Report

On

An Analysis of the Current and Future State of the Chinese Mining Industry

Submitted To

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1.0 INTRODUCTION

This year, the 2007 graduating class from the Norman B. Keevil Institute of Mining Engineering decided to travel to China to gain knowledge in a mining industry and culture very different from our own. China's influence in the global market is growing at a rapid rate. Many feel that China will be the next industrial superpower. Twenty-two students and two professors went for fifteen days from February 8-24. The trip was organized entirely by the students and funds for five months leading up to the trip. We first travelled to Shandong Province for the technical portion of the trip, touring four gold mines and a bacterial oxidation plant. The second half was the cultural part of the trip in Beijing. This included visiting historical sites and cultural relics, and taking part in the Spring Festival and Chinese New Year.

The mining industry of today is much more than just the sum of its technical aspects. It requires a social and environmental conscience as well as respect and understanding of local cultures. An engineer must be skilled in all these areas in order to be successful in his or her career. Consequently, being able to witness Chinese operations and culture at firsthand has been a priceless experience. China is a growing market in the industry and we felt that it was important to dispel any false impressions and be able to form our own opinions on the status of the Chinese mining industry. In our careers we will no doubt have interaction with China and likely will be working there at some point.

2.0 DESCRIPTION OF SITE VISITS

2.1 Yingezhuag Gold Mine

2.1.1 Mine Details

Yingezhuag Mine produces 3 200 tpd, mining from 76 to 630 meters underground via overhand cut-and-fill. The ore is, on average, 2.5 g/t and is mildly hydrothermal-altered. There is little variation in the grade of the ore. The total operating cost is approximately $120 RMB per tonne. The current plan is to expand mining down to 1 000 metres underground with an extension to the current shaft. There is an estimated 20 million tonnes of ore yet to be mined, translating into roughly 81 tonnes of gold. The mine is highly mechanized and employs Tamrock drills as well as 30 10-ton trucks. Yingezhuag claims to have a good safety record, but actual figures were not disclosed. Because of the spring festival, the mine was closed so we did not actually go underground. The company is publicly traded, but the local government owns the controlling bulk of shares. This type of ownership is typical, as the government, by law, must own at least 50 per cent of every mine.

2.1.2 Milling Process

The milling process was actually almost exactly what you would see at a Canadian mine. The processes and equipment were virtually identical. Primary crushing is done in-pit with a crusher from BTI Canada. To capitalize on the presence of free gold in the ore, the mine employs a Knelson Gravity Concentrator which then feeds to a Gemini table for further cleaning. This produces a product of 50 to 60 per cent gold.

The flotation of rougher concentrate produces a gold concentrate at 50 to 80 g/t with the concentrate going straight to a central smelter owned by the company. The cleaner flotation produces a silver concentrate of 200 g/t. This product is trucked by dump truck to another site also owned by company.

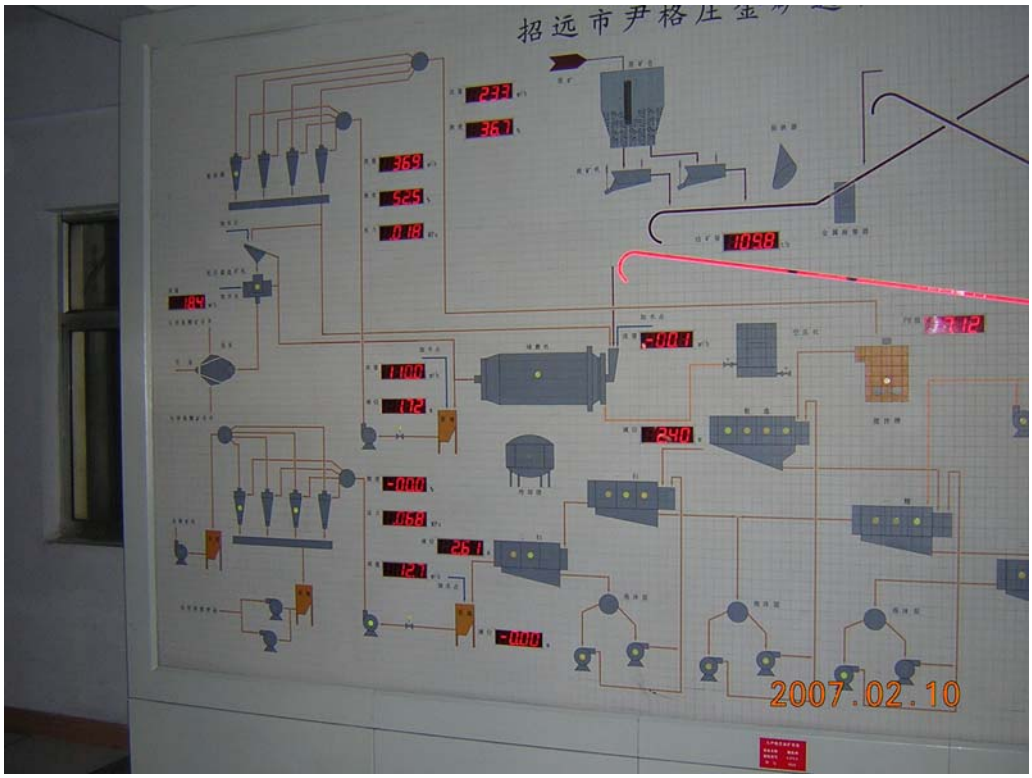

Figure 2-1 Mill flowsheet for Yingezhuag Mine (Source: B. Klein

2.1.3 Staff and Management

The workforce consists of 780 employees working in three eight-hour shifts. We noticed throughout the trip that twelve hour shifts were not used in China. All new employees are required to have a one week safety orientation as part of their training. Pay for technical staff was stated to be “good”. An estimate from our guide put the average annual salary at $30 000 RMB, the equivalent of about $5 000 CAD. The impression we got from the guide was that this was a reasonable wage in China. There is a high level of employee loyalty to the company. A portion of the staff lives on-site while the remainder live in nearby towns.

2.1.4 Environment

By law, no harmful contaminants can be released into the environment from the mine site. The current tailings pond that is in place has the capacity to satisfy the mine's needs for the next 20 years. As a result of the geographical location of the dam, drainage is able to be gravity fed back to the plant for use in processing. It is worth noting that 100 per cent of the water used in the process plant is recycled. The final plan for the impoundment is to turf and plant trees in sections. When we viewed the dam, it was noted that there appeared to be significant seepage into the surrounding farmland. The farmland continued to at least halfway up the side of the dam. People lived and farmed in harmony with the operation of the mine. When watching two women wash their clothes in a diversion ditch at the dam's base, it can be said that the mining industry in China really does integrate the community into its operation.

Figure 2-2 Women washing clothing at the base of the tailings dam (Source: D.Little)

2.2 Sanshandao Gold Mine

2.2.1 Mining Details

The Sanshandao Mine is a 3 800 tpd operation that produces both gold and silver through overhand cut-and-fill using 3 m drifts. The cut-off grade is 0.8 g/t for gold with an average grade of 2.5 g/t. Annually, the mine produces three tonnes of gold. The amount of silver produced was not disclosed. During our visit underground both the ore and the host rock appeared competent, requiring only 1.8 m split-set bolting at 1.5 by 1.5 m. The orebody was described to us as mild-hydrothermal altered as the mine is located in close proximity to the sea. As a consequence of the location, water is a major concern in the mine. It is required to eliminate 15 000 cubic meters of water daily, but this water is later put to use on the processing side. The mine is ventilated by two wing raises as well as the ramp in an exhausting system.

Figure 2-3 Seawater flowing into Sanshandao Mine (Source: N.Irwin)

2.2.2 Milling Process

The mill uses a three-stage crushing process. The cone crushers are maintained daily. The plant operates preferentially at night so as not to over tax the local grids. The primary grind brings the product down to 100 per cent passing 250 mm. From the primary grind the product enters a two-stage rougher flotation with the tailings going directly to final tails. The rougher concentrate is sent to regrind, then to cleaner flotation. This stage yields a 96.5 per cent gold recovery at 48 g/t. This concentrate is then put through cyanidation, yielding 98 per cent recovery to further purify the product. The gold and silver are further isolated using the Merrill-Crowe process (i.e. using zinc to induce precipitation). The leech waste yields lead and sulphur concentrates through another flotation circuit. These products are sold off to different factories in the region.

2.2.3 Staff and Management

The Sanshandao Mine currently employs 2 400 workers, 480 of which are female. By law, females are not allowed to work underground for safety reasons. Instead they are relegated to lab, administration, or planning work.

2.2.4 Environment

The water used in all stages of the mine operation come directly from the infiltration from the sea, and as such, has a high salt content. This has detrimental effects on much of the equipment. In particular, it negatively affects the filter cloth after precipitation. This means however, that the mine does not draw from local fresh water supplies for its processing needs which is an advantage for the environment.

2.3 Jiaojia Gold Mine

2.3.1 Mine Details

The Jiaojia Gold Mine is located in the Shandong Province of China and it first started development in 1975, but it wasn't commissioned into production until 1980. This mine is an underground gold mine with two separate shafts. The main shaft produces 1 800 tonnes per day and the smaller shaft produces 1 000 tonnes per day. This equals 2 800 tonnes per day of total production at this mine. The mine is reported to have 20 million tonnes of ore when first put into development and to date 12 million tonnes have been mined out of the deposit. Overhand cut and fill is the mining method engaged at this mine. The rock is mined upward using drifts that are 3 m high. The drifts are small because of the weak rock mass.

The ore is dominantly pyrite, with gold being either free or disseminated within the pyrite. The orebody itself is 1 000 m long, 9 m thick, 600 m deep, and dips at 30 degrees Celsius. There is also potential at this mine for a second much deeper orebody. There is a drilling exploration program in progress that is drilling for it. The average grade of this orebody is between 3.1-3.2 g/t with the cut-off grade being 1.5 g/t. The rock is considered weak, but in China there is not a system for measuring rock mass. Instead rock mass is determined entirely by "feel". Since the rock is relatively weak, the mine uses shotcrete with a 10 per cent cement composition as well as split sets and bolting with 2 m long rock bolts in a 1 m by 1 m grid.

This mine also has water problems, so 2 800 cubic meters of water is pumped daily out of the mine. This water is reused in the mill. Jiaojia Mine is completely

mechanized. Scoops are used to haul the ore from the drift to the ore bins. From the ore bins the rail cars are filled and the ore is transported to the shaft and then brought to the surface and sent to the mill for processing.

Figure 2-4 Main Haulage Drift at Jiaojia Mine (Source: N. Tweedle)

2.3.2 Milling Process

There are two processing plants that the Jiaojia Gold Mine has in place because there are two different shafts that are located a fair distance apart. The 1 800 tonnes per day processing plan will be discussed because that is the one that was visited on the tour. The ore at this plant goes through three stages of crushing before being sent to the floatation process. The floatation process contains one rougher, one scavenger and one cleaner floatation unit. The tailings from the rougher and scavenger cells go immediately to the tailings pond while the tailings from the cleaner cell are sent back to the regrind mill and then fed back into the floatation circuit. However, not all tailings go to the tailings pond. Only

the finest tailings go into the pond while the rest are recycled and used as backfill in the mine (60 per cent) or made into cinder blocks for construction (10 to 15 per cent). The waste rock is recycled. Therefore, a waste rock dump is not required. All of the waste rock is sold as construction material to the railroad industry at a profit.

This mine has its own cyanide leech plant with two separate leeching circuits. One of these circuits is for the ore from the mine itself, while the second circuit is for ore purchased from another mine that does not have leeching capabilities. This mine uses the Meryl-Crowe process after leeching to recover the gold sludge as concentrate. The concentrate is shipped off to a bio-ox plant or smelter. The overall grade of the final concentrate is 92 per cent

Figure 2-5 Flotation Circuit at Jiaojia Mine (Source: N.Irwin)

2.3.3 Staff and Management

The costs at this mine are relatively high at $300 RMB per tonne operating cost and $160 RMB cash costs. Labour costs account for thirty per cent of the operating cost. This mine employs 3 000 workers, which explains the high cost of operation. The head office controls management and marketing at this mine, but the production of the mine is completely controlled by the mine manager on site.

Figure 2-6 Our interpreter James Yu (left) talking with Jiaojia Mine Engineer (Source: N.Irwin)

2.3.4 Environment

There is a minor problem with acid rock drainage. The mine is currently monitoring this condition. The problem has also been tested and it meets clean water standards under government regulations.

2.4 Tarzan Gold Mine

2.4.1 Mine Details

The Tarzan Gold Mine, built in 1984 is a small mine located in the Shandong province of China close to the town of Laizhou. The mine contains 4 shafts with a combined production of 1 000 tonnes per day. Overhand cut and fill with three meter high stopes is employed. The mined out stopes are backfilled with tailings discarded from the mill. This mine has a 10 to15 year mine life as of present. The geology contributes to the high grade of this deposit averaging around 20 g/t. The host rock is granite containing many small faults. This is the reason why the grade at this mine is much higher than surrounding mines. The orebody varies widely in thickness from 1 m to 40 m, which helps to explain why some stopes are richer than others. The minerals found in this deposit are pyrite, chalcopyrite and free gold. Most of the gold is free and found in a continuous intrusion, which differs from other mines where most of the gold is disseminated into the pyrite. This geological trait also contributes to the high ore grade. The copper grade however is low. It is not worth processing and is regarded as gangue. This mine like many in the area has problems with the water seeping through the fault. Seventy-one cubic meters of water is pumped out of three shafts each day and then reused in the processing plant. The host rock is granite and is quite competent. Stopes have faces of three squared meters and no other form of support is required. Some stopes have higher grades than others. Instead of alternating stopes to average out the grade, they blend the ore in a stockpile before processing it in the mill.

Figure 2-7 Skip at Tarzan Mine (Source: D. Little)

2.4.2 Milling Process

The processing plant for Tarzan Gold Mine is only capable of handling a throughput of 700 tonnes per day and since the mine produces 1 000 tonnes per day, a stockpiling system is used. This same stockpile is also the source for blending the high grade ore (30 g/t) with the low grade ore (1 g/t). The ore goes through three stages of crushing before entering the grinding/floatation circuit. This plant uses one rougher, one scavenger and one cleaner floatation unit. The tailings from the rougher and scavenger are used as backfill in the mine and the cleaner tails are sent back into the grinding circuit for regrinding. The concentrate is sent to the filter presses to be dried. The final grade of the concentrate out of the filter press is 50 to 60 g/t with a recovery of 95 per cent.

2.4.3 Staff and Management

This mine employs 1 200 employees and 800 that work underground. The majority of the employees live in the surrounding small villages. For some that choose to live in the larger town of Laizhou nearby apartment blocks are provided as well as transportation to site via company bus. The operating cost at Tarzan Gold Mine is $230 RMB per tonne mined. The mine places a large emphasis on safety. Annual safety and technical seminars are held for community members involved in the industry. Employees are also given safety training two times a year. Tarzan is one of few mines in China with a mine rescue team.

2.4.4 Environment

Originally, the mine had its own leach plant for processing. However, when a bio-ox plant opened near by, it became more economical to sell the concentrates to the bio-ox facility. The closure of the leach plant minimizes the risk of polluting the environment.

2.5 Bacterial Oxidation Plant

2.5.1 Plant Details

The majority owner of the Bio-oxidation plant is Michelago (MIC) of Australia. This company has 99.5 per cent ownership. The plant purchases the concentrate from surrounding mines to process. The ore is first ground to 80 per cent passing 400 mesh. The ground concentrate is then sent through 6 leech tanks, 3 primary and 3 secondary reactors. All base metals are dissolved during the leach process which makes the cyanide process more efficient. The waste is thickened, dried, and then sent to the tailing disposal. The remaining concentrate is sent to the leech circuit to be processed. Since sulphides still remain, leeching is needed to oxidize the concentrate. The bacteria used in the process needs to be at 40 degrees Celsius to be able to survive and perform effectively. The bacteria oxidation process was created by BioGold SFJV and they hold the patent to the process and the bacteria. This bacteria was specialized to handle high levels of arsenic. The current throughput at the plant is 100 tonnes per day, and they plan to double this limit by adding 6 more reactors. There is a gold smelter and refinery on site and the final product is gold bullion. The plant produces 150 000 ounces of 99.99 per cent gold bullion per year at the current throughput.

Figure 2-8 Standing above leech tanks at MIC BioGold

Figure 2-9 Leech Tank at MIC BioGold (Source: B.Klein)

2.5.2 Environment

The tailings are cleaned and dried and then sent to a disposal area where it is contained. Most of the reagents are reused if possible to cut down on costs, which is beneficial to the environment. The waste water at the plant is also reused. A really amazing fact about this smelter was the fact that nearly everything was used. The pyrite was sold to be used in sulphuric acid production. Because of this the actual amount of tailings was very low. This process of using all valuable products is a testament to the advanced thinking of the Chinese mining industry. Canadian mines could really benefit from this kind of forward thinking, which goes to show that China is on par with the world mining industry.

3.0 IMPRESSIONS OF THE CHINESE MINING INDUSTRY

3.1 Economic Evaluation

As China emerges on the global scene, more and more foreign companies are looking to do business in the east. In terms of statistical figures, China is an attractive market. It is the world's third largest landmass and contains 25 per cent of the world's population[1]. It has huge mineral resources waiting to be developed. Its advantages include a favourable exchange rate (0.1496 Yuan/Canadian dollar)[2], a large workforce and low labour costs. China historically is a manufacturing giant, so production costs are low and materials are easy to obtain. China is a place of potential: it has the people and the resources that foreign companies need to develop new business ventures. Shell, Ivanhoe and Teck Cominco are just a few of the Western companies looking to ride the economic boom. In 2004, 92 per cent of the China's one time energy, 80 per cent of its industrial raw materials and 70 per cent of agricultural production materials came from its mineral resources.

The government recognizes the importance of developing this industry. Currently, there are more than ten countries including Canada that actively participate in the exploration and exploitation of China's mineral resources. China has cooperated with these countries to promote their resources, especially with South-eastern Asia. Foreign investments in the mining sector are encouraged by the Chinese government. The World Bank, as well as other foreign banks, is taking initiatives with China to provide financing to facilitate foreign investment. Metal prices are predicted to continue rising steadily as China industrializes, keeping demands and commodity prices high in the world market. In the year 2000, China's mining industry attracted foreign investments

[1] www.ftdmag.co.nz/articles/sept_china.htm
[2] As of March 27, 2007 from MSN Money, http://moneycentral.msn.com/investor/market/rates.asp

in 162 projects which accounts for 72 per cent of the nation's total. This is an increase of 24.26 per cent compared to 1999. The total value of these foreign investments is $506.4 million US which is a 57.16 per cent increase from the previous year. In 2001 there were 149 foreign projects with a contract value of $64 448 million US. The year 2002 had 164 projects from foreign enterprises. The contract value was $380.88 million US.

Canada and China currently have a strong business relationship in the mining sector and it continues to develop. Canadian mining companies are investing aggressively in China. For example, with rising prices in metal Teck Cominco opened up an office in Beijing in 2006 to invest in China's zinc, copper, and gold resources. Canada has already recognized that China has rich reserves and potential. In response, China fosters this relationship by their involvement in the Canadian industry. China has been supportive of important Canadian mineral programs such as Prospectors and Developers Association of Canada Annual Convention and Natural Resources Canada's Mining Investment Forum held in Toronto. Canada has also played a role in helping to advance its partnership with China. Natural Resources Canada hosted Chinese mining officials in executive training programs and internships in Canada in 2004. With joint programs and activities, and cooperation between the two governments both countries can mutually benefit from one another.

3.2 Challenges for Foreign Investors

Though China is a thriving market, there are still many obstacles a foreign company must overcome. There is the obvious language barrier. In the town of Lauzhou, the vast majority of the population had never seen a foreigner. At the mine sites, everyone, including the mine managers did not speak a word of English. In China, one cannot expect English to be the language of business, and

any foreign country must make the initiative to learn Mandarin, China's official language.

The problems for a foreign company doing business in China go well beyond the language barrier. The Chinese government has ultimate control over the market and economy. Though the strict socialist regime in China has relaxed, it is still a totalitarian society. In the case of mining companies, the government must own at least 50 per cent of any mine in China. Just six days after we returned to Canada, the Asian Stock Market crashed due to the Chinese government's efforts to control the market. Corruption runs rampant, and you may find officials "looking the other way" more often than not. There is no transparency, and "creative accounting"[3] means any corporate body outside of the country would have very little business control. The fact is business in China is still risky. The market is unstable; the government has the last word. Foreign companies also have to compete with domestic companies that may not be held to the same standard of care that a foreign company would be held to. In other words foreign investors may not be held to the same environmental, labour, health and safety standards resulting in unfair competition.

[3] www.ftdmag.co.nz/articles/sept_china.htm

3.3 Economic Future

"When looking at financing a mining project, you look at two things: what China has, and what China needs."

-Dr. Michael Hitch

For the first time in history, China consumes more raw materials than it can produce. Construction throughout China is in overdrive, and it will only increase as China enters the global arena. As the difference between domestic supply and demand increases, China is increasingly looking to import goods from world markets.

The rest of the world, particularly North America, is well aware of the potential in China. Metal prices are climbing faster than a crane in Beijing. There is no more waiting for China to industrialize, it is happening. The construction we saw throughout China was above and beyond the pre-Olympic schedule we see in Vancouver.

Figure 3-1: China's National Bird: The crane (Source: D. Medilek)

The question remains: Can China sustain such rapid growth? It was hard to picture the need for fancy apartments and high rises when we saw people on the side of the road living a meagre existence. Davies also hinted that he felt China was a "bubble waiting to burst". It seems that the Chinese seem to try to build as fast as possible without worrying about cost efficiency. This can be seen above in Figure 3-1, where at least twenty cranes are being used to build one apartment complex. In a country that is looking to compete with the rest of the developed world it is only a matter of time before this "blitzkrieg" style must be abandoned. Currently, the government is encouraging as much development as fast as possible, but sooner or later someone is going to have to pay the bill. When you look at the scepticism surrounding Vancouver, a wealthy western city's ability to meet economic growth, you have to question how long China can sustain this development.

There is no doubt that the mining industry will continue to grow in the future, but the mines will likely become more profit-driven as foreign investment increases. We found that Chinese mines operated on marginal profits. Dr. Bern Klein commented that he wouldn't doubt that many of the mines we saw were "just breaking even". The government owned all of the mines and focused on creating the most jobs within the community rather than optimizing processes. Compared to mines in Canada using the same mining method, the cut-off grades in China were extremely low, leading us to question how profitable these ventures were.

The Chinese government cannot be criticized for improving the life of the people, but the fact is someday the government will not be able to continue operating these mines at a loss. If the Chinese wish to remain in control of their mining industry they are going to have to revolutionize their practice. Environmental standards must be enforced, and health and safety will have to improve. The number of employees must be reduced and processes must be optimized. Cheaper mining methods and more automation will have to be implemented.

Unless the government is willing to make this change, you will likely see a lot of mines either switching over to foreign companies or closing. Currently, the government must own at least 50 per cent of every mine operating in China. This is the perfect facilitator for trade agreements. Foreign companies have the opportunity to expand in the Asian market, while the Chinese can gain knowledge needed to run a safe and efficient mining industry.

3.4 Environmental Protection

The Chinese government also recognizes the need for environmental protection for the sustainability of the industry. By keeping a closer eye on all aspects of the mining including exploration, mineral processing and transportation, the government hopes to increase resource utilization and minimize waste and pollution. An example of China's involvement in promoting sustainable resource development is their participation in the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development. The Chinese Vice-Premier Zeng Peiyan voiced his concerns on this subject at China Mining 2004, an international mining symposium. He stated that the government would take steps to decrease construction projects that use high volumes of water and energy. Environmental-friendly operating equipment and products would replace outdated ones that heavily pollute the environment. Cleaner methods of producing coal and keeping the use of energy and scarce resources to a minimum would be encouraged. The government plans to take action to tighten environmental policies and to better regulate the mining industry.

3.5 Health and Safety

Safety issues are a concern in China and it is recognized as a major problem by both government officials and mine management. They are working towards improving that area of the industry. China feels that better safety and work conditions will contribute to its goal of a sustainable and prosperous mining industry. The main reason for the high accident rate is there is not very much value placed on the lives of workers. Mining companies view workers as easily replaceable. Currently, there is little consequence on accidents and deaths at a mine site. The government is making changes to address this problem. By the end of 2008, only one company will be able to operate a mine. The aim of this move is to decrease competition at a mine between companies to put a stop to

over-production. The provincial government is responsible for implementing and reinforcing this new policy. Mines that fail to cooperate will be shut down.

To place greater responsibility on companies and government officials to follow and adhere to stricter safety procedures, other new measures have been in-acted. Recently this year, Premier Wen Jiabao released that Beijing would be required to set aside money to compensate for miners who are injured or killed. Work safety records will be a criteria in evaluating the performance of government officials. Smaller enterprises tend to be more poorly regulated than larger mining corporations. Large companies have better management and stricter policies and consequently less injuries and accidents. Therefore, as part of the plan to improve safety, larger corporations are being encouraged to join with smaller, privately owned ones. Small ventures that do not meet certain specifications will be forced to close down. Presently, approximately two thirds of China's mines are privately owned and poorly regulated.

4.0 CONCLUSION

What we saw in China was an industry on the verge of major changes. The mining industry is not the horror scene that many westerners believe it is, but it still has some growing up to do. We found that the mines were modern and the technology on par with the rest of the world. However, the intent of the mining companies seemed to be more focused on generating community wealth than with maximizing profit. The mines seemed to have excellent community relations. The community functioned harmoniously with the mine. The commercial and agricultural industries did not appear to be affected at all by the mine operation. The technology was the same as mines in Canada. The problems we witnessed were sub-optimal operation, over-employment, and minimal health, safety and environmental regulation.

The trip was an experience we will never forget. It was the opportunity of a lifetime and everyone involved agreed it was a huge success. After seeing the mines through our own eyes we have a better understanding of the issues that often come up when people think of Chinese mines. It will be interesting to see what the future holds for the industry. Whether the management of the mines shifts from domestic to foreign companies is yet to be seen. However, no matter what happens there is no doubt that China will be a huge influence on the worldwide mining industry.

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