Implications of Ore Textures for Gold Recovery at Esaase Deposit, Asanko Gold Mine*

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Abstract

The Esaase Deposit of the Asanko Gold Mine Ltd (AGM) contains a system of epigenetic gold-related quartz veins hosted by tightly folded and foliated metasedimentary rocks. The gold mineralisation is associated with disseminated sulphide minerals in the quartz-carbonate veins and within the alteration zones of the host metasedimentary rocks. AGM employs a combination of Gravity Concentration and Carbon-In-Leach (CIL) methods to recover its gold and this has resulted in a recovery rate that ranges from 81.3% to 94.1%. The high recovery rate (>90%) suggests that the gold is free and therefore not locked up in the sulphides that are associated with the mineralisation. However, the recovery rate drops from 94.1 to 81.3% even when the samples contain high amounts of sulphides. Since the presence of sulphides in altered rock is one major indicator of gold mineralisation, this research was conducted to determine the ore textural relationship between gold and sulphides and the implication of the ore textures on the current gold recovery methods employed on the deposit. Polished block sections were prepared from samples from the ore zones: Transition and Cobra. Ore petrographic studies were conducted on the samples using the Leica DM2700P petrographic microscope at the University of Mines and Technology, Tarkwa, Ghana. These studies revealed that the low gold recoveries may be attributed to the gold occurrence as inclusions in the sulphides, which is typical for refractory ores, thus, making it difficult to be extracted by the current method employed at Asanko. Therefore, AGM may have to consider the economics of employing a combination of other methods to liberate the refractory gold and possibly, result in optimum recovery.

Keywords: Ore Textures, Gold Recovery, Refractory Ore, Ghana, Asanko

1 Introduction

Various methods are employed in the recovery of gold from ore materials. The type of recovery method depends on the type of ore. For example, if gold occurs in quartz or loosely in gangue assemblage within altered rock, the simple separation by milling and gravity concentration is enough pre-treatment procedure to liberate the gold. However, if it is locked up in sulphides as refractory ore, then follow-up treatment by Carbon-In-Leach (CIL), roasting or bioleaching is appropriate to liberate the gold (Stamboliadis *et al*., 2002), although environmental issues associated with the use of cyanide (CIL) or roasting (release of smoke) would imply that bioleaching is the appropriate method (Gökelma *et al*., 2016 and Hilson *et al*., 2006).

The Esaase gold deposit, which is hosted in the Asankrangwa gold belt (AGB) within the Kumasi Basin, forms part of the Asanko Gold Mine Ltd (AGM). The Esaase deposit comprises epigenetic gold-related quartz veins which are contained by deeply folded metasedimentary strata. Sulphide minerals related to gold mineralization is found in quartz veins and alteration zones of the host (carbonaceous) metasedimentary rocks. Pyrite dominates the sulfide minerals, with subordinate amounts of arsenopyrite (Clay *et al*., 2013). Deposition of gold with iron-bearing sulfides (e.g., pyrite, arsenopyrite, etc.) often requires iron-bearing silicates (e.g., chlorites) or oxides (e.g., magnetite, hematite, etc.) in the host rocks or by simple reduction of the gold-sulfur-complexed hydrothermal fluid by reduced carbon in carbonaceous rocks (Evans *et al*., 2006).

The Esaase project is built on open-pit mining operations, with gravity concentration, flotation, and concentrate CIL technologies used in the on-site mineral processing plant. The Mine uses the gravity method as its pretreatment recovery method because previous metallurgical test works on samples from the Esaase deposit responded well to the gravity method. Recovery rates varied from 81.3 to 94.1 % overall. The employment of the gravity concentration method on the mine and the higher recovery rate near ~94 % indicate that the gold is free. This means that gold is not locked up in the sulphide minerals. However, despite the high amounts of sulphides associated with mineralisation within the altered zones at Esaase, it is quite surprising that gold recovery could also be as low as ~81.3 %. Could this imply the occurrence of gold as a refractory ore? Therefore, this research conducted petrographic studies to ascertain the ore textural relationship and its implication on the nature of gold occurrence and recovery at the Esaase deposit.

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1.1 Regional Geology

The two dominant geologic units of economic importance in Ghana are the Birimian and Tarkwaian. The Birimian is characterised by alternating narrow greenstone (volcanic) belts and wide sedimentary basins. The belts are 20 to 60km wide and can be traced for hundreds of kilometers along strike. At the local and regional scales, faults are prevalent along the belt-basin boundaries. These structures are crucial in the formation of gold deposits, for which the region is well-known. Recently, the central portions within the Basins, particularly the Kumasi Basin, have also experienced fault-block rifting. This has also resulted in the localization of gold-bearing quartz veins (Feybesse *et al.*, 2006; Clay *et al.*, 2013; Chudasama *et al*., 2015).

AGM is located in the central part of the Kumasi Basin. The Mine is approximately equidistant between the northwest flank of the Ashanti Belt and the southeast flank of the Sefwi-Bibiani Belt, and forms part of a complex northeast-trending, central axis shear system known as the Asankrangwa Gold Belt (AGB) Feybesse *et al.*, 2006; Chudasama *et al*., 2015; Agbenyezi *et al*., 2020; and Brako *et al*., 2020). The AGB can be traced for a northeast-southwest distance of ~150 km and bears quartz reefs and granitic intrusives within a zone of about 15 km wide.

1.2 Local Geology

In Esaase gold project area, strongly folded and foliated metamorphosed sedimentary strata host a system of gold-bearing quartz veins (Stone, 2015). The geological units within the Esaase Project area were interpreted based on airborne geophysical resistivity Surveying (Versatile Time-Domain Electromagnetic mapping or "VTEM"), resource definition drilling, and associated outcrop mapping (Schwarz, 2019). A structural barrier (known as the footwall fault), which separates the distorted, altered, and mineralized siltstone-shale unit in the hanging wall from the more massively bedded footwall sandstones defines the Esaase gold mineralisation (Fig 1). The foliation growth in siltstone and shale is moderate-to-strong, with shale showing stronger foliation development than siltstone. Based on core logging and data interpretation records by Stone, (2015), similar directions for bedding and foliation were registered as NNE –SSW trends and 70° – 90° dips.

The ore zone is categorised into two: (1) Transition Zone and (2) Cobra Zone. The Transition zone is low-grade ore, and it grades from the unmineralized units of the footwall and hanging wall. The Cobra zone is the high-grade ore, which is bound by the Transition zone. All of the rocks within the ore zone are strongly foliated and variably altered.

Fig. 1 A photograph Showing the Esaase Pit (looking south)

Gold mineralisation at Esaase is found in quartz-carbonate veins within parallel NE-trending, moderately-to-steeply W-dipping and highly deformed interbed of siltstone-shale sequences. The hydrothermal alteration associated with the gold mineralization is of the disseminated quartz-sericite-pyrite ("QSP") type. This type of alteration is commonly found in oxidised rocks and does not have a distinguishing coloration in the fresh core, thereby making it difficult to detect (Schwarz, (2019).

The quartz-carbonate veins are categorised into three stages. The first stage constitutes a deformed and brecciated, early unmineralised quartz-only vein. The second stage consists of an abundance of fine quartz-carbonate veins that resemble spider webs. Invariably, these veins are also early, deformed, and offset. The third stage consists of quartz-carbonate-sulphide veins with visible free gold. The associated sulphide is mainly pyrite, with subordinate amounts of arsenopyrite. Later phases of calcite veins crosscut all previous structures Stone, (2015).

The mineralised quartz-carbonate veins are planar or S-shaped and typically strike NNW to NNE with sub-vertical dips. They were most likely deposited within a fold-thrust deformation that transitioned to left-lateral strike-slip deformation.

2 Resources and Methods Used

2.1 Petrographic studies

Twenty samples were obtained from the Esaase Pit during a field investigation and studied for indicators of quartz-carbonate veining, alteration and mineralisation: Five (5) from footwall, 10 from ore zones (Transition: T1 to T5 and, Cobra: C1 to C5) and 5 from hanging wall. Based on the direction of this study, only 6 mineralised samples were considered to be representative of rock material with quartz-carbonate veins and dominant presence of sulphides. These samples, all of which came from the Transition and Cobra Zones, were selected for ore microscopic studies (See Table 1). A total of 20 polished block samples were prepared from the selected 6 samples.

At the Petrology Laboratory of the Department of Geological Engineering, University of Mines and Technology (UMaT), Tarkwa, ore petrographic analysis on ten-block sections from the samples were investigated to determine petrographic characteristics of the samples using LEICA DM2700P microscope and a Leica MC 120HD digital camera linked to a computer for image capture. The ore and gangue minerals were characterised and identified based on their textural relationships and optical properties such as colour, isotropism, anisotropy, bireflectance, twining, extinction angle cleavage, and pleochroism.

Table 1 Description selected Samples from the Ore Zone, Esaase Deposit

Sample	Zone	Colour	Grain Size	Sulphide Mineral	Remarks
T1	Transition	Dark grey	Fine-grained	present	The rock is strongly foliated; Quartz veins and veinlet present
T2	Transition	Dark grey	Fine-grained	present	The rock is strongly foliated; Quartz veins present
T3	Transition	Dark grey	Fine-grained	present	The rock is strongly foliated; Quartz veins and veinlet present
C1	Cobra	Light to dark grey	Fine-grained	present	The rock is strongly foliated; Quartz veins present
C2	Cobra	Dark grey	Fine-grained	present	The rock is strongly foliated; Quartz veins present
C3	Cobra	Light to dark	Fine-grained	present	The rock is strongly foliated; Quartz veins present

3 Results and Discussion

3.1 Petrography

3.1.1 Hand Specimen Description

The samples from the Transition Zone (Fig 2) are dark to light grey, fine-grained, and strongly foliated. The samples also contain quartz veins of which some are parallel to the foliation plane and some, cut across the foliation plane. Disseminated sulphide minerals are present in the quartz veins that are parallel to the foliation planes but absent in the quartz veinlets that cut across the foliation planes.

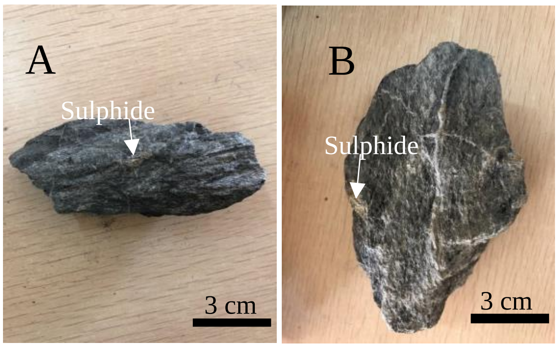

Fig. 2 Photographs (A) and (B) Showing Samples from the Transition Zone

The samples from the Cobra Zone (Fig 2) are light to dark grey, fine-grained, and also strongly foliated. The samples also contain quartz veins of variable sizes, with disseminated sulphide minerals present.

The strong foliations in samples from both the Transition and Cobra Zones indicate that at least one deformational event occurred in the study area. The sulphide ore minerals occur as disseminations in the rock samples but appeared to have been developed across the foliation planes in both rocks from the Transition and Cobra Zones. The nature of this occurrence implies that the gold mineralization event occurred after the deformational event that resulted in the foliated nature of these rocks.

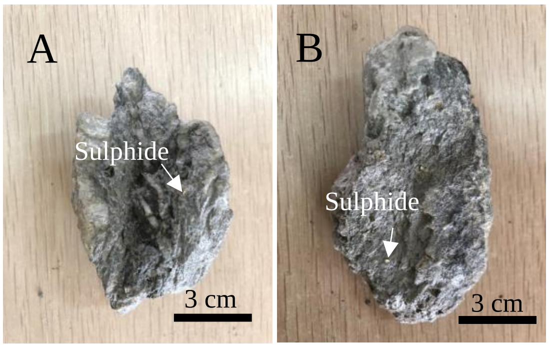

Fig. 3 Photographs (A) and (B) showing samples from the Cobra Zone

3.1.2 Ore Textures

It has often been said that pyrite is the major mineral at Esaase. However, from the petrographic studies, the major sulphide minerals present in all the samples are pyrite and arsenopyrite (Figs 4 and 5A). In reflected light microscopy, both pyrite and arsenopyrite exhibit euhedral through anhedral forms. (Fig 4). It was observed that pyrite and arsenopyrite mutually co-existed with mutual boundary texture. This contact relationship suggests that both pyrite and arsenopyrite precipitated contemporaneously during mineralisation. However, many of the gold grains observed in this study occurred as inclusions in pyrite (Figs 5, 6 and 7), and silicate gangue mineral assemblage (Fig 7). No gold was observed in arsenopyrite, which may be due to the number of samples analysed or the timing of ore precipitation mechanisms within the ore-forming fluid that triggered sequential deposition of gold in pyrite and the gangue materials.

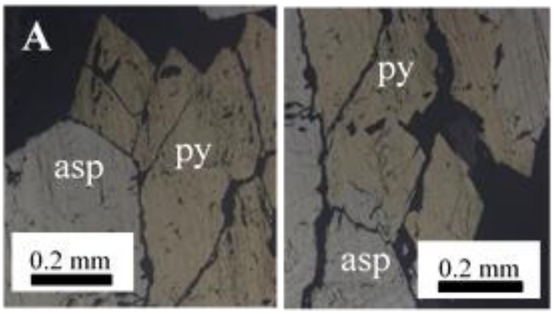

Fig. 4 Photomicrograph (A and B) Showing Mutual Boundary Textures between Pyrite and Arsenopyrite

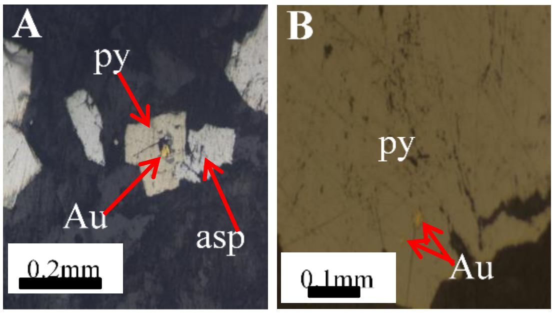

Fig. 5 Photomicrograph (A and B) Showing Gold Occurrence as (A) Cavity-fill in Pyrite (Free-milling Ore) and (B) Inclusion in Pyrite (Refractory Ore)

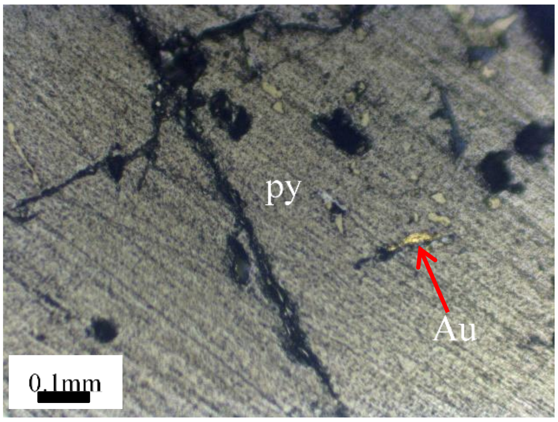

Fig. 6 Photomicrograph showing gold occurring as Inclusion in Pyrite

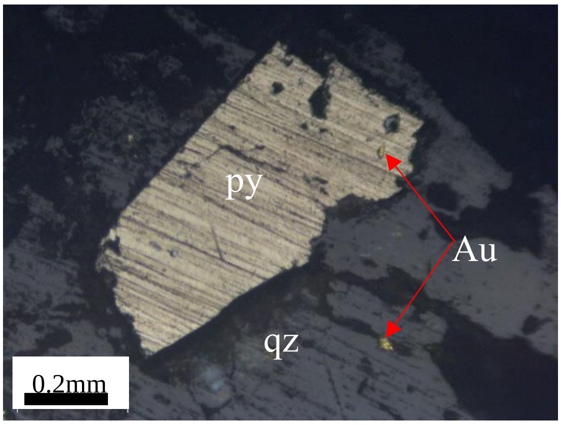

Fig. 7 Photomicrograph Showing Gold in Quartz (Free-milling Ore) and as an Inclusion in Pyrite (Refractory Ore)

3.2 Implications for Gold Recovery at Esaase

Gravitational concentration and CIL methods are the two gold recovery methods that are currently employed by AGM on the Esaase deposit. This is because previous metallurgical tests results suggested that the samples respond well to the gravitational and carbon-in-leach methods. Overall recoveries varied from 81.3 % to 94.1 %. The 94.1 % accounts for gold found in quartz, quartz-carbonate veins, and other gangue minerals, according to the mill feed. This type of gold is amendable to the free-milling process, which is the gravity method. However, from this current study, ore textural studies revealed that a number of gold grains occur as inclusions locked in pyrite as refractory ore. This inclusion texture is considered in this study to be the possible reason for the drop in the recovery rate from 94.1% to 81.3% and not the high amounts of sulphides in the samples that are subjected to free-milling at AGM. This is because just grinding the samples cannot easily liberate the refractory gold. Therefore, it is possible that high amounts of sulphides could equally hold high amount of gold. Hence, for the low-grade recoveries, the management of AGM need to think of other recovery methods for the refractory ores in other to obtain optimum recovery of the gold.

4 Conclusions and Recommendations

4.1 Conclusions

(i) This research revealed that there are two types of ore textures associated with gold mineralization: (1) gold occurring in gangue alteration assemblage and, (2) gold occurring as inclusions locked up in pyrite (i.e., refractory ore)

(ii) The low recovery rate of gold is not due to the high amounts of sulphides present but rather, because of the occurrence of gold as refractory sulphide ore.

(iii) The current gold recovery methods at AGM are good for the free milling gold ores. However, to obtain an optimum recovery for the refractory ore, AGM may need to consider a new (or additional) recovery process such as hydro flotation and bioleaching.

4.2 Recommendations

(i) More samples should be studied for ore textural relationship between gold and sulphides to assess whether there is a substantial amounts of refractory ore.

(ii) A cost-effective analysis should be carried out on the Mine to see whether it would be worth vying into other methods such as hydro flotation and bioleaching in other to optimise gold recovery from the refractory ores.

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