While using advanced equipment had its advantages, it also meant high capital costs, and with such low grade, it was amazing how low their operating cost was. Everything underground was clean and organized. The miners appeared very well trained, and most of their safety precautions were very similar to western mines. However, one major difference was rock mechanics. The mine manager told us that rock support is based on experience only, and only one person was responsible for this job. This was very hard to believe because by western standards, rock mechanics is one of the most important things in mining. It was amazing to see that there were no empirical methods for determining factor of safety, and that only one person was in charge of this responsibility.

The processing plant was extremely well organized. It was interesting to see how similar the processing equipment was. The major difference from the processing plants in Canada was the classifier and pressure filter. They were used because of the lower capital cost, but they would not be feasible in Canada because of high operating costs. During the tour of the processing plant, the tour guide did not emphasize environmental or mine waste management programs. The manager mentioned that there was a slight acid rock drainage problem, but it was solved because the rock was naturally alkaline. The lack of emphasis on the tailings process made us wonder if there were any real issues that they did not want to talk about. In Canada, many mines would give a strong focus on their environmental policies, and have a group of environmental engineers responsible. In contrast, the mining company in China was only concerned about meeting the minimum requirements for government standards.

Overall, the Sanshandao gold mine was the most advanced gold mine compared to the other mines in the region. The operation had impressive management, safety record, and innovations. However, it was difficult to get a complete view of the mine, as it was obvious that the mine manager only wanted to show us the positive side. The environmental aspect was not mentioned very often, and it was difficult for us to learn about their revenue. By Canadian standards, at such a low grade, it would be impossible to sustain the mine for long. Also, the mine was located in the centre of a small city. It will be a huge problem for the town when the mine shuts down.

4.0 JIAOJIA GOLD MINE

The third mine site that the group visited was the Jiaojia Gold Mine located 32 km south of Laizhou city in the town of Huang Jin, which means gold in Mandarin. This mine is also owned and operated by the Shandong Gold Mining Corporation. The group toured underground, and through the plant.

4.1 MINING OPERATIONS

The geology of the mine was described as a mild hydrothermal rock with a major fault. The orebody contained both disseminated and free gold, with pyrite as the dominant sulphide mineral. The orebody depth ranged from 500 m to 600 m with a dip of 30 degrees, and a strike length of 1,000 m. The mine was commissioned in 1980, with a measured and indicated ore reserve of 20 million tonnes. The mine had mined a total of twelve million tonnes by the time of our tour. The mine had a production capacity of 2,800 tonnes per day and had a total of 3,000 employees. The mine operated at an overall cost of $45 Canadian per ton with an average grade of 3.2 g/t of gold. The mining method employed at Jiaojia was overhand cut and fill, with 3 m cuts. The mine access was through two shafts: a 1,800 tonne per day shaft and a 1,000 tonne per day shaft.

There were no set standards for rock mechanics at this mine, and the ground support employed at each part of the mine was based on past experience of the geologist and engineers. The rock strength was determined to be weak. Throughout the mine, shotcrete with 10% cement content was used for ground support in permanent headings. Bolting was also done for additional ground support; throughout the mine a bolting pattern of 1m by 1m with 2m long bolts was employed (See Figure 4 in Appendix A). The underground equipment used for transporting ore was a combination of scoops to move the ore from a working face to rail bins where rail cars were loaded, and an underground rail system to move ore to the shaft. A total of 2,800 cubic meters of water was pumped to surface daily, which was then used in the process plant. The cut-off grade for the mine was 1.5 g/t of gold, with a mining cost of $24 Canadian per tonne.

4.2 PROCESSING OPERATIONS

The mineral processing flow sheet consisted of primary, secondary and tertiary crushing, grinding mills, rougher, scavenger and cleaner flotation, and a two stage cyanide leech and rinse. In the first step of the process, the ore was crushed through a three stage crushing process and the fines were separated using a spiral classifier (See Figure 5 in Appendix A). The coarse ore was then sent for grinding to two ball mills in closed circuit with cyclone classifiers. The fine product from grinding was sent to flotation with the fines from the spiral classifier. The concentrate from the rougher and scavenger flotation were then sent to a regrind ball mill, then cleaner flotation before cyanidation. Finally, the Merrill-Crowe process was used to extract the gold. The tailings from the process passed through a classifier to separate a coarse product from the fines before the tailings were sent to the tailings pond. The coarse and medium tailings were then further recycled: about 60% of the total tails were used as backfill and 10-15% was used to make cinder blocks to be sold on the market. The average gold recovery of the plant was 92%.

4.3 IMPRESSIONS

An intriguing thing about the mines visited in China was that underground all the main haulage ways and drifts were completely lit. This practice is not typically seen in North America, and intuitively seems inefficient and costly. Again, it was surprising to see no set method being used for rock mechanics underground. Ground control was based on experience, and historic practices. The engineer that gave the group the underground tour said that operators are trained to recognize and self assess rock mechanics issues. This was unique to this mine. Ventilation, no more in this mine than the others visited, was executed differently than in most North American underground mines. Ventilation for the mine was provided through intake from a main shaft and it was distributed throughout the mine by pressure difference between the main shafts. No booster fans were encountered underground to help distribute the air. In addition there was no indication that mine personnel were taking flow readings, which is general practice in mines in Canada.

Jiaojia continued to operate using the familiar Chinese designed mill. This mill was the first we saw to employ cyclones for size classification instead of spirals. This site also purchased concentrates from other operations nearby to add to their cyanidation feed. This allowed them to gain some extra money for the operation, while providing a needed service to the area.

5.0 TARZAN GOLD MINE

On February 15th the group visited the Tarzan gold mine. This was a small scale underground gold mine located 32 km south of Laizhou city and owned by the Shandong Tarzan Mining Corporation. The group toured the underground operations and the basic mill processing facilities.

5.1 MINING OPERATIONS

The geology of this mine was different in comparison to the other gold mines the group visited in the Shandong province. Unlike the other gold mines visited, the orebody at the Tarzan mine was a continuous intrusion in a granite host rock. There are several small faults in the granite host rock that produce the higher grade orebody in comparison to the other orebodies in the region. The gold in the deposit occurs as free gold, and the main sulphide minerals are pyrite, and chalcopyrite. The orebody ran north with a dip of 30 to 35 degrees and a thickness ranging from 1 to 40 m.

The Tarzan mine was built in 1984 with a designed mining capacity of 100 tonnes per day. The mine now produces 1,000 tonnes per day, with a total 1,200 employees working on site. The measured and indicated ore reserves are 2.5 million tonnes of ore at an average grade of 20 grams per tonne. The mine operates at a total cost of $35 Canadian per tonne. The mining method employed at the Tarzan mine is overhand cut and fill. The underground mine is accessed through four shafts; the main shaft is a 500 tonne per day shaft, as well as three other shafts that hoist a total of 500 tonnes per day altogether.

The host rock was classified as strong and competent, with a maximum unsupported span of 3 m^2. There is no ground support used in most of the underground developments, which is achieved by keeping the back span under to 3 m^2. Additional support, timber logs and brick walls (See Figure 6 in Appendix A), are used in areas of the mine that require additional ground support. Ore was transported underground by a combination of ore passes to a central loading station for rail bins. Ore was then transported via rail cars to the ore shafts. A total of 3,000 cubic meters of water was pumped to surface daily. This water was then used in further mill processes.

5.2 PROCESSING OPERATIONS

Since the Tarzan mine is in close vicinity to the MIC BioGold facilities, their mineral processing facilities are designed for tailoring a product for the bio-oxidation process. To produce a feed with uniform properties, the feed to the plant is first blended from stockpiles of ore. The target for mill feed is seven grams of gold per tonne. The mineral processing flow sheet is fairly simple as the main objective is to beneficiate the gold to a reasonable grade for the BioGold plant. The process starts with three stage crushing, followed by the crushed product grinded to a fine size. After the grinding stage there is a three stage flotation process (See Figure 7 in Appendix A) that produces a gold concentrate of 50 to 60 grams of gold per tonne.

5.3 IMPRESSIONS

In comparison with the other mines visited by the group, this mine was operating on a much smaller scale. The technology and equipment used was very basic compared with Canadian standards and even other mine's visited in the region. The working face visited did not have an abundant supply of fresh air and it was accessed by a single, somewhat primitive, ladder. Safety standards, such as the Mine's Act, would not permit employees to use a similar ladder in Canada.

When the Biogold facility opened nearby, Tarzan was able to simplify their process to a simple crushing, grinding, and flotation plant. Instead of continuing to run their own cyanidation process, they were able to sell their flotation concentrates to the Biogold facility.

6.0 MIC BIOGOLD

The MIC BioGold plant was the last site visit on the tour. The plant is located approximately 150 km north of Qingdao in close vicinity to the Tarzan gold mine. The facility is primarily owned by the Australian company Michaelago. The bacterial oxidation plant is a new addition to the site complex. Prior to this addition the facility was producing 3,402 kg of gold per year using direct cyanidation followed by refining. Most of the concentrate treated at this complex is purchased from all over China. The main reason for the addition of the bacterial oxidation plant to the existing cyanidation and zinc precipitation process was to increase production to 5,670 kg of gold per year. Without the use of oxidation pre-treatment, gold recovery from refractory concentrates using traditional cyanidation process is typically about 20%.

6.1 PROCESSING OPERATIONS

The flow sheet at the BioGold plant consisted of three main parts: the Bactech/Mintek bacterial oxidation plant, the cyanide leach treatment plant, and the gold refinery. Concentrates from all over China were stockpiled at site (See Figure 8 in Appendix A), then blended to produce an optimum feed for each part of the process. Non-refractory gold concentrates have no need for treatment in the bacterial oxidation plant and so are fed through the standard cyanide leach circuit. The feed into the bioreactors was re-ground for size control, treated with appropriate nutrients, and treated for pH for the bacteria based on the content of the material. There were six bioreactors in total with three acting as parallel primary reactors, with the remaining three operated in series as secondary reactors, the working volume of each bioreactor was 700 m^3 (See Figure 9 in Appendix A). It was crucial for the bacteria's performance and survival to control the temperature of these bioreactors in the range of 40°C to 45°C. At the MIC BioGold plant four jet engines were dedicated to cooling these reactors. The bacteria worked by oxidizing the sulphide minerals in the concentrate, allowing for higher recoveries through more effective cyanidation of refractory gold concentrates. After cyanidation, gold was recovered using the Merril-Crowe process, as was seen in the other plants in the region. The ore recovered on site was then processed in the gold refinery on site to produce pure gold and silver bars.

6.2 IMPRESSIONS

The Biogold plant was the most advanced facility we toured during our trip. This process was significantly less environmentally harmful than a roasting process which would have been used in China in the past. The process allowed for significant reduction of cyanide consumption for treating the refractory ores. The site was able to purchase these refractory ores for significantly reduced prices, allowing them to create significant value by processing them.

The Biogold process was very capital intensive. A large amount of gold was held in the reactors for several days, which forced a significant portion of the operation's value to be tied up on site. Other than the bioreactors, most of the site used the typical technology we found other places in China. This forces the plant to maintain a very large labour force, which would not be seen in Canada.

7.0 CONCLUSION

The opportunity to study the Chinese mining industry firsthand was an incredible experience for the group. Chinese influence on the global mining industry is currently very strong, and graduating mining engineers will undoubtedly encounter the effects of China's development both directly and indirectly over the course of their careers. The knowledge gained during our visit will certainly be put to use in the coming years.

Underground, we found that Chinese operations used a large amount of electricity. Main drifts were completely illuminated instead of giving each miner a personal lamp. Many of the mines also used electric railcars powered from overhead lines to transport rock underground. Interviews with the technical staff indicated that power was extremely inexpensive in China, and close proximity to towns allowed the mines to easily connect to grid power. Rock mechanics and ground support were not as regulated in China as in Canada. Each site designed its support based only on previous site experience, rather than standardized calculations. In some areas, this dictated no support at all where a Canadian mine would still act cautiously and install pattern bolting. Ventilation was also an issue underground. Few of the sites visited had extra ventilation networks to distribute air to working faces; instead mines relied solely on airflow through a main ventilation shaft. This left a few areas rather low on oxygen, and with a large concentration of diesel fumes. Operators sometimes wore personal respirators, but not all miners were provided with this safety equipment. The overall impression was that miners did not fully understand the dangers they were exposed to and consequently the best methods for improving these potentially hazardous environments.

We found the mill layouts to be similar to Canadian operations. Most consisted of primary and tertiary crushing, followed by ball mills and flotation circuits. There were several major differences however. Instead of cyclones, spiral classifiers were often used. Also, most facilities operated only a ball mill in closed circuit after the crushing stage. In Canada, it would be expected instead to see a SAG mill with less crushing stages, then a rod mill followed by a ball mill in closed circuit. Also, instead of western high capacity vacuum filters, all of the operations used an older design which required labourers to scrape the cake off of the filter fabric. Some innovative plant technologies we saw included the bacterial oxidation process, and triple thickeners. China also experienced challenges with water supplies. To compensate, saline water pumped from underground was used in the mill. Combined with recycled water from the tailings pond when available; the mills did not take in water from rivers from the nearby towns. Plants were kept very clean in China, compared to Canadian operations. This improved safety by reducing tripping hazards, which can be a major cause of accidents in a plant.

With low labour and power costs in China, mining operations are able to operate with very low feed grades and still make a profit. While government subsidization was not directly mentioned by any of the mines, it is suspected that it plays a key role in the operation and profitability of all the facilities visited. Despite the potential for a larger savings on labour costs, Chinese operations employed a significantly larger labour force than a similar Canadian mine. The equipment and personnel in China do not come close to achieving the same efficiency that one would expect to see from a mine in Canada.

The Chinese government has set very strict safety and environmental requirements that the industry is striving hard to meet. While safety is a major priority in the industry, there seems to be minimal effort to exceed environmental regulations. Principles of sustainability as well as Western technology and expertise are going to be the next step in the future for the Chinese mining industry as they become a modern industrial power.

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APPENDIX A

Figure 1: Tailings Damn for Yingezhuag Gold Mine

Figure 2: Imported Swedish Truck for Sanshandao Gold Mine


Figure 3: Regrind Mill in Shashandao Gold Mine

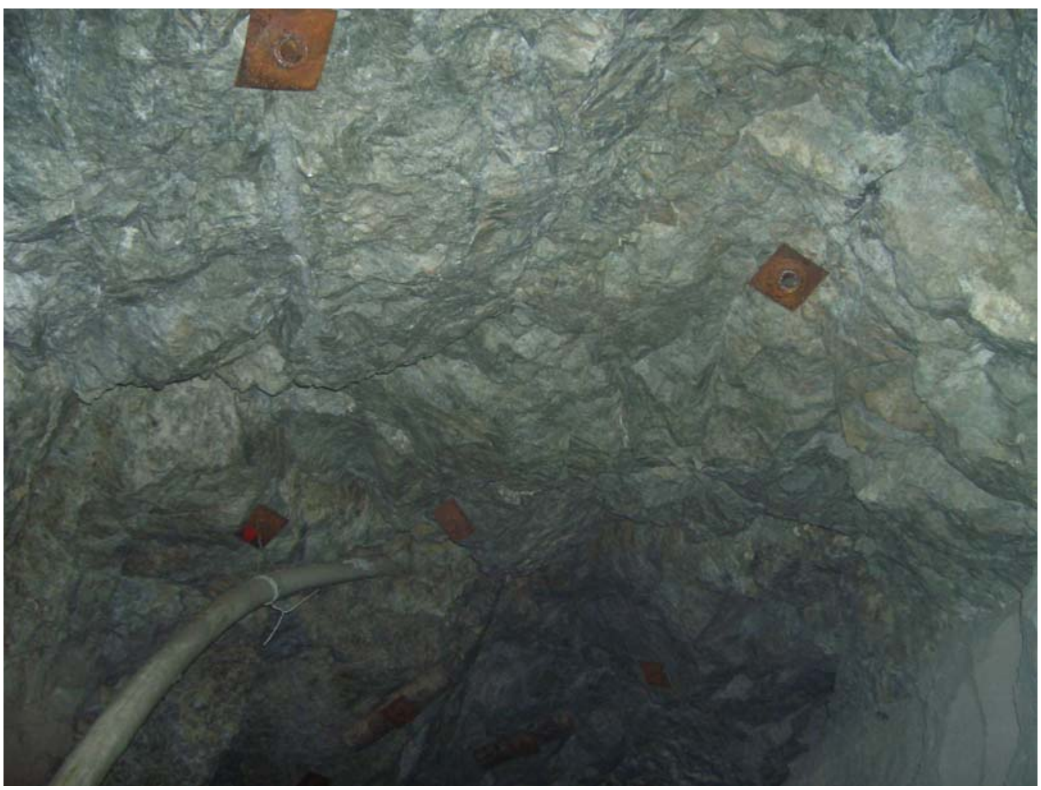
Figure 4: Bolting Pattern in JiaoJia Gold Mine


Figure 5: Spiral Classifier at Jiaojia Gold Mine


Figure 6: Timber Used as Ground Support in Tarzan Gold Mine

Figure 7: Flotation Circuit at Tarzan Gold Mine

Figure 8: Stockpile for MIC BioGold


Figure 9: Bioreactor for MIC BioGold