

Gold Bearing Quartz Vein Dyke Swarms and Shear Zones in the Aburna Gold District and Its Implication as a Low Rank Dextral Shear System

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Abstract

This paper describes field mapping and structural analysis of the Aburna gold district to identify the structural controls on gold mineralization. The study links NE-trending shear corridors, quartz-carbonate-sulphide vein generations, and silica flooding to an orogenic gold system developed within a dextral transpressional setting. The main conclusion is that gold is concentrated in subsidiary shear zones within a broader regional Dextral shear framework. The structural data indicates that regional dextral shearing was responsible for a low rank dextral shear system. Subsidiary dextral shear systems create critical ore depositional space through a combination of shear extension and compression.

Keywords

Silica Flooding, Dextral, Transpressional, Orogenic Gold, Gold District

1. Introduction

Aburna gold district is located in the south western part of Eritrea (**Figure 1**).

Much exploration and mining activities in the map area were done during the old colonial times Jelence [1] in his book description Mineral Occurrences of Ethiopia. He further [1] explains that gold treatment equipment was installed at the bank of River Dase 4 km west of Aburna (outside the present map) in order to beneficiate the gold bearing quartz mined in various areas as follows: Jelence [1] gave the full description of individual quartz veins as follows: Gold bearing quartz deposit A [1] was the nearest to the treatment equipment. Open pit operations have

been developed along this quartz deposit. The results from deposit A are reported as 2.7 and 19 g. per metric tone of gold [1] is located 500 m east of the A deposit. The gold results reported during those years were 5 and 42.6 g. per tone of gold.

Gold bearing quartz deposit C [1] was the richest and gold was often visible. Small scale gold Production as well as minor research took place from 1915-1941. The stamps installed at this place had a capacity of 4 - 6 metric tons of gold ore daily. The reported gold result from gold bearing quartz deposit C was from an open-cut type. The ore from this quartz has indicated nearly 60 g. per metric ton of gold. All these quartz veins mentioned in [1] are basically situated in the Aber-teta shear zone and are part and parcel of the quartz vein dike swarms of this paper. Usoni [2] in his book *Minerarie Del Africa Orientale* describes the mining activities all over Eritrea during the old colonial mine. The present map area had less focus than other parts of Eritrea as a result of which many companies were working outside this area.

Regional mapping and rock geochemistry were also done south of the present map area [3].

Regional mapping and reconnaissance exploration works were also conducted south of the present map area [4]. Much broader transpersonal belts in Eritrea after [5] encircle the present map area (Figure 1).

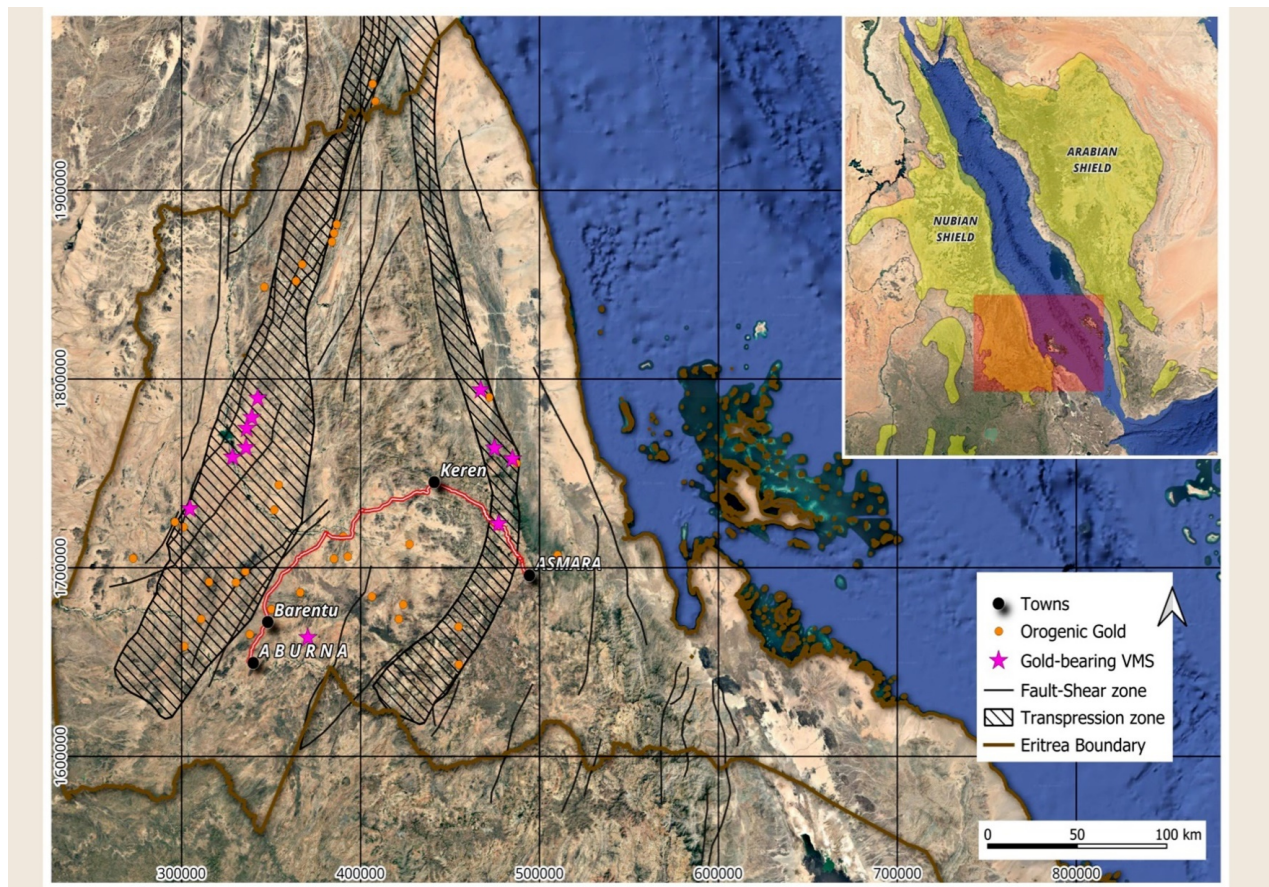


Figure 1. Aburna location map.

An integration of ASTER and Soil Survey Data by Principal Components Analysis in Southwestern Eritrea has been completed by [6]. Much recently Petrogenesis works were also done on Anagulu area south of the present map [7]. This last paper briefly explains Neoproterozoic Granodiorite hosting Porphyry copper Cu-Au mineralization in the Anagulu district, Western Eritrea: implication for tectonics and Porphyry Cu mineralization in the Arabian-Nubian Shield. The present mapping of Auburn gold prospect is bounded within the following coordinates (Table 1).

Table 1. UTM coordinates of the map area.

| ID | UTM E | UTM N |
|----|--------|---------|
| 1 | 340000 | 1648000 |
| 2 | 345000 | 1648000 |
| 3 | 340000 | 1657500 |
| 4 | 345000 | 1657500 |

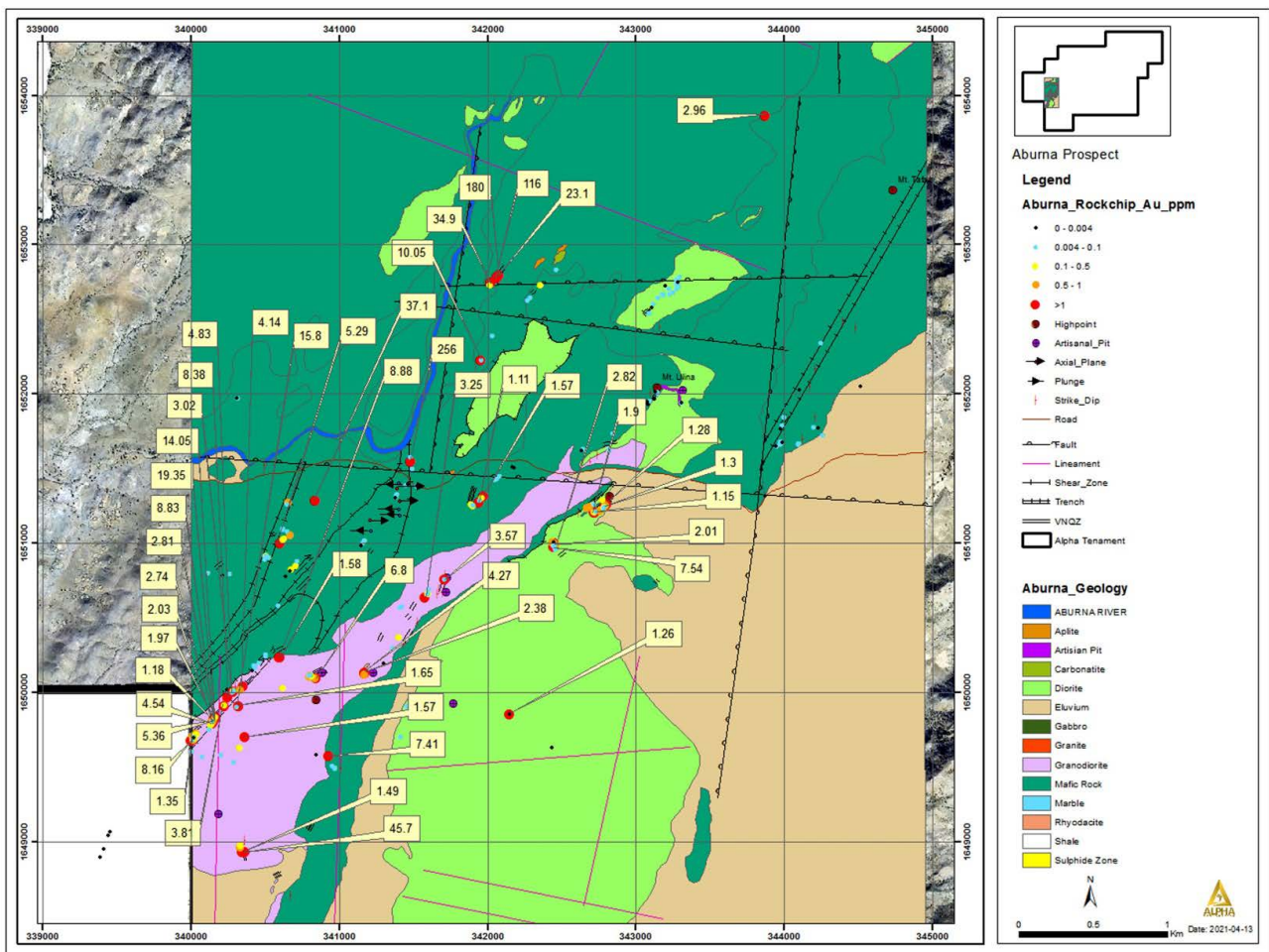


Figure 2. Gold grade distribution within Auburn gold district.

ented NE and appears to dip steeply to the south east. Within this sequence we have several gold targets including the old colonial mine and many other artisanal workings

Significant structural measurements were taken during mapping later augmented by Structural measurements from diamond core drilling. All gold analysis was made at the commercial laboratory ALS England and also at Intertek, Ghana.

One of the principal lithofacies at Aburna is a coarse grained porphyritic granodiorite which is the protolith of the gold bearing mylonite and schist hosting the auriferous quartz veins. Diorite and rhyolite dykes also are outcropping within the map area The granodiorite dike forms an elongated sub parallel to the regional Abereta shear zone and the old mines were in that particular shear.

During 1:5000 scale geological mapping four major shear zones have been identified namely Torina, Aburna Abereta and Tafafa shear zone (**Figure 3**).

The four major fault zones represent first order structures in the hierarchy of the fault system. Out of which the first three major shear zones are sub parallel to each other however the Tafafa shear zone seem to be at an angle to Abereta shear zone (**Figure 3**). The first three shear zones are developed sub parallel to each other.

The NE trending shear system encompassing most of the prospective targets is developed on the Structural foot wall of a large north east trending and south east dipping granodiorite body.

2. Analysis of Structural Data

Detailed geological and structural mapping shows that much of the geometry complexity of the supracrustal rocks of the Aburna prospect shows two principal generations identified as D1 and D2. D1 is the principal regional deformation and includes regional NE trending steeply dipping S1 foliation and associated gently plunging mineral stretching lineation L1 (**Figure 4(A)**). S1 is mainly defined by the preferred orientation of phyllosilicates in fine grained volcano-sedimentary rocks. This surface is dominantly oriented N29° and dips at an average of 67° towards the southeast (**Figure 4(A)**). The planes of S1 have a unimodal distribution and define a general NNE-trending strike and deep steeply towards the ESE with a dominant attitude of N29.63.° E (**Figure 4(A)**). The main S2 planes are oriented WNW, dip steeply towards NNE. This dominant crenulation cleavage is at times associated with two sub-sets of crenulation cleavages that are respectively oriented E-W with a dip of 50°s and NNW-SSE with a dip subhorizontal (**Figure 4(B)**). The dominant WNW trending S2 cleavages is coplaner with the axial plane of cm scale F2 Folds. F2 ranges from open buckle with rounded hinges to cm scale symmetrical crenulation folds with angular hinges (**Figure 4(C)**).

D1 appears to be the results of a bulk NW-SE horizontal compression and was dominated by a combined component of shortening and simple shearing. Ongoing deformation during D1 resulted in the formation of Major ductile brittle shear zone located along contrasting competencies. These shear zones recorded evidence of strike slip and oblique-slip faulting and are best interpreted in terms of trans-

pressional deformational zones [5].



Figure 4. (A) S1 foliation and L1 mineral Lineation. (B) S2 crenulation cleavage and F2 Fold Axes. (C) is plane view of chevron Like F2 fold hinge with angular hinge and plunging steeply to the East at Aburna shear zone. (D) V1 vein with dextral sense of movement, folds developed within the zone display an asymmetric geometry (Z-folds) indicating clockwise rotation of the fold limbs. (E) The only quartz vein mapped trending NW at Aburna old mine. (F) Nebulitic quartz veining with dextral sense of movement associated with gold mineralization at Torina shear. (G) Silica flooding at Aburna. (H) Old excavation at Abereta shear zone.

D2 structures are defined by steeply dipping and variably oriented crenulation cleavage that are best developed within strong anisotropic tectonites. S2 cleavages are axial planner to several styles of buckle folds.

3. Aburna Low Rank Shear Environment

The Aburna Gold district is characterized by low rank dextral shear zones referred as low-grade or shallow shear zones often forming under brittle or brittle-ductile environments. Typical example is that all Aburna rocks are characterized by brittle or semi-brittle behavior. Fault, breccias, and, shears are typical examples of brittle-ductile- transition.

4. Ductile-Brittle Shear Zone

Ductile deformation is very common at Aburna gold district and ductile shear zones are Abundant. The main deformation corridors defined as the Torina, Aburna, Abereeta and Tafafa shear zones and have been recognized and correspond to broad zones of schists and mylonites that can be followed along strike for more than 5 km. At the scale of the prospect these four Major fault zones represent first order structures in the hierarchy of the fault system. The steeply discontinuous ductile shear zones are oriented sub-parallel to or at low angle to the S1 foliation. Shear zone boundries have sharp contact. Quartz veins that have returned significant gold values occupy the central part of these anastomosing shears.

The southwestern end of the Tafafa ridge proved to have the most interesting geology in the form of one of the best exposures of a shear zone seen during mapping. A fine grained silty lithology develops intense ductile shearing which cuts the coarser tuffaceous host rocks to produce a series of tight fold structures deforming the quartz veining present (**Figure 4(D)**).

The ductile shearing strikes 030 whilst the surrounding fabric within the tuffs strikes 044. M folds are present which on a larger scale could be interpreted as saddle reefs.

5. Quartz Vein

Several quartz vein dyke swarms have been mapped between the three sub parallel shear zones Outcropping in the supracrustal rocks of Aburna gold district and the NE elongated granodiorite Hanging wall. Several mineralized quartz veins and altered host rocks have been identified at Aburna gold district. The principal auriferous vein set found in the central part of the ductile brittle shear zones and is composed of shear veins showing a dominant NE trend and a dip angle of 70° towards the SE. Quartz veins that have returned gold values appear to be confined to the most portion of the host shear zone. Gold return from quartz vein and alteration zones is both from surface exploration work and the present drilling activities. As far as the One significant location where we have encountered a NW oriented gold bearing vein is located between 340500 E and 1649000 N (**Figure 4(E)**). This is the only vein of an old mine trending NW which is also called the

perpendiculars because it is at high angle with dominant NE trending V1 vein. The mineralized quartz vein system comprises three generations of quartz-carbonate sulphide veins that include foliation parallel V1 veins and cross cutting V2A and V2B veins.

V1 veins are the most significant and display a dominant NE-trending orientation and sub parallel to the attitude of the prospective fault system.

V1 veins are the main veins that are parallel to S1 foliation in the schists and dykes. V1 veins whose orientation is NE-SW with a dip of 60 - 70° to the south east whose dimension ranges from few millimeter to 5cm thick. V1 veins exceeding 10 cm in thickness are rare but when observed they contain cm scale alteration of wall rock indicating that they were emplaced after initial development of the S1 foliation. Sometimes showing brecciated texture together with silica flooding. Significantly the quartz veining associated with gold mineralisation, which lies within the main foliation, is, in places, nebulitic and unstrained, but is also affected by the shearing (**Figure 4(F)** and **Figure 4(G)**).

V1 veins do extend for tens of meters along strike. V1 veins are related to the main gold mineralization stage on the structural foot wall of a large north east trending and south east dipping granodiorite body where old mining works were practiced (**Figure 4(H)**). It has been emplaced after the buildup of high fluid pressure in their host rocks (**Figure 5(A)** and **Figure 5(B)**).



A



B

Figure 5. Both photos (A) and (B) show a ductile shear zones at Tafafa. Quartz veins are deformed. M folds are developed and are within the NE trending brittle-ductile shear zone, the location of which is at UTM coordinate 343971E 1651676 N.

V2 veins are late cross cutting planer lodes that transact obliquely the S1 foliation and the lithological contacts (Figure 6). These veins are 1 mm to 2 cm in width and are composed of various proportions of quartz carbonate and sericite. V2 are generally surrounded by well-developed alteration envelopes of sericite and quartz giving a bleached appearance to the host lithology.

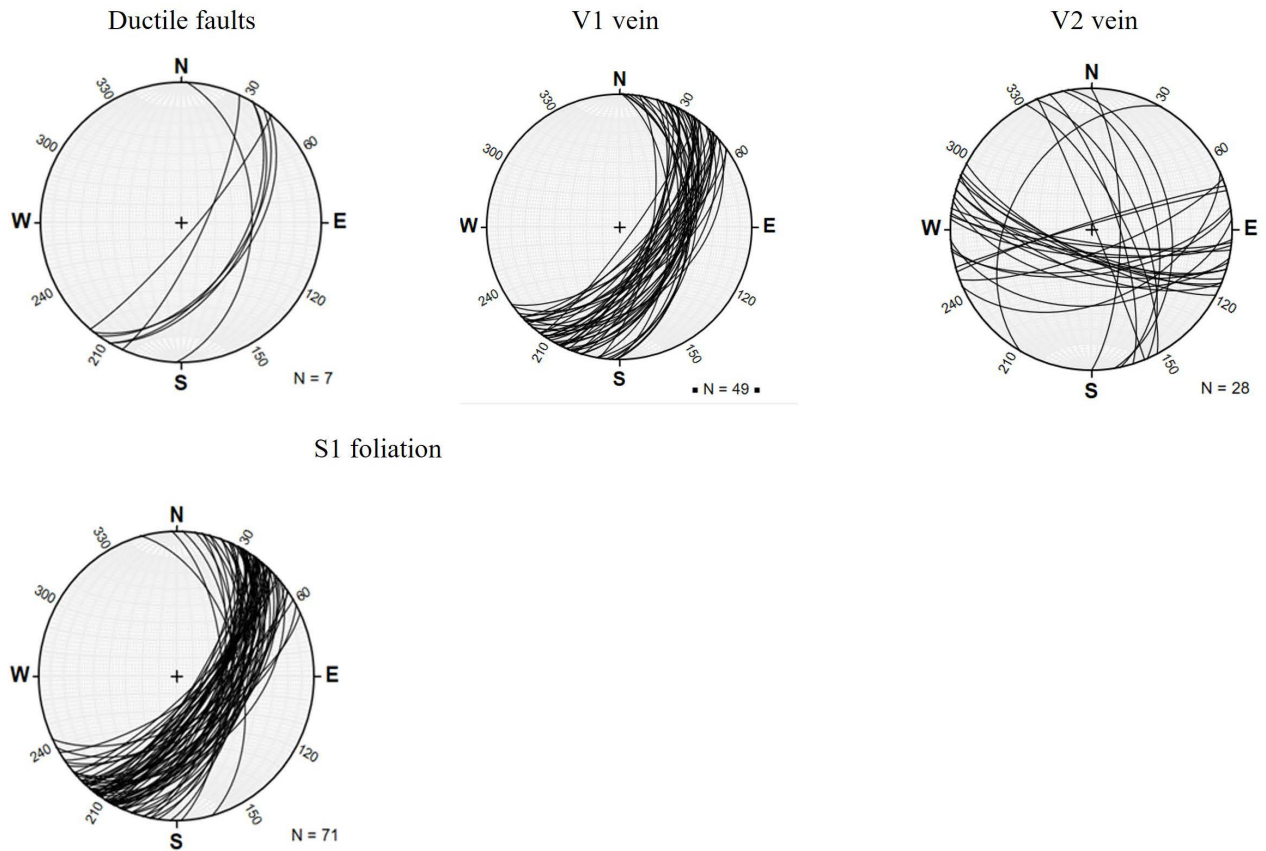


Figure 6. Equal area stereographic projections of ductile-brittle shear zones and shear Veins (V1 and V2) measured at Aburna. Note the parallelism of V1 veins and S1 foliation.

V2 are subdivided in to two sets (V2A and V2B) according to their orientation and geometrical Relationship. V2A veins are commonly oriented East-West and dip sub vertical. The east west veins are results of extensional fractures from the component of vertical extension along and within the fault zone. Although V2A veins are in the geometric position of extensional fractures relative to the regional NW-SE shortening during regional D1 deformation these veins are texturally massive and devoid of opening textures such as cavities or mineral fibers.

V2B veins are similar in mineralogy to V2A but are dominantly NS trending and dip approximately 70° towards the east (Figure 7). Both sets of V2 veins are almost perpendicular and are clearly not conjugate in geometer (Figure 8). V2 veins could potentially represent quartz-filled extensional joints. V2A and V2B often contain comb-textured mineral fillings (e.g., quartz, tourmaline) that indicate growth perpendicular to the vein walls. This Perpendicular growth is charac-

teristic of extension fractures where walls move apart.

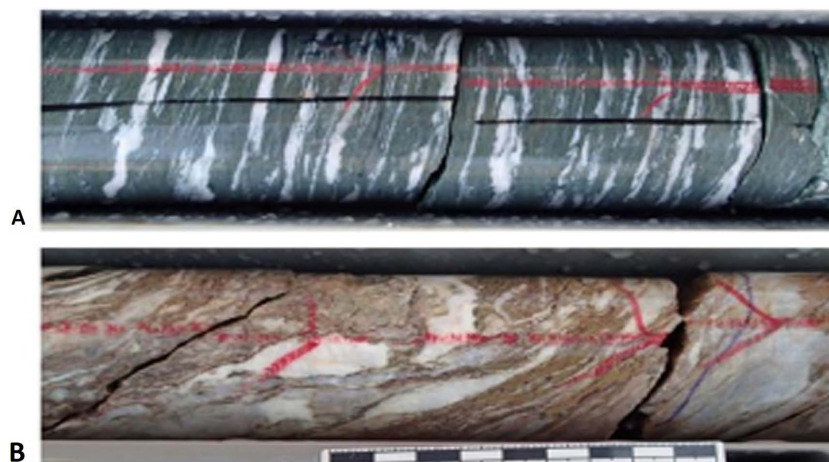


Figure 7. Quartz vein generations at Aburna gold district. Typical V1 veins observed at Hill 52 (Torina shear zone). (A) Foliation-parallel V1 veins of quartz and calcite in the chlorite-carbonate schists, ABD011, 90 m; (B) Deformed V1 veins in ductile-brittle fault overprinting a felsic dyke. ABD012, 207 m.



Figure 8. Quartz vein V2 generations at Aburna gold district. V2 veins at Hill 52. (A) V2 veins in a chlorite, carbonate, and epidote schists ABD011, 89 m. (B) V2B veins of calcite crosscutting quartz-carbonate-pyrite V1 vein in a fault zone, ABD014, 185 - 188 m. (C) Left, N-trending vertical V2 vein crosscutting S1 in an anticlockwise sense, Right, E-W-trending v2 veins crosscutting S1 in a clockwise direction, ABD011, 81 and 84 m.

6. Zone of Silica Flooding

Zone of silica flooding refers to an area of rock where pervasive hydrothermal fluids have deposited quartz or other silica minerals completely soaking and replacing the original rock matrix (**Figure 9(A)**). Silicification is a process in which silica rich fluids seep in to the voids of rocks and replace the original material with

silica (**Figure 9(B)**). The presence of hydrothermal fluid is essential as a medium for geochemical reaction during silicification. The replacement of silica involves two processes namely dissolution of rock minerals and precipitation of silica which is a typical case here in Aburna both on surface and on drill holes. In my first logging of the first Aburna diamond hole ABD001 I have noticed that rocks have undergone more than 30-40% silicification and alteration.



Figure 9. Core drill photographs of silica flooding. (A) ABD012, 117 m; (B) Silica flooding within a major ductile-brittle fault ABD013 from 36 to 41 m.

The silica flooding zones are typically parallel to S1 and /or to the boundaries of their host fault zones. Pyrite (disseminated pyrite) with variable chlorite sericite-carbonate alteration also appears to be associated with the silica flooded zone. It is suggested that these zones represent fluid pathways for the rising Au-bearing hydrothermal fluids. In addition to intense silicification, the mineralized rocks are characterized by a pervasive bleaching of wall rocks. The bleached Alteration faces is a mixture of Sericite-carbonate quartz and very fine grained disseminated Pyrite. Gold is also associated with silica flooding zones and with carbonate-Sericite pyrite alteration.

7. Discussion

This report summarizes the result of a field based structural and geological mapping conducted at a scale of 1:5000 in 2019-2020 and added some drilling photographs done on the mapped shear zones then after.

Pronounced rheological contrasts between the competent intrusive rocks and the volcano-sedimentary units prompted the development of a large anastomosing shear zone system encompassing the gold bearing targets. The orogenic gold mineralization corresponds to disseminated pyrite in the host rock and to abundant quartz-carbonate + -sulphide veins and veinlets. The mineralized system comprises three generations of quartz-carbonate sulphide veins that include foli-

ation-parallel V1 veins, and crosscutting V2A and V2B veins.

Gold is also associated with silica flooded zones and with carbonate-sericite pyrite alteration (**Figure 9**).

The mineralized corridor at Torina shear is open to the northeast and apparently weakening the southwest. There is good depth and along strike potential to the north east. V1 veins are the most significant and display a dominant NE-trending orientation and are sub parallel to the attitude of the prospective fault system. V1 veins were the first to be emplaced and occupy openings created by the over-riding of undulations and irregularities of S1 foliation and slip planes during progressive dextral shearing movement. In this model, V2A and V2B veins represent synthetic (R) and antithetic (R') respectively (**Figure 10**).

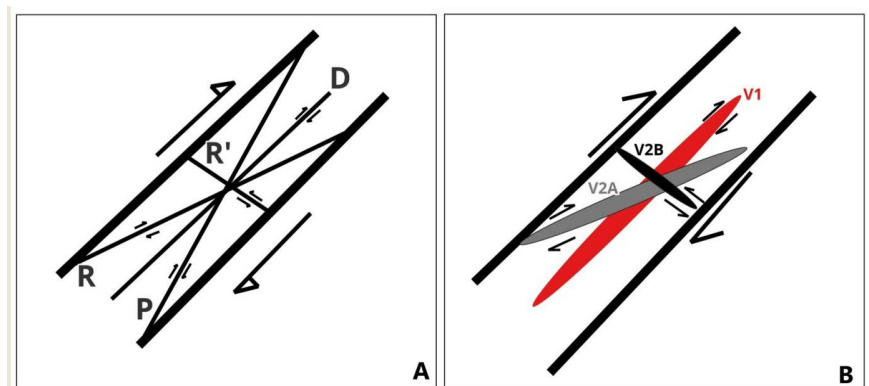


Figure 10. Schematic summary representation of shear and quartz vein generations at Aburna gold district. (A) Typical pattern of Riedal shear fractures formed in a strike slip dextral faults zones. In this model V1 are parallel to the shear zone boundaries and correspond to D shear, V2A cut V1 at small clockwise acute angle and are similar to synthetic Riedals R while V2B are similar to antithetic Riedals (R'). (B) Sketch showing the structural relationship between V1, V2A and V2b veins within a dextral fault zone. Due to pervasive carbonatization and sericitization along the D1 structures (*i.e.* S1 planes, D1 faults) at Aburna have acted as the main fluid conducted for the rising Au-bearing hydrothermal fluids. The v1 quartz veining and the steep silica flooding zones are best developed in units adjacent to the D1 faults.

Detailed structural mapping shows that much of the geometry complexity of the supracrustal rocks of the Aburna prospect shows two principal generations identified as D1 and D2. D1 is the principal regional deformation and includes regional NE trending steeply dipping S1 foliation and associated gently plunging mineral stretching lineation L1. Deformation D1 is the earliest compressional strain event recorded in the volcano-sedimentary and intrusive rocks at Aburna and is well-expressed by the development of a regional S1 foliation and localized L1 mineral Stretching lineation. Planar and linear structural features are ascribed to two principal generations of structures defined as D1 and D2. Structures D1 are the most significant since they control the spatial distribution of lithologies and the dominant tectonic grain of the studied area. Structures D2 are developed in the most anisotropic rock panels, and they have only a minor

geometric influence on the structural architecture; D2 structures only distorted and reorient the more penetrative D1 fabric. Deformation fabric intensities are generally inhomogeneous at the prospect scale and the D1 fabric is heterogeneously developed.

Three main deformation corridors defined as the Torina, Aburna and Abereta shear zones have been recognized and correspond to broad zones of schists and mylonite that can be followed along strike for more than 5 kilometres. At the scale of the prospect, these three major fault zones represent first-order structures in the hierarchy of the fault system. The steep discontinuities form a well-developed network of ductile shear zones oriented sub-parallel to or at a low angle to the S1 foliation. They probably developed at a late stage of D1 after the development of S1.

In detail, these high strain zones are composed of several m-scale slip planes that anastomosed and isolated lens-shaped rock panels of less deformed tectonites. These lens-shaped domains are well preserved within the Aburna shear zone where several carbonate-rich lensoidal tectonite are surrounded by zones of mica schist.

8. Conclusions

Potential gold mineralization in Aburna gold district is explained by the presence of old colonial mines, several active artisanal mining sites and by the presence of an extensive Au soil anomaly conducted in 2018-2020. Drill at the main shear zones has already intercepted several gold meters after this mapping. Map able gold targets within the Aburna shear zones are controlled by the presence of low Rank shear zones manifested by second order shear zones. The second order shear zones host gold quartz veins and associated sulphide dissemination typical of orogenic gold deposits. The Aburna gold mineralized system comprises three generations of quartz-carbonate-sulfide veins that include foliation-parallel V1 veins, and crosscutting V2A and V2B veins. V1 veins are the most significant and display a dominant NE-trending orientation and are subparallel to the attitude of the prospective fault system. Gold is also associated with silica flooded zones and with carbonate-sericite-pyrite alteration. The architecture of the Aburna vein system is compatible with the geometry of the shear and Riedel fractures observed in dextral strike-slip and/or dextral transpressional zone (**Figure 10**).

Further exploration works and drilling would better define the connection between the different gold targets within the district and further extend the mineralization along strike.

Although mineralization seems to continue like a pinching and swelling in some of the Aburna gold targets, the geological framework for the district is favorable for a widespread potential gold mineralization.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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