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Tarkwaian Paleoplacer Gold Recovery Relationship with the Matrix

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ABSTRACT

The study was carried out to characterize selected conglomerates of the Banket Series of the Tarkwaian at Tarkwa area and related the textures and mineralogy to gold grade and recovery. The conglomerates contain 60-90% quartz pebbles, with the matrix being fine to medium and rarely composed of coarse-grained quartz. The gold ore also comprizes of minor fine-grained ore minerals, sericite, and chlorite. The quartz pebbles were glassy, milky and partially recrystallized into sugary varieties. Primary sedimentary textural characteristics of sub-rounded to rounded pebbles of about 0.5 cm to 3.0 cm diameter are common. The quartz pebbles are moderately sorted and well packed. Gold in the ore ranges from 0.78 - 3.86 g/t such that high-grade ores had glassy quartz pebbles whiles medium to low-grade ores had sugary varieties. Gold recovery (38.66 - 95.08%), generally increased with increase in the percentage of the matrix volume. It is also higher in ore containing gray quartz and containing much ore minerals; lowest recoveries have high quartz, low matrix volume, and richer in quartz. Also, associated with lower recovery was higher chlorite content which may require more metallurgical treatment for efficient recovery.

Introduction

The Tarkwaian rocks, and at the immediate west of the Birimian Supergroup consists of penecontemporanous, low-grade metamorphosed sedimentary and volcano-clastic rocks [1]. The Tarkwaian Group, best developed within the Ashanti Belt, is a sequence of clastic sedimentary rocks which comprizes of sandstones, conglomerates and phyllites. In the Ashanti Belt, the Group thickness is approximately 2,500 m, in the Bui Belt, it reaches a thickness of about 9,000 m, occurrences occur on the eastern margin of the Sefwi Belt, in the Kibi-Winneba belt and the northern Nangodi Belt [2, 3]. The depositional setting of the Tarkwaian Group units is very different to that of the underlying Birimian Supergroup sedimentary units. The conglomeratic units of the Tarkwaian Group are interpreted as having been deposited in alluvial fans and then reworked by braided stream channels [4, 5, 3]. The Tarkwaian conglomerates of the Bui Belt also contain substantial concentrations of Paleoplacer gold [3]. The maximum age of deposition for the Tarkwaian Group is constrained to approximately 2133 to 2132 Ma based on detrital zircons from the Kawere Group and Banket Series [6, 7, 8, 9].

Available concordant zircon data show that deposition could have started as late as 2107 Ma [9]. With regards to the mesothermal quartz vein-associated gold mineralization that overprinted the Tarkwaian paleoplacer mineralization, U-Pb ages on hydrothermal xenotime record 2063 ± 9 Ma [8]. Metagabbro sills [10] and granitoid [11] intrusions occur in the Tarkwaian.

The Banket Series marked by some well-packed quartz pebble conglomerates that were deposited by south easterly to north westerly flowing rivers [12]. Economic gold concentrations occur in the matrix of the quartz pebbles of mature and clean reworked conglomerates interbedded with sandstones at Abosso-Damang, Iduapriem, Tarkwa and Teberebe areas [13]. Low-grade metamorphic mineralogy include chlorite-sericite assemblages [13].

The conglomerates that host the gold mineralization in the Banket Series are oligomictic, well-sorted and consist mostly of vein-quartz pebbles (> 90%) and subordinate schist and quartzite pebbles [14, 13, 15, 16]. The matrix is made up of fine to medium-grained quartz and heavy minerals with the later comprizing hematite, ilmenite, magnetite and rutile [14]. Quartz veins crosscut the mineralized conglomerates in places and contain minor gold and pyrite [1] and other sulfides [16]. In addition to occurrence close to quartz veins, sulfides occur in proximity to the faults and dykes in the conglomerates [1].

Gold recovery after crushing and milling the Tarkwaian conglomerate is about 90% at a lime consumption rate of 1.0 kg/t to 1.5 kg/t using moderate cyanide consumption [18]. This study concerned the mineralogy and textures of the conglomerate ore and their relationship with gold recoveries.

Methods Used

Banket conglomerate ore samples from various small-scale mine sites within the Tarkwa Municipality near Teberebe (A1 and A2), Long-Ji, Efuanta (B1-B2), Opposite Tarkwa Senior High School (Tasco) (B3), University of Mines and Technology Basic School (UBaS) area (C1), Pepe pit (C2) and Teberebe Cut 4 (C3) (Fig. 1). Samples were washed before description with a hand lens (x 10 magnification). Thin and polished section analyses were conducted at the Petrology Laboratory at the Geological Engineering Department, University of Mines and Technology, Tarkwa, Ghana (UMaT). Photomicrographs were labelled using abbreviations [20].

For effective comminution, about 1 kg of the individual samples was crushed using the jaw crusher, cone and roll crushers at the Minerals Engineering laboratory, UMaT. Portions were milled using the ball mill for grindability

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Table 1. Divisions of the Tarkwaian [19].

Group	Series	Thickness (m)	Composite Lithology
Tarkwaian	Huni Sandstone (and Dompim Phyllites)	1370	Sandstones, grits and quartzites with bands of phyllites.
	Tarkwa Phyllites	120 – 400	Huni sandstone transitional beds; green and greenish gray chloritic and sericitic phyllites and schists.
	Banket Series	120 – 160	Tarkwa phyllites transitional beds and sandstones, quartzites, grits, breccia and conglomerates.
	Kawere Group	250 – 700	Quartzites, grits, phyllites and conglomerates.

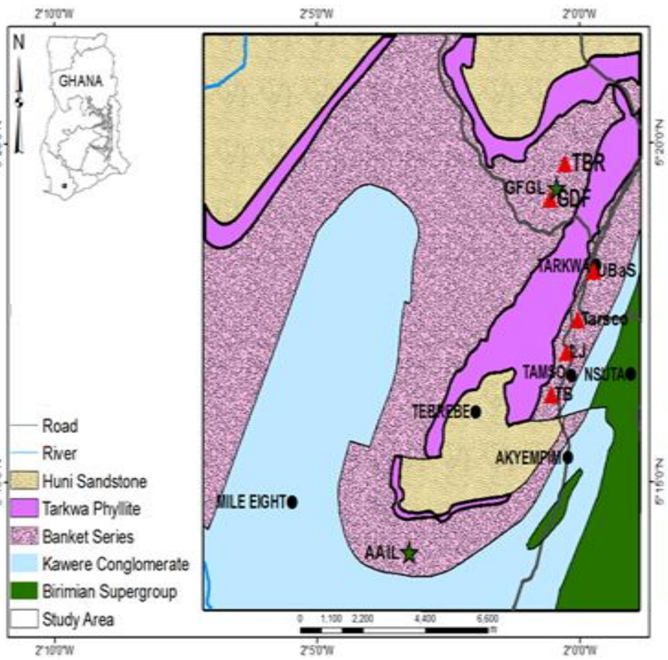

Fig. 1. Simplified Geological Map of the Study Area [19].

analysis to ascertain the time required for the samples to be milled before cyanide leaching. The samples (80% passing 106 µm) timed to 13-15 minutes were poured into bottles, followed by addition of cyanide and some amount of lime to leach at determined lime consumption rates for neutralization of the pH. The leached samples were placed on a roller for 24 hours with subsequent lime and cyanide top-ups to neutralize the reaction at specified time intervals.

After 24 hours, removed samples from the rollers had pH individually recorded, filtered, and a portion of the filtrate (concentrate) titrated against silver nitrate solution to determine the amount of cyanide consumed after the period. Acid digestion continued on dried tailing samples after leaching using HNO_3 and HCl in the ratio of 1:3, and slightly heated to determine the presence of some gold particles which could have remained in the tailings; then filtered to collect the concentrate for AAS analysis. Calculated recovered gold grade based on the results from the AAS analysis gave the head grade (grade of gold in the concentrate and that in the tailings).

Petrography

The conglomerate ore is white to dark gray with patches of brown or gray. It is laminated with current bedding (e.g. B3, C1). Pebbles are very coarse-grained of glassy quartz, made up of subrounded to well rounded, moderately sorted to poorly sorted, and poorly packed (e.g. B1, B3, C1) (Fig. 2). The rock fragments are sheared, occupied by chlorite, foliated and contain opaque minerals. Elsewhere, dark gray pebble (greywacke) is composed of quartz, plagioclase, amphibole, and opaque minerals (B1 and B2). Gray quartz is sheared into milky varieties (A1). There is recrystallized quartz aggregate with preserved primary texture along bedding planes, interlaminated with hematite (Fig. 4). Fractures found in glassy pebble varieties which are non-sheared but pushed and offset bedding planes (B3). Elsewhere, sheared and elongated quartz pebble is recrystallized, elongated and caught up in a shear zone marked by magnetite-rich layers (B3). Sample from Pepe pit (C2) contains sericite along sheared zones within the matrix and at the margins of the quartz pebbles. The medium-grained recrystallized quartz pebbles are weakly sheared, sugary and elongated (C2) (Fig. 5). Though sample C1 which indicates primary alternation of fine to medium-grained sugary quartz, spotted with hematite and inter-bedded with hematite in millimeter scale bands (Fig. 3), it occasionally shows current bedding. Some glassy quartz were fractured, stained along fractures by ore minerals (C3). The quartz fragments were recrystallized into sugary textures (B1 and B2) just as some quartz-rich bands in laminated variety form veins across hematite-rich layers or are recrystallized. Quartz pebbles when recrystallized are glassy, milky and also fractured (C2). Closely packed quartz is rarely elongated, with quartz veinlets parallel to shear (C3). Gray quartz in the matrix is medium grained and dusty with fine-grained ore minerals (B1 and B2) and cut by quartz veinlets (C3). Moderately sheared quartz is drawn out into augen textures or recrystallized into sugary varieties with triple junctions (C3); a few quartz is caught up in rare shear zone (C1).

The pebbles are generally held together by a dark gray matrix which is medium-grained. Sericite along shear zones within the matrix made up coarse to medium-grained quartz with smaller quartz pebbles, elongated and sutured at the margins (C2). The modal percentage of the conglomerates is difficult to determine as the pebbles could be up to cobble size. The modal percentage of minerals in the matrix of the various conglomerate samples shows quartz (pebbles and the matrix determined in thin section) ranges from 60-90%, plagioclase up to 5%, chlorite 2-30%, sericite is up to 3%, ore minerals 2-30% (Table 2). Table 3 and Figure 6 show modal percentage of total quartz including quartz in matrix together with gold recovery and grades.

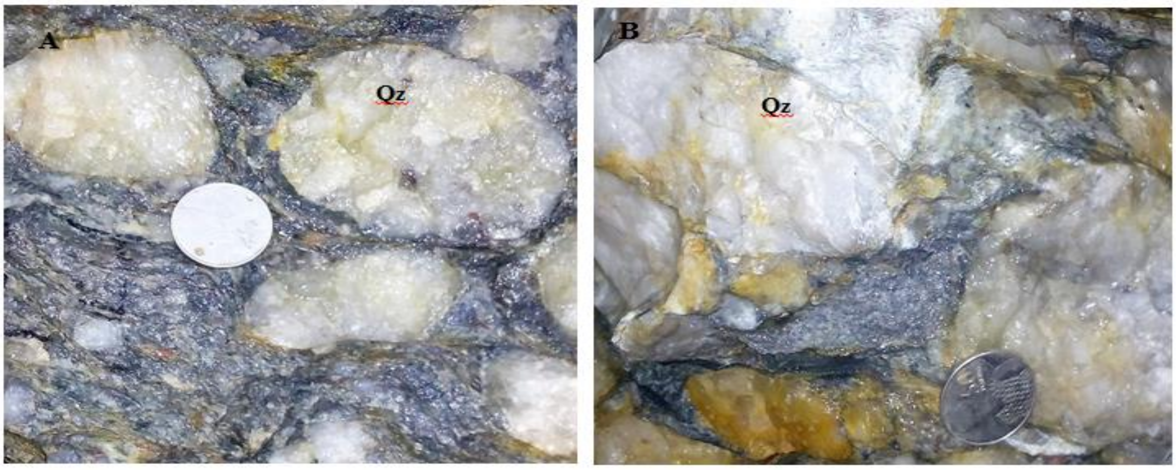

Fig. 2. Photograph of Conglomerate from Efuanta B1 (A, B) showing Glassy Quartz Pebbles.

Fig. 3. Photograph of Conglomerate (Sample C1) showing Sugary Quartz Pebble.

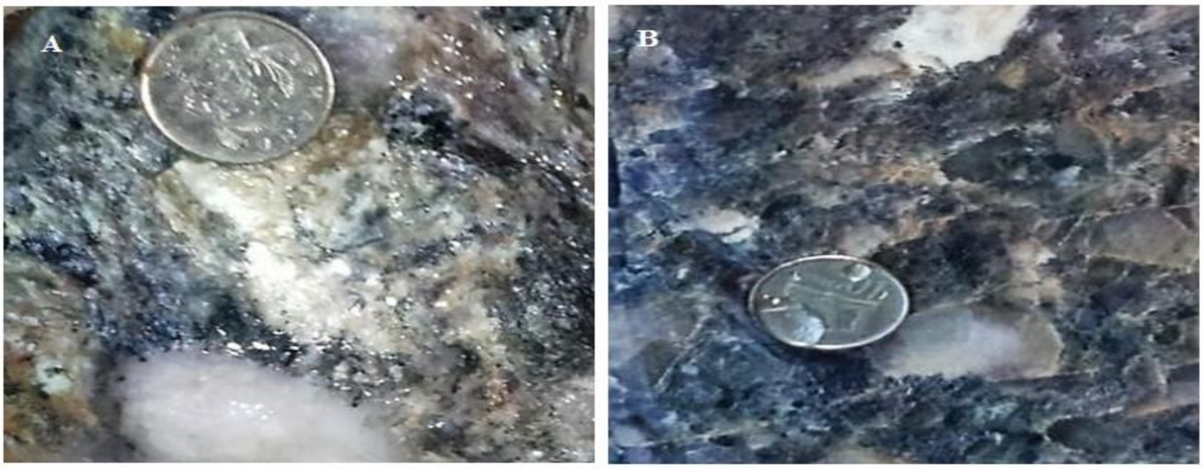

Fig. 4. Photograph of Conglomerate sample C2 (A, B) showing Glassy Quartz partially recrystallized.

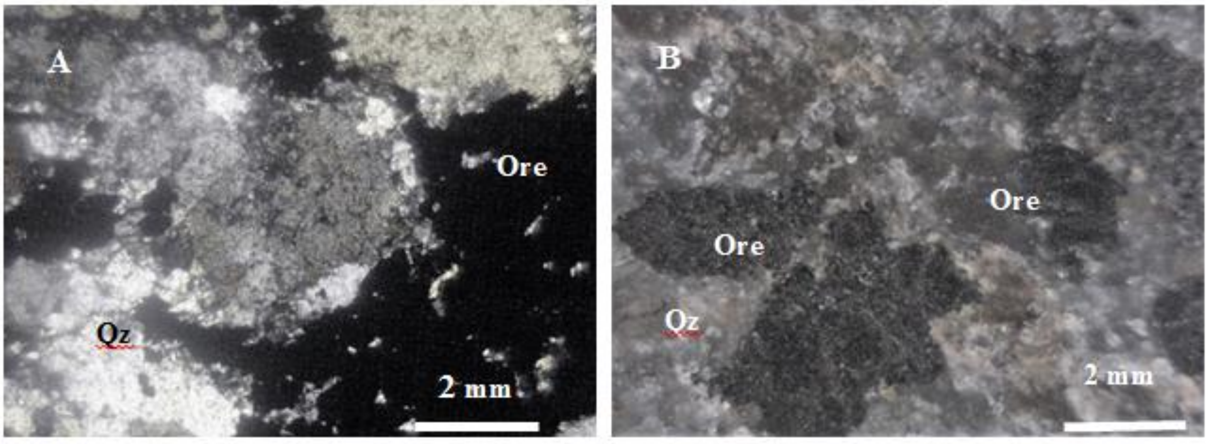

Fig. 5. Photomicrograph of Conglomerate from sample C2 under Cross Polarized Light showing (A) Recrystallized Quartz, and (B) A Cluster of Granular Ore minerals.

Table 2. Modal Percentage of Minerals and Minerals in the Matrix of Various Conglomerate Samples

Sample ID	Quartz (%)	Plagioclase(%)	Chlorite (%)	Sericite (%)	Ore Minerals (%)	Gray Quartz (%)
A1	60	4	3	1	2	30
A2	65	4	3	1	2	25
B1	60	5	30	-	5	-
B2	90	-	8	-	2	-
B3	80	-	2	1	17	-
C1	60	-	10	-	30	-
C2	90	2	6	-	2	-
C3	60	5	15	3	17	-

Table 3. Modal % of Quartz Pebble, and Matrix with % Au Recovery and Au Grade.

Sample ID	Total Quartz%	Matrix	%Au Recovery	Au Grade (g/t)
A1	90	40	79.82	1.09
A2	90	40	79.82	1.24
B1	90	10	66.67	0.78
B2	90	10	83.53	0.85
B3	60	40	95.08	3.86
C1	60	40	92.86	2.38
C2	90	40	38.66	1.94
C3	80	20	90.34	1.76

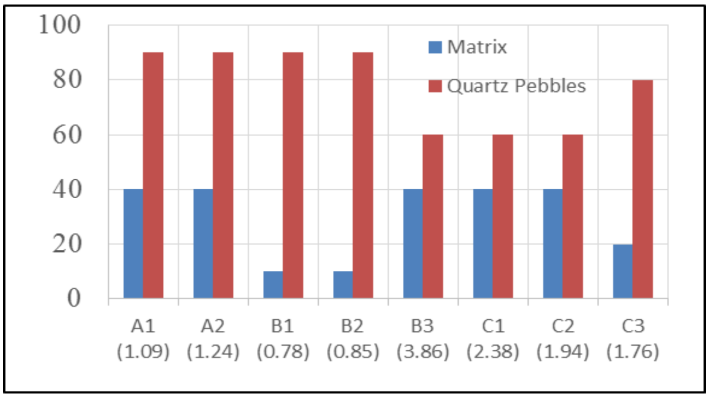

Fig. 6. Graph of modal % Quartz Pebble, and Matrix against Gold Grade.

Discussion

The Tarkwaian Banket conglomerate ore contains 60-90% quartz made up of pebbles and matrix. The matrix is composed of fine to medium and some coarse-grained quartz, with minor sericite, and chlorite. Ore minerals include pyrite, hematite, magnetite, ilmenite, rutile and zircon [4, 14, 7]. The pebbles are sub-rounded to rounded, with about 0.5 cm to 3.0 cm diameter, coarse-grained, moderately sorted and well packed. The pebbles are glassy, milky and have been partially recrystallized into sugary varieties. Fractured, white, smoky, bluish or gray to black quartz veins at the Obuasi mine in the Birimian Supergroup are generally richer in microscopic gold inclusions [21]. The gray quartz in the Tarkwaian, however, are not primary pebbles but formed during recrystallization. The conglomerate contains high quartz (90%) or moderate quartz (60%) of which the higher quartz conglomerates could also contain higher matrix volumes (>40%) or lower to moderate matrix (10-20%) (Table 3, Fig. 6). Gold grade ranges between 0.78 - 3.86 g/t of which higher grade ores contain glassy quartz pebbles, whilst medium to low grade ores are associated with sugary varieties. Gold recovery range from 38.66 - 95.08%, and generally increase with increase in the percentage of the matrix, e.g. samples B3, C1, and C3. The recovery, however, rarely decrease with increase in quartz composition e.g. sample C3 (Table 3). Hence generally high recoveries (80-90%) conform to moderate quartz percentage (60-80%) and variable matrix volumes (10-40%) while lowest recoveries have high quartz (90%) and low matrix (10%); example samples A1, A2, B1, B2. Sample C2 with lowest gold recovery of 36.66% contains high quartz (90%) with moderate matrix (40%) and so the matrix is also rich in quartz grains. This turned out low recovery of 38.66% (Table 3, Fig. 6). Therefore the recovery of gold from the Tarkwaian matrix is paramount and dependent on the volume of matrix and it is adversely affected by higher modal percentage of quartz composition. Free gold sizes in the Tarkwaian Banket conglomerate range between 0.002 mm and 0.500 mm and related to the size of gold, the size and packing of the quartz pebbles [14]. There is increasing diameter of larger quartz grains in the matrix which conforms to increase in gold grade [22]. Increase reagent consumption rate is associated with ores with more chlorite and much iron oxide minerals in the matrix [18]. Ores containing gray quartz (samples A1, and A2) and higher ore mineral composition (samples B3, C1) generally have higher recovery (Table 2).

The presence of hematite significantly reduced the dissolution of gold as hematite formed coatings on gold surfaces to prevent leaching [23]. The B3 and C1 samples which contain high ore minerals may, therefore, comprize less hematite in favor of magnetite [4, 14, 7]. Lower recovery of sample B1 also has highest chlorite content (30%) (Tables 2 and 3). Therefore conglomerate ores with high chlorite content may require higher roasting temperature and more reagent consumption for efficient recovery. Ore separation for special treatment is therefore recommended.

Conclusions

The Tarkwaian Banket conglomerate ores contain 60-90% quartz, in both pebbles and matrix. The pebbles are sub-rounded to rounded, with about 0.5 cm to 3.0 cm diameter, coarse-grained, moderately sorted and well packed.

The pebbles are glassy, milky and partially recrystallized into sugary varieties. The matrix is composed of fine coarse-grained quartz, with minor pyrite, hematite, sericite, and chlorite. Gold grade ranges between 0.78 - 3.86 g/t. High-grade ores have glassy quartz pebbles whiles medium to low-grade ores have sugary varieties. Gold recovery ranged from 38.66 - 95.08% and generally increased with increase in the percentage of the matrix volume. Higher gold recoveries conform to moderate quartz percentage (60- 80%) and variable matrix volumes (10-40%) while lowest recoveries have high quartz, low matrix volume but with the matrix richer in quartz. The ores containing higher gray quartz and higher ore minerals generally have higher recovery; while lower recovery associated with the ore with higher chlorite content which may require more reagent consumption for efficient gold recovery.

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