Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.01.2022.31.37

ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

RESEARCH ARTICLE

EFFECT OF PEBBLE SIZE ON GOLD DISTRIBUTION IN THE BANKET SERIES OF THE STRATIGRAPHY IN TARKWAIAN SUPERGROUP

Matthew Coffie Wilson, Lydia Nnipaa Osei Opuni

Kwame Nkrumah University of Science and Technology, Department of Geological Engineering, University Post Office, Kumasi – Ghana.
****Corresponding Author Email: regimatt2003@yahoo.co.uk; mcwilson.coe@knust.edu.gh***

ARTICLE DETAILS

Article History:

Received 27 June 2022
Accepted 29 July 2022
Available online 01 August 2022

ABSTRACT

The purpose of this research is to establish the relationship between the gold grades and the various pebble sizes from a mine. This objective was reached by choosing parameters of interest from the logging and sampling data, lithological data and assay data from the mine. These parameters were further processed using Microsoft Excel to plot graph of pebble size against gold grade. In order to build a concrete ground for the analysis, an average gold grade for the various samples used was calculated and compared to the cut-off grade at the Mine which is 0.45g/t. Upon further analysis, it was observed that, gold grade which are considered economically feasible at the mine is associated with the coarse pebbles, which has a diameter range of (5mm-30mm) and those which are considered as waste are associated with the fine pebbles (less than 5mm diameter). Some of these coarser pebbles are not economically feasible, since their average gold grade when calculated falls below the cut-off grade at the mine. The mode of deposition as well as the topography of the medium at the time of deposition of gold determine the gold grade of a reef. The degree of roundness and sorting of the conglomerates associated with mineralization as well as ore dilution within the depositional medium by the pebbly quartzite and quartzite waste account for the fall in gold grade of the reef.

KEYWORDS

Pebble size, gold grade, reef thickness, mineralization, waste

1. INTRODUCTION

In the year 1700 Alluvial gold mining started in Tarkwa. Then 50 years after, in 1750, the Wassaw syndicate, the first organized mining company was formed. In the 1850, Dunkwa, Obuasi, Bibiani, Prestea and Konongo came to form the Amalgamated Banket Area (ABA) that is 100 years after the Wassaw syndicate was formed, as a gold mining area. All these companies were private mining companies (Karpeta, 2000). All these mining companies operated and still operate in different Supergroups such as the Birimian and Tarkwaian. There are four stratigraphic units in the Tarkwaian Supergroup, namely Huni Sandstone, Tarkwa Phyllite, Banket Series and Kawere Conglomerates (Kesse, 1985). The study concentrates in a mine in the Banket Series comprising reefs and wastes of the quartzite and conglomerate lithological units.

The mineralogy of gold is quite complex. To begin with, gold can occur in a wide variety of forms. In massive quartz reefs, gold occurs as disseminated, irregular grains, scales, plates and veinlets with microscopic dimensions, and as larger compact, reticulated, spongy or hackly masses or slugs. While all gold has a crystalline structure, distinct crystals showing well-formed faces are relatively rare. They require special conditions to form, in particular space in which to grow. Hence crystals of gold are found in cavities in quartz reefs or in softer minerals such as iron oxides where they have been able to push aside the enclosing material as they grew. Gold crystallizes in the cubic system, and perhaps the most common variety is the eight-sided octahedron. Other important metal-bearing minerals can also be found in the quartz reefs with the gold (Birch, 2013).

The presence or absence of some minerals can be used to help classify the type of gold field. The most common and widespread are pyrite and arsenopyrite, two minerals containing iron and sulphur. The relative softness of gold means it can be scratched by harder grains during erosion and transport. However, gold's malleability often leads to particles being bent or twisted, rather than reduced in size. Gold grains that have not travelled far from the quartz reefs often preserve many of their original features, such as their basic shape or the imprints of quartz crystals (Birch, 2013). Generally speaking, finer gold particles known as gold dust have been carried further from their source reefs, possibly by fast-flowing streams (Birch, 2013). Quartz pebble conglomerate gold deposits represent the largest repository of gold on earth. This is largely due to the deposits of the Witwatersrand basin, which amount for nearly forty percent (40%) of the total gold produced throughout the earth's history. The second largest quartz-pebble-conglomerate gold system behind the Kaapval craton is found in Tarkwa, Ghana. This deposit has had controversial history in regards to genetic models. However, most researchers conclude that the paleo-placer deposits that have been modified by metamorphism and hydrothermal fluid flow subsequent to initial sedimentation (Taylor and Anderson, 2018).

Grains of native gold are found within coarse grain sediment beds, either directly above erosion surface as heavy mineral concentrates or at the top of individual beds left by winnowing. Some of these gold grains are of obvious detrital origin, but many are crystallized forms, which indicates hydrothermal emplacement caused by localized remobilization. (Taylor and Anderson, 2018). There are different grain sizes in different rock types

Quick Response Code	Access this article online	
	Website: www.geologicalbehavior.com	**DOI:** 10.26480/gbr.01.2022.31.37

Cite The Article: Matthew Coffie Wilson, Lydia Nnipaa Osei Opuni (2022). Effect of Pebble Size on Gold Distribution in The Banket Series of The Stratigraphy in Tarkwaian Supergroup, *Geological Behaviour 6(1): 31-37.*

and rock formations. The effect of these grain and pebble sizes have got their effects on gold distribution. The research article is on the reef and waste in an unnamed Mine in the Tarkwaian Supergroup. Auriferous conglomerates in an undefined mine in the Tarkwaian Supergroup are categorized as matrix-supported and clast-supported conglomerates. Majority of gold grades above the cut-off grade at the Mine are associated with the clast supported conglomerates. However, this situation is not always uniform. Gold grades which are calculated after detailed sampling of some of the clast supported conglomerates (5mm-30mm pebble diameter) fall below the cut-off grade. Hence, this research work seeks to find out how the various pebble sizes affect the grades.

This article aims at analyzing how grain sizes affect gold distribution in the stratigraphic Banket Series at a Mine in the Tarkwaian Supergroup. The specific objectives to help arrive at this main aim are to: determine the average gold grade(g/t); analyze the relationship between the pebbles size and the grades; and also establish the relationship between gold grade and reef thickness. If the factors controlling the gold concentration are not understood, resources will be wasted. To ensure precise determination of the average concentration, there is the need to understand how the grain sizes influence mineralization and the average concentration determination. A careful analysis of this will reduce the financial loss that the mine can incur, hence the relevance of this project.

2. Geologic Setting

A primary gold area of the world exists in the Proterozoic Birimian and Tarkwaian supracrustal rocks of West Africa. The majority of the gold comes from the primary deposit of gold occurring within the definite boundaries of the Birimian rocks of Ghana (Dzigbodi-Adjimah, 1993). Five of the gold belts in Ghana (namely Kibi-Winneba, Ashanti, Sehwi, Bui-Banda and Bole-Nangodi gold belts) are in the north-easterly striking, broadly synclinal structure made up of Lower Proterozoic sediments and volcanics underlain by the metavolcanics and metasediments of the Birimian System. The Tarkwaian unconformably overlies the Birimian and is characterized by lower intensity metamorphism and the predominance of coarse-grained, immature sedimentary unit. (Goldfields Annual Review, 2012). The Tarkwaian Supergroup of Proterozoic Age (2132 to 2095Ma) comprise the Kawere, Banket, Tarkwa Phyllite and Huni “Series” and rest unconformably on the Birimian (Kesse, 1985). The Kawere “Series” consists of between 250m and 700m of repeated fining upward sequences of erosively-based, polymitic, poorly sorted, often matrix supported, conglomerates grading up through immature pebbly quartzites to parallel-laminated or cross-bedded, feldspathic quartzites (Kesse, 1985). Clasts comprise mainly basic lavas with subordinate felsic lavas, cherts, pyroclastic rocks, quartz and granitoids. Magnetite is the dominant detrital heavy mineral, hematite being notably absent. Limited palaeocurrent information is unimodal, indicating derivation from the east (Kesse, 1985).

Table 1: Summarized stratigraphy of the Tarkwaian Group (Modified after Kesse, 1985)

Group	Series	Thickness (m)	Lithology
Tarkwaian	Huni Sandstone	1370	Sandstones, minor phyllites
	Tarkwa Phyllite	120-400	Chloritic and sericitic phyllites and schists
	Banket Series	120-160	Quartzites, grits and conglomerates
	Kawere Conglomerate	250-700	Quartzites, grits and conglomerates
Major Unconformity			
Birimian	Birimian		Meta-volcanics, volcaniclastics and sediments

2.1 The Conglomeratic Unit

Conglomerates found within the study area are categorized into two distinct groups, namely, clast-supported conglomerate and matrix-supported conglomerate. Clast supported conglomerate is characterized by large quartz pebble size, which are in contact and cemented by cementing materials such as silica. Matrix-supported conglomerate is characterized by separated quartz pebble, and the matrix surrounds each pebble.

Table 2: Pebble size classification is done using the grain size classification library

Pebble Classification	Pebble Description
AP	Aphanitic (<<1mm - none visible)
CG	Coarse grained (5-30mm)
FG	Fine grained (1-5mm)
GL	Glassy
PG	Pegmatitic, v-coarse (>30mm)

Figure 1: Clast-supported conglomerate from C-Pit

Figure 2: Matrix supported conglomerate from M-Pit

3. Materials and Methodology

The field work was done and the data acquired at a mine in Southwestern part of Ghana, whilst the data analysis was carried out at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi-Ghana between May, 2021 and May, 2022. The data was obtained from logging and sampling to pit mapping. Logging and sampling employ two distinct methods, namely: Reverse Circulation Drilling and Diamond Drilling.

3.1 Reverse Circulation (RC) Drilling

Prior to RC drilling, surveyors complete pegging the points from the RC holes plan. Drilling is done by a contractor employed by the company. Before the drilling commenced, the rig was first set followed by checking of dips and azimuth by the geologist in charge. The drilling was done along a 25m x 25m gridlines across the strike of the ore body in order to intersect the ore zones (Woodfield, 1966). Sampling is done with the help of sample bags, splitter and trays. Samples are taken at 1m interval. The samples came up through the sample tube into thick rubber sample bags attached to the base of the cyclone. Every meter sample taken is poured into the splitter and mixed with a stirrer to attain homogeneity before splitting up into two sample trays placed at the base of the splitter.

Sample checks such as duplicate is inserted to check accuracy from the assay laboratory. This is done by pouring one of the samples back into the splitter and dividing it into two smaller sample trays. Two samples with labelled ID's were taken at every one (1) meter interval, each having a weight of about 2kg. A handful or two of the remaining sample (coarse reject) at every 1m hole drilled was washed in a mesh and shown to the geologist in charge to log by simple observation. The logging was performed on a Psion Series palm top computer as drilling was still in progress with respect to the percentage volume of quartz fragments to the total volume of material as clast supported (CC), matrix supported (MC), pebbly quartzite (PQ) and quartzite (Q) per the logging code of the mine.

3.2 Diamond Drilling (DD)

The DD core logging was performed on a Psion Series palm top computer. The logging begun from the start of the hole, normally to overburden or hanging wall (HW), through to the footwall (FW). Emphasis was laid on identifying the lithological units as quartzite (Q), pebbly quartzite (PQ), matrix supported conglomerate (MC) and clast supported conglomerate (CC) (Table 3). Sampling was followed by drawing a split line along the entire core axis from the start to the end. The cores were then split with a rotary diamond saw and the two halves returned to the core box for sampling at intervals not less than 20cm and not more than 50cm in the case of conglomerate and pebbly quartzites and up to 1m in the continuous units of quartzite.

3.3 Pit Mapping

This is done by making rip or cut lines with a dozer across strike of the beds on the second flitch floor of a blasted material. Division or ore mark outs of the various reefs is done by the geologist using spray marker and tapes to mark the various contacts. The collar or starting point of the ripline to be mapped is indicated with the spray and the surveyor's tape which is stretched from the end of the bottom contact of the reef under mapping starting from the footwall to the hanging wall. The coordinates of the ripline are also taken and recorded with the help of a total station by a surveyor. Ripline had to be logged considering their lithological characteristics which are assigned standard accepted logging codes. The mapping was conducted across the ore body from the footwall to the hanging wall, using instruments such as geological compass, datasheet, measuring tape, and geological hammer. A tape was aligned on a ripline with an identified number and collar indicated with spray marker. The lithological units [quartzite (Q), pebbly quartzite (PQ), matrix supported conglomerates (MC) and clast supported conglomerate (CC) (Table 3)] along the line were mapped stating their distances. Alteration minerals such as, hematite, magnetite and chlorite were also recorded. Azimuths of riplines were also taken. Structures such as faults were also recorded.

Table 3: Logging Codes for Lithology

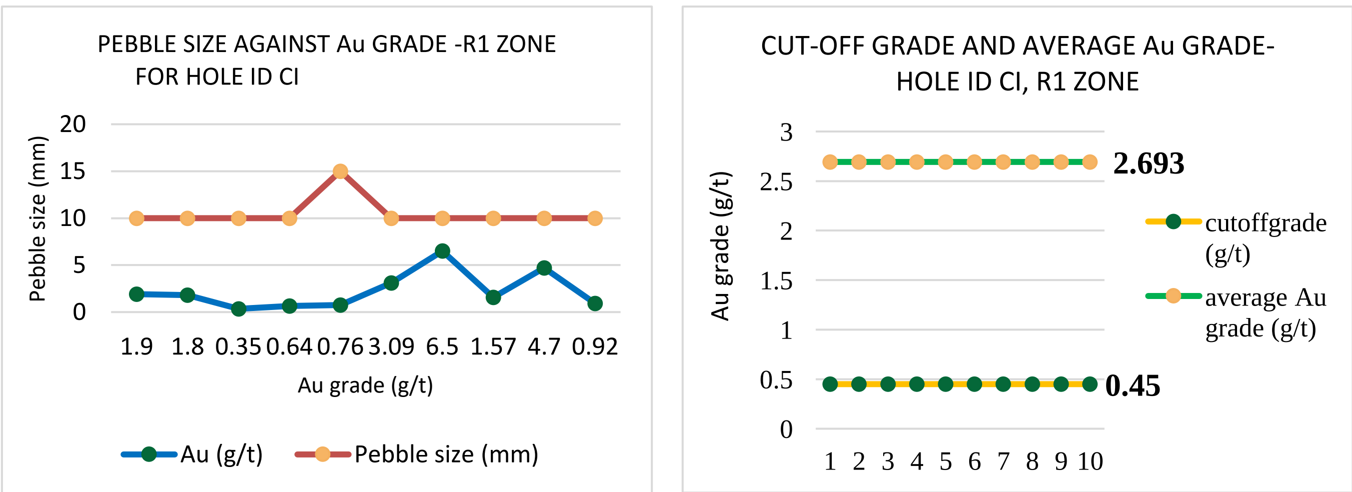
Lithology code	Lithology	Description
Q PB MC CC R	Quartzite (sand) Pebbly quartzite(sand) Matrix supported conglomerate(gravel) Clast supported conglomerate(gravel) R1, R2, R3	Grain size from 0 - 400μm Quartzite with pebbles that are widely spaced Pebble spacing is generally than three times the average pebble diameter Pebbles are closely packed and may be touching. Inter pebble spacing is less than one pebble diameter R is the main Reef and also ore-bearing zone divided into R1, R2 and R3
Rf	Rfc and Rfd	Rfc and Rfd zones are sub-reef and also waste within the main "R" reef

4. Results and Discussion

4.1 Results

Table 4: Analysis for Hole ID CI-R1 zone

SAMPLE_ID	DEPTH FROM (m)	DEPTH TO (m)	ZONE	Au (g/t)	PEBBLE SIZE (mm)	CUTOFF GRADE (g/t)	AVERAGE Au GRADE (g/t)	COMMENT(S)
CI_67	66	67	R1	1.9	10	0.45	2.693	Above cutoff grade
CI_68	67	68	R1	1.8	10			
CI_69	68	69	R1	0.35	10			
CI_70	69	70	R1	0.64	10			
CI_71	70	71	R1	0.76	15			
CI_72	71	72	R1	3.09	10			
CI_73	72	73	R1	6.5	10			
CI_74	73	74	R1	1.57	10			
CI_75	74	75	R1	4.7	10			
CI_76	75	76	R1	0.92	10			

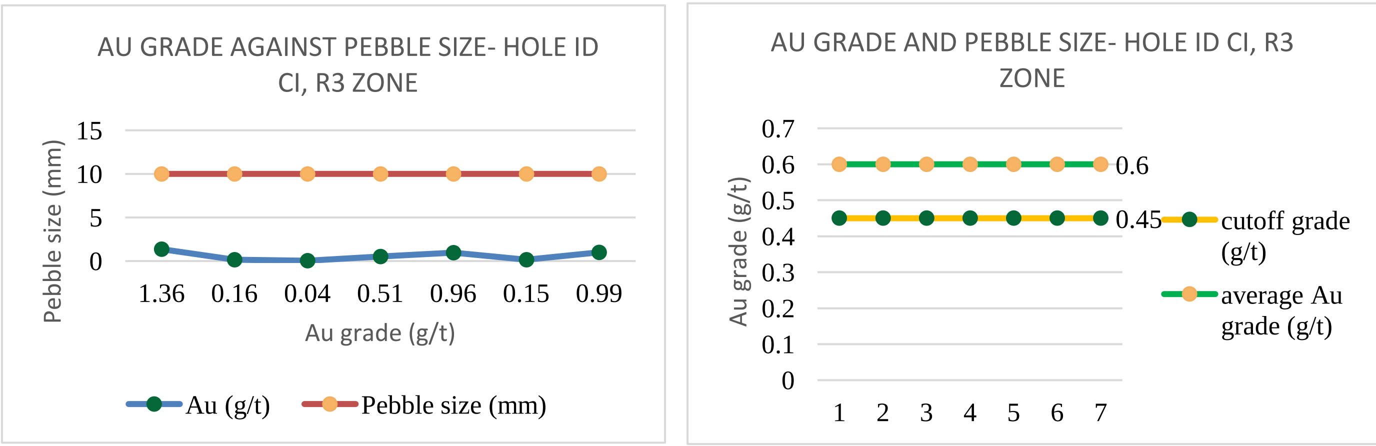


(a) (b)

Figure 3: (a) Au grade against pebble size-R1 zone; (b) Cutoff grade and average Au grade - Hole ID CI, R1 zone

Table 5: Analysis for Hole ID CI-R3 zone

SAMPLE ID	DEPTH FROM (m)	DEPTH TO (m)	ZONE	AU(g/t)	PEBBLE SIZE (mm)	CUTOFF GRADE (g/t)	AVERAGE Au GRADE (g/t)	COMMENT(S)
CI_30	29	30	R3	1.36	10	0.45	0.595714286	above cutoff grade
CI_31	30	31	R3	0.16	10			
CI_32	31	32	R3	0.04	10			
CI_33	32	33	R3	0.51	10			
CI_34	33	34	R3	0.96	10			
CI_35	34	35	R3	0.15	10			
CI_36	35	36	R3	0.99	10			

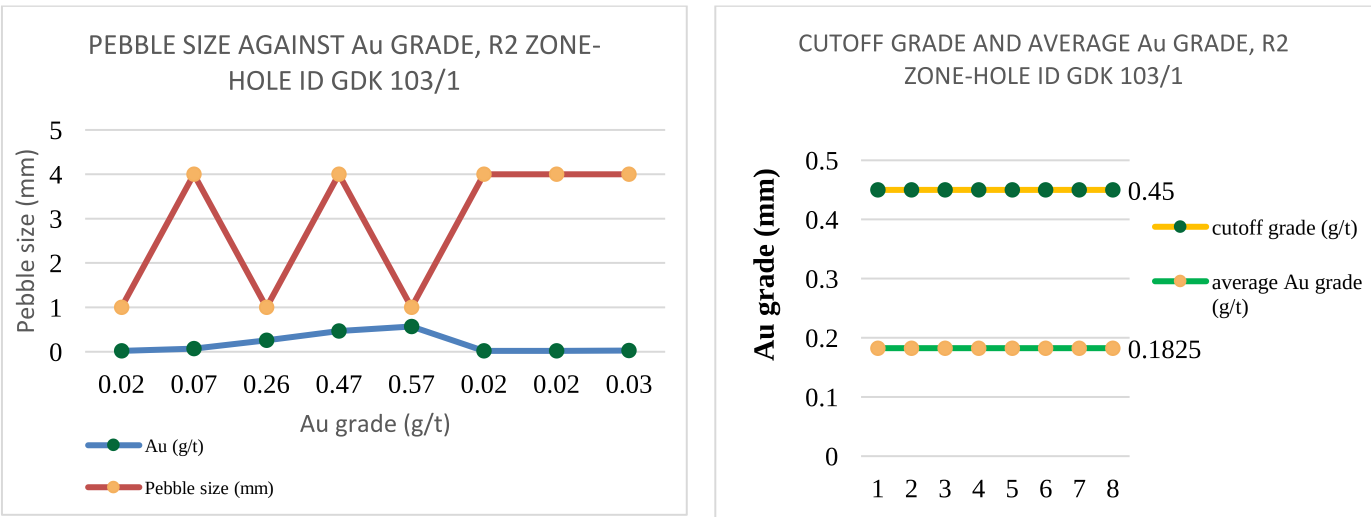


(a) (b)

Figure 4: (a) Au grade against Pebble size - Hole ID CI, A3 Zone; (b) Cutoff grade against Average Au grade-Hole ID CI, A3 Zone

Table 6: Analysis for Hole ID CI-R2 Zone

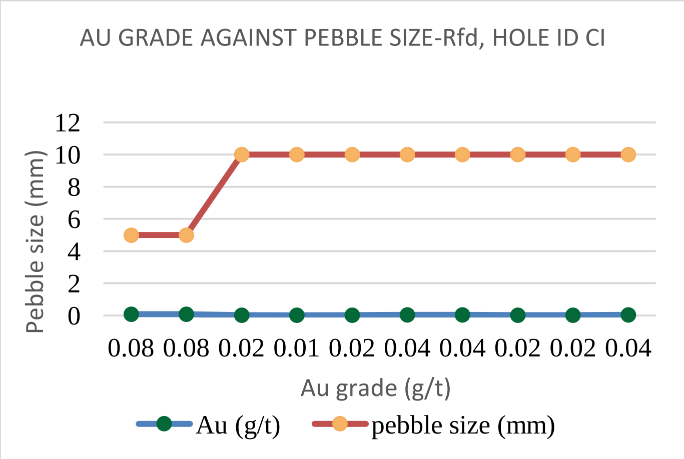
SAMPLE ID	DEPTH FROM (m)	DEPTH TO (m)	ZONE	Au (g/t)	PEBBLE SIZE (mm)	CUTOFF GRADE (g/t)	AVERAGE Au GRADE (g/t)	COMMENT(S)
A0_460	129	132.63	R2	0.02	1	0.45	0.1825	Below cutoff grade
A0_471	135.71	135.81	R2	0.07	4			
A0_482	138.05	138.81	R2	0.26	1			
A0_484	138.81	138.98	R2	0.47	4			
A0_485	138.98	139.18	R2	0.57	1			
A0_489	139.53	139.8	R2	0.02	4			
A0_490	140	140.3	R2	0.02	4			
A0_492	140.3	140.51	R2	0.03	4			



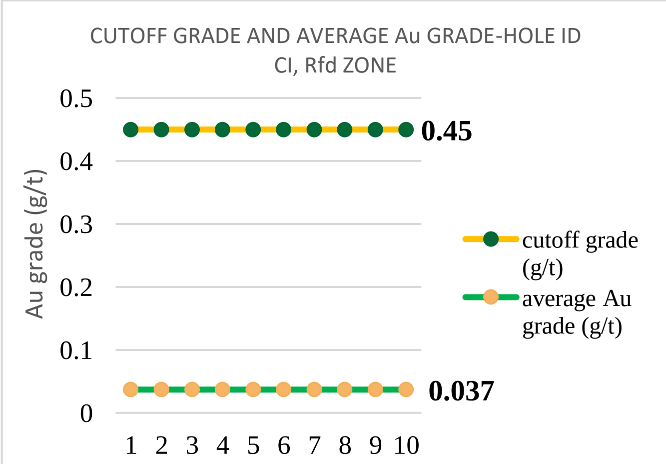
(a) (b)

Figure 5: (a) Pebble size against Au grade, R2 Zone-Hole ID GDK 103/1; (b) Cutoff grade and average Au grade, R2 Zone-Hole ID GDK 103/1

Table 7: Analysis for Hole Id Ci-Rfd Zone								
SAMPLE ID	**DEPTH FROM (m)**	**DEPTH TO (m)**	**ZONE**	**Au (g/t)**	**PEBBLE SIZE (mm)**	**CUTOFF GRADE (g/t)**	**AVERAGE Au GRADE (g/t)**	**COMMENT(S)**
CI_1	0	1	Rfd	0.08	5	0.45	0.037	below cutoff grade
CI_2	1	2	Rfd	0.08	5			
CI_3	2	3	Rfd	0.02	10			
CI_4	3	4	Rfd	0.01	10			
CI_5	4	5	Rfd	0.02	10			
CI_6	5	6	Rfd	0.04	10			
CI_7	6	7	Rfd	0.04	10			
CI_8	7	8	Rfd	0.02	10			
CI_9	8	9	Rfd	0.02	10			
CI_10	9	10	Rfd	0.04	10			



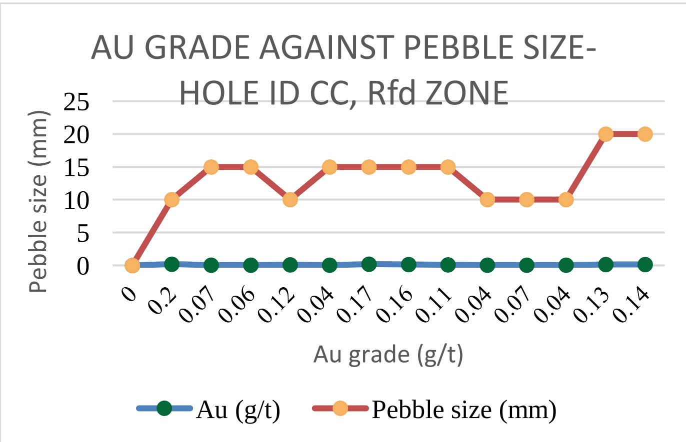
(a)



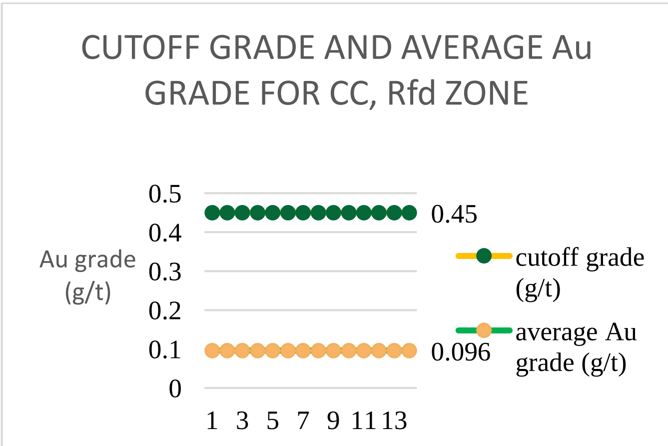
(b)

Figure 6: (a) Au grade against pebble size-Rfd, Hole ID CI; (b) Cutoff grade against average Au grade - Hole ID CI, Rfd zone

Table 8: Analysis of Hole Id Cc, Rfd Zone								
SAMPLE ID	**DEPTH FROM (m)**	**DEPTH TO (m)**	**LITHOLOGY**	**Au (g/t)**	**PEBBLE SIZE (mm)**	**CUTOFF GRADE (g/t)**	**AVERAGE Au GRADE (g/t)**	**COMMENT(S)**
CC_1	0	1	GAP	-	-	0.45	0.096428571	Below cutoff grade
CC_2	1	2	Q	0.2	10			
CC_3	2	3	PQ	0.07	15			
CC_4	3	4	PQ	0.06	15			
CC_5	4	5	Q	0.12	10			
CC_6	5	6	PQ	0.04	15			
CC_7	6	7	PQ	0.17	15			
CC_8	7	8	MC	0.16	15			
CC_9	8	9	PQ	0.11	15			
CC_10	9	10	Q	0.04	10			
CC_11	10	11	Q	0.07	10			
CC_12	11	12	Q	0.04	10			
CC_13	12	13	MC	0.13	20			



(a)

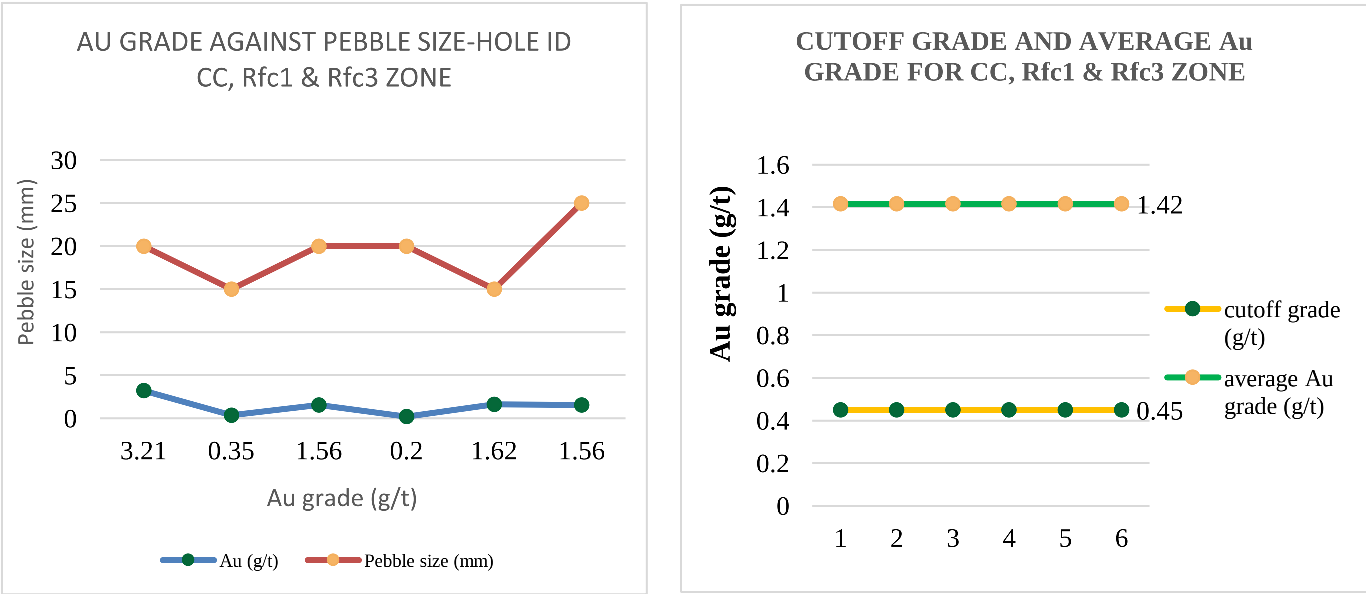


(b)

Figure 7: (a) Pebble size against Au grade -Hole ID CC, Rfd zone; (b) Cutoff grade and Au grade for CC, Rfd zone

Table 9: Analysis of Hole Id Cc, Rfc3 & Rfc1 Zone

SAMPLE ID	DEPTH FROM (m)	DEPTH TO (m)	LITHOLOGY	Au (g/t)	PEBBLE SIZE (mm)	CUTOFF GRADE (g/t)	AVERAGE Au GRADE (g/t)	COMMENT(S)
CC_15	14	15	MC (Rfc3)	3.21	20	0.45	1.416666667	Above cutoff grade
CC_16	15	16	PQ (Rfc3)	0.35	15			
CC_21	20	21	Q (Rfc1)	1.56	20			
CC_22	21	22	Q (Rfc1)	0.2	20			
CC_23	22	23	PQ (Rfc1)	1.62	15			
CC_24	23	24	MC (Rfc1)	1.56	25			



(a) (b)

Figure 8: (a) Pebble size against Au Grade-Hole ID CC, Rfc1 & Rfc3 zone; (b) Cutoff grade and average Au grade-CC, Rfc1 & Rfc3 zone

Table 10: Analysis for Hole Id Ce

SAMPLE ID	DEPTH FROM (m)	DEPTH TO (m)	Au (g/t)	REEF THICKNESS (m)
CE_1	0	1	0.01	1
CE_10	9	10	0.32	1
CE_11	10	11	0.14	1
CE_12	11	12	0.07	1
CE_13	12	13	0.04	1
CE_14	13	14	0.05	1
CE_15	14	15	0.06	1
CE_16	15	16	0.03	1
CE_17	16	17	0.19	1
CE_18	17	18	0.03	1

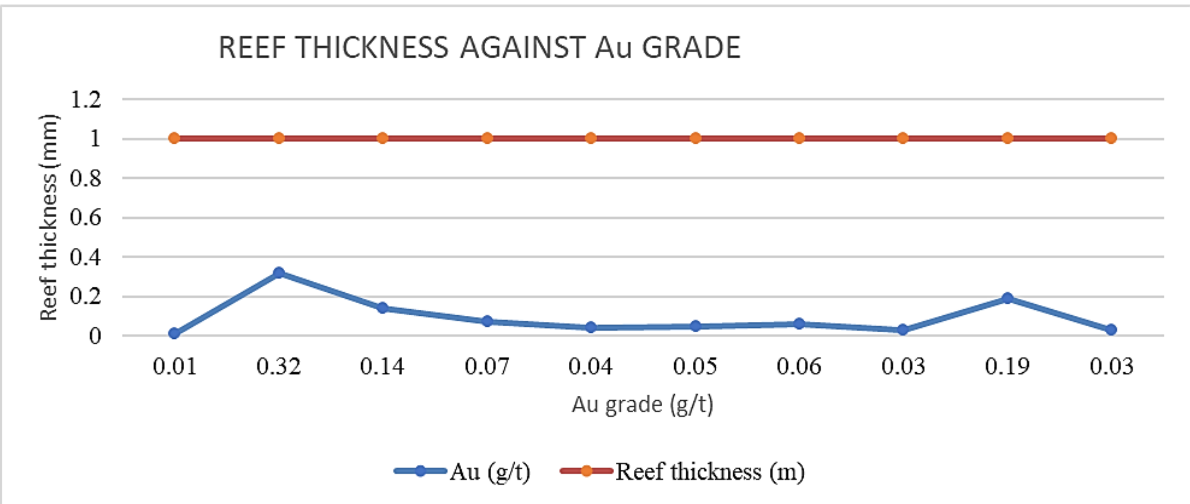


Figure 9: Reef thickness against Au grade

4.2 Discussion

4.2.1 Relationship Between Gold (Au) Grade and Pebble Size-Coarse Pebble Size

Pebble size of diameter ranging from 5mm-30mm is considered to be coarse at the mine. These pebbles sizes could be characterized by longer distance of transportation resulting in high degree of roundness of these pebbles and fine texture. From the results obtained above, pebble sizes in Tables 4, 5, 7, 8 and 9 are considered as coarse. Modelling is done using the assay results as a grade control measure, hence in modelling of the reef thickness, the grade of the rock material sampled at every meter is considered. The current cut-off grade (the minimum grade of a mineral deposit below which it is considered uneconomical) is 0.45g/t. Mineralization that is considered economically feasible are usually associated with the coarser pebble size, which most often have an average Au grade that is above the cutoff grade (Tables 4, 5, 9). However, there are some instances that the average Au grade of the coarser pebbles falls below the cutoff grade of the mine. This fall in Au grade when correlated to the cutoff grade can be attributed to the following under-listed parameters;

4.2.1.1 Degree of roundness

In Paleo-placers deposition, sedimentary materials are characterized by movement under the influence of gravity from their protolith to a new depositional environment. The degree of smoothness of the pebbles as a result of abrasion of the sedimentary particles is referred to as roundness. The intensity of smoothing is a function of the distance of transportation from their protolith to place of deposition. The gold particles associated with these conglomerates are enveloped around the conglomerates, hence depending on the distance transported and intensity of abrasion there could be a fall in the Au grade of the conglomerates. A well-rounded pebble implies a longer distance of transportation, and greater intensity of abrasion which will result in eroding some gold particles and decreasing the Au grade.

4.2.1.2 Sorting

This refers to how pebbles are distributed, either in unconsolidated deposit or consolidated deposit. A well sorted conglomerate pebble implies a uniform diameter of pebbles which gives rise to a uniform range of Au grade. A poorly sorted conglomeratic deposit implies non-uniform Au grade, since there are variable pebble sizes with varying Au grade.

4.2.1.3 Dilution

The Rfd zone is a sub-reef within the main "R" reef. From the sedimentological profile of the pit, "R" is considered as an ore bearing zone. The Rfd zone dilutes the ore bearing "R" reef, resulting in decrease in the average Au grade of pebbles deposited within the Rfd zone. Hence, the whole Rfd zone is considered as a waste although it contains coarser pebbles.

4.2.2 Relationship Between Gold (Au) Grade and Pebble Size, Fine Pebble Size

Pebble size of diameter below 5mm is characterized as fine at the Mine. Generally, mineralization which are considered economically feasible are not associated with these pebble size, since their average Au grade always lie below the cutoff grade (Table 6). "R2" is a sub zone within the "R" reef (Table 3) and it is categorized as a waste from the stratigraphic relation of the various zones. Hence deposits which are considered economically feasible when mine are not associated with it. This is because gold formation is associated with pebbles of high density (coarse pebble).

4.2.3 Effect of Reef Thickness on Grade

From Figure 9, it can be seen that the thickness as observed is constant with varying gold (Au) grades. At Au grade of 0.01(g/t), the corresponding reef thickness is 1m. At another point where the thickness is 1m, the corresponding Au grade is 0.19g/t (Table 10). This means that the thickness of a reef does not necessarily determine its grade but may be due to other parameters such as specific gravity and degree of roundness.

5. Conclusion

From the discussion, it can be concluded that:

- The gold grade of a particular reef may be due to parameters such as the mode of deposition and the topography of the medium at the time of deposition.
- The fall in gold grade of a particular reef may be due to parameters such as the degree of roundness and sorting of the conglomerates associated with mineralization.
- Ore dilution in the depositional medium by the pebbly quartzite and quartzite waste seated at the bottom of the reef also accounts for the fall in gold grade.
- The thickness of a reef does not necessarily determine its grade but due to the parameters mentioned above.

Recommendation

- The ore reserve of the mine should be estimated. This would help to determine the future and longevity of the mine.
- If the cutoff grade of the mine is to be lowered, more ore would be excavated to fetch the company more money and help them economically and financially.

Acknowledgement

I hereby acknowledge the tireless effort and effective contribution of my co-author towards the production of this article.

References

Birch, B., 2022. Geology of Gold www.sbs.com.au/gold/story.php?storyid128 Accessed May, 2022

Dzigbodi –Adjimah, K., 1993. J*ournal of exploration geochemistry,* 47, Pp. 305-320.

Goldfields Annual Review. 2012. Geological Setting and Mineralization www.goldfields.com/reports Accessed on March, 2022

Karpeta, P., 2000. Tarkwa Gold Mine Ghana.

Kesse, G.O., 1985. The Rock and Mineral Resources of Ghana. A. A. Ballkema Publishers, Rotterdam, Netherlands, Pp. 610.

Taylor, R.D., Anderson, E.D., 2018. *Quartz Pebble Conglomerate Gold Deposits*. U.S Geological Survey, Reston, VA https://pubs.er.usgs.gov/publication/sir20105070P Accessed on October, 2021

Woodfield, P.D., 1966. The geology of ¼ Field Sheet No. 91 Fumson N.W. Ghana Geol. Surv. Bull., 30, Pp. 66.