NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 5, ISSUE 6, June -2018

PEBBLES IN THE TARKWAIAN BANKET CONGLOMERATE: INFERENCE OF GOLD GRADE AND PALEO-TRANSPORT DIRECTION

GEORGE M. TETTEH
Department of Geological Engineering, University of Mines and Technology,
P. O. Box 237, Tarkwa, Ghana.

JUBILANT GBAGBO
Total Petroleum Ghana Ltd., Total House, 25 Liberia Road, P. O. Box 553, Accra, Ghana.

ABSTRACT
Tarkwaian Banket conglomerate at Tarkwa area contains rounded to sub-rounded quartz pebbles of which the B reef horizon has larger pebble sizes, showed preferred northeast-southwest orientation with their longest axes in the north to northwest and probably of SE paleo-transport direction. Interestingly, samples from zones with pebbles trending in northeast-southwest directions have higher gold grades. Pebbles of the B reef, trend towards the northwest and probably came from the east, and characterize highest average gold grade of 2.50 g/t while those with the averagetrend of SW were associated with lowest average grade of 1.95 g/t. Pebbles in the C reef trend towards the north to northwest and could have travelled from the east; those with the averagetrend of SE had a higher average grade of 1.12 g/t compared to the lower grade variety of 0.73 g/t which trends NW.

KEYWORDS: Tarkwaian, paleoplacer, quartz pebble trends, gold grade, paleo-transport direction

INTRODUCTION
Conglomerate is a clastic sedimentary rock that contains rounded fragments greater than two millimeters in diameter with the spaces between the clasts generally filled with smaller grains and or chemical precipitate that bind the grains together; bigger pebbles and heavy minerals may concentrate where great flow decelerates (Bridge and Demicco, 2008). Denser minerals are, usually, deposited with bigger pebbles, therefore, the larger the pebble sizes, t. he higher the grade and vice versa (Swensson, 1990). Many placers have undergone multiple stages of reworking and increased concentration. Immediately before deposition, non-spherical grains tend to be oriented to the bed-load transport direction (Bridge and Demicco, 2008).
The Tarkwaian is shallow water continental deposit derived from the Birimian. The paleo-sedimentary rocks were, probably formed from the freshwater deposition of sediments in high energy alluvial fans entering a steep basin (Sestini, 1973; Kesse, 1985; Strogen, 1988). The conglomerate consists of coarse-grained, poorly sorted, immature clasts with low roundness typical of a braided stream environment. Angular pebbles mostly have their longest axis oriented in the direction of flow before deposition while rounded pebbles which are primarily aligned such that their maximum projection planes dip upstream. Gold in the Tarkwaian conglomerate concentrate at the base of the pebbles (Kesse, 1985). Major opaque minerals located in the matrix are hematite and magnetite (Hirdes and Nunoo, 1994).
The Tarkwaian formation was affected by the Eburnean thermo-tectonic orogeny resulting in some folding, metamorphism and the introduction of granitoids (Black, 1980). The Tarkwaian had also been intruded by sills and dykes which are made up of medium to coarse-grained gabbro. These intrusives tend to dilute gold grade (Kesse, 1985).
In the Tarkwaian, gold grades link the sizes of pebbles such that the bigger the pebble sizes, the higher the gold grade (Kesse, 1985). There is no study on the correlation between gold grade and pebble orientation. This paper showed the connection between pebble sizes in conglomerate horizons, their orientation and relationship with gold mineralization.
The mine at the outskirts of Tarkwa in the Western Region of Ghanais about 85 km north-west of Takoradi and 240 km west of Accra.

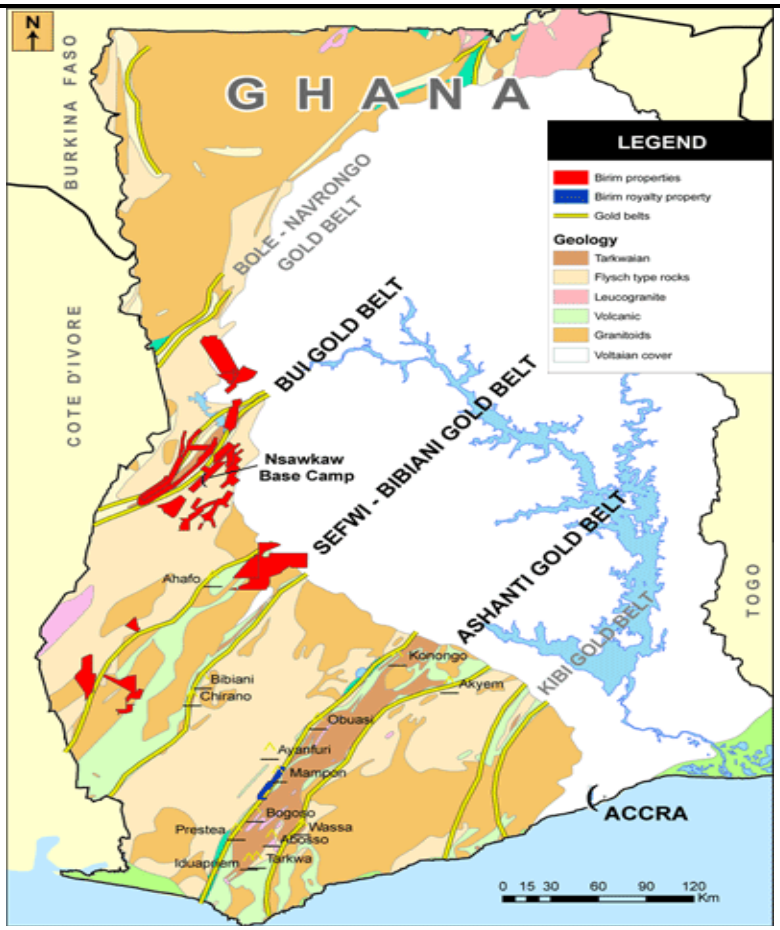

Fig. 1 Map of Ghana showing the location of Iduapriem and Tarkwa mines on the Tarkwaian Group (After, Junneret al., 1942)

The Birimian Supergroup underlying the Tarkwaian Group consists of metamorphosed lava and pyroclastic rock which contains abundant greywacke, phyllite and intrusive rocks. As a result of deformation, some of the metamorphic rocks contain chlorite which makes the rocks green, sheared and altered by the hydrothermal solution. The Tarkwaian group is subdivided into four main units in the order of younging (Table 1).

Table 1 Tarkwaian Group Stratigraphic Succession (After, Junner et al., 1942)

Rock	Thickness(m)	Composite Lithology
Huni sandstone	1370	Sandstone, grits, quartzite, phyllite (Dompim type).
Tarkwa Phyllite	120-400	Phyllite, chlorite-sericite schist
Banket Series	120-160	Tarkwa phyllite transitional beds and sandstones, quartzite, grits, brecciaand conglomerates.
Kawere Group	250-700	Sandstone, quartzite, grits, and conglomerate.

The Banket Reef zone comprises of individual quartz conglomerate beds (Bankets), Breccia, meta-sandstone (also called quartzite) and grits. Gold mineralization characterized the conglomerates specifically in the matrix and related to size and packing of quartz pebbles such that grain size of the free gold range between 0.002 mm and 0.500 mm and has a mean size of 0.130 mm (Kesse, 1985).Gold mineralization is placer deposited and not affected by metamorphism and hydrothermal alteration. Four reefs A, B, C and D may also be branded as Sub-basal, Basal (or Main), Middle and Breccia Reefs respectively. The grain size of free gold ranges between 2 and 500 microns and averages 130 microns. Traces of sulfide occur but have no significance with gold (Kesse 1985).

The Tarkwaian Group is folded into a syncline locally referred to as Tarkwa syncline. The dips vary due to variation in the extent of structural deformation. Thrust faults are contemporaneous with the fold (Anon., 2002).

World-class, quartz pebble conglomerate deposits, include Witwatersrand Supergroup of South Africa, Jacobina deposit of Brazil and the Tarkwaian group of Ghana. The rock types present in the Witwatersrand are oligomictic conglomerate found in less mature conglomerate and sandstone deposited on Archean granite and greenstone (Cox, 1967). Pebbles are well-rounded, well-sorted and well-packed; the mineralogy comprises quartz, gold, pyrite and other minor minerals (Allsop and Welke, 1986).

Rock types in the Jacobina paleoplacer deposit are auriferous oligomictic conglomerates, pyritic conglomerates and chaotic breccia layers (Filho and Lyer, 2001). The pebble sizes vary up to boulder size, and the matrix is of pure quartz sand, heavy minerals and pyritiferous (Scarpelli, 1991). The conglomerates are made of highly sorted, rounded quartz-pebbles to cobble sizes (Scarpelli, 1991).

Tarkwaian, oligomictic conglomerate with more than 90 percent pebbles comprize vein-quartz, quartzites and schist; p, ebbles, are sub-rounded to rounded moderate to well sorted, well packed and mature (Kesse, 1985).

Gold, mostly concentrated at 20 cm at the base of reefs which take the form of lenses of sorted conglomerate oriented along the direction of the paleo-flow, intercalated quartzites also contain detrital hematite and gold but gold content in a number of conglomerate bands is lower in middle horizon and far lower in the lowermost rudites and uppermost horizons (Kesse, 1985).

The concentration of placer deposits is largely controlled by hydraulic mechanism (Evans, 1993). The orientation of pebbles may lie flat, rest on an edge, or may assume any orientation. Variation in pebble sizes is dependent on the distance of transporting medium. The mean pebble sizes decrease exponentially in the direction of transport. These are mainly due to a downstream decrease in the bed shear stress and turbulence of the transport medium, such that most coarse grains are lost in the downstream direction (Bridge and Demicco, 2008). Downstream reduction in size due to progressive abrasion, associated with grain collision is less significant because only the bigger and softer pebbles suffer appreciable abrasion.

METHODS USED

Geological mapping of conglomerate horizons at a mine pit was conducted by measuring pebble sizes within blocks B and C reefs of the conglomerate horizons. The conglomerate horizons were grouped based on the average grades of the area such that Reef B and C have gold grade ranging from 1.00 to 3.50 g/t and 0.80 to 3.00 g/t respectively. Measured longest axes orientations were plotted using Georient software and correlated to gold grades using MS Excel.

RESULTS

The conglomeratic horizons comprize of quartz-pebble conglomerate and breccia. The banket is usually, interbedded by massive footwall quartzite which contains well-sorted grains (Fig.2). Table 2 shows pebble sizes and their orientations with corresponding gold grades. Figure 3 is a histogram to show correlation between pebble sizes and average gold grade in the B Reef. Rose diagrams of pebble orientations in the B and C Reefs are displayed in Figures 4A and B respectively.

Fig. 2 Banket Conglomerate showing well - Sorted Quartz Pebbles

Table 2 Pebble Size and Orientations in Conglomerate with Gold Grades

Reef	Pebble size range (mm)	No. of readings	Average Au grade (g/t)	Orientation (degrees)	No. of Readings	Average Au grade (g/t)
	10-15	52	2.01	100-150	5	2.5
	15-20	66	2.05	150-200	36	2.02
	20-25	40	2.08	200-250	50	1.95
	25-30	23	2.09	250-300	55	2.03
	30-35	5	2.16	300-350	42	2.12
B	35-40	4	2.28	350-360	2	2.44
	5-15	66	0.5	100-150	3	1.12
	15-25	42	0.75	150-200	34	0.8
	25-35	57	1.08	200-250	58	0.88
	35-45	16	1.39	250-300	62	0.84
	45-55	9	1.56	300-350	30	0.88
C				350-360	3	0.73

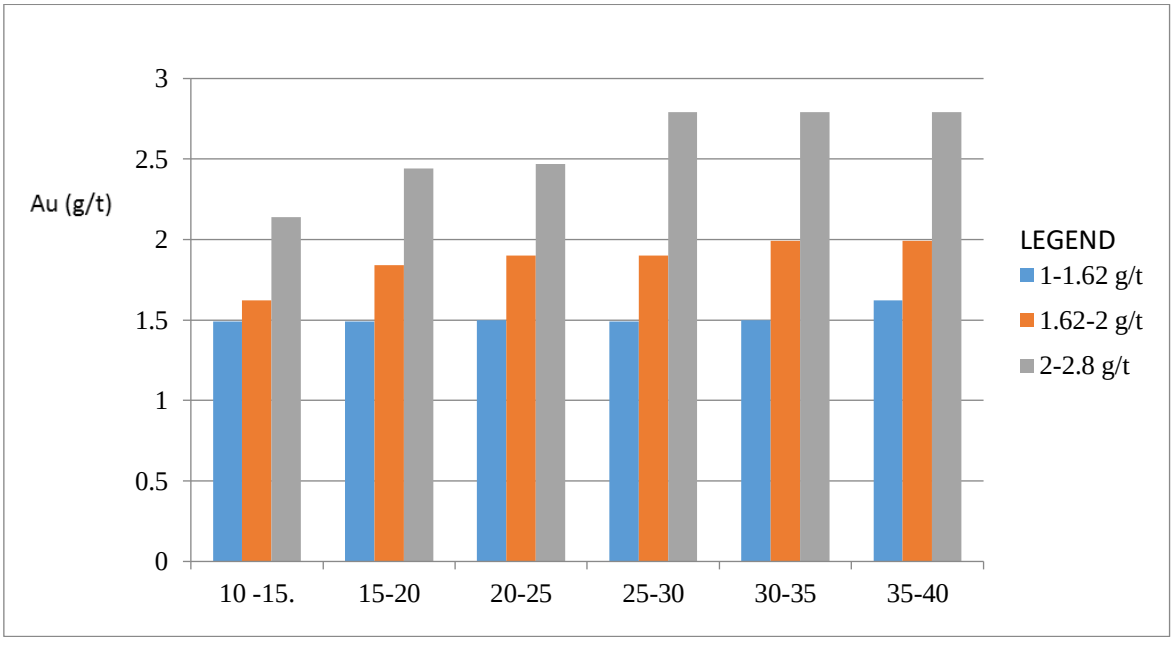

Fig. 3 Correlation of Pebble Sizes (mm) and Average Grade in B Reef

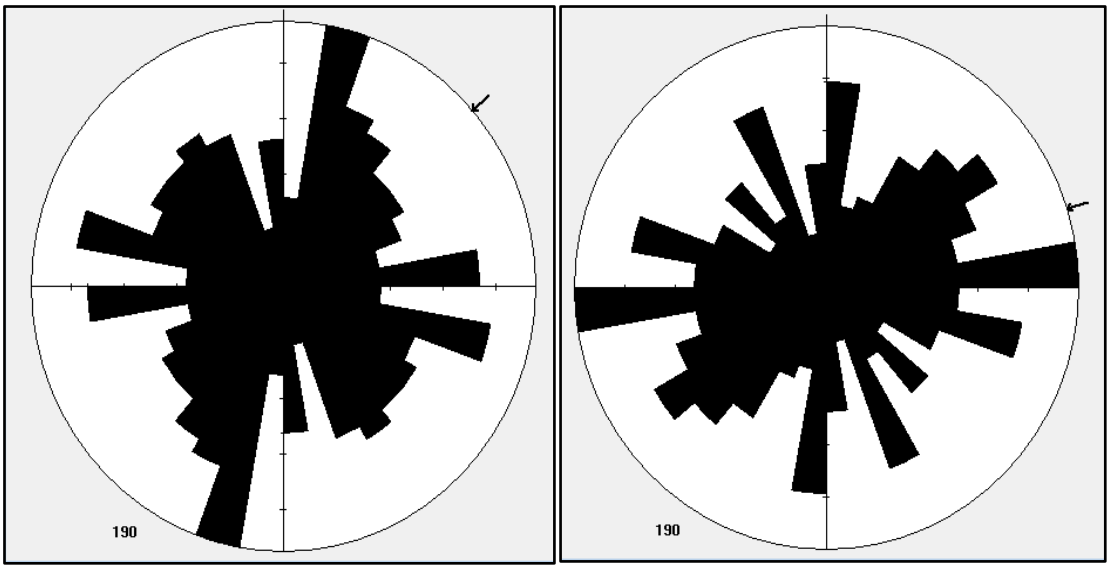

Fig. 4 Rose diagrams showing Pebble orientation in (A) B Reef and (B) C Reef

DISCUSSION

The B reef in the Tarkwaian Banket conglomerate consists of pebble sizes which range from 35 to 40 mm with higher average grade being (2.28 g/t); Pebble sizes which range from 20 to 25 mm correspond with medium average grade (2.08 g/t) and those which range from 10 to 15 mm have the lowest average grade (2.01 g/t) (Table 2). Pebbles of the B reef showed major preferred direction in the northeast-southwest (N49˚E-S229˚W) with minor orientation in northwest-southeast (Fig. 4A). Hirdes and Nunoo (1994) showed that prominent paleo-transport direction was north to north-west within the main reef of the Tarkwaian deposit. Bridge and Demicco (2008) showed that rounded to sub-rounded pebbles during transport tend to be oriented with their maximum axes dipping upstream. Hence, pebbles within the B reef of the Tarkwaian could dip upstream in the paleo-transport direction towards north to the northwest (Fig. 2). This is also base on the observation of C ollinson and Thompson (1989) that sedimentary particles transported by fluvial means have their principal axes perpendicular to the direction of transport. Since Kesse (1985) is of the view that Banket conglomerate was, also derived from the Birimian, it's pebbles could have been transported eastward from the Birimian. Pebbles within the B reef could have been from the east, trend averagely 125˚, have the highest average gold grade of 2.50 g/t while those with the average trend of 225˚ have the lowest average grade of 1.95 g/t (Table 2, Fig. 3).

The C reef conglomerate consists of pebble sizes which range from 45 to 55 mm with higher average grade (1.56 g/t); pebble sizes between 25 to 35 mm have medium grade (1.08 g/t),and those from 5 to 15 mm have the lowest average grade (0.50 g/t) (Table 2). Pebbles within the C reef also showed major preferred direction in the northeast-southwest (N72˚E-S252˚W) with minor orientation of northwest-southeast. Hirdes and Nunoo (1994) explained that prominent transport direction within the west reef was westwards and the second maxima to the north; southward transport direction is common in the west reef. Based on the deductions of Bridge (2008), pebbles of the C reef could trend upstream in the paleo-transport direction towards north to the northwest (Fig. 3). The source of C reef pebbles could be from the east which according to Kesse (1985) was due to uplift to the east of the Tarkwaian constructing a westerly paleo-slope to receive erosion materials from the Birimian terrain. Pebbles with the average trend of 125˚ have the highest average grade of 1.12 g/t, those with the average trend of 350˚ the lowest grade of 0.73 g/t (Table 2, Fig. 4B).Gold grade should, therefore, be modelled from trend of pebbles in order to find the source of highest gold in the Tarkwaian and track its relationship to the Birimian mineralization.

CONCLUSIONS

Tarkwaian Banket conglomerates at Tarkwa area have bigger pebbles in the B reef at about 35 to 45 mm size and 45 to 55 mm in the C reef. Gold grade is highest (2.28 g/t) in the B reef and 1.56 g/t in the C reef.

The conglomerate with the smallest pebbles (5 to 15 mm) has the lowest gold grade in the B reef (0.50 g/t), while conglomerate with the pebbles orientated to 125 ɵ correspond with highest average gold grade (2.50 g/t). In the C reef, pebbles at 125 ɵ have the highest average gold grade (1.12 g/t). The general direction of transport of the pebbles found in the conglomerate in the area could be from the east. Gold grade in the Banket conglomerate should, therefore, be modelled also on the trend of pebbles as the source of the gold in the Birimian could vary and of different gold mineralization potential.

REFERENCES

I. Allsopp, H. L. & Welke, H. J. (1986). Age limits to the Witwatersrand Supergroup. In: Anhaeusser, C. R. & Maske, S. (Eds.). Mineral Deposits of Southern Africa I. Geol. Soc. S. Afr., 495- 496.
II. Anon. (2002). Review of operations, Ghana.www.anglogold.com. Accessed: March 14, 2018.
III. Black, R. (1980). Precambrian of West Africa. Episodes, 4, 3-8.
IV. Bridge, J. & Demicco, R. (2008). Earth surface processes, landforms and sediment deposits. Cambridge University Press, Demicco R. (ed.).
V. Collinson, J. D. & Thompson D. B. (1989). The nature, process and origin of imbricated disc and blade-like clasts. Open File Report.
VI. Evans, A. M. (1993).Ore geology and industrial minerals; an introduction. Blackwell Scientific Publications, London.
VII. Hirdes, W. & Nunoo, B. (1994). The Proterozoic paleoplacers at Tarkwa Gold Mine, SW Ghana. Geol. Jb. D100, 260-272.
VIII. Hirdes, W, Saager R, & Leube A. (1988). New structural, radiometric and mineralogical aspects of the Au-bearing Tarkwaian Group of Ghana. Bicentennial Gold '88, Melbourne Abstr, 146-148.
IX. Junner, N. R., Hirst, T. & Service, H. (1942).The Tarkwa Goldfields. Gold Coast Geological Survey Memoir 6, Accra, Ghana.
X. Kesse, G. O. (1985). The Mineral and Rock Resources of Ghana. A.A. Balkema, Rotterdam, Netherlands.
XI. Scarpelli, W. (1991). Precambrian auriferous quartz pebble conglomerates in Brazil. Gisements Alluvianxd Or La Paz, 1(5), 261-273.
XII. Sestini, G. (1973). Sedimentology of a paleoplacer: The Gold-bearing Tarkwaian of Ghana. In: Ores in Sediments, Amstutz G. C., Bernard A. J., editors. International Union of Geological Science, Springer-Verlag, Heidelberg.
XIII. Strogen, P. (1988). The structure and sedimentology of the Tarkwaian, and its relevance to gold mining exploration and development. In: International Conference and Workshop on the Geology of Ghana with Special Emphasis on Gold Programme and Abstracts, Accra, Ghana.
XIV. Swensson, C. G. (1990). Early Tertiary deep dead gold deposit of Victoria. Geology of the Mineral Deposits in Australia and Papua New Guinea, The Australian Institute of Mining and Metallurgy, Melbourne, Hughes F. E. (ed.), 1637-1641.