MINE 493

Graduation Trip Report

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1.0 Introduction

Over the past years it has become tradition for the graduating class to plan and fund an educational trip. For our graduation field trip destination we choose China, in particular the Shandong province. Fundraising was achieved from barbeques, raffle-draws, and industry sponsorship. Planning commenced in late September, and with the assistance of a travel agent, a detail itinerary was created in late November. Shandong is China's largest gold producing province and is located on the east coast. The province was established by the Ming Dynasty and included much of modern-day Liaoning (in south Manchuria) at the time. During the nineteenth century, China became increasingly exposed to Western influence and Shandong was especially affected because of its geographical location. In 1897, Qingdao was leased to Germany and in 1898, Weihai to Britain. Qingdao reverted to Chinese control in 1922 and Weihai followed in 1930. In 1937 Japan took control of Shandong and this lasted until the surrender of Japan in 1945. In recent years the eastern coast of Shandong has significant economic development, making it one of the richest provinces of China. In Shandong we visited four gold mines and one bio-oxidation plant. The four gold mines visited were Yingezhuag Gold Mine, Sanshandao Gold Mine, Jiaojia Gold Mine, and Tarzan Gold Mine. The Bio-Oxidation plant visited was MIC Biogold.

2.0 The Yingezhuang Gold Mine

The Yingezhuang Gold Mine is located in the Shandong province. The area in which it is located produces 30% of China's gold. Yingezhuang Gold Mine was originally constructed in 1984.   It is publicly traded on the Shanghai Stock Exchange; however, the local government owns 51% of the shares. The mine began production with a daily production of 2000 tonnes. The overall operating costs are 120 RMB per tonne.

2.1 Geology

The deposit is a very deep and is comprised of mild hydrothermal altered rock. Gold is associated with pyrite at low grades. The deposit has a very uniform grade distribution with no significant variation.   Current reserves are at 20 million tons of ore or 81 million tons of material yet to be mined. The cut off grade is 0.5 to 1 g/t Au using a highly mechanized cut and fill mining method.

2.2 Mining Method

Yingezhuang employs a fleet of thirty 10t trucks they also use Tamrock drills. The coarse tailings are reused underground as fill material. Backfill material is typically un-cemented, with a few exceptions. Generally the rock mechanics are good; a rock-bolting program is in place. Yingezhuang is currently mining at the 500m level. The deepest level is at 630m; however, plans extend to the 1000m level.   The shaft currently extends to the 600m level with plans to sink it even further. The head frame is 76 meters high. Unfortunately we were unable to go underground and explore the mine workings as the mine was shut down for Chinese New Year.

2.3 Mineral Processing

In the year 2000, production increased to 3200 tonnes per day with an upgrade to the processing plant. The average feed grade to the plant is 2.5g/t. The ore is fed through an underground crusher, purchased from BTI Canada, before it reaches the processing plant. Free gold is recovered using a Knelson concentrator then cleaned using a Gemini table. This produces a concentrate of approximately 50 to 60 percent gold. The Knelson Concentrator has a gold recovery of 10 percent. Rougher flotation concentrate is 50 to 80 grams per tonne gold and is sent directly for smelting. The silver concentrate has a grade of 200 grams per tonne and is sold to another department of the company. The water used in the process is pumped from underground and is 100% recycled. There is a buffer pond on the surface as a precaution. Water from the tailings dam can be easily utilized due to the topography. The mine receives all of its power off the local grid and is charged a flat rate of 70RMB cents per kW.

2.4 Environmental

According to Yingezhuang Gold Mine, they have a good environmental record. There aren't any harmful contaminants in the ore. The tailings dam can hold twenty years worth of tailings. Once the tailings impoundment is full it will be reclaimed with turf and trees. The government had very strict environmental regulations in this area. There are two planned visits by government officials each year as well as surprise visits.

2.5 Miscellaneous

Yingezhuang Gold mine employs roughly 780 employees from all over the world. Employees have the option of living on site or in the surrounding communities. Bus service is provided from the nearby towns. Pay for technical staff is competitive in order to retain employees as well as attract new ones. The average annual salary for an employee is 30 000 RMB. New employees are provided one week of safety orientation. The day is split into three 8-hour shifts. The mine has a good safety record relative to other Chinese underground mines.

3.0 Sanshandao Gold Mine

The Sanshandao Gold Mine is located 30 minutes outside of the city of Laizhou in the Shandong Province. There are 2400 employees at the mine, and the mine and mill have a capacity of 3800tpd, which results in 3000kg of gold produced annually. The working schedule is three 8hr shifts operating 7 days a week and employees work 5 days a week. About 20% of the workforce is females, but women are not allowed underground. Women will work in other aspects of the operation such as the mill or offices which are above ground. Their intention is to keep women from entering underground because of safety reasons, not out of disrespect.

3.1 Geology

The deposit is known as a mild hydrothermal ore body. The cut-off grade is 0.8g/t Au at an average of 2.5 g/t, while averaging about 12g/t Ag as well.

3.2 Mining Method

Overhand cut and fill is the method used to mine the deposit and this is done with ramp access as opposed to shaft access like the other underground mines we visited in China. The hanging wall was composed of fairly competent rock and the ground support uses bolt spacing of 1.5m by 1.5m and 1.8m long split sets. The ventilation through the mine is achieved through a 2 wing raise exhausting system. This ventilation system was very poor; making it was hot and there was little air flow. The trucks used in the mine were electric trucks imported from Sweden so air quality was a bit higher (less DPM) which may have been the part of the reasoning behind the lower ventilation requirements.

3.3 Mineral Processing

After the ore is mined it is sent through three stages of crushing at the mill which then leads to a primary grind of 100% passing 250mm. There are two rougher flotation circuits and the rougher concentrate is sent to a regrind mill, and then fed into the cleaner flotation. The recovery is 96.5% from the floatation yielding a grade of 48g/t Au, which is then sent through cyanidation for a 98% recovery using the Meryl-Crowe process.

3.4 Environmental

As we noticed while underground, water is a major issue, this is because the ore is located between sea and land. 15,000 cubic meters of water is pumped out daily and some of this sea water is re-used in the processing of the ore. This water also causes corrosion of the machinery in many parts of the mine. Much of the waste rock is re-used as fill and because cut and fill is a very selective process, not much waste is produced.

4.0 Jiaojia Gold Mine

The Jiaojia Gold Mine is located near Jingcheng Town, Shandong Province. The mine was founded in 1975 and was commissioned in 1980. The Mine is owned by Shandong Gold Corp. and is listed on the Shanghai Stock Exchange. The mine currently employees approximately 3000, and produces around 50 000 ounces of gold per year.

4.1 Geology

The deposit type was the first of its kind found, and is thus classified as a Jiaojia Type Deposit. The deposit has been studied by specialists from over 18 countries, including Canada. Currently there are approximately 30 similar ore deposits worldwide which are of this type.

The mineral resource is a mild hydrothermal deposit that occurs at the intersection of secondary faults, and yields an average ore grade of 3.1-3.2 g/t. The major fault is 300 km long, and the Jiaojia region fault is 20-30 km. The fault's thickness varies from 20 m to 300 m. The dominate sulphide mineral is pyrite, and gold occurs as free, disseminated or invisible. The ore body has a dip of 30 degrees, average thickness of 9 m, 1000 m in length, and so far has been defined to a depth of 600 m. There are plans for exploration below 600 m depth; however, management did not provide a date. The size of the deposit is 20 million tons measured and indicated. So far 12 million tons have been mined. The shape and orientation of this ore body are typical to other deposits in the Jiaojia fault region.

4.2 Mining Method

The mining method employed is a fully mechanized overhand cut and fill. The backfill has a cement content of 10% and uses the tailings. The drift dimensions are 3 m by 3 m, and the average stope lengths are 45 to 60 m long. LHDs load the muck from stope to nearby ore bins that are then transported via an underground rail system to the shaft. Current production is around 2400 t/d, with a mine life of approximately 9 years.

The ventilation system used for the mine was the two wing raise method as discussed above. The ventilation was poor relative to Canadian Standards. During our visit, no equipment was operating due to the Lunar Holiday, so the air quality situation is definitely worse once the mine starts operating. The rock bolt pattern employed is a 1 m x 1 m pattern with 2 m split sets and without mesh. Engineering told us that the bolts were placed based on experience. Overall we found that this bolt pattern was the most common pattern employed. There were also some instances of shotcreted. We believe that this must be their minimum ground support strategy. However, we found that there were instances of over engineering and 'underground luxuries' that needed to be address. The level that we toured, near the shaft, the mine workings resembled a subway station more than a mining operation. In addition, the nearby refuge station had granite flooring, a luxury that our hotel is Laizhou did not have. Figure 1 shows the workings near the shaft exit.


Figure 1 – Underground workings near shaft exit.

4.3 Mineral Processing

For mineral processing, the ore is crushed via a 3 stage circuit. After grinding, rougher, cleaner and scavenger floatation is employed. The cleaner floatation goes back to the mill for regrind. The floatation product is then leeched via a 2 stage leech and 2 stage rinse. Leeching is conducted in two separate circuits because one is for ore from the mine, and the other circuit is for ore from another mine. The Merrill-Crowe Process is used for the leeching, and a filter press is used to recover the gold. The recovery for gold is 92%. Some of the water used for mineral processing is the pumped water from underground workings.

4.4 Environmental

The main environmental issue that the mine faces is ARD. The rock contains some alkalinity. The mine and local government conduct water tests, and so far there have been no issues with meeting government standards. Tailings pond is 1.8 m^3 big. The mine tries to limit the amount of material that goes to the tailings pond. The engineers estimated that around 60% of the tailings is used for backfill, 10-15% is used to make concrete blocks, and the finest material goes to the tailings pond. The concrete blocks are sold to construction companies for a profit. All of the waste rock is reused to make roads and a locomotive station.

5.0 Tarzan Gold Mine

The Tarzan gold mine was built in 1984. The original capacity of the mine was 100 tonnes per day, now it is 500 tonnes per day. The operating cost is 230 RMB per tonne.

5.1 Geology

The geological work was conducted locally. Indicated ore reserves are 2.5 million tonnes, with 50 tonnes of gold. The estimated mine life is an additional 10 to 15 years. The host rock is granite, with many faults. The intrusion is continuous as apposed to the other mines that are mostly disseminated. Gold grades are much higher than the previous mines at around 20 grams per tonne. The ore zone runs north with a dip of 30 to 35 degrees. The ore zone ranges from 1 to 40 meters in thickness. The main gold bearing minerals are pyrite, chalcopyrite and free gold.

5.2 Mining Method

Tarzan gold mine utilizes four different shafts producing a combined 1000 tonnes per day. They use an overhand cut and fill mining method, with slight variations in each of the four mining areas. The largest back opening area is 3 square meters. Tarzan does not use rock bolts or any other form of ground support in the active stopes. The mining of stopes is not sequenced, as blending occurs at the stockpiles. Ground water is major concern at Tarzan Gold Mine. Three thousand cubic meters is pumped out of the shaft that we visited on a daily basis. The other three shafts have equally bad ground water problems. Ventilation is done with an exhaust fan.

5.3 Mineral Processing

The mill feed rate is 700 tonnes per day. The feed grade varies from 1 to 30 grams per tonne. An average mill feed grade is 7 grams per tonne is achieved through a stock pile blending program. The ore contains trace amounts of copper; however, only the gold and the silver are recovered. The process consists of a rougher, cleaner and two scavenger floation circuits. The floatation concentrate grade is 50 to 60 grams per tonne and the overall gold recovery is 95%. The process does not contain any gravity concentration. The on site process used to include a leach plant, but now the concentrate is sold to the bio-gold plant on an annual contract. The water in the plant is recycled as in the other mines.

5.4 Miscellaneous

Tarzan gold mine has 1200 employees, 800 of whom work underground in different capacities. Some of the employees live in Laizhou in company apartments where transportation is provided to and from the mine. The day is split into three 8 hour shifts. Safety is a major concern at Tarzan Gold Mine. There is a mine rescue team and annual safety and technical seminars. Also safety training is done twice a year.

6.0 MIC BIOGOLD

The MIC Biogold is a mineral processing plant that specializes in gold but also produces refined silver and zinc and lead concentrates. The plant operates uses a variety of mineral processing approaches which will be discussed below and a company overview will also be discussed.

6.1 Overview

MIC Biogold was established through a joint venture with Michelago of Australia and Shandong Tarzan Mining in 2005. Michelago increased its shareholding to 99.5% later that year. In December of 2006, Michelago merged with Golden China Resources of Toronto Canada.

The gold concentrate used for the plant is purchased from all over China, and from several other countries. An expansion of the plant will take place over the next six months, and this will make MIC Biogold the largest gold process plant in Asia. All gold produced is sold on the Shanghai Gold Exchange. Golden China Resources is the only foreign member on the exchange.

The MIC Biogold operates a CL Plant, Floatation Plant, Bacterial Oxidation Plant, and a refinery. The CL Plant treats non-refractory gold. The Merrill-Crowe process is employed. The CL Plant treats up to 200 tpd, and produces around 120 000 oz Au per year. The Floatation Plant is used to separate zinc and lead from the CL concentrates that are received. The concentrates are sold to a local smelter. The floatation tailings contain significant quantities of pyrite, and the tailings are sold at a local chemical plant for acid manufacturing. The Floatation Plant produces approximately 55000 tonnes of zinc and lead concentrate per year. The zinc precipitates from the CL Plant and Bacterial Oxidation Plant are sent to the refinery where refined gold product of 99.99% and silver product of 99.5% is produced. The Bacterial Oxidation Plant was the focus of the MIC Biogold tour and will be discussed in the sections below.

The Bacterial Oxidation Plant plays an important role in the processing of refractory ores in China. Recently the Chinese government has made a push towards sustainability, and has banned roasting. Autoclaves are expensive, so Bacterial Oxidation provides suitable alternative. The operating cost of the plant is 800-100 RMB/t. The current capacity of the plant is 100 tpd, but after the expansion it will be 200 tpd.

Management has said that the profit margins on the CL Plant are low because of the large amount of competition. However, the Bacterial Oxidation Plant, since it is able to treat refractory concentrates, has less competition and higher profit margins.

6.2 Bacterial Oxidation Plant Process Description

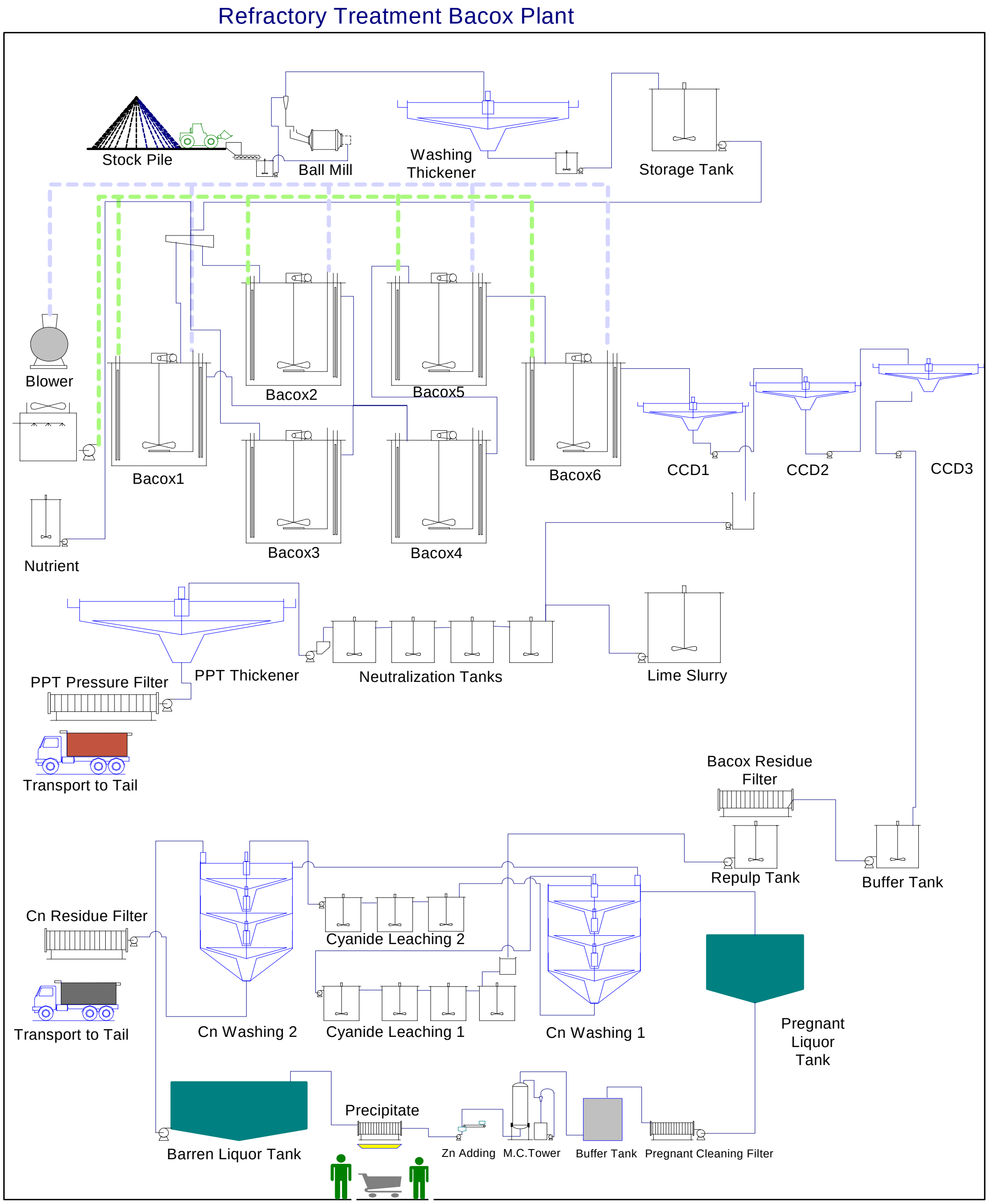
The bacterial oxidation plant employs the BACOX technology. The process requires a P80 of -400 mesh, therefore a closed circuit grinding circuit is used with cyclones as classifiers. The cyclone overflow reports to a washer and thickener. This is done to remove any reagents from prior floatation. The slurry then is stored in an agitated feed tank for 24 hours at a minimum solids content of 50%. This is done to ensure that the primary bioreactors receive feed at a constant rate.

The role of the bacteria is to attach itself to the mineral surface, convert ferrous to ferric solution to make leaching amenable and to generate acid to aid leaching. The bacteria used is classified as mesophiles, and require a temperature of 25-40^{o}C to function. The BACOX technology operates at the higher end of the 25-40^{o}C range, and a pH range of 1-1.4. There are many types of mesophiles, and the plant employs 300 different bacteria species, each with different roles. The bacteria is able to operate at sulfur contents as high as 40-50%, and arsenic levels up to 6%. The plant blends the concentrates to achieve an optimum sulfur and arsenic content.

The slurry from the storage tanks is sent to one of three primary bioreactors. After the primary bioreactors, the slurry is sent to three secondary bioreactors in series. All reactors have a capacity of 385 m^3. The feed rate is based on the amount of sulphur and arsenic in the feed. The overall residence time for the bacterial oxidation is 6 days. The oxidation can handle up to 40-50% sulfur, and 6% arsenic. Originally the bacteria could withstand only 2% arsenic. The tailings from the circuit go through a decanting, thickener and then neutralization process, before being trucked to a nearby tailings pond. The product/residue is sent for cyanide leaching. After cyanide leaching the product then reports to the refinery.

Refer to Appendix A, Figure A-1, for a diagram showing the circuit.

Figure A-1 – Refractory Treatment Circuit (Guo, Junxiang)



7.0 Occupational Health and Safety

The importance of occupational health and safety in mines is paramount. From our tours we noticed rock mechanics, ventilation and safety equipment fell significantly below western standards.

7.1 Rock Mechanics

From our field trip, the occupational health and safety of the mines did not meet the requirements of western countries. The main areas that we believe need improvement are rock mechanics, ventilation, and personnel safety equipment. In terms of rock mechanics, it seems that the mines either over or under engineered their ground support systems. The over engineering aspect was most evident at the Jaiojia Mine, where the area near the shaft exhibited a subway station. In terms of under engineering, this was most evident at the Tarzan Mine. At this mine, the focus was to provide just enough ground support to keep the excavation from failing. When the mine manager was asked if they had any safety incidents with ground support, he replied ‘not many’. At many of the mines it also seemed that there were two approaches for ground support in stopes. The first approach was to use a set ground support design and the other was to design as the operator sees fit. A minimum ground support strategy is common at many western mines; however, there are procedures in place to make sure that deviations from this strategy are done when necessary. At the mines, we did not noticed deviations from the set design, even in different rock types. Ground support in China needs significant improvements and should adopt western ground support standards.

7.2 Ventilation

The ventilation of all mines was well below western standards. The main differences were the design types and the priorities towards achieving good ventilation. It is important to note first, that our field trip was during the lunar holiday, and that many of the of mines were not operating at full capacity, meaning that the ventilation we experienced is likely better than during normal operating conditions. The ventilation systems all tried to mitigate the use of underground ducting. This approach led to very poor ventilation in the stopes. The ventilation in the main development headings was very poor as well. This means that in order for the ventilation to improve, a complete overhaul of the system needs to take place. This may mean that the ventilation circuit design needs to be improved, and perhaps more powerful fans need to be employed as well. Another observation was the lack of effective prioritizing in the approach towards improving ventilation. At the many of the mines, a focus was placed on employing electrical equipment. Employing more electrical equipment will lower the amount of diesel particulate matter, however, dust and in-situ gas control is not improved. Ventilation in China needs to make significant improvements to improve the operating conditions of the underground mines.

7.3 Safety Equipment

From the mine tours we noticed a prevalent safety culture similar to that of western mines. All the mines showed posters of family and a desire in management for our safety during the tours. However, all the mines we visited lacked self rescuers and steel toed boots. Dust masks were offered to protect against silicosis, non steel toed rubber boots were offered to protect against water, all the main headings were well lit, and a flash light was offered to every miner. From the safety equipment we were offered it was apparent that the safety priorities of the mine we were misconceived. If stronger rules were placed on the mines by government restrictions then the safety of miners could be drastically increased. The first step should be the requirement of steel toed boots, self rescuers would be another necessity for the defense against ventilation incidents. For future mine development the culture should be geared towards providing better personal lighting and not lighting the majority of the mine, which is not cost effective. In stopes there was very poor lighting, even though most of the equipment and personnel activity is in those areas. Head lamps should be implemented once this approach is taken. Personnel safety equipment is a cost-effective and quick way to improve the safety at the mines.

8.0 Economic Outlook

China has reached a pivotal point in its history and is struggling to transform itself into a first world country. That transition, which took countries like America and Canada centuries, is taking China decades. The rapid growth that is occurring presently is similar to a recent event that occurred in history, known as the 1997 East Asian financial crisis. The East Asian financial crisis was caused by the mass exodus of foreign investments in emerging markets and at the same time these emerging markets kept their currency pegged to the American dollar. The divestment led to a collapse of monetary values in emerging markets and an increase in the value of the American dollar.

From our trip to China we learned a lot of information about the local Shandong mining industry, but a small amount in comparison to the entire Chinese industry. When asking questions about the mine's productivity we never received accurate answers and we were always given responses of, "we can achieve values up to," indicating that they were giving a best case scenario, but not realistic values. We learned that many of the mines are operating at a loss even though the metal prices are relatively high. The only reason this could be explained is because of the high involvement of the Chinese government. The only way these mines can operate at a loss is because of subsidies from the Chinese government. The only reason the government may be subsidizing these companies is so the country can maintain low levels of unemployment. This is economically unsustainable. Will this spiral the Chinese economy into a similar collapse to the East Asian financial crisis of 1997, or will the shear strength and size of the Chinese economy absorb these obstacles and lead it into a modern era?

9.0 Conclusion

China has reached a pivotal point in its history and is struggling to transform itself into a first world country. That transition, which took countries like America and Canada centuries, is taking China decades. The rapid growth that is occurring presently is similar to a recent event that occurred in history, known as the 1997 East Asian financial crisis. The East Asian financial crisis was caused by the mass exodus of foreign investments in emerging markets and at the same time these emerging markets kept their currency pegged to the American dollar. The divestment led to a collapse of monetary values in emerging markets and an increase in the value of the American dollar.

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