The Geology of the Gold Deposits of Prestea Gold Belt of Ghana*

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Abstract

This paper presents the geology of the gold deposits along the Prestea gold belt of Ghana to assist exploration work for new orebodies along the belt. Prestea district is the third largest gold producer in West Africa after Obuasi and Tarkwa districts (over 250 metric tonnes Au during the last century). The gold deposits are structurally controlled and occur in a deep-seated fault or fissure zone that is regarded as the ore channel. This structure, which lies at the contact between metavolcanic and metasedimentary rocks in Birimian rocks, is more open (and contains more quartz lodes) at the southern end around Prestea than at Bogoso to the north. The gold deposits consist of the Quartz Vein Type, (QVT) and the Disseminated Sulphide Type (DST). The QVT orebodies, which generally carry higher Au grades, lie within a graphitic gouge in the fissure zones whilst the DST is found mostly in sheared or crushed rocks near the fissure zones.

Deposits were grouped into three in terms of geographic location and state of development; The deposits south of Prestea are the least developed but have been extensively explored by Takoradi Gold Company. Those at Prestea have been worked exclusively as underground mines on QVT orebodies by Prestea Goldfields Limited and its forerunners; Ariston and Ghana Main Reef companies until 1998 whilst the deposits north of Prestea, which were first worked as surface mines (on DST orebodies) by Marlu Mines up to 1952, were revived by Billiton Bogoso Gold in 1990.

Bogoso Gold Limited, a subsidiary of Golden Star Resources, now runs the mines, which are currently working "Oxide ore" (the oxidised derivate of the DST ore) by surface operations in open cut mines at Bogoso and Prestea. Active exploration is presently underway to find extensions to the orebodies and extend the life of the mines. The summary of the special attributes of the deposits presented in this paper may be useful in re-evaluation of the orebodies.

1 Introduction

The Prestea gold belt is situated at the southern end of the Ashanti volcanic greenstone gold belt, which is the most prominent of five evenly spaced, parallel running and NE trending sedimentary-volcanic belts found in the Birimian of Ghana (Fig. 1).

It is about 8 km wide and 50 km long and stretches from Opon River northwest of the Prestea township to Fura River in southwestern Ghana. Auriferous deposits located on the belt include (from northeast to southwest): Beppo, Bogoso, Marlu, Odumasi, Densu, Buesichem, Chuga, Nankafa, Broomassie, Abrefa, Prestea (Ariston), Anfargah, Bondaye-Tuappim, Gambia and Kutukrom orebodies. Prestea (Latitude 5° 26' and Longitude 2° 08') is at the centre of the belt (Fig 2). The concessions, which were the first mineral properties to be granted in the then Gold Coast, were taken in 1877 by Monsieur Pierre Bonnat of France ("The Father of mechanised mining in Ghana").

Up to 1957 the various deposits were developed and worked by several independent companies. For example, Marlu Gold mines worked the deposits at Bogoso, Odumasi and Beppo whilst Ariston (1926) Ltd worked at Prestea and the Gold Coast Main Reef (1929) Ltd concentrated on the deposits at Bondaye and Tuappim in the south. In 1960 the Government of Ghana bought the assets of the various companies along the belt and formed the Prestea Goldfields with limited liability under the Ghana State Gold Mining Corporation (SGMC) which, with the exception of Ashanti Gold mines at Obuasi, had taken over the management of all other gold mining operations in Ghana (including the Bibiani, Konongo, Dunkwa, and Tarkwa Goldfields).

Gold production by Prestea Goldfields Limited declined from an annual output of 110 533 fine oz Au in 1978 (Kesse, 1985) to 20 579 fine oz Au in 1988 (Appiah, 1991). The deposits at the northern section of the belt including Chujah, Odumasi and the operations of the defunct Marlu mines at Bogosu were ceded off and given to a new company the Canadian Bogoso Resources in 1990. In 1996, the Prestea Goldfields which had been the most productive mine of the SGMC (employing over 2,000 workers at its peak) was put on divestiture.

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Its assets were taken over by Barnex (Prestea)/JCI of South Africa with reductions of the underground operations that led to a final closure in September 1998. Ex-employees of Barnex then took over the running of the mine under a new company; the Prestea Gold Resources Limited (PGRL) and continued the underground mine operations till 2000 when proven underground reserves ran out. Currently mining activities at Prestea have been taken over by Bogoso Gold Limited a subsidiary of Golden Star Resources.

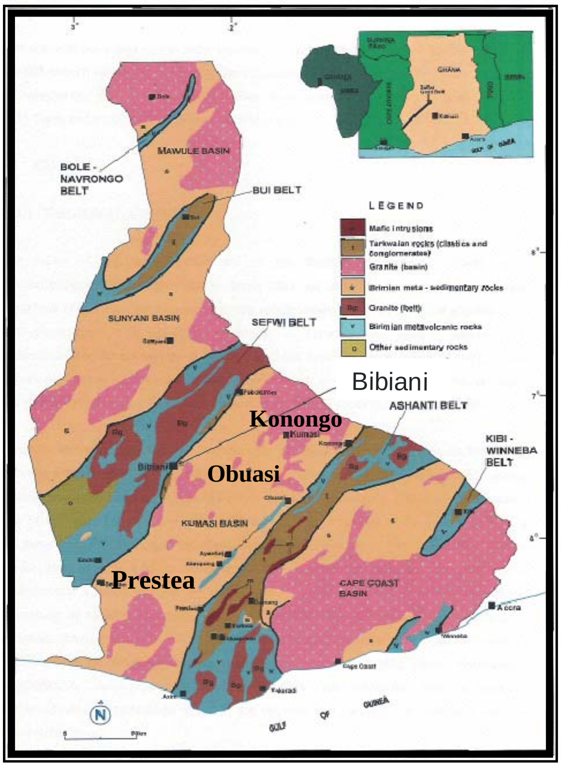

Fig. 1 Regional Geology of Western Ghana (*after Allibone et al., 2002*) showing Gold Deposits at Prestea, Bogoso, Obuasi and Konongo in the Northeast-striking Ashanti Gold Belt.

2 Geological Setting

The Prestea Gold belt is a typical Birimian volcanic gold belt. Birimian volcanic gold belts generally extend for more than 100 km in length and up to 40 km in width and are separated by basins of isoclinally folded metasedimentary rocks averaging 90 km in width. The belts consist predominantly of metamorphosed tholeiitic to calc-alkaline basalts and form synclinoria that are made of variable proportions of metamorphosed basaltic lavas of bimodal composition comprising andesitic and dacitic pyroclastic rocks and rarely rhyolitic rocks (Abouchami *et al*., 1990).

Volcanoclastic rocks, which form a minor constituent of the volcanic belts, become more dominant in the intervening basins especially near the margins but subside, giving way to fine-grained wackes of similar rock chemistry towards the centre of the basins (Hirdes et al., 1988, Sylvester and Attoh, 1992; Hirdes *et al*., 1993). The lowest part of the belt is dominated by metamorphosed tholeiitic basalts with pillow structures and variolitic textures (Hirdes *et al.*, 1993).

3 Structure and Metamorphism

Birimian rocks are isoclinally folded and form an overthrust fold with axis trending NE and near vertical axial planes dipping from 65° to 90° (Leube *et al*., 1990). Regionally, two deformation types, low strain and high strain, are recognised in Birimian rocks (Ledru *et al*., 1988; Eisenlohr 1989; Eisenlohr and Hirdes, 1992). The low strain deformation resulted in development of NE trending sub-vertical (S_1) foliation whilst rocks of the high strain deformation occur mostly along the northwestern margins of the volcanic belts near the contact with the Tarkwaian rocks and is characterised by a more intense penetrative NE trending (S_2) foliation that is represented by development of elongate recrystallised quartz grains and well

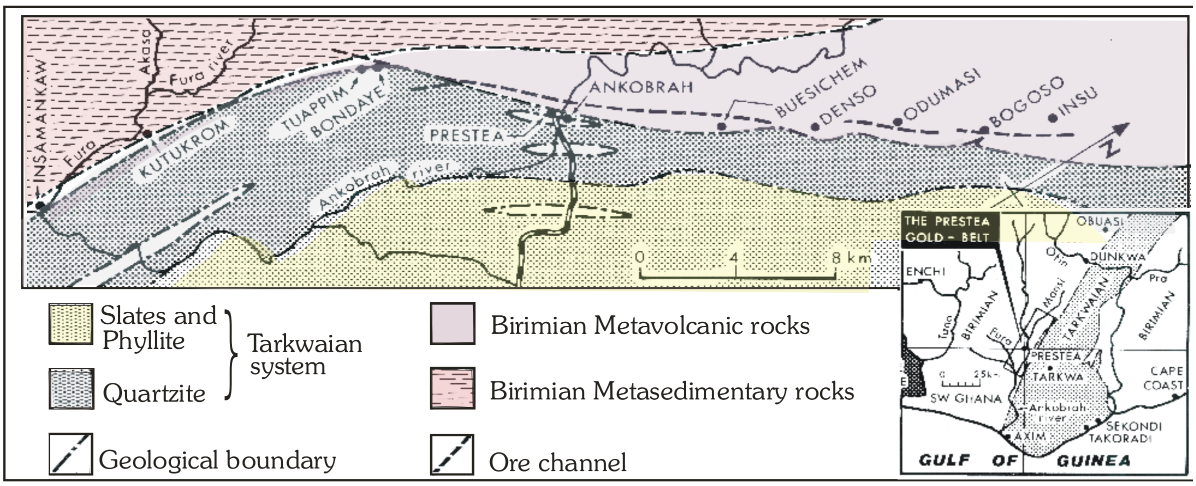

Fig. 2 Geology of the Prestea Gold-Belt (*modified after Cooper, 1932*)

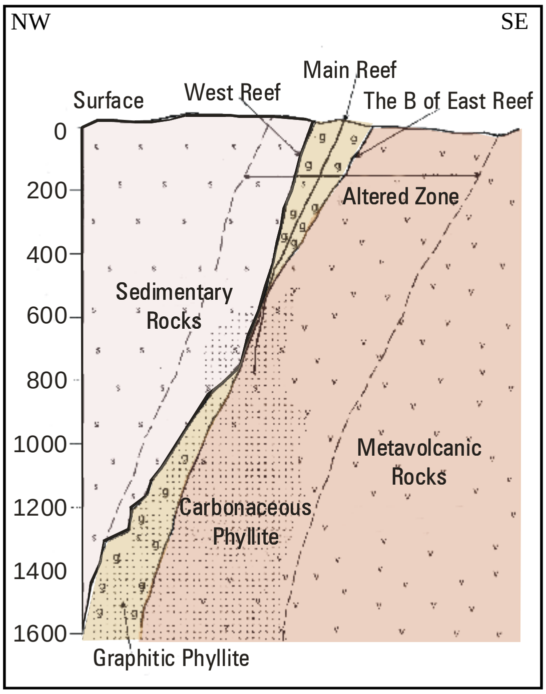

Fig. 3 Schematic Section of the Prestea Mine indicating Various Reef Zones (*modified after Appiah and Baafi, 1991).*

aligned phyllosilicates. The Birimian-Tarkwaian contact is strongly tectonised with repetition of stratigraphy; overturned bedding and the stretching lineation orientation indicating that the Birimian volcanic rocks were thrust obliquely onto the Tarkwaian rocks. Milesi *et al.,* (1989) and (1991) referred to the two deformations as compressive Dl and D2 deformations and associated them with Eburnean I and Eburnean II Orogenic Events. The orebodies at Prestea are hosted by complex shear zones located on the inverted limb of overturned folds (Cooper, 1934; Eisenlohr, 1989). In mine environs, thick sequences of northwesterly dipping phyllites, carbonaceous phyllites, metatuffs, metagreywackes and schists which have been isoclinally folded form overthrust faults and shear planes that trend northeast in many places. In the mines at Prestea, three ore channels are recognised as the Main, West and East "Reef' channels (Fig. 3). The Main "Reef' channel contains the most persistent and productive orebodies. The other reef channels that lie respectively west and east of the Main "Reef' channel are not as wide and as persistent and are generally considered as spurs of the main ore channel. The West "Reef' orebody dips at 65° NW and has a width ranging from a few centimetres to 0.9 m. whilst the East or B "Reef' has a width of 0.3-0.5 m. Generally, the ore channels are strongest, and the auriferous lenses of quartz are largest, in the section of the fissure zone between Prestea and Broomassie. From Denso to beyond Bogosu North and Beppo the reef zone

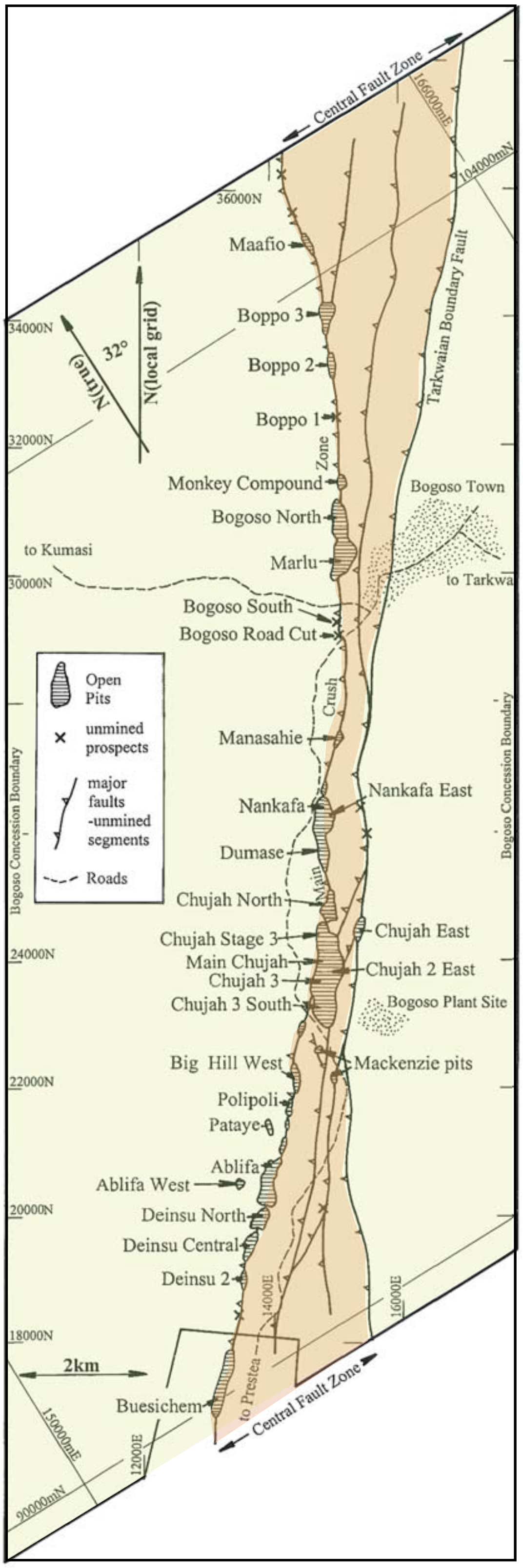

Fig. 4 Map of the Bogoso District illustrating the Location of Various Open Pits, Key Prospects located along 2-4 km wide N-NE striking fault zone (*after Allibone et al., 2002*)

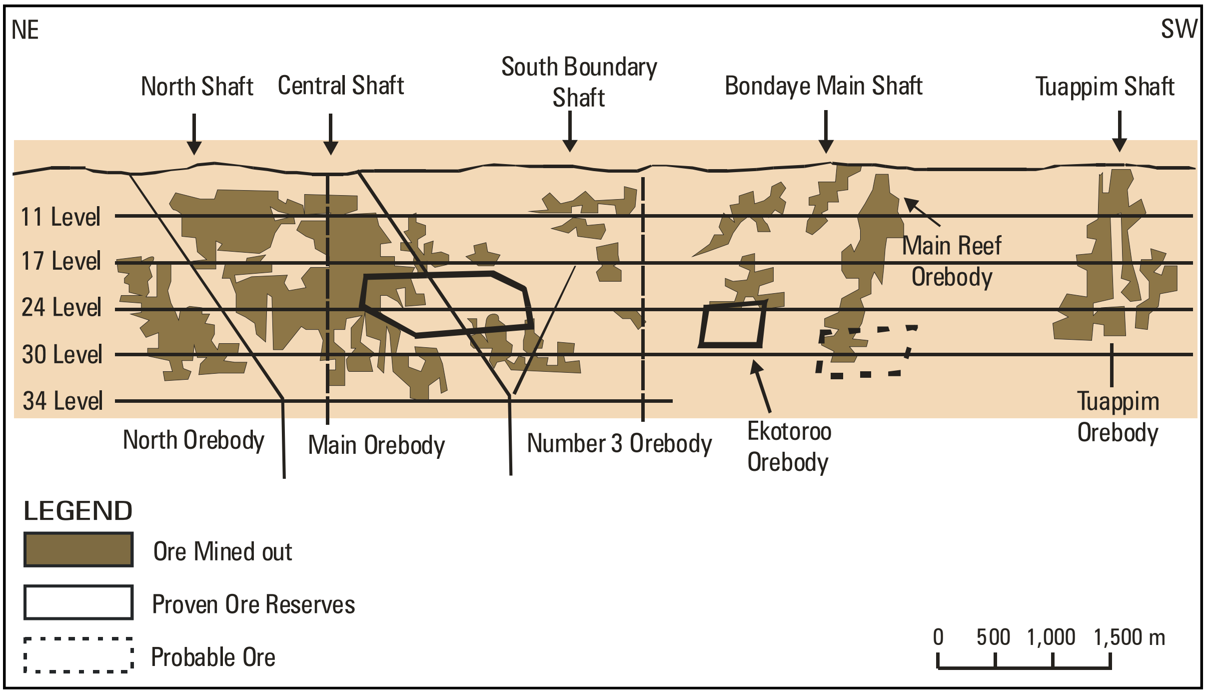

Fig. 5 The Longitudinal Section through Prestea Goldfields showing the Position of the Orebodies (*after Adadey, 1991*)

consists in places of wide crush zones containing lenses of quartz and mineralised crushed schist. Two and, in places, three or more parallel lines of auriferous lodes occur in the ore channel. At Bogoso, Allibone *et al.*, (2002) reported that the orebodies are commonly localised in left-handed dilatorial jogs in the strike of the controlling faults. The jogs coincide with intersecting minor faults (Fig. 4). The graphitic gouge generally defines the fault zones. The major ore zone is referred to as the Central fault zone. It contains the main Crush zone along the western boundary of the Central fault zone and is the largest of the four distinctive NE-ENE striking major faults. The main Crush zone dips 40° to 70° NW. Granitoid emplacements that intruded Birimian rocks during the Eburnean orogeny at 2. 1 ± 0.l Ga (Cohen *et al.*, 1984) caused deformation and metamorphism to between pumpellyite-prehnite facies and almandine- amphibolite facies with most of the rocks being in the chlorite subfacies of the greenschist facies (Hirdes *et al.*, 1993). Regional metamorphism does not exceed the greenschist/amphibolite transition (Eisenlohr, 1989; Eisenlohr and Hirdes, 1992), with quartz + muscovite as the typical metamorphic assemblages in the pelitic rocks. The absence of biotite is cited to indicate that the metamorphism did not exceed 420 °C. John *et al.*, (1999), however, believe that all the rocks in the Ashanti greenstone belt have experienced a clockwise P-T path through peak amphibolite facies conditions to retrograde greenschist facies conditions with typical mineral assemblages consisting of plagioclase-amphibole-quartz-epidote ± biotite ± chlorite ± sphene ± ilmenite ± sulphides ± carbonate ± K-feldspar.

4 The Auriferous Deposits

The gold deposits along the belt may be grouped into four depending on the style of mineralisation and level of development as:

* Gold Deposits at Prestea
* Gold Occurrences south of Prestea
* Gold Occurrences north of Prestea
* Deposits at Bogoso

The deposits lie predominantly in the metavolcanic rocks along a shear zone that closely follows the Birimian-Tarkwaian contact and extends for a strike length of 16 km (Fig. 2).

Generally, the main ore channel follows the contact between the Birimian rocks to the west and the Tarkwaian rocks to the east. However, towards the NE and SW ends of the gold belt, Tarkwaian rocks are farther away from the ore channel than they are in the central section and the orebodies are located close to the contact of the metavolcanic and metasedimentary rocks.

4.1 The Gold Deposits at Prestea

Prestea gold deposits in the present discussion consist of all orebodies that lie from North Shaft (Ankobrah) through Prestea township to Tuappim in the SE, a distance of 10.8 km (Fig. 5). They are mostly developed as QVT underground workings and include, from north to south, the North orebody (at North Shaft), the Main orebody, and Nos.

2, and 3 orebodies (at the Central Shaft or Ariston mine); the South orebody (at Anfargah) and the Bondaye and Tuappim orebodies (at the southern end of the mine).

The QVT orebodies at Prestea occur in deep-seated faults or fissure zones consisting of a carbonaceous shear zone. The DST orebodies, on the other hand, are found in sheared rocks along the ore channels and are currently worked by surface operations. The orebodies in the Main Reef channel of Prestea are large composite quartz lenses that averaged about 500 m in length on the lower levels and in places are more than 12 m wide. The orebodies dip at about 70° NW and pitch to the southwest at low angles. The main orebody, which was about 1000 m long near the surface, petered out between the 10th and 13th levels, but increased in size from the 15th level and was mined down to 26th level where it finally pinched off.

The No. 2 and No. 3 orebodies were situated southwest of the main orebody. The No. 2 orebody was worked to the 35th level whilst the No.3 orebody, which lies below the South orebody, was developed from 24th level to 30th level. At the Central Shaft, Prestea, the QVT orebodies dip at 60°-70° NW but at Anfargah area dips become gentle and vary from 50° to 60° with a corresponding decrease of widths to between 0.60 m to 1.2 m. The country rocks are steep westerly-dipping carbonaceous phyllites, greywacke and sericite-schist. In places the lode channel cuts through a highly altered dyke and two basic dykes occur in the footwall rocks (Cooper, 1934). At Bondaye, three auriferous quartz lenses with dips ranging between 60° and 80°NW were worked. Several small traverse spur quartz veins occur in the footwall of the main lenses. The southwestern lens, which occurs in a channel of highly crushed black phyllites and schists and according to Cooper (1934), was about 200 m long, 1.6 m wide and averaged about 18 g/t Au. Steeply dipping, NE striking phyllites occur at the hangingwall of the orebody whilst the footwall is occupied by a decayed dyke which is followed to the southeast by ashes and carbonaceous phyllites dipping to the NNE. North of these quartz lenses, the ore channel cuts through a bulge in the dyke and a little further to the northeast, two auriferous quartz 60 to 100 m long occur. At its northern end, the quartz orebody curves to the east and dips to the north. The QVT orebodies at this section of the mine are connected with a thrust fault along the axis of a northerly pitching anticline. The Tuappim orebody, which is 180 m long and 2 m wide is nearly vertical and lies completely in sheared graphitic phyllite.

4.2 Gold Occurrences South of Prestea

The gold occurrences south of Prestea include Tintina, Insimankaw, Pejatwini and Tiakwa a distance of over 10 km. They are the least developed in the district. Insimankaw, Pejatwini and Tiakwa are situated respectively north, southeast and south of Kutukrom near the Fura Ankobra confluence.

- At Tintina. 2 km south southwest from Prestea railway station, two areas of old workings about a kilometre apart have been reported.
- At Insimankaw**,** a wide lenticular quartz lens striking N 10° E and dipping to the west at 85° occurs on top of a small hill. The country rocks are phyllite and ash.
- At Pejatwini the quartz lenses, showed some gold on dollying.
- At Tiakwa two northerly striking quartz lenses are exposed on the south bank of the Tiakwa stream. The east lens is hard and vertically dipping whilst west lens is inclined. Between these two lenses there is a zone of highly sheared auriferous quartz, about 0.6 m wide.

4.3 Gold Occurrences North of Prestea

At Broomassie**,** Cooper (1934), reported that the orebodies consist of large isolated lenses of quartz in a strong graphitic fault fissure, which is similar to that in which the orebodies occur at Prestea. The lenses are 150 m or more in length, 8 m or more in width and 200 m in depth. They dip at 65°-70° to the northwest and pitch to the southwest. A subsidiary quartz lens occurs in the hanging wall of the main channel and joins it at both ends. The wallrocks are grey and black phyllites and sericite schist, and the ore consists of laminated grey quartz and quartz-breccias similar to those at Prestea. Ankerite, pyrite, arsenopyrite and rarely galena are present in the quartz lenses. The ores were rich and the average grade nearly 27 g/t. to 29 g/t.

At Mpasem, 8 km northeast of Broomassie, the orebody, which is similar to the dark quartz-breccias of Prestea, is over 120 m long, trends ENE dips at a high angle to the NNW. The wall rocks are phyllite and greywacke. Hornstone carrying sulphides is exposed at 120-450 m NE of the old workings approximately along the reef line.

Buesichem lies about 1.6 km NE of Mpasem and was developed by means of open-cuts and a shaft. The deposit was worked at the surface for about 150 m (50 m NE and 100 m SW of the shaft). To the northeast the quartz lens, where it is exposed in an open-cut, has a width of 0.5-0.7 m and dips 70°-75° NW. The country rocks are phyllite and altered igneous rocks.

4.4 Deposits at Bogoso

The Bogoso deposits comprise about 20 pits scattered along an 18 km fault zone between Chujah and Insu (Fig. 4). The Bogoso mine is situated about 19 km NE of Prestea and consists of Chujah, Odumasie, Bogoso, Marlu, Bogoso North and the Beppo deposits.

4.4.1 Chujah

The Chujah pit was on a quartz lens carrying relatively low values and two low-grade disseminated orebodies in the oxidized zone. The main deposit consists of large lenticular masses of crushed schist with small lenses and stringers or quartz, located along and close to the contact between phyllites to the west and greenstones (lavas, tuffs and ashes) to the east. The deposit is traced for a length to some 1200 m and one section 330 m long, averages 5.6 g/t, over a width of 26 m. The core of the orebody averages 8.3 g/t, over a width of 10 m and a length of 200 m. Below the oxidised zone the ore is crushed graphitic schist with veinlets of quartz containing pyrite and arsenopyrite. The other deposit, lying some 300 m to the east of the main orebody, is traced for a length of 67 m. It consists of a narrow zone of mineralised quartz veins and crushed schist carrying lower values than the main deposit.

4.4.2 Odumasi

Odumasi workings lie north of Odumasi village and consist of two parallel northwesterly dipping zones of auriferous crushed schist containing quartz lenses and several transverse and branching veins of auriferous quartz (Fig 4). The country rocks are Birimian phyllites, ash and greywacke dipping generally to the NW; a decomposed basic igneous rock, similar to that at Bogoso North and Chujah, occurs in the hanging-wall of the westerly crush zone. The structure is a pitching over-folded anticline. Ore grades are lower than that at Marlu and Bogosu North, and the crush zone are narrower. Mansahaie lies between Odumasi and Bogoso and has three mineralized zones one of which has been traced for 240 m.

4.4.3 Marlu, Bogoso North and Beppo No. 1

Marlu is about 0.67 km northeast of Bogoso and the Bogoso North and Beppo No.1 workings are about a 0.4 km northeast of Marlu.

At Marlu the orebody consisted of a large lens of quartz, nearly 120 m long and up to 12 m wide, in a wide shear zone dipping steeply NW. Fault gouge is well developed on the hanging-wall of the reef. The country rocks are decayed ashes and phyllites dipping generally at about 70° NW. A decomposed basic rock occurs in the hanging-wall rocks.

The Bogoso deposit is a lenticular quartz orebody that ranges from 0.1 to 4 m in width, averaging 1.2 m; it trends NE and dips to the 60° NW. Old superficial workings extend for some 67 m to the SW and 100 m NE of No 2 shaft. The lode consists of greyish mottled quartz and the wall rocks are phyllites and altered lavas and tuffs.

4.4.4 Bogoso North and Beppo No. 1

There are two main ore channels in a wide belt of crushed mineralized phyllite traversed by innumerable veinlets of quartz. The eastern orebody, which dips 70° to 80° NW, consists partly of isolated small lenses of solid quartz, but mostly of crushed phyllite penetrated by abundant veinlets of quartz carrying some pyrite.

The west lode dips 35°-40° NW, parallel to the bedding of the wall rocks, which are thinly banded phyllites showing small- scale over folding. The quartz lens was 8 m wide in places and averaging about 7.5 g/t. In an adit to the southwest of, and below the other workings a small vein of quartz about 0.16 m wide occurs near the position of the west lode, and for practically the whole width between this vein and the east lode channel highly crushed phyllite, penetrated by veinlets of quartz. The ore in Bogoso North and Beppo No 1 occurs as disseminated deposits containing very finely divided gold.

5 Petrography

Brief petrographic descriptions of the main rock types found in the gold belt are provided in this section. Generally the metavolcanic rocks lie at the footwall side of the ore channels and metasedimentary rocks are encountered at the hangingwall side of the orebodies. Phyllites are found at the immediate footwall side of the orebodies with metawackes flanking the immediate hangingwall side as shown in Fig 3.

5.1 Metasedimentary Rocks

The metasedimentary rocks consist of phyllites and metawackes. Schists are rare. Carbonaceous matter, which is usually restricted to the dark bands in the metasedimentary rocks, is amorphous to X-ray diffraction and appears to have originated from organic matter in the metasedimentary rocks.
The phyllites range from soft and friable black carbonaceous and graphitic types to hard and compact greyish siliceous types and may be subdivided as:

- Grey siliceous phyllites
- Carbonaceous and graphitic phyllites
- Spotted or "Carbonated" phyllites and
- Tuffaceous phyllites

The grey siliceous phyllites are the most prominent and are characterised by development of parallel and alternating dark bands (composed of carbonaceous material and tiny flakes of sericite) and light -coloured bands of predominantly lensoid quartz grains (Fig. 6A). Groundmass quartz occurs either

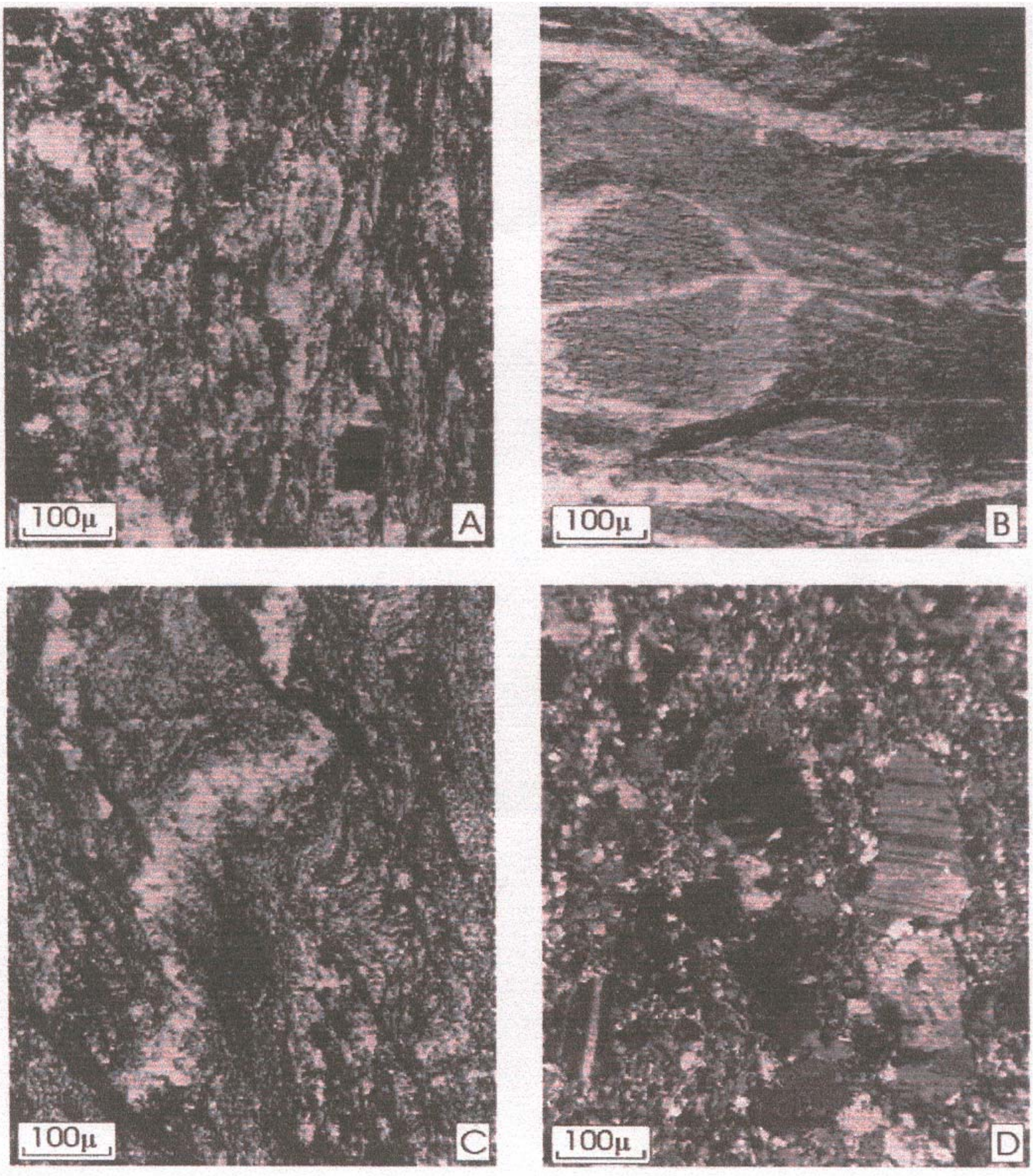

Fig. 6 Photomicrographs of the metasedimentary rocks_at Prestea (All pictures under cross polars). Sheared carbonaceous B Spotted Phylite C Graphitic Phyllite D Metawackes

as elongate single grains or as narrow lenses of pod-like aggregates which measure (0.02 to 0.01) mm by (0.01 to 0.05) mm. Porphyroblasts of cloudy, untwinned ferriferous carbonate are ubiquitous. Carbonate augen measuring (1.5 to 2.6) mm by (0.5 to 1.3) mm are particularly well developed in the immediate northwestern side of the main ore channel (Fig 5B). In this vicinity, knötenschiefer texture is prevalent and the rocks are described as "spotted phyllites". Carbonaceous matter, which occurs in all phyllitic rocks and averages between 4 to 10 % (modal), often rises to between 29 to 45 % (modal) with the rocks grading into black carbonaceous phyllite near the ore channels. Within fault zones carbonaceous matter develops into lustrous graphitic gouge, which surrounds the quartz lenses within the fissure zones where the carbonaceous matter rises to over 60%

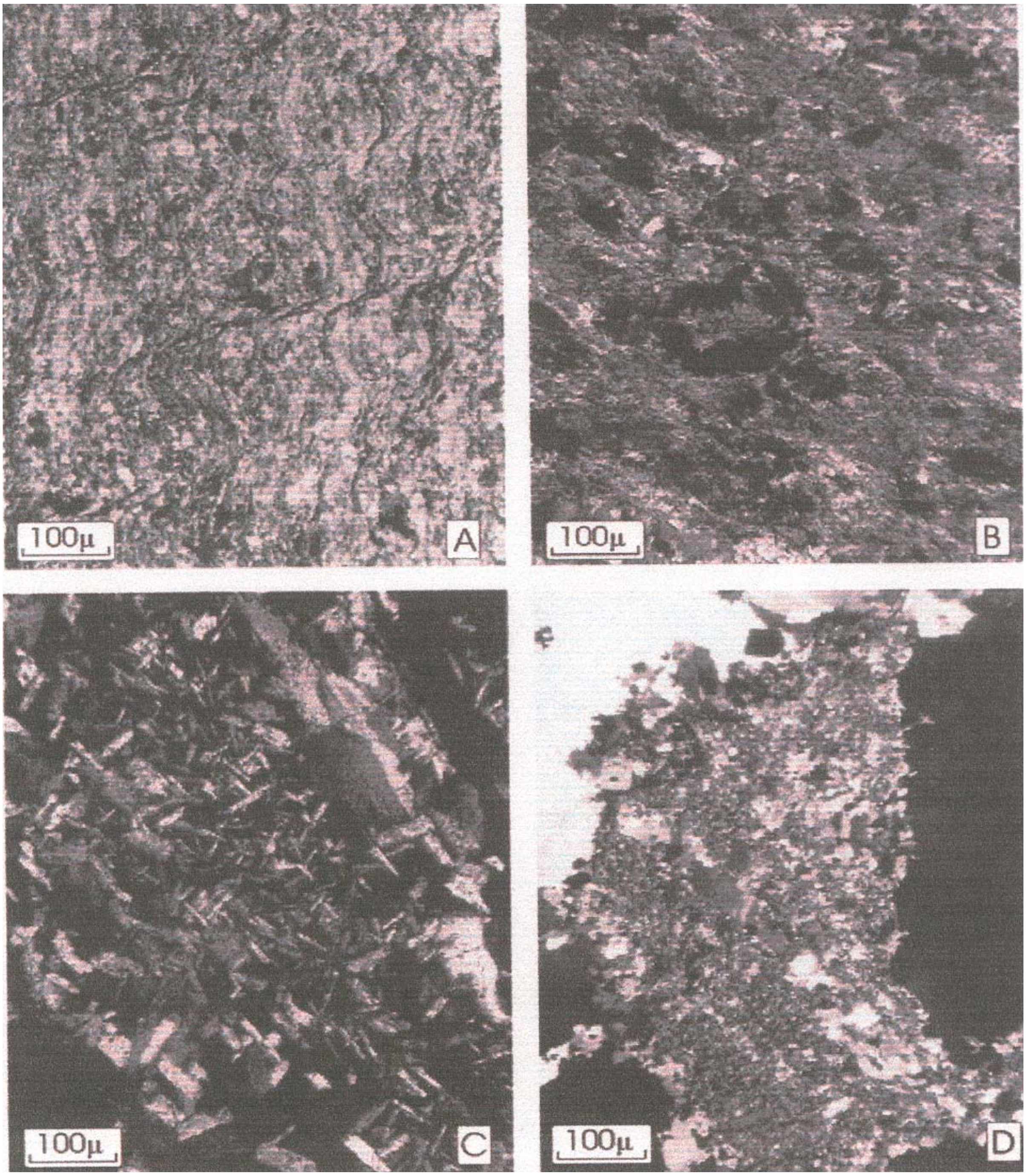

Fig. 7 Photomicrograph of the metavolcanic and igneous rocks: A. Tuff , B. Metavolcanic rock, C. Diabasic Dyke and D. QVT Orebody.

(modal). In these sections, the quartz veins are often folded, rolled and boudinaged giving rise to "sausage or ribbon" quartz veins in graphitic phyllite (Fig. 6C).

5.1.1 The Metawackes

The Metawackes are interbedded with the spotted phyllites and occur at the hangingwall side of the ore channel. No lithic fragments were seen in the rocks in thin section and samples of the rocks plot in the volcanic wacke field (Fig. 6). The metawackes are hard, grey, generally non-foliated and slightly arenaceous rocks composed of subangular sand-sized grains of quartz and feldspar randomly dispersed in a poorly sorted but finer grained matrix of quartz feldspar and clay minerals. Some of the feldspars are relatively fresh while others are saussuriterised to minute flakes of sericite. The matrix is generally very fine grained and is made up of silt-sized particles of quartz, carbonate, carbonaceous matter, sericite and chlorite (Fig. 6D).

5.1.2 Tuffs and Volcanoclastic Rocks

Volcanoclastic rocks of andesitic composition (Adjimah, 1988) consisting of ash and tuff occur among the felsic volcanic rocks to the SE of the ore- channels. Distinctions between the porphyroclastic and epiclastic rocks are difficult in the field, hence, the names 'tuffaceous phyllites' and 'tuff' as used on the mines are essentially descriptive; where the rocks are so fine grained as to be composed of dusty ash-size particles and appear to be volcanic they are recognised as tuff (Fig.7A). Microscopically, the tuffs are devoid of carbonaceous matter whilst in the tuffaceous phyllites, carbonaceous matter is essential component. Some samples of tuff appear to have been reworked and contain carbonaceous matter like the metasedimentary rocks, they are described as tuffaceous phyllites. The rocks are folded and have carbonate augens and flakes of sericite as found in phyllites.

5.2 Metavolcanic Rocks or Greenstones

The metavolcanic rocks or greenstones of the Prestea belt are metamorphosed volcanogenic flow rocks, which are interbedded with the epiclastic sediments. They are dark to greenish grey and are commonly described as "greenstones". They are massive and show flow structure and may be distinguished from the metasedimentary rocks by the general lack of foliation and the absence of carbonaceous matter. Two varieties of the greenstones are recognised in the mines of Prestea.

i. One type is an altered spilitic rock which occurs close to the ore channel and has the composition of silica deficient tholeiitic basalt (Adjimah, 1988). The original textures and minerals are obliterated and presently, the rock is composed of sericite, chlorite, carbonate and quartz. Parts of the rock now consist of ferruginous carbonate (siderite), which carry dendritic patches of opaque Fe and Ti ore minerals whilst some parts criss-crossed by quartz veinlets giving it a stockwork texture. Spilitisation has produced euhedral albite close to the margins and, often, inside the quartz networks (Fig. 7B).
ii. The second variety of metavolcanic rock was encountered at 7 1eve11/284 south cross-cut and 17 level/277 (footwall) cross-cut very close to the Birimian-Tarkwaian contact SE of the ore-channels and was identified as altered rhyodacite (keratophyre) (Adjimah, 1988). The rock is felsic, light grey in colour, dense and compact and non-foliated with micro-porphyritic in texture. Subhedral grains of quartz and albite occur in a very fine-grained groundmass of sericite, feldspar and possibly devitrified glass.

The greenstones contain disseminated aggregates of tiny rutile grains and pyrrhotite together with euhedral pyrite and idioblastic pyrite that are developed across the rock forming minerals.

5.3 Intrusive Igneous Rocks

Two intrusive igneous rocks occur at the footwall side of the ore channels on 7 level in 284 south crosscut. The most northerly is dark green in colour and the second dyke, which is emplaced due south is light grey and rhyolitic. Both intrusive rocks are emplaced parallel to the foliation of the enclosing metasedimentary rocks.

Diabasic dyke is micro-porphyritic to vitrophyric in texture with laths of zoisite and epidote as either columnar crystals or radial clusters in a very aphanitic groundmass in which are dispersed tiny crystals of feldspar and quartz. The rock has radiating clusters of zoisite, clinozoisite and augite in a matrix that is dominantly chloritoid (Fig. 7C).

Rhyodacite (Keratophyre) is dense glassy rock that is porphyritic with rounded quartz and feldspar in a very fine (almost) sub-microscopic groundmass of feldspar, quartz and sericite. Chemical composition of the rock (Adjimah 1988) shows that the rock is a trachyte but modal composition of 14 % feldspar with 69 % quartz suggests a rhyodacite which has been altered by carbonate and sericite alteration to a keratophyre.

6 Discussion

6.1 Structure

The structure and style of gold mineralisation along the gold belt is very similar to other Birimian lode gold deposits. The gold deposits are structurally controlled and the fissure or crushed zones are the controlling structure. The Main Reef channel is the dominant structural feature but the spurs or jogs that lie on either side of it (the East and West Reef) are major contributors. Shearing is an important feature to the gold mineralisation and metasedimentary rocks and the mineralised quartz veins are sheared. Unfractured quartz veins are generally barren. The deposits at Prestea have been developed by underground working whilst those at Bogosu have been worked mostly as surface operations. It appears the fault zone is more dilatant at Prestea giving rise to the development or more persistent and wider quartz lodes whilst the fault zone at Bogoso appears less open. At Bogoso, Allibone *et al*., (2002) have identified three distinct structural groups of ore mineralisation as:

- Ore shoots located at steeply pitching, left-handed flexures and splays
- Gently dipping ore shoots located at right-hand splays in bounding faults and
- Ore shoots in strongly discordant wall rocks with controlling faults.

Allibone *et al.*, (2002) concluded that gold mineralisation at Bogoso formed during a late minor phase of sinistral offset on a network of older thrust faults that originally developed early during the Eburnean 2 orogeny

6.2 Hydrothermal Alteration

Hydrothermal alteration is a prominent feature along the belt and is very prevalent along the ore channels. The most prominent alteration types, by characteristic mineral are carbonate, sericite, silica, and graphite (Leube *et al*., 1990; Dzigbodi-Adjimah, 1993). At least two generations of carbonate were observed in the rocks. These are the earlier clouded or dusty carbonate core that appears to post-date development of rock cleavage and a relatively younger clearer carbonate rim.

The carbonate is sheared and stretched into "augens" that are rotated by a later deformation episode. Sericitisation involving the addition of K and H and the removal of Na from wall rocks at the selvages, probably by plagioclase hydrolysis is also common and most high-grade sections in the quartz orebodies show good correlation between gold and sericite, pyrite and arsenopyrite. Gold association with green mica (flichsite mariposite) is also a notable feature especially in the QVT orebodies.

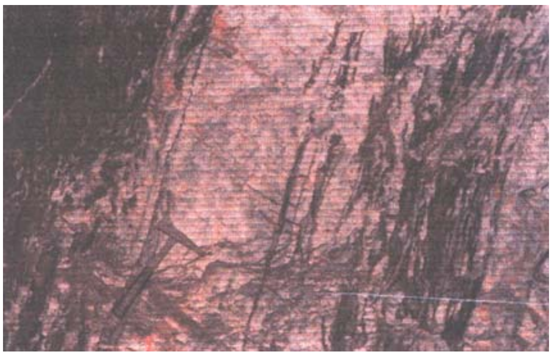

Fig. 8 The Orebody at Prestea with Inclusions (Xenoliths ?) of the Graphitic Phyllite

Silicification resulting in the formation of quartz veins is younger than rock deformation, as many of the veins lie parallel along foliation planes of the rocks. There are several generations of quartz veins as some are sheared, folded or fractured (Fig. 5C) whilst others are relatively undisturbed.

Graphitic alteration involves the conversion of carbonaceous matter (which is common in the metasedimentary rocks but not observed in the metavolcanic rocks) into "graphitic matter?' along the fissure zones. Though the carbonaceous material in the sediments is amorphous to X-ray, the "graphitic" matter found in the quartz lenses within the ore channels shows high anisotropism similar to graphite.

6.3 The QVT Orebody

The QVT orebodies are epigenetic veins that were emplaced along rock foliation. They have included partings of wall rocks (Figs 7D and 8) that underlie their "intrusive" nature. They do not portray any sedimentary features as current bedding, coloform banding or botryoidal textures and thus do not appear to be chemical sediments as suggested by Ntiamoah Agyakwa (1979); Sylvester and Attoh (1992) and Leube and Hirdes (1986). It is unclear how chemical sediments could have acquired these included fragments of wallrocks. Quartz vein emplacement and the continued subsequent shearing appear to be of primary importance for gold transport and precipitation. Fracturing of the quartz veins facilitates hydrothermal fluid ascent and probably rapid fluid degassing, resulting in Au-complex destabilization on a micro-scale as suggested by Leube *et al*., (1990).

7. Conclusions

The gold deposits along the Prestea gold belt have made substantial contributions to the Ghanaian economy over the last century and appear to have the potential of producing more gold in the future. The QVT orebodies at Prestea have been exploited down to a depth of 1 km whilst the accompanying DST ores have barely been touched. The reverse situation occurs at Bogoso where the QVT ores have not been extensively developed but most mine development has been on the "oxide ore" which is a weathered supergene product of the DST ore. The gold occurrences lying south of Prestea (from Tuappim to Nsamankaw) have hardly been touched and contain potentials for both QVT and DST along this 20 km stretch of the gold belt. In designing exploration programmes to re-evaluate the deposits, the following conclusions may be helpful:

- The gold deposits are all structurally controlled and the fissure or crushed zones are the main controlling structure. The "Main Reef' channel is the dominant structural feature but the spurs or jogs are major contributors.
- Shearing is an important feature to the gold mineralisation and all mineralised metasedimentary rocks and quartz veins are sheared. Un-fractured quartz veins are generally bar-

ren.

- Carbonaceous matter is an integral part of the metasedimentary rocks but is unknown in the metavolcanic rocks.
- The quartz veins are epigenetic metamorphogenic bodies that were emplaced along cleavage and foliation planes of the country rocks. They do not appear to be chemical sediments.

References

Abouchami, W., Boher, M., Michael, A. and Albarède, F., (1990), "A major 2.1 Ga event of mafic magmatism in West Africa: An early stage of crustal accretion". *Journal of Geophysical Research, 95, B11)*: pp. 17 605-17 629.

Adadey, E., (1991), "The Bondaye-Ekotokroo Mine – A Review", *Unpublished Report*, SGMC, 9 pp.

Adjimah, C. L., (1988), "Petrological Studies on the Genesis of Gold Deposits of Prestea, Ghana". (Unpublished). *Dr. rer. nat. Dissertation. Technische* Universität Berlin, 274 pp.

Allibone, A, Teasdale, J., Cameron, G., Etherige, M., Uttley, P., Soboh, A., Appiah-Kubi, J., Adanu, A., Arthur, R., Mamphey, J., Odoom, B., Zuta, J., Tsikata, A., Pataye, F., Famiyeh S., and Lamb, E., (2002), "Timing and Structural Controls on Gold Mineralisation at the Bogoso Gold Mine, Ghana, West Africa". *Economic Geology*, vol. 97, pp. 949-969.

Appiah, H. (1991), "Geology and Mine Exploration Trends of Prestea Goldfields, Ghana". *Journal of African Earth Sciences*, vol. 13, No. 2, pp. 235-241.

Appiah, H and Baafi, E., (1991), "An Overview of the Geology and Sampling Practices of Prestea Goldflelds". In G. O. Kesse (ed.), *Proceedings First National Conference on Mineral Exploration and Development and their Impact on the Economy of Ghana*. Accra, December 7 1990, Geological Society of Ghana, pp. 37-51.

Cohen, I., Snelling, N. J., Delhal, J. and Vail, J. R. (1984), *The Geochronology and Evolution of Africa.* Oxford: Clarendon Press, 512 pp.

Cooper, W. G. G., (1934), "The Geology of the Prestea Goldfleld". *Gold Coast Geological Survey, Memoir*. 3 46 pp.

Dzigbodi-Adjimah, K., (1991), "On the Genesis of Birimian Gold Deposits of Ghana". In G.O, Kesse (editor). *Proceedings International Conference on the Geology of Ghana with Special Emphasis on Gold*. Accra October 9-15 1988 Geological Society Ghana, vol. 1, pp. F1-F29.

Dzigbodi-Adjimah, K., (1992), "The Birimian Lode Gold Deposits: An Archaean Greenstone - type?". *In Proceedings Second National Conference*, Accra, December 6, 7, 1991, Geological Society of Ghana, Accra, pp. 125-146.

Dzigbodi-Adjimah K., (1993), "Geology and Geochemical Patterns of Birimian Gold Deposits, Ghana West Africa". *Journal of Geochemical Exploration. Elsevier Science* Publishers B. V. Amsterdam, vol. 47, pp. 305-320.

Eisenlohr, B. N., (1989), "The Structural Geology of the Birimian and Tarkwaian Rocks of the Southwestern Ghana". *Report of Technical Cooperation Project* No. 80, 20406. Ghanaian German Mineral Prospecting Project. Bundensanstalt für Geoswissenschaften, 66 pp.

Hirdes, W., Saager, R. and Leube, A. (1988), "The Tarkwaian Group of Ghana: Some thoughts Relating to its Setting, Age, Ore Mineralogy and Provenance. In G. O. Kesse, (ed.) *Proceedings International Conference on the Geology of Ghana with Special Emphasis on Gold*. Geological Society of Ghana, Accra, vol. 2, 31 pp.

Hirdes, W., Davis, D.W. and Eisenlohr, B. N., (1992), "Reassessment of Proterozoic Granitoid Ages in Ghana on the basis of U/Pb Zircon and Monazite Dating". *Precambrian Research*, vol. 56, pp. 89-96.

Hirdes, W., Senger, R., Adjei, J., Efa, E., Loh, G and Tettey, A., (1993), "Explanatory Notes for the Geological Map Southwestern Ghana 1:100 000". *Geoloisches Jahrbuuch*, Hanover, B83, 139 pp.

John, T., Klend, R., Hirdes, W., Loh, G., (1999), "The Metamorphic Evolution of the Paleoproterozoic (Birimian) volcanic Ashanti Belt (Ghana, West Africa)". *Precambrian Research* vol. 98 pp. 11-30.

Junner, N. R., (1935), "Gold in the Gold Coast". *Gold Coast Geological Survey Memoir No. 3*, 467 pp.

Kesse, G.O., (1985), *The Mineral and Rock Resources of Ghana*. Balkema, Rotterdam, 610 pp.

Ledru, P., Milesi, J. P., Vinchon, C., Ankrah, P. T., Johan, V., and Marcoux, E., (1988), Geology of the Birimian Series of Ghana. In Kesse G. O. (ed). *Proceedings of the International Conference on the Geology of Ghana with special emphasis on Gold.* Geological Society of Ghana, Accra, pp. 26-27.

Leube A., Hirdes, W., Mauer, R. and Kesse, G.O., (1990), "The Early Proterozoic Birimian Supergroup of Ghana and Some Aspects of its Associated Gold Mineralisation. *Precambrian Research,* vol. 46, pp. 139-165.

Leube, A. and Hirdes, W., (1986). "The Birimian Supergroup of Ghana - Depositional Environment, Structural Development and Conceptual Model of Early Proterozoic Suite. *Bundesanstalt fur Geowiss*. Rohstoffe, Hannover, (unpublished) 259 pp.

Milesi, J. R, Ledru, P., Vinchon, C. and Marcoux,. E., (1991), "The Metallogenetic Relation between Birimian and Tarkwaian Gold Deposits in Ghana. *Mineral Deposita*, vol. 26, pp. 228-238.

Milesi, J. P., Ledru, P., Febesse, J-L., Dommanget, A. and Marcoux, E., (1992), "Early Proterozoic Ore Deposits and Tectonics of the Birimian Orogenic Belt, West Africa". *Precambrian Research*, vol. 58, pp. 305-344.

Milesi, J. P., Ledru, P., Febesse, J-L., Dommanget, A. and Marcoux, E., Prost, A., Vinchon, C., Sylvain, J.P., Johan, V., Tegyey M., Calvez, J. Y. and Lagny, Ph., (1989), "West African gold deposits in the Lower Proterozoic Lithostructural Setting". *Chronologique Recherches Minieres* 497 Editions of BRGM, Orleans, France, 96 pp.

Mumin, A. H. and Fleet, M. E., (1995), "Evolution of Gold Mineralisation in the Ashanti Gold Belt; Ghana: Evidence from Carbonate Compositions and Paragenesis". *Mineralogy and Petrography*, *vol. 55*, pp. 265-280.

Ntiamoah Agyakwa, Y., (1979), "The Relationship between Gold and Manganese Mineralisation in the Birimian of West Africa". *Geological Magazine* vol. 116(5) pp. 345-352.

Sylvester, P. J. and Attoh, K., (1992), "Lithostratigraphy and Composition of 2.1 Ga Greenstone Belts of the West African Craton and their Bearing on Crustal Evolution and the Achaean Proterozoic Boundary". *Journal of Geology*, vol. 100, pp. 377-393.

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