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Origin and Structural Control of Gold Mineralization in Bishewa Area, Central Nigeria

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Abstract

A low–grade gold mineralization occurrence has been mapped around Bishewa area, Central Nigeria. This is closely related to series of parallel subsidiary shear zones that are associated with regional lineaments. Petrographic studies revealed spatial and temporal associations existing between gold mineralization and quartz-filled shear zones. This suggests that the gold mineralization in Bishewa is structurally controlled but with no lithological preference.

Keywords: Gold mineralization, Bishewa, Nigeria, Structural Control, ShearZones, Lineaments

Introduction

The use of gold as an ornament and as money makes it a precious metal with the attendant rush for its exploration and exploitation worldwide. In Nigeria, several authors [1][2][3][4][5][6][7] have shown that there are many areas of the occurrence of gold in the Nigerian Schist Belts, especially in the western part of the country. Such areas include Ife-Ilesha (Iperindo) and Egbe-Isanlu-Dogondaji (Okolom) in the southwest; and Minna-Birnin Gwari, Yauri-Anka-Maru in the northwest (Fig. 1).

In several areas of the Nigerian schist belt, gold deposits in placers and primary veins commonly occur in alluvial stream sediments and in quartz veins respectively within several lithologies of the supracrustal belts. The primary gold mineralizations have been found in practically all lithological units of the supracrustal and basement and are commonly associated with veins, stringers, lenses, reefs and similar bodies like quartz, quartz-feldspar and quartz-tourmaline rocks.

The veins containing the gold range in thickness from several centimeters to a few meters, often displaying lenticular or pinch and swell (boudinaged) structures, and invariably steeply inclined and occurring as isolated bodies or as parallel or en-echelon vein systems [6][7]. The gold-bearing veins are commonly associated with fractures and shear zones while the adjacent mineralization wall rocks may be impregnated with fine-grained sulphide minerals [3]. However, there is no systematic correlation between gold mineralization and the type of country rock [7].

Generally, the lithologies of the enclosed schist belts consist of Upper Proterozoic fine grained clastics, pelitic schists, phyllites, banded iron formations, marble and amphibolites with imprints of the Kibarian (1.2ba) and Pan-African (0.6ba) thermotectonic events [3]. The Nigerian schist belts do have many features in common with Archean greenstone belts especially with respect to their size, synclinal structures, low metamorphic grade, presence of volcanic and clastic rocks and their associated banded iron formation and gold mineralization. These schist belts are characterized by the predominance of metasediments and lesser volume of volcanic rocks compared with the Archean greenstone belts[8].

This work was aimed at the origin and structural control of gold mineralization in Bishewa area with a view to proposing a genetic model for its exploration. The study area is bounded by Lat. 8^0 $39^{'}$N and 8^0 $46^{'}$N and Long. 5^0 $03^{'}$E and 5^0 $11^{'}$E, covering an approximate area of 220Km^2 (Fig. 2).

Geology of the Area

Rocks of Bishewa area form part of the northern limit of the Migmatite-Gneiss Complex (MGC)[9] in the southwestern sector of the Nigerian Basement Complex (Fig. 2). This complex forms part of the African

crystalline shield and is believed to be part of the Neo- Proterozoic to Early Paleozoic Pan African mobile belt which lies between the West African Craton to the west and the Congo Craton to the southeast. Lithologicaly, the rocks in Bishewa area include the early metamorphic tectonites, which include the biotite-gneiss and the migmatitic-gneiss (Fig. 3); the metasedimentary rocks comprising the biotite-hornblende-feldspar schist, quartz-mica schist, tremolite-talc schist, foliated quartzite and amphibolites; a group of felsic rocks including porphyritic granite, granodiorite, medium-grained granite, medium-coarse grained biotite granite, leucogranite, pegmatite, aplite and quartz vein; and the unmetamorphosed mafic rocks including the hornblende-quartz diorite and lamprophyre(Fig. 3).

Structural features identified in this area can be grouped into relict sedimentary structures, ductile, and brittle deformation structures. The relict sedimentary structures are associated with metasedimentary rocks. These structures include lithological banding in the quartz-mica schist and biotite gneiss. This lithological banding represents the original sedimentary bedding in the primordial parent rock (Fig. 4). Where subsequent deformation was not strong enough to cause complete obliterations, small biotite flakes were observed to be parallel to such lithologic layering.

Rocks of the Basement Complex within the study area show evidence of multiple episodes of orogenic deformations which created the N-S, NE-SW and the NW-SE structural grains found in the Basement Complex. This multiple reactivation of the Basement Complex led to formation of tectonic structures of ductile deformation. The ductile deformational structures e.g foliation, show distinct evidence of tectonic deformation as observed in some localities in the mica schist, biotite gneiss and migmatitic gneiss terrains (Fig. 4). Most foliation planes in the study area trend N-S, NE-SW and NW-SE. Figures 5 and 6 show the pole to point of foliation planes in the schistose rocks around Bishewa.

Lineation was observed in the biotite gneiss and migmatitic-gneiss due to intersection between the foliation planes and the fold axial planes which give rise to intersection lineation and sometimes lead to the formation of

mullon structure (Fig. 7). Biotite streaks as well as aligned feldspar and quartz crystals are few of the mineral lineation observed in some gneissic outcrops in the study area. The average plunge of the mineral lineation observed on foliation surfaces in the gneissic rock varies from 25^0 to 42^0 while the plunge azimuth ranges from070^0 through 320^0 to 360^0.

Fold is the commonest and most striking deformational feature mapped on gneisses and schists. Field evidences suggest that the study area was affected by polyphase folding. Some of the folds observed include minor asymmetric tight isoclinal folds (Fig. 8) associated with biotite gneiss and migmatitic gneiss. These tight isoclinal folds have average plunge of its axes to be 28^0 in the direction of 160^0 and they are observed to be parallel to the prominent axial planar schistocity that defines the structural grains of the schist terrains. Other types of fold seen are ptygmatic folds, which are mostly formed in the migmatitic gneisses (Fig. 9). A later folding episode is represented by flow structures defining similar folds in the quartz-mica schist (Fig. 10) and quartz-biotite-hornblende-feldspar schist (Fig. 11). The average plunge of the fold axial plane of these similar folds is about 15^0 in the direction of 155^0. The last episode of folding in the area is defined by the distinctive band of schistocity associated with the quartz-mica schist that outcrops between Bishewa and Ologomo (Fig. 8). This episode of folding is accompanied by the semi-brittle deformation that sheared and folded the major pegmatite body, which runs NW-SE from the southern part of Bishewa to the southeastern segment of the study area. Shears in this area are associated with the zones of intense ductile deformation just before the inception of brittle faulting in the basement. These are narrow (usually few millimeters wide), vertical to sub-vertical structures whose planes of foliation are often subjected to some amount of dragging, forming drag folds. Good examples of shear structure in the study area occur in intensely deformed portions of biotite-gneiss, schist and migmatitic gneiss (Fig. 12). Some of the shear planes are filled with mylonitized rock or quartzo-feldsparthic materials. The shears trend in NNW-SSE and dip steeply cross-cutting most pre-existing structures.

The brittle deformational structures in Bishewa area are narrow sub-vertical brittle structures and represent the last major tectonic deformation cutting across pre-existing features within the basement rocks. These brittle structures are essentially faults and joints.

Most of the faults mapped in the study area are minor in scale and are generally N-S trending with various magnitudes of displacements that range from few to several tens of centimeters. These faults are mostly sinistral and are found in mica schist and gneisses (Fig. 13). Some of the fault planes are filled with quartz or quartzo-feldsparthic rocks and show evidence of dragging with the resultant drag folds (Fig. 14). A major inferred fault zone in the study area was observed to host the largest pegmatite body of about 0.5Km in width and runs from the southern part of Bishewa to the southeastern sector of the mapped area. Prominent joint set in the area studied trend in ENE-WSW, WNW-ESE and N-S (Figs. 15 and 16). Both cross and parallel joints were mapped and are cross-cutting. Another type of joint observed is exfoliation joints which are associated with the granitic rocks.

Structural Evolution

Field evidences suggest at least three episodes of deformation in the study area. The first episode of structural deformation (D_1) in the area probably produced the primary metamorphic fabrics represented by the lithological and mineralogical banding (S_0, S_1). This episode of deformation changed the physico-chemical structure of the sedimentary precursor. The second tectonic deformation episode (D_2) folded the S_0, S_1 surfaces which is axial planar to F_1 (Fig. 8). In a few outcrops of the biotite gneiss and migmatitic gneiss, a superimposition on earlier planar fabrics (S_0, S_1) of a later axial planar cleavage (S_2) was observed (Fig. 4). S_1 trends NW-SE dipping northeasterly while the S_2 foliation plane which is the pervasive planar fabric in the study area trends mostly NE-SW while dipping southeasterly or northwesterly. The third and possibly the last major episode of tectonic deformations (D_3) were observed. The D_3 deformation refolded the S_2 surface resulting in the formation of the major folds (F_2) which are

sometimes recumbent and plunging (Fig. 10), upright, open or close (Fig. 8). D_3 is also perhaps responsible for the formation of the inferred regional fold in the study area. D_3 predates development of several fractures, joints, shears and minor faults mapped in the area.

Methodology

The method adopted in this work involved systematic surface mapping of outcrops, field observations, mapping and recording of structural features and collection of representative samples. Rock heterogeneity, quartz veining and gold mineralization guided the sampling. Stream sediments were collected from the stream beds of Rivers Wara and Onigbongbo at an average sampling interval of 300m and at a depth of about 30cm below the stream bed.

A total of 78 rocks and 45 stream sediment samples were collected while 15 rock and 5 stream sediment samples were subjected to X-Ray Fluorescence (XRF) geochemical analysis for oxide of 12 major elements, 14 rare earth elements and 31 trace elements at the Activation Laboratory in Canada. These rock samples were crushed and reduced to 1mm size using a Geocrusher and Pulverizer while 200g of the samples were ground to 200 mesh using a disc mill. Sample contamination was prevented by carrying out air cleaning at each stage. Hot digestion of 0.5g of the sample in a mixture of HNO_3, $HCLO_3$ and HF was carried before the XRF analysis for chemical composition of the 20 selected samples. The structural data were plotted on equal area stereonet while Rosette diagram of joint/fracture trends in the granites and gneisses were plotted.

Result and Discussion

The result of the geochemical analyses where Au, Ni, Cu, Pb and Zn are determined is shown in Table 1. From the table, the least value of Au of <0.5 ppm is recorded in amphibolites, quartz-biotite feldspar schist, medium grained granite, pegmatite, medium-coarse grained biotite-hornblende granite and stream sediments while the highest value of 2.2ppm is recorded in granodiorite. Cu has the least value of 3.9 ppm in Biotite-Hornblende gneiss while its highest value of 111.3 ppm is recorded in lamprophyre. Pb

has 0.1ppm as its least value and 5.2ppm as its highest value in smoky quartz and lamprophyre respectively. Zn has 243ppm in stream sediments as its least value and 3003ppm in amphibolites as its highest value. The least concentration of Ni is 2.2ppm in pegmatite and medium-coarse grained biotite-hornblende granite while the highest is 236.8ppm in tremolite/talc schist.

The gold distribution pattern and seeming lack of lithologic preference for the gold-bearing veins in the study area (Table 1) is consistent with the setting of the auriferous quartz veins of the Okolom and Ilesha gold fields [2]. The study area is an integral part of the northwestern extension of the Okolom-Dogondaji gold field [2]. It is therefore not unreasonable to speculate a low-level migration of gold through subsidiary fissures away from the Okolom area that forms the epicenter of the gold field possibly during a later low temperature (160^0 - 180^0C) mineralization episode, which redistributed gold to the northwestern part of the field including Bishewa, Gidan Sanni and Egbero areas. This probably accounted for the lower average concentration of gold in these areas when compared to the Okolom area.

Several evidences from petrographic, structural and geochemical data have revealed an anomalous concentration of gold which is fairly disseminated within virtually all the basement rocks in the study area. Gold concentration values in the media sampled range from <0.5 to 2.2ppm (Table 1), which is generally above the background concentration of about 0.002ppm Au in average crustal rocks [10]. The most gold-impregnated lithologies include the lamprophyre, granodiorite, porphyritic granite, quartz-hornblende diorite and vein quartz with gold concentration values ranging between 1.3 to 2.2ppm.

Gold content in the study area is patchy but sporadic high values have been encountered in some localized quartz vein less than a kilometer northwest of Bishewa. Such “pay quartz” veins when crushed and panned produce high gold concentration values. There are also occasional occurrences of small rich pockets of gold veins in otherwise relatively low-grade deposits in most

potential source rocks. A cursory panning of some mafic minerals suspected to be sulphide ores extracted from alluvial sediments along some major streams, which were pulverized, also yielded high gold concentration.

The Bishewa gold mineralization is clearly structurally controlled, the emplacement of which is regionally consistent with the NE-SW and NW-SE fissure directions. Many of these fissures can be related to the major pre-mineralized "master shear" dislocation zone southeast of Bishewa within which the major pegmatite body was emplaced (Fig. 3). This master shear zone is possibly related to the regional Ifewara fault and may have been formed during the final phase of Older Granite emplacement in the Pan-African time.

The gold mineralization is probably formed by hot circulating connate fluid which leached out metals from the wall rocks. The hot metalliferous fluid then convects upward under pressure through fractures and faults into cooler areas in the upper levels of the earth where it was precipitated within quartz-filled fractures under favourable physico-chemical conditions. Gold mineralization in the study area usually occurs in parallel N-S trending quartz veins and reefs which rarely exceed few centimeters in thickness. The small sizes of tonnage have positive implications for tonnage.

The steep axial shearing imposed on the moderate to shallow dipping micaceous schist creates abundant quartz-filled tension gashes, which follow an en-echelon pattern within the schist. These tension gashes correspond to parallel shear zones which possibly represent axial planes of anticlinal tight isoclinals folds in the area. Gold is perhaps present as flattened flakes and blebs in small-scale shear zones which are irregularly dispersed through the mineralized area.

Subsequent metamorphic deformations possibly led to the redistribution of the gold, disseminating it within several lithologies in the study area. Mechanical disintegration and denudation of these rocks led to remobilization of the gold which are worn and re-concentrated as alluvial deposits along some major streams in the area.

A paragenesis of the gold mineralization in Okolom gold field have been suggested [2] and by implication in Bishewa area. This includes gold, pyrrhotite, pyrite, marcasite, chalcopyrite and argentite deposited during the late stage deformational episode of the Pan-African Older Granite emplacement. A remarkable development of sericite, chlorite, tourmaline, zircon, rutile and hematite has been observed within the altered wall rock adjacent to vein contact in Okolom area. These minerals are also associated with the rocks of Bishewa area.

A general enrichment of lamprophyre, granodiorite, porphyritic granite, quartz-hornblende diorite and vein quartz in heavy metals such as Cu, Pb, Zn and Ni with corresponding higher gold values in Bishewa area as evident in Table 1 suggest a close association between the mineralization of the former and the latter. This perhaps indicates that traces of interstitial gold are locked up within massive pyrrhotite and pyrite with minor marcasite, argentite and chalcopyrite. Field observation shows that pyrite and iron oxides are disseminated throughout the gold mineralization zone.

Field and geochemical evidences support a genetic model in which metamorphic dewatering and shearing processes form the major processes involved in the gold mineralization and distribution in Bishewa area as suggested by [2] for auriferous lode formation at Okolom and Bin-Yauri gold fields. The gold mineralization process in the study area is possibly related to a hot circulating underground fluid system, which leached out metals from the wall rock as it convects upward through fractures and shear zones into the upper parts of the earth where the metalliferous fluid precipitates gold in quartz veins and reefs. Spatial and temporal relationship have been observed to exist between gold mineralization and the lenses of lamprophyre (mantle-derived magmas rich in volatiles) as well as the enclosing granodiorite (Table 1) in line with the epigenetic origin proposed by [11] in Western Australia and Canada. However, this only suggests that the degassing of mantle volatiles may have contributed to the hydrothermal solution of meteoric origin which deposited gold around Bishewa area.

Field and petrographic data have shown that the study area is underlain by the Basement Complex rocks which have been affected by series of polycyclic deformations that affected the southwestern sector of the of the Nigeria Basement Complex. Geochemical data revealed a low-level gold mineralization around Bishewa area, which is closely related to late stage thermotectonic D_2 deformation along series of parallel to sub-parallel subsidiary fracture and shear planes that are associated with regional lineaments in the study area. In mineral exploration, understanding the structural features and their sequence of development is very important because they could serve as guides to economic mineralization [12].

The usual spatial and temporal association that exists between gold mineralization and quartz-filled shear zones suggest that the Bishewa gold is structurally controlled and confined to shear zones that are distributed within virtually all lithologies of the basement rocks in the study area. This is consistent with the mineralization setting of the auriferous quartz veins of Okolom and Ilesha area as reported by earlier workers.

Highly mineralized rocks in the study area include lamprophyre, granodiorite, porphyritic granite and quartz-hornblende diorite. The structural control of mineralization in fractures generated during the major folding episodes in the study area is recognized but the control of the location, dimension and orientation of the ore shoots is not known. The high concentration of Cu, Pb, Zn and Ni with the corresponding high gold values in lamprophyre, granodiorite, porphyritic granite and quartz-hornblende diorite suggests a close association between sulphide and gold mineralizations in the study area. This perhaps indicates that traces of gold occur as interstitial mineral within the heavy metal sulphides.

Conclusion

From the field observations and geochemical analyses, it is concluded that the mineralization is structurally controlled. The faults and shear zones, especially those trending N-S, have served as conduits for disseminating the mineralizing fluid from Okolom area to Bishewa area. The primary source of mineralization is from the detrital gold and metal ions leached from the

wall rock. Degassing of mantle volatiles might have contributed to the gold mineralization solutions that produced the gold deposit.

Future potential target in the area should be focused on, or close to, the lamprophyre, porphyritic granite, and granodiorite. This may serve as a potent exploratory tool for gold in Bishewa area and other parts of the Nigerian schist belts. It is recommended that the stream sediments close to the lamprophyre, granodiorite and porphyritic granite be panned to exploit the alluvial gold while these rocks should be crushed and panned to exploit the primary gold.

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Table 1: Average Au, Cu, Pb Zn and Ni concentrations (ppm) in rocks around Bishewa area.

Rock Type	Au	Cu	Pb	Zn	Ni
Lamprophyre	2.1	111.3	5.2	656	29
Granodiorite	2.2	22.4	3.5	2161	121.7
Porphyritic Granite	1.8	10.1	3.8	2657	4.7
Quartz-Hornblende-Diorite	1.7	50.5	2.6	561	10.1
Vein Quartz	1.3	9.4	0.2	1237	5.1
Smoky Quartz	1.3	13.4	0.1	2464	7.3
Biotite-Hornblende Gneiss	0.9	3.9	0.5	531	7.4
Quartzite	0.8	8.4	0.3	1070	3.5
Tremolite/Talc Schist	0.8	5	0.3	643	236.8
Quartz-BiotiteFeldspar Schist	<0.5	4.5	0.5	1179	5.2
Amphibolite	<0.5	25.2	3.5	3003	13.3
Medium-Grained Granite	<0.5	16.9	2.2	435	4.6
Quartz-Mica Schist	<0.5	9.4	2.2	3.0	13.5
Pegmatite	<0.5	7.3	2.7	2391	2.2
Medium-Coarse Grained Biotite-Hornblende Granite	<0.5	5.4	1.8	1341	2.2
Stream Sediment (Average)	<0.5	6.74	2.46	243	4.34

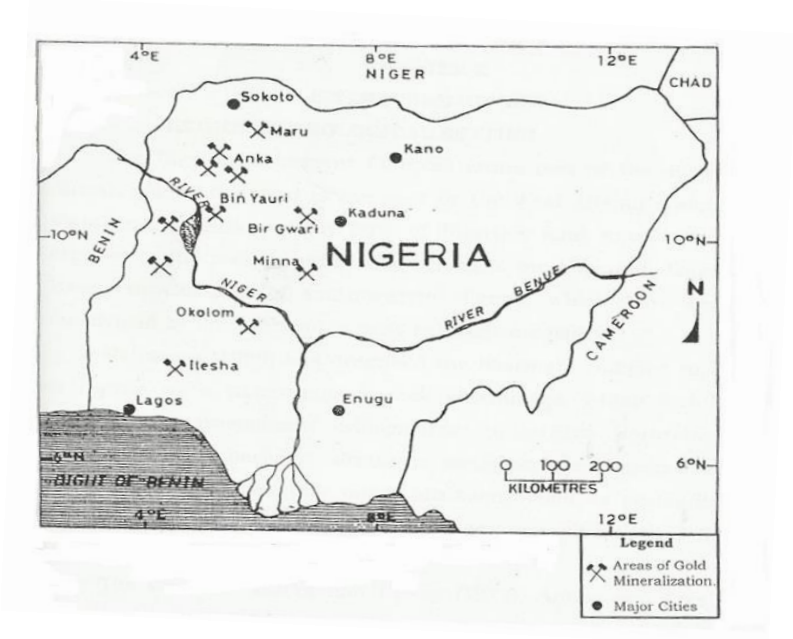


FIG. 1: Map showing major area of gold mineralization in Nigeria [6]

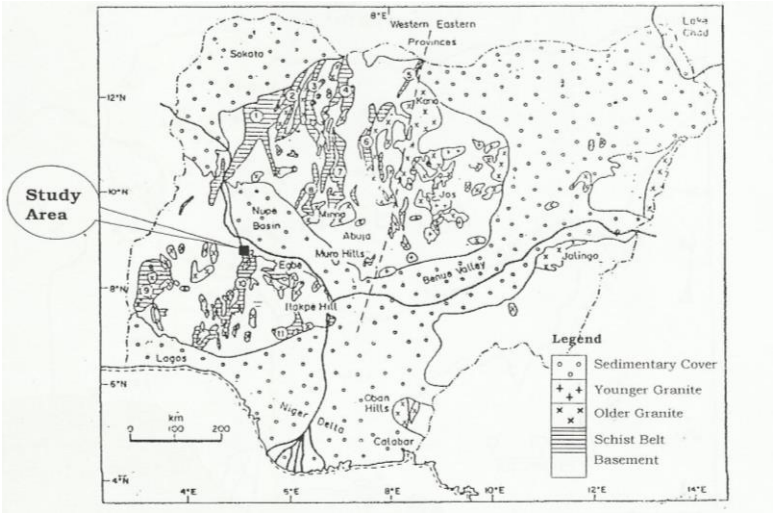


Fig. 2: Geological map of Nigeria showing the study area [13].

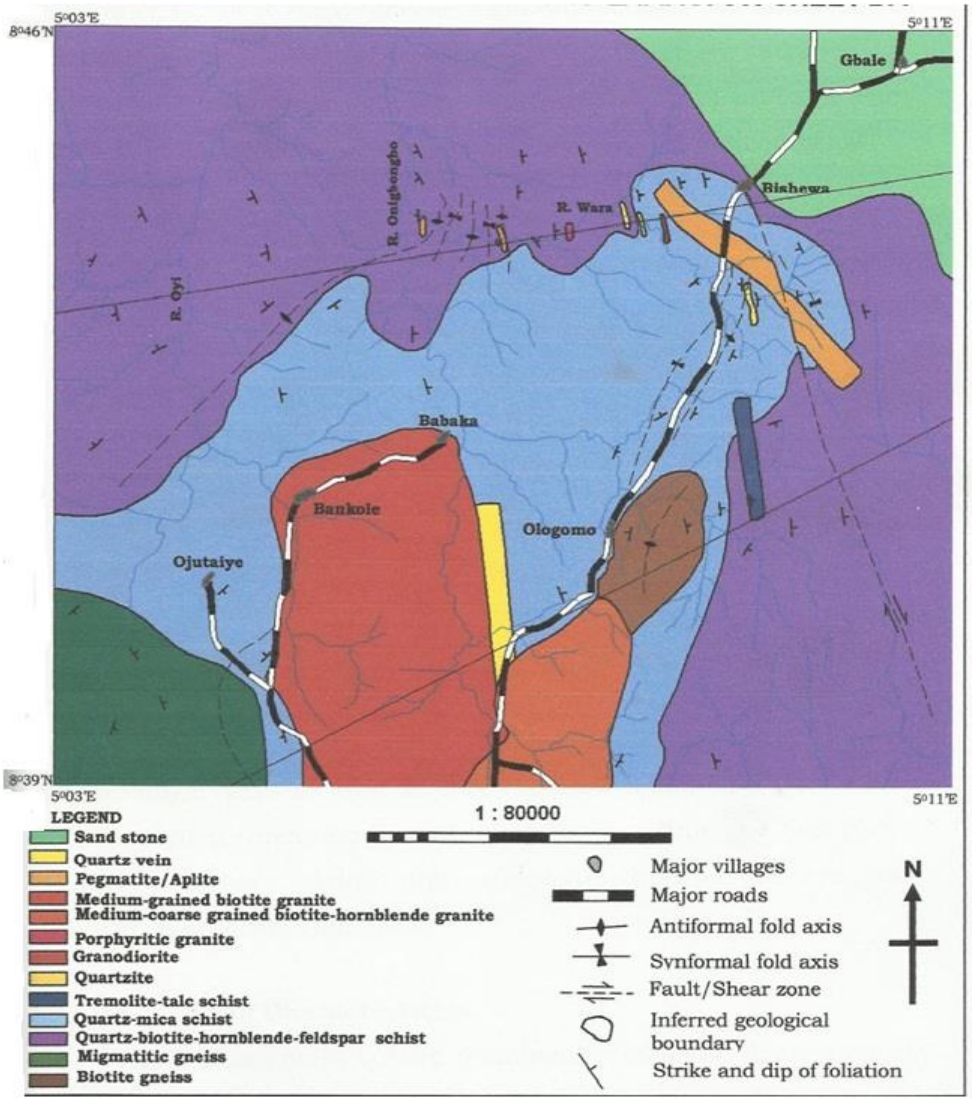


Fig. 3: Geological map of the study area

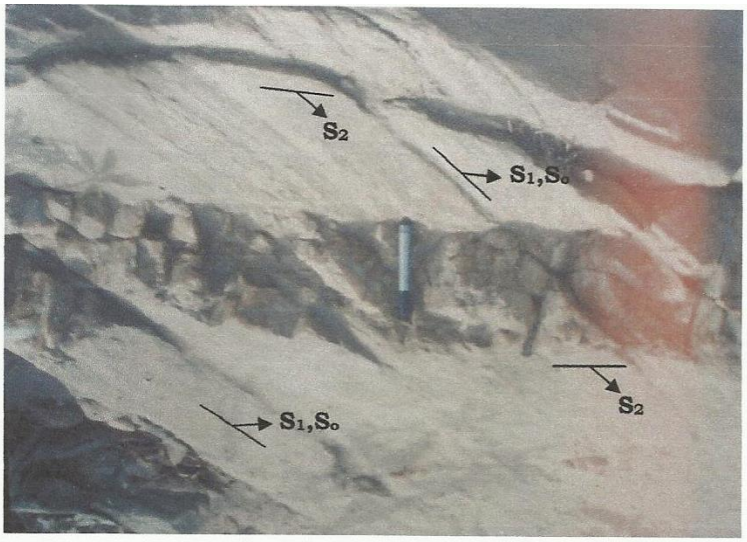


Fig. 4: Field photography of biotite-gneiss showing the axial planar cleavage foliation plane (S_2) superimposed on relict lithologic foliation plane (S_1, S_0) formed from pelitic bands of sedimentary origin

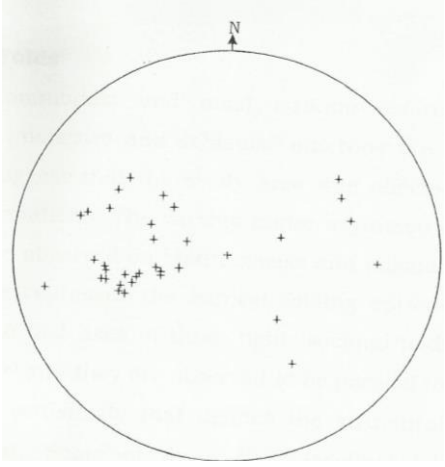


Fig. 5: Pole to point of schistose foliation planes in the quartz-mica schist around Bishewa area

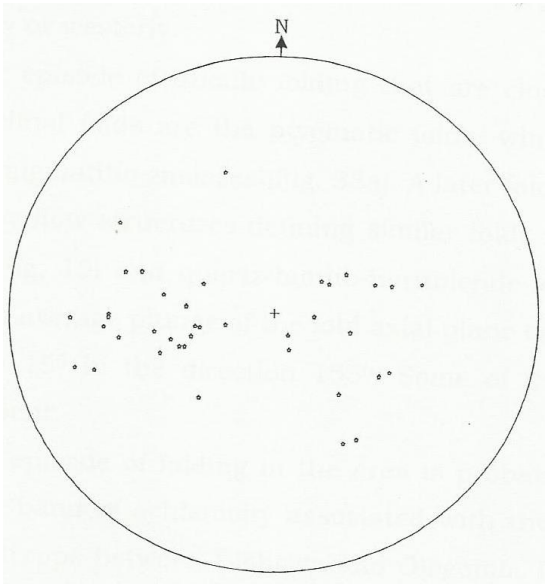


Fig. 6: Pole to point of schistose foliation planes in the quartz-biotite-hornblende-feldspar schist around Bishewa area



Fig. 7: Field photography showing mineral lineation traces on a mullion structure in biotite-gneiss.



Fig. 8: Field photograph showing polyphase folding system in migmatitic gneiss with tight isoclinals fold (F_1) and a major upright fold (F_2)



Fig. 9: Field photography showing Ptygmatic fold in migmatitic gneiss

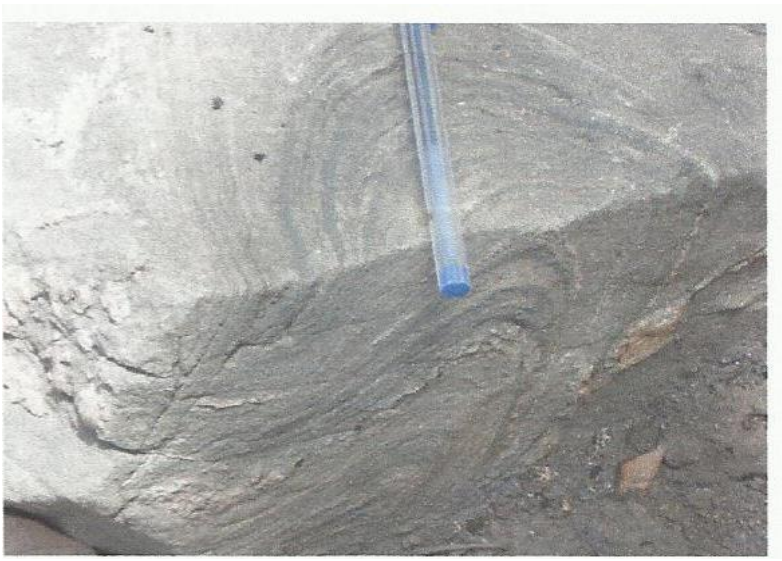


Fig. 10: Field photograph showing isoclinal fold in the biotite-hornblende-feldspar schist



Fig. 11: Field photograph of quartz-mica schist showing asymmetric similar fold in SW Bishewa



Fig. 12: Field photograph showing dicktyonitic structure in migmatitic gneiss with drag folds

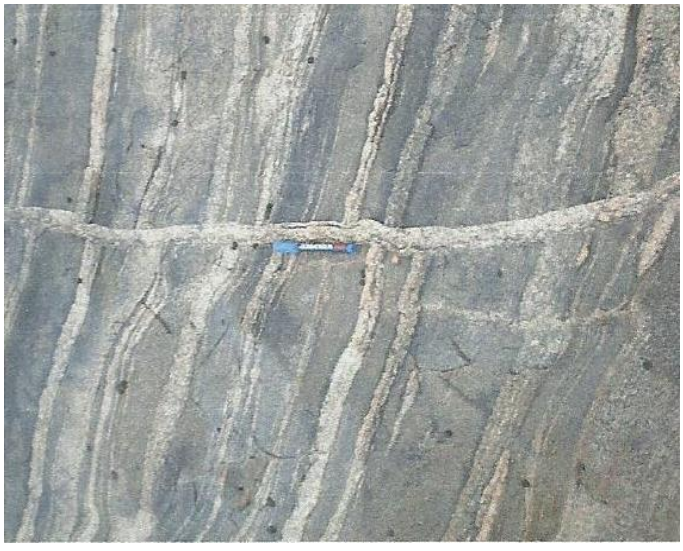


Fig. 13: Field photograph showing sinistral faulting and stromatic structure in migmatitic gneiss

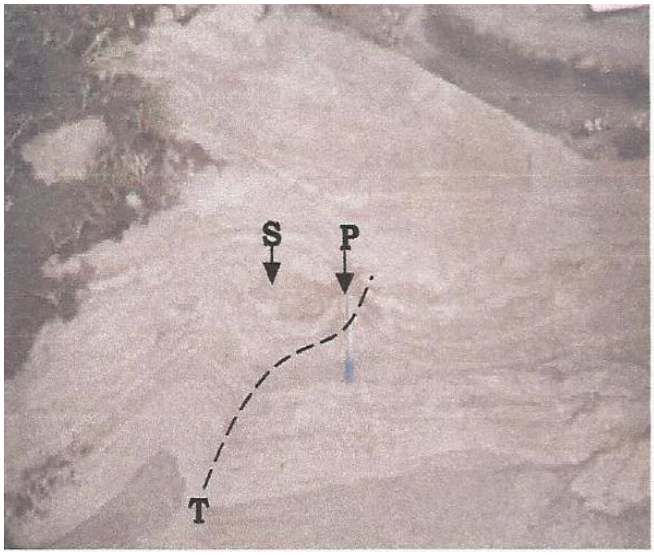


Fig. 14: Field photograph showing pinch (P) and swell (S) structure in migmatitic gneiss. Thrust (shear) plane (T)

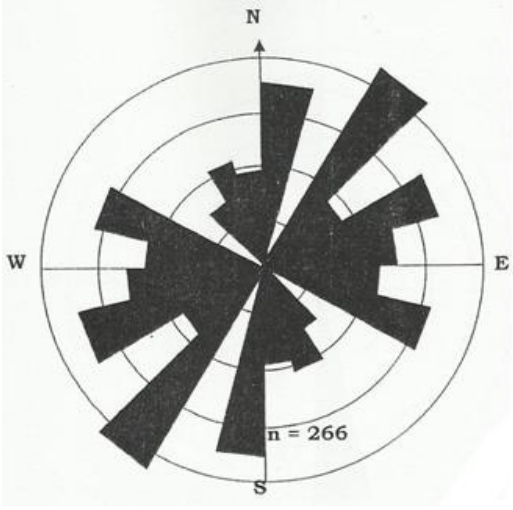


Fig. 15: Rosette diagram of joint/fracture trends in the gneisses around Bishewa

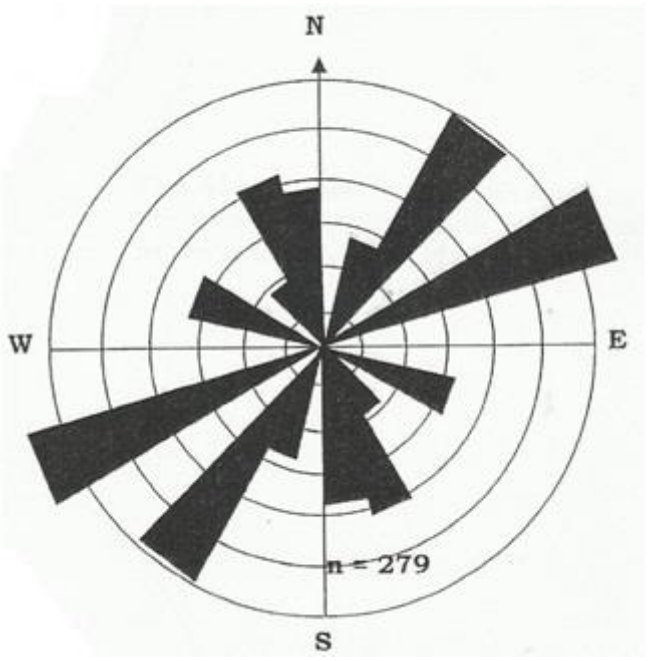


Fig. 16: Rosette diagram of joint/fracture trends in the granites around Bishewa