Issues and Challenges Facing the Resumption of Underground Mining at Golden Star Resources' Prestea Mine

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Abstract

Underground mining at Prestea has been carried out for the past 100 years and has resulted in the development of a significant underground infrastructure. However, due to lack of capital investment in the 1980's and 1990's combined with low gold prices during the late 1990's, the operational capabilities of the underground suffered resulting in closure of the operation in 2002 and it being placed on care & maintenance. Since becoming involved with Prestea Underground in 2002, Golden Star Resources has invested approximately $43M in exploration, evaluation, and care and maintenance of the property.

Key issues that confront the Prestea underground include the condition of the Central and Bondaye Shafts, age of the primary mine infrastructure and the fact that much of the known reserves have been depleted. The current approach to re-starting the operation involves returning the shafts to safe and operable conditions and initiating a program of concentrated rehabilitation and development activities necessary to support a small but efficient mining operation.

Another major challenge involves the socio-economic impacts to the catchment communities of Prestea. With over a century of mining history, the people of Prestea and its environs have high expectations of improvements in both their social and economic well being that would result from re-starting the mine.

1. Introduction

The Bogoso/Prestea region has a rich mining history dating back to 1877 at Prestea and 1906 at Bogoso. At Prestea, the Ghana Chamber of Mines records indicate that between 1912 and 1996 7.1 M-oz were produced from the two main mining concerns on the concession, and overall, some 9 M-oz are reported as having been produced since the mid-1880s. Mining at Prestea has been predominantly from underground operations, mining the non-refractory reef-hosted ores situated in the mid and southern sections of the concession.

Since 1999, the Bogoso/Prestea mining operation in western Ghana has been operated by Golden Star Bogoso/Prestea Limited (GSBPL), a Ghanaian registered company owned 90% by Golden Star Resources Ltd. (GSR) of Canada, and 10% by the Government of Ghana. The current mining activities involve the mining of various open pits with subsequent processing at the Bogoso treatment plant. The New Century Mines (NCM) Joint Venture was formed in March 2002 by which GSBPL obtained access to the Prestea Underground Concession. The Prestea Underground mine, which is controlled by the NCM Joint Venture, is currently under care and maintenance while being further evaluated to determine the potential of this historic mining area.

2. Location

The Bogoso property is situated approximately 10 km south of the town of Bogoso in the Wassa West District in the Western Region of Ghana. Bogoso is located 35 km by road from the district capital of Tarkwa, which is an important mining centre for the region, and a further 85 km from the major port of Takoradi, on the Gulf of Guinea. The Prestea property is situated directly southwest of, and contiguous with, the Bogoso concession and stretches to the south of the town of Prestea. Figure 1 shows the location of the Bogoso/Prestea Concessions and the Prestea Underground.

3. Geology

The Bogoso and Prestea concessions are both situated along the Ashanti trend, host to a number of major gold deposits including AngloGold Ashanti's Obuasi Mine. The deposits lie within the Lower Proterozoic of the West African Precambrian shield, along a shear contact zone between the Birimian volcano-sedimentary sequences to the west, and the overlying Tarkwaian sedimentary group to the east. Mineralization at Prestea is mainly associated with fault-fill quartz veins which are developed along shear planes or faults within the broader zone of deformation. The mostly free-milling gold quartz veins are commonly referred to as reefs. The mineralization is characterized by disseminated gold within sulphide impregnated zones.

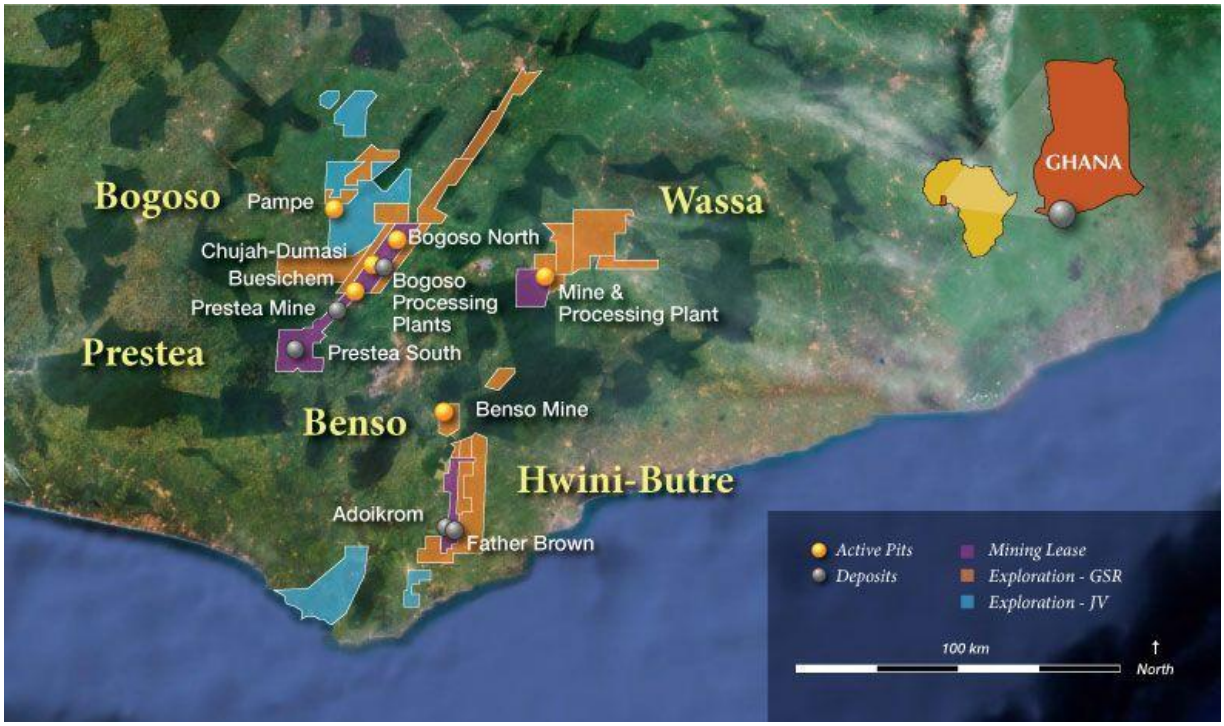

Figure 1: Bogoso/Prestea Mining Concession

At the Prestea underground, three major quartz vein channels, adjoined by graphitic fault gouges with carbonaceous / broken quartz materials, have been the principal source of mining production. They are the Main, East and West Reefs. The Main Reef is located along the principal fault zone, while the East and West Reefs are fault-fill quartz veins developed along subsidiary fault structures. They occur as discontinuous lenses, trend at N249^{o} and dip averagely 65^{o} to the NW. There are several subsidiary shear zones bifurcating from the main shear zone, also host mineralization (A-Reef, J-Reef and Bondaye Footwall Reef Spurs).

Mineral Resources

The total Prestea Underground Mineral Resource stands at 1.4 million tonnes (Mt) of Indicated Mineral Resource grading 13.36 grams per tonne (g/t) gold and 4.1 Mt of Inferred Mineral Resource grading 7.79 g/t gold. The majority of the Inferred Mineral Resource is contained within the Main Reef and represents pillar areas or previously defined stoping blocks where GSR has not yet been able to fully validate the geological data and/or establish accessibility.

Between 2003 and 2006, GSR has undertaken extensive exploration drilling to better delineate the underground resource with the majority of the Indicated Resources being defined as a result of this drilling. However, underground exploration activities ceased in

2006 as a result of the poor conditions of the underground infrastructure. Going forward, the ability to increase the level of Indicated Resources will be dependent on remediation efforts to allow access to these areas of the mine.

One of the most significant results of the exploration was the delineation of the West Reef below 17L. West Reef is a steeply dipping laminated quartz vein within a graphitic shear zone running sub-parallel to and in the hanging wall of the Prestea Main Reef. As at December 31, 2009, the West Reef has an Indicated Mineral Resource of 0.86 Mt grading 18.2 g/t gold for 505,000 contained ounces. In addition, the West Reef has an Inferred Mineral Resource of 0.50 Mt grading 11.7 g/t gold.

4. Mining History

Underground mining has been carried out within the Prestea area since the late 1800's through various entities however the modern mining era was ushered in with the formation of Ariston Gold Mines (1929) Ltd which was responsible for the sinking of the Central Shaft and installation of the major underground and infrastructure. During the 1960's, the independent concessions belonging to Ariston and other companies were amalgamated under the umbrella of the government-owned State Gold Mining Corporation (SGMC), with the subsidiary Prestea Goldfields Limited (PGL) as operator. The period between 1970 and 1990 saw a sharp decline in gold production from the Prestea underground operations.

In the early 1990's, SGMC pursued privatization of the Prestea underground. In 1996, a development agreement was formed between Barnato Exploration Limited ("Barnex"), JCI Limited, and the Government of Ghana to allow Barnex to assume control of the underground and carry out exploration, evaluation and rehabilitation. However, due to ongoing operational difficulties and low gold prices, Barnex withdrew from Prestea in early 1999. Subsequent to this, Prestea Gold Resource (PGR) was formed to continue with the underground operations however the sustained low gold prices and condition of the infrastructure led to a stoppage of PGR mining operations in early 2002. Golden Star Resources, having acquired the Bogoso Gold Limited open pit operations in 1999 and the Prestea surface concessions in 2000, assumed control of the Prestea Underground though the formation of the New Century Mines (NCM) Joint Venture in March 2002. Since that time, the underground has been on a care-and–maintenance basis only however there has been significant exploration drilling along with several engineering studies to resume operations.

In total GSR has invested well over $43M towards the maintenance, remediation and exploration of the Prestea Underground.

Previous Mining Methods

A number of mining methods have been used at Prestea however essentially all have been non-mechanized methods using hand held compressed air powered rock drills and track-confined haulage equipment. The principal method had been inclined cut and fill mining. This method involved ladder raise access from the haulage level and establishment of a sill drift above the level. Ore would then be slashed from the back to create a "cone" of ore centrally in the stope. Filling would typically be accomplished via a centrally located stope raise to the haulage level above. Backfill was typically waste rock although in the upper levels some sand tailings were used. The waste rock when tipped down the raise would form a cone inside the stope. Timbers would be placed over the waste and the next blast of ore would then proceed with the broken ore riling down the timbers to the chute below. Shrinkage stoping was also used albeit to a lesser extent – likely due to the difficulties with getting sufficient quantities of backfill to the stopes. In both cases, stope productivities were generally low due to the degree on manual work required.

5. Key Mining Infrastructure

The underground workings extend over an 8 km strike length and up to 1,400 m depth. The resource is open at depth and along strike in various locales. Numerous surface and sub-vertical shafts have been used over the years to access the working areas. The two principal shafts being contemplated by GSR for future long term use are the Central and Bondaye shafts which are located approximately 4 km apart. Other primary shafts such as Prestea and North Shaft along with Tuapim and Beta have been either demolished during mining of Plant North pit or dismantled and capped. Existing infrastructure includes the Central Shaft and Bondaye Main Shaft. Additional infrastructure consists primarily of haulage levels on approximate 50 m vertical spacing and various smaller surface and sub-vertical shafts to the lowest (35) level. Figure 2 shows a long section of the Prestea Underground.

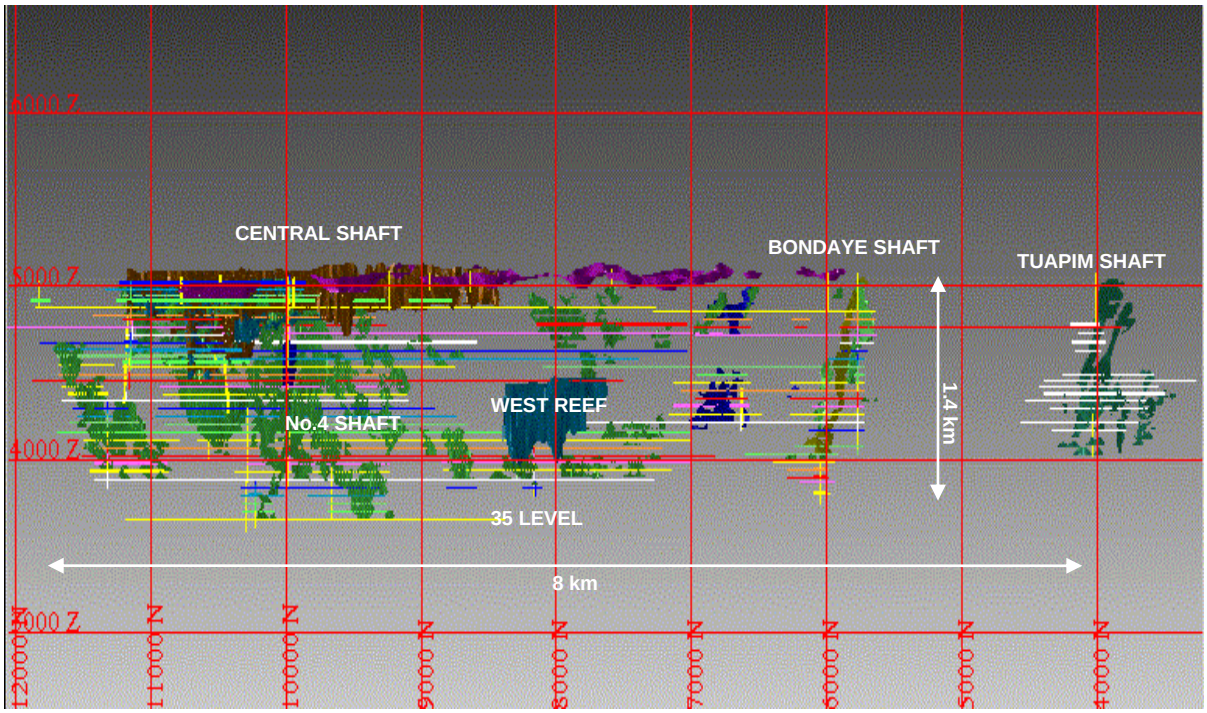

Figure 2: Bogoso/Prestea Mining Concession

Central Shaft

The Prestea Central Shaft is a 4-compartment, rectangular unlined/unsupported shaft approximately 1,238 m (4,061 ft) deep. The shaft provides access to the main underground workings between surface and 30L. The shaft design incorporates a "free-standing" steel tower design to support the conveyances. Two compartments are used for hoisting men and materials while 2 compartments are restricted to rock hoisting only. The shaft provides reticulation for mine services as well as a ladder way for emergency egress. Rock handling infrastructure is located at 20½ L, 25 L and 30 L.

Central Shaft is equipped with two (2) Markham & Co (England) winders, both installed in 1991. SW#1, classified as the Rock Hoist, is a 3.3 meter diameter double drum hoist equipped with a 970 kW motor. SW#2, classified as the Man Hoist, is a similar sized unit equipped with a 600 kW motor. Hoisting speeds are rated at 7.1 m/s and 6.0 m/s respectively however due to the condition of the shafts, current travelling speeds is restricted to 1.5 – 2.5 m/s. The Rock Hoist is rated for 7.5 tonnes skip loads. Historical records indicate sustained production levels of between 1,000 and 1,200 tonnes/day.

Bondaye Main Shaft

Bondaye Main Shaft is also a rectangular unlined and unsupported shaft approximately 1,013 m deep but of smaller dimension than Central Shaft. Bondaye is only a 3-comparment shaft (2 for conveyances and 1 for ladder way and mine services). The shaft provides access to the main underground workings between surface and 23L. Station interval varies but is generally around 45 m or 150 ft. The construction of Bondaye Main internal tower follows a similar construction to Central Shaft. Due to lack of specific rock handling systems in the shaft, hoisting of rock to surface was accomplished by manual cage hoisting of loaded ore cars. Historical production rates are not certain but it was likely in the order of ≤200 tonnes/day.

Bondaye Shaft is equipped with a single winder manufactured by David McClure Co.; date of installation is unknown but is it estimated to be more than 50 years old. The hoist is a 2.9 meter diameter double drum hoist equipped with a 260 kW motor. Maximum hoisting speed is rated at 5 m/s however reduced to 4.3 m/s for cage hoisting of rock. Again due to concerns with shaft infrastructure, current travelling speeds are kept to below 2.0 m/s.

No. 4 Shaft

The No. 4 shaft is an internal shaft sunk between the 23L and 35L (1,378m). Currently this is the only method of access to below the 30L. The shaft is a small rectangular, 3-compartment shaft and is equipped with a steel tower similar to the Central and Bondaye Main shafts.

No. 4 shaft is not equipped with rock handling facilities so production from below 30L was achieved through cage hoisting to 30L. No. 4 shaft is equipped with a small, double drum hoist used primarily to transport men and equipment to 30L and below. The winder unit itself in more than 40 years old and much of the controls and braking system are in need of replacement.

6. Operational Integrity of Underground Infrastructure

An ongoing issue facing any plan to resume mining operations relates to the condition and integrity of the underground infrastructure. The underground mine suffered from a severe lack of maintenance and refurbishment of the primary infrastructure for the past 20 to 25 years prior to GSR's involvement in 2002. This was most evident in the condition of the steelwork in both the Central and Bondaye Main shafts. Most of the steelwork is from the

initial shaft installations and has undergone significant corrosion (>80% loss of mass) such that sustained operations were not deemed to be safe or effective. The rock handling system in Central Shaft is severely corroded and is not in operating condition. Significant work will be required to refurbish the loading pockets, head gear and surface ore bin in order to support routine skip hoisting. Furthermore, the ladder ways in both shafts were not in operational condition and were in violation of mining regulations. Figure 3 provides an example of conditions of the shaft infrastructure. The electrical and mechanical components for the winders are generally sound however small issues with the controllers and braking systems will need addressing.

Another significant issue is related to the age and condition of the electrical reticulation system. The system and its components were well over 50 years of age and had also not been upgraded or suitably maintained. The system was installed using a 55 kV/3.3kV format, considered non-standard in the modern age. Power from the VRA (at 55 kV) is stepped down to 3.3 KV at the mine site to power the winders, compressors and underground reticulation. As well, much of the power for the surround communities is fed from the Central Shaft sub stations. Apart from the "non-standard" voltage configuration, the poor condition of the underground reticulation system have made them highly unreliable to support sustained operations as well as posing a potential safety risk beyond the minimal usage being applied.

Both the compressors and pumping systems are also deemed to be less than ideal however they are considered capable to support limited mining operations with limited upgrades. In the case of the pumping system, GSR has invested in several new high capacity pumps and motors to replace the old units that were incapable of operation. As for the compressors, despite their age of over 50 years, they continue to operate and can supply sufficient air quantities. The critical issue will be to refurbish the delivery system to ensure the required air is distributed to the various underground working places.

In general, the overall condition of the underground infrastructure and related facilities can be classified as poor and suffering from serious deterioration. With that in mind, any mining re-start plan must take into account the cost and time involved in refurbishing or replacing these components so as to ensure safe and efficient operations on a sustained basis. Since late 2006, GSR has completed significant shaft rehabilitation at both Central Shaft and Bondaye Main Shaft to improve the safety and integrity of the shafts. This work program has involved replacement of steel within the shaft towers, trimming and ground support installation of the

shaft walls and re-establishment of the shaft ladder ways for emergency egress. And while there is still a significant amount of work remaining in this program, it represents a major improvement accomplishment in that all of the work has been performed by NCM employees without a Lost Time Accident (LTI) in over 4 years.

Figure 3: Condition of Shaft Infrastructure

7. Outline of Re-start Strategy

Since the acquisition of the underground in 2002, GSR has examined several strategies to resume mining operations. However, one of the major hurdles faced by GSR was the condition of the infrastructure and its ability to sustain routine operations. Another major obstacle was the location of the West Reef deposit, which offered the most attractive mineral resource inventory, with respect to not only the Central Shaft but to established level development. A pre-feasibility study was carried between 2007 and 2008 to examine the potential to implement a mechanized long hole stoping mining method to extract the ore from the West Reef.

The outcomes of study did not justify the capital requirements for the shaft and other mining infrastructure required to support the production plan. For one, the time frame required to

achieve the desired steady-state production rate of approximately 750 tpd was approximately 4-5 years which would coincide with the depletion of the known GSBPL open reserves at that time. There was also a question of the long term strategic value of both Central Shaft and Bondaye Main Shaft with respect to the accessing resources below 30L. Furthermore, during the summer of 2008 significant economic pressures within Ghana (electricity rate increase of approximately 200%, fuel cost increases, etc) forced GSR to halt re-start plans and re-evaluate the underground.

The outcome of this re-evaluation was to considerably lower both the production output expectations as well as the capital expenditure required to support this level of production. As well, it was decided to include mining resource outside of the West Reef; areas which had been excluded from the initial pre-feasibility study due to lack of geological data.

The key aspects of this revised production strategy can be summarized as follows:

- Develop mine plan based on resumption of traditional Prestea underground mining methods (i.e. Cut-and-Fill, Shrinkage)
- Achieve a minimum daily production target of ~250 tpd (7,000 tonnes/month)
- Target active stoping areas mined by PGR prior to cessation operations for initial production while developing new stoping areas (i.e. West Reef)
- Utilize the existing infrastructure where possible but identify and refurbish/replace critical infrastructure components (shaft steelwork, electrical reticulation system, winder controls, pumping, etc.).
- Ensure high levels of safety in line with GSR corporate and Minerals Commission standards.
- Assume all production is moved via the Central Shaft; Bondaye Main Shaft remains as its current duty (dewatering, ventilation, 2nd egress)
- Recruitment and training of local work force – will need to develop skill base of both existing and new workers as the duration of the care-and-maintenance program has meant critical mining skills have either been lost or significantly deteriorated.
- Continue with underground exploration program to better delineate the resource base as well as identify new resource targets (potentially at depth).

Rehabilitation of the shaft steel work and refurbishment of the rock hoisting facilities is the initial priority as this will re-establish the capacity to move rock out of the mine. Initially it

was thought that limited production could be achieved quickly through implementation of a cage hoisting strategy at Central Shaft. The engineering assessment indicated that there was significant shaft work required to return Central Shaft to a condition sufficient to support a nominal rate of 50 -70 tpd from cage hoisting. As this level of production did not meet the re-start strategy requirements and would not support future mine development needs (i.e. waste removal), the strategy of initial cage hoisting has been discarded. The engineering assessment calculated that refurbishment of the rock hoisting system would allow for production level of 400 tpd or greater.

Other key infrastructure targeted for replacement and/or refurbishment include the electrical reticulation system and the dewatering system. Due to the age of the current electrical system, replacement of the underground electrical switchgear and cabling will be required to support the mining operations. The current pumping system would be augmented with newer, more efficient pumps to remove the water from lower levels of the mine. The ventilation and compressed air systems would still utilize the existing infrastructure with minimal upgrades.

The mine plan will evaluate the merits of the two main mining methods: Shrinkage stoping and Cut-and-Fill. The advantages of the shrinkage method is that no backfill is required during the stope production cycle and however disadvantages included limits to achievable production rates and the potential to trap substantial high grade resources inside pillars. The advantages to cut-and-fill include potential for higher stope production rates and better control of wall dilution while disadvantages would include the need to develop a reliable backfill system and the potential for ore loss into the fill material. At this time, it is envisioned that the Prestea underground will likely incorporate both methods of mining within different stoping areas. With regards to the PGR "Active" stoping areas, individual stope blocks have been evaluated as to not only the potential mineral inventory remaining in the block but the rehabilitation required to resume production. Stope blocks will then be targeted for refurbishment based on their priority ranking, with initial production being targeted from these stopes. Mining of the West Reef are will require the development of main levels between 17L and 24L and stope accesses.

Other areas that are also to be addressed as part of the rehabilitation program will be the main haulage levels and ore pass system. Many of the main haulages have small profiles and contain numerous restriction areas. To ensure efficient ore movement from the stope blocks to Central Shaft, track refurbishment and in some cases, enlargement to allow for double

tracking will be undertaken. The ore pass system will need to be re-established between the upper levels and loading pocket levels at Central Shaft. Many of these passes are obstructed and will need to be cleaned out and chutes re-constructed. In addition, new ore passes will be driven to support mining of the West Reef.

8. Discussion of Community and Economic Issues

There is a long history of underground mining in the Prestea area and there is a strong sense of identification by the inhabitants of the surrounding communities (Prestea, Bondaye, and Himan) with the Prestea Underground. From the time that mining operations ceased in 2002, there has been a great deal of interest on the part of the community as to the schedule for re-opening the mine. The main reason for this interest revolves around employment opportunities for the community. During its peak periods (1960-1990), Prestea Goldfields Limited (PGL) employed between 2,000 and 3,000 people, including the underground mine, processing plant, administration and affiliated services, however this number decreased to approximately 1,000 to 1,500 during the tenure of Prestea Gold Resources (PGR). When underground operations were halted in 2002, the majority of the workforce was re-trenched with only a small contingent retained to support the care-and-maintenance functions.

Despite community expectations that employment levels will return to these previous levels, GSR re-start plan has indicated that employment levels will be limited to approximately 300 to 350 workers to support the target production rates. Currently the mine employs approximately 150 staff but these are mostly in support services and maintenance. Critical mining skills are lacking and it is recognized that in order for the operations to be successful, comprehensive training will be required to build a competent and safe workforce. The employment and training plan will call for identification and recruitment within the Bondaye/Prestea/Bogoso area. Following selection, employees will be seconded to the AngloGold-Ashanti (AGA) training school (Obuasi) to undergo an intensive 3-month training program in all aspects of underground mining. Following successful completion, the candidates are returned to Prestea to begin their employment. Due to size limitations of the AGA training school, only 30 candidates can be accommodated per class. Thus a phased approach of selection and training will be carried out until the manpower compliment is filled.

In addition to direct employment at the mine, GSR anticipates some levels of economic spin-off from the re-opening of the mine. Local vendors will be used to provide supplies and services to the mine where possible. It is also anticipated that in combination with the commencement of surface mining within the Prestea surface concessions, there will be further enhancement to the secondary employment market.

One of the most significant issues that will impact the underground (and the surface operations) is the proliferation of illegal (Galamsay) mining along the Prestea concession. This represents a serious threat to the GSR re-start plan both from the standpoint of safety and from the standpoint of infrastructure integrity. The primary concern on the part of GSR relates to the detrimental impacts continued or elevated Galamsay activity would pose to underground infrastructure. The Galamsay activities create channels for surface water to infiltrate into the underground work areas. During periods of heavy rainfall, the threat is that the inflow of water could inundate the dewatering system, potentially jeopardizing the safety of the workforce. In addition, uncontrolled blasting near the surface or in close proximity to the shafts would be harmful to the infrastructure given its age and deteriorated condition. Despite numerous discussions with community leaders and government officials, illegal mining continues unimpeded. Without a commitment to control these activities, resumption of mining operations remains at a high level of risk.

Underground mining presents a higher cost profile as compared to open pit mining. This is further exaggerated in the case of the Prestea Underground due to the age of the mine and the nature of the ore bodies. Thin, tabular reef deposits such as the ones at Prestea require precise and selective mining methods which also tend to be labor intensive. Despite the planned rehabilitation and refurbishment of the underground infrastructure, it is expected that there will be significant operational "bottlenecks" - hoisting speeds, haulage distances and sizes, mine services issues to name a few that will impact production. In addition, it will be the primary objective of any operating plan that production activities will be carried out in compliance to the highest standards of safety. Safety must not be allowed to be compromised for the sake of production. The end result is that both production rates (tonnes/day) and productivities (tonnes/manshift) at the Prestea underground will tend to be low as compared to other underground mines. Continuing robust gold prices (>$1,000 per ounce) will be supportive of ongoing development of the underground. While there is little that can done about gold prices, optimizing mining costs will also have a significant influence on the

underground operations. One of the major costs to the underground is electrical power – required for pumping, hoisting and ventilation. Should domestic power rates dramatically increase over the near term, economic viability of the underground could be drawn into question. Continued volatility with respect to power rates will have a direct impact on the future of the underground.

In conclusion, Golden Star Resources still remains a strong proponent of the Prestea underground and the resumption of mining operations. Total investment to date by GSR has exceeded $43M including approximately $10M in exploration costs and over $500K associated with various engineering studies. There are mutual benefits which can be realized through the re-opening however significant work remains in terms of improving the infrastructure, ensuring safe operations and identifying new resources.

9. References

Golden Star Resources Ltd. (2009), 2009 Annual Report,

Anon (2007), Prestea Underground Mine Project Description, Golden Star Bogoso/Prestea Ltd. Internal Document, May 2007