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FIELD OCCURRENCE AND STRUCTURAL CHARACTERISTICS OF BASEMENT ROCKS AROUND KABBA-BUNU AREA IN PART OF KABBA-LOKOJA-IGARRA SCHIST BELT, SOUTHWESTERN NIGERIA

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ABSTRACT

Field and structural mapping on a scale of 1:50000 was carried out to determine the lithologic and structural features in the Kabba-Bunu area of the Kabba-Lokoja-Igarra schist belt. The area is underlain predominantly by migmatite-schist suite comprising migmatite gneiss, migmatised schist and a quartz-mica schist-quartzite complex in which quartzite occurs as elongated ridges especially around Aiyegunle-Iluke-Olle and Osomule-Ofere areas. The migmatite-schist suite is interbanded in some places by short lenses of amphibolites. This metamorphic sequence is intruded by north-south trending granite plutons, which form prominent topographic features, and are closely associated with dolerite, pegmatitic and aplitic veins. Polydeformation and polymetamorphism of the rock units produced orientations in different directions. From the field disposition of the competent quartzite bands, the study area has suffered at least two thermotectonic orogenic events: one with E-W fold axis produced by N-S compressional forces assumed to be probably Eburnian in age and the other with N-S fold axis produced by E-W compressional stress usually associated with the Pan-African event. Foliation and lineation in the E-W to NE-SW directions is interpreted to be the ductile and earlier major structures, while minor brittle shear overprinted structures in the NW-SE to N-S directions are filled by quartz veins, dolerites and pegmatite dykes and serve as conduits and pathway of the gold bearing ore fluids.

KEYWORDS: Structures, rocks, schist, N-S trend, polymetamorphsim.

INTRODUCTION

The Nigerian basement complex lies within the remobilized zone of the West African basement. The major rock types in the area as classified by Russ, (1957); McCurry, (1976) and Fitches, *et al.,* (1985) are (a) the gneiss-migmatite-quartzite complex; (b) the schist belts which are low to medium grade supracrustal and meta-igneous rocks; (c) the Pan African granitoids (Older Granites) and (d) minor felsic and mafic intrusive such as pegmatite, aplite, dolerite and lamprophye. These minor rocks intrude into the migmatite-gneiss-quartzite complex. The schistose rocks which occur in defined belts are known to be a dominant feature and constitute a distinct component of the western half of the Precambrian basement complex of Nigeria.

Trends of structures and magmatic induced quartz veins and pegmatite dykes in the Nigerian basement have been documented by Ajibade, *et al.,* (1987); Rahaman, (1988) and Goki, *et al., (*2010). Goki, *et al*., (2010) noted that deformation of the basement appears to be in two phases, a ductile phase which is responsible for the formation of planar structures (foliations and lineations) and a brittle phase resulting in joints and fractures that have been filled with quartzo-feldspathic veins, pegmatite, aplite, and dolerite dykes.

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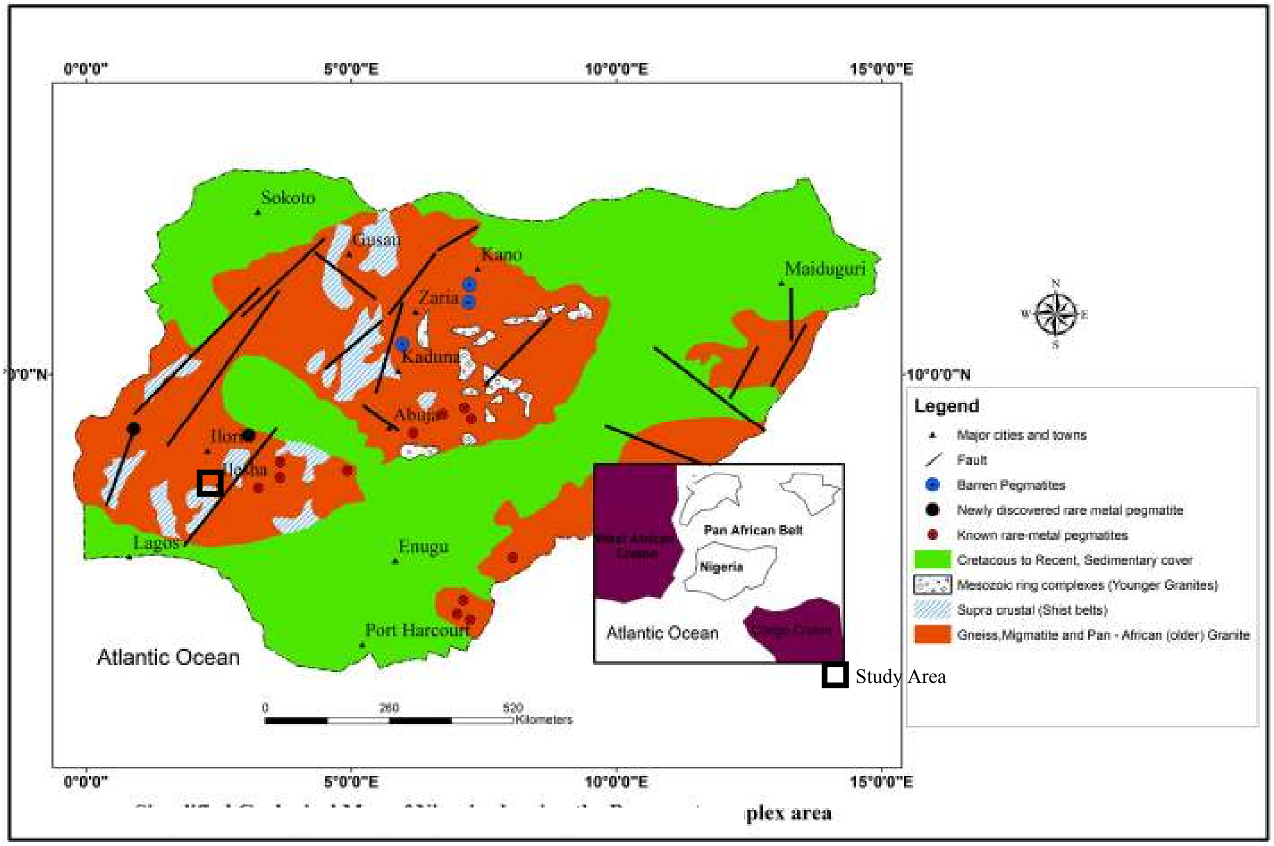

Fig. 1: Simplified geological map of Nigeria showing the schist belts and location of the study area. Inset: location of Basement Complex of Nigeria between the west Africa and Congo cratons. (Adapted from Akoh and Ogunleye 2014).

Mineralizations in the basement such as iron-ore, gold vein emplacements are generally confined within the N-S to NNE-SSW brittle structures. Okunlola (2008) observed that the principal fracture directions in the basement complex of Nigeria are N-S, NNE-SSW, NNW-SSE and NW-SE and to a lesser extent E-W where the N-S fractures are marked by considerable shearing and brecciations. The NE-SW and NW-SE conjugate sets are mostly strike slip faults with the north eastern set characterised by dextral sense of movements.

The schist belts of Nigeria are best developed in the northwest and south-western portions of the country. The schist belts occur predominantly as series of synformal trough and strike ridges, intercalated with relics of migmatites and gneisses or intruded by granites which separate and/or lie within them. All the schist belts are predominantly composed of pelitic to semi-pelitic rocks usually micaceous schists, phyllites, amphibolites, quartzites and ferrunginous quartzites with acid and intermediate volcanic and plutonic rocks interbedded with the metasedimentary rocks as described by Danbatta (2008) and Ekwueme, (1985). Detail studies have been carried out on the schist belts that outcrop in the south-western part of the country with the exception of the northern portion of Igarra-Kabba-Lokoja schist belt (the study area). However workers like Annor, (1983), Annor and Freeth, (1984); Hockey *et al*., (1964); Gabako (1988), Ezepue and Odigi, (1993, 1994), Olobaniyi, *et al*., (2001), Olobaniyi and Annor, (2003), Elueze and Okunlola, (2003) etc have reported on the aspects of the geology and petrogenesis of the rocks in the study area on a regional scale and have made detailed mapping of the adjacent and neighbouring schist belts. The preference given to the schist belts is due to the fact that they are known to host important economic mineral deposits, and constitute a major lithostratigraphic unit necessary for unravelling the geochemical and geodynamic evolution of the basement complex (Ekwueme, 2003; Danbatta, 2008; Ekwueme and Ephraim, 2005).

Although, the study area and other adjoining belts like Igarra, Egbe-Isanlu and Lokoja-Jakura have benefited from this interest by mineral prospectors, geochemists and economic geologist, relatively little information has emerged concerning it structure, lithology, field relations and geochemical controls of mineralization in the area.

In this paper, field geologic data obtained from ground geologic mapping on a scale of 1: 50000 have been used to determine the field lithologic occurrence, structural features and trends in the rocks that outcrop in the area with a view to presenting a preliminary petrogenetic and geotectonic history of the study area.

2.0 MATERIALS AND METHODS OF STUDY

A detailed and systematic field mapping of the study area was carried out on a scale of 1:50,000 to delineate the major and minor rock boundaries accurately using

Aiyegunle SW sheet 226 as base topographic map. Field relations of the rock units within the area were determined and field structural measurements taken using Bruton compass clinometer. In the field, joints, fractures and faults, lineations and foliations were the main structural elements measured. All the readings were taken and data plotted on equal area lower hemisphere (Schmidt net) stereographic projection and Rose diagrams using GeoRose 0.5.1 software.

3.0 RESULTS AND DISCUSSION

3.1 Field Relations of Rock Types

Field geologic data obtained from ground geologic mapping was used to produce a geologic map of the study area on a scale of 1:50,000 (Fig 2a). A geologic cross section along the profile AB in the study area is shown in Fig. 2b. The rocks mapped from the area can be classified into two main suites, namely: the gneiss-schist suites and the Intrusive suites. The gneiss – schist suite refers to the metamorphic tectonites and includes migmatite gneiss, migmatized schist, quartz-mica schist, quartzites and metaigneous bodies which form the host rocks into which undeformed to partially deformed granitoids intrude. This suite accounts for about 65% of the study area and is believed to be the northward continuation of the Igarra schist belt (fig 1). The intrusive suites form prominent topographic features at the western and south-eastern corner of the map area. These granite plutons are mainly composed of fine to medium grained granite, medium-coarse granodiorite, porphyritic granites, garnetiferous granite and foliated granite. They are associated with dolerite, pegmatite and aplite veins.

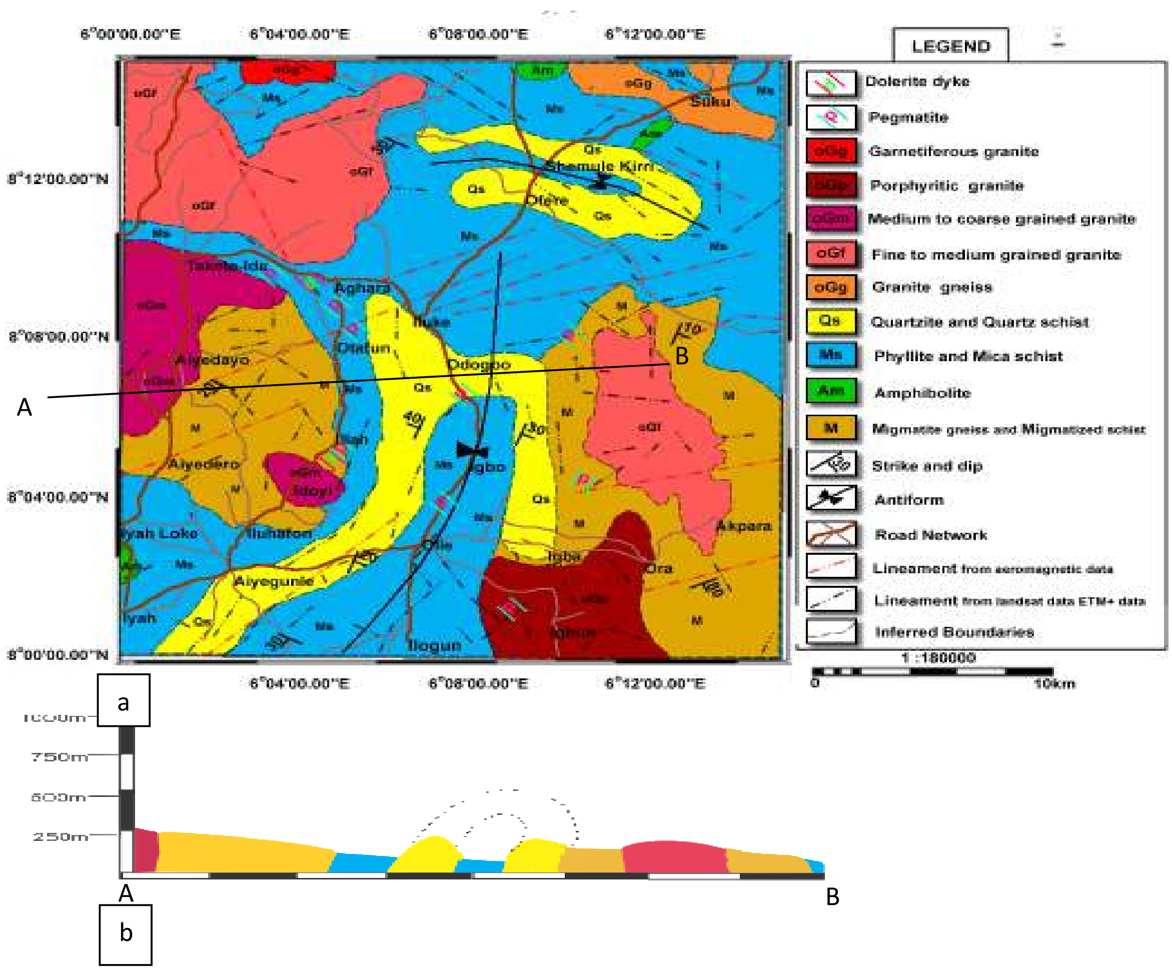

Fig. 2: (a) Geological map and **(b)** geologic cross section along line AB of the study area

3.1.1 Gneiss-schist suite

The gneiss-schist suite comprises an early metasedimentry unit and later metaigneous rocks. The metasedimentary units consist mainly of semi-pelitic rocks and quartzite horizon while the metaigneous unit consists of thin intercalation of amphibolite. There is a concordant interbanding relationship between the metasediments and the metaigneous rocks. The gneiss-schist suite rocks account for about 65% of the area. The mineral constitutents of these rocks include feldspar (orthoclase), quartz, mica, hornblende and opaque minerals, the average modal mineral compostions of these rocks are shown in Table 1.

Table 1: Average Modal Composition of Gniess-Schist Suite in the area

Mineral	Quartzite (foliated) (%)	Quartzite (massive) (%)	Migmatized gnies/schist (%)	Quartz mica schist (%)	Amphibolite (%)
Muscovite	4	6	10	15	
K-feldspar	5	4	18	10	
Plagioclase	6	3	12	15	10
Biotite	2		33	25	15
Quartz	78	80	15	32	13
Hornblende			7		52
Pyroxene					8
Opaque Minerals	5	7	5	3	2

The gneiss-schist units in the area consists of migmatite-gniess and migmatized schist, foliated and massive quartzite, mica schist and quartz schist with subordinate bands of metaigneous body (amphibolite). They are fine to medium grained rocks and are slightly migmatised especially at the contact with the granite plutons. The migmatite-gneiss and migmatized schists are foliated with a general NW-SE trending foliation plane and consist of clear mineralogical banding with the alternation of dark and light minerals and thin lenses of leucosome pods measuring about 10cm often concordant to the foliation of the palaesome giving the rock a compositional variation (plates 1a and b).

The supracrustal rocks mapped in the area generally consist of pelitic and semi-pelitic schist mainly mica schist, quartz-mica schist and quartzite. The mica schist and the quartz mica schist are highly weathered rocks outcropping in the low flat valleys in the central part of the map area (plate 2a). They occur in association with an almost N-S and NNE-SSW trending unit of migmatite-gniess. They are characterized by a silky sheen on the cleavage surface. These supracrustal rocks form the northern portion of the Kabba-Lokoja-Igarra schist belt. Quartzites in the study area are of two types, massive and schistose varieties (plate 2b and c). They are white to gray in colour and form long and prominent ridges with rubbles at Aiyegunle-Iluke-Olle and Osomule-Ofere areas. The massive quartzites occur as boulders and rubbles with a sharp contact with the quartz-biotite schist. They trend in NE-SW and NW-SE directions, strike azimuth of 352^0 to 360^0 and dip east or west with average dip angle of about 040^0. The schistose variety has books of micas between the quartz and the schistocity is defined by the alternating micaceous bands within the quartzites.

Plate 1: Outcrops of **(a)** migmatite gneiss with leucosome pods and **(b)** migmatized schist along Iluke-Ohura road.

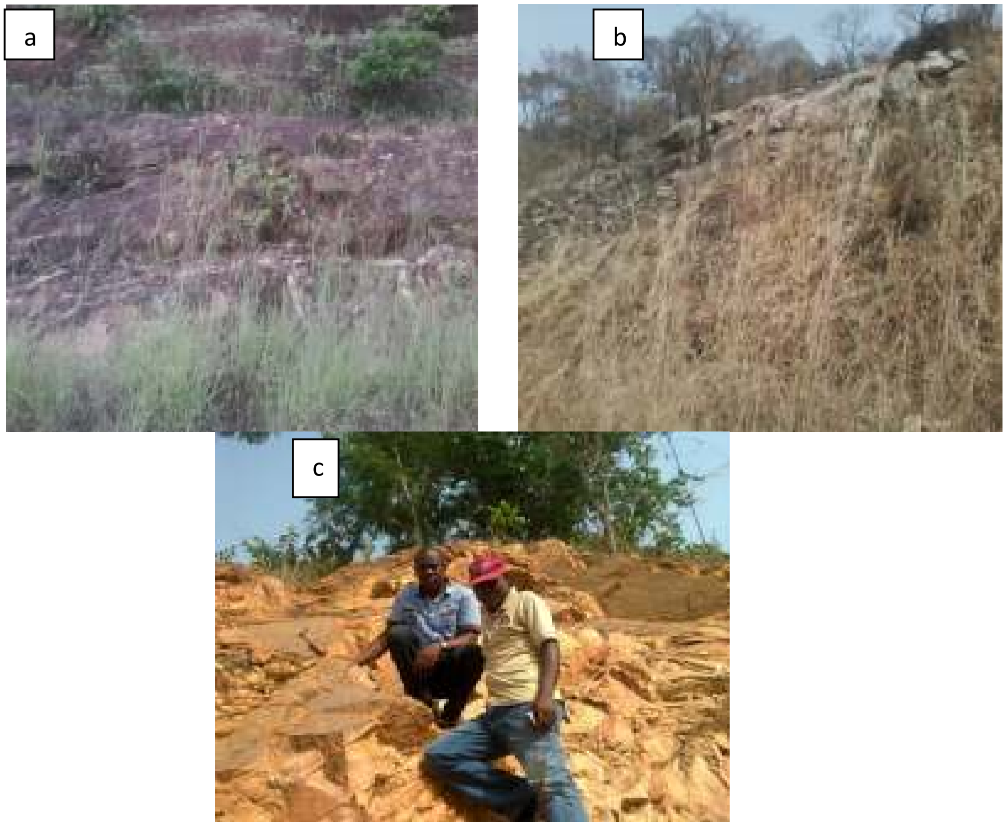

Plate 2: Outcrops of **(a)** quartz-mica schist around Aiyegunle village **(b)** massive quartzite along Igbo-Iluke road and **(c)** foliated quartzite along Aiyegunle-Iluke road.

The gneiss-schist suite is interbanded in places by short and narrow metabasic dike/lenses of amphibolite schist around Igbo-Bunu, Osomule and west of Iyaloke (plate 3). According to Cooray (1974), talc schists and amphibole-rich rocks are derived from probably the hydrothermal alteration of pyroxenites or other basic and ultrabasic intrusion under greenschist facies metamorphic conditions.

Plate 3: Outcrops of Amphibolite along Ofere-Suku road.

3.1.2 Granitic suite

The granitic plutons in the area are generally unfoliated except at the contact with the country rocks where they are weakly foliated with the elongation of the mineral grains, especially the feldspar and quartz grains. These granitoids consist of fine-medium grained granites at the eastern and north western parts; porphyritic and locally foliated at contacts in the south-eastern part and medium-coarse grained granodiorite that forms prominent inselbergs and whaleback outcrops at the western part. Fine-medium grained foliated granite and garnetiferous varieties were also mapped at the northern part of the study area.

Table 2: Modal Composition of granitic rocks from the area

Minerals	Fine-Medium grained granite (%)	Grano-diorite (%)	Porphyritic granite (%)	Granite gneiss (%)	Garnetiferious granite (%)	Pegmatite (%)
Quartz	40	35	35	30	28	30
Biotite	25	30	10	20	16	10
Plagioclase	5	11	13	10	10	10
K-feldspar	10	6	30	20	18	40
Muscovite	15	14	5	8	10	5
Garnet					13	
Hornblende	2		3	7	3	2
Opaque (Others)	3	4	4	5	2	3

From field disposition of the granitic rocks, the fine-medium grained granite is assumed to be the youngest, and it intrudes into the biotite granite and the medium to coarse grained granodiorite (plate 4a). These granitic bodies carry xenolithic (sometimes partially assimilated) bodies of gneiss- schist suite (plate 4b) and often contain isolated dark, fine-grained irregularly shaped biotite-rich enclaves (plate 5a). According to Didier & Barbarin (1991), xenoliths are extraneous pieces of older country rock introduced into magma whereas enclaves are residues of melting or coeval magma. The granitic plutons intrude into the schistose rocks and cover 30% of the study area, forming distinct topographic features and exhibiting in some places sharp contacts with the country rocks (plate 5b). The granite bodies also generally have pegmatitic and aplitic veins or dykes which are commonly mineralized and are being worked for metallic minerals such as cassiterite, columbite, tourmaline and beryl at different locations in the area. Dolerite dykes in the area occur as tabular, unmetamorphed rock cross-cutting the foliation of the host rocks. They are black, fine-medium grained in texture generally trending N 312^0 W and in some cases contain pale green spots of olivine. Quartz veins mapped in the area are generally unmineralized but are in some places auriferous where they cut amphibolites and are presently being worked by artisans.

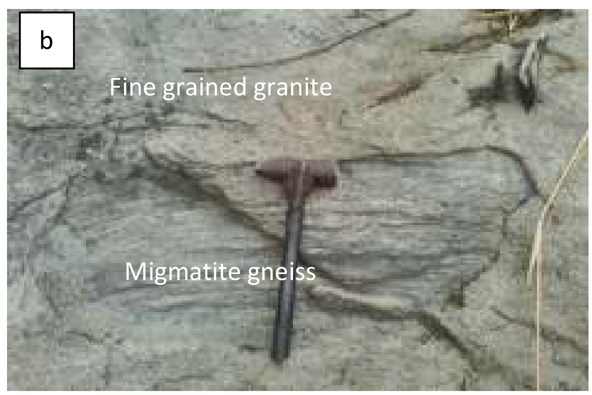

Plate 4: Outcrops of fine-medium grained granite showing xenoliths of **(a)** biotite granite and granodiorite and **(b)** migmatite gneiss.

Plate 5: Outcrops **(a)** granodiorite with enclave of mafic mineral and **(b)** sharp boundary between fine grained granite and granite gneiss.

3.2 Structural Features

Structural features that have been identified from field geological mapping are foliations, lineations, folds, joints, fractures and faults. The structures observed on the rocks in the field include those formed due to compressional forces resulting in ductile structures such as foliations, lineations and folds while the brittle structures include joints, fractures and faults formed from tensional forces. The planar (foliation) surfaces were observed in the metasedimentary rocks and gneisses while the tensile structures cut across all lithologies in the area. The orientation of the ductile structures as determined from the strike azimuth frequency data of the structures (Table 3) are given below:

- NNE/NE (70%)
- E - W (3%)
- NNW/NW (27%)

The orientation of the brittle structures (joints/fractures, quartz and pegmatite veins) are as follow:

- NNW/NW- (65.68%)
- E - W (8.28%)
- NE - SW (26.04%).

The brittle structures trend predominantly in the NNW/NW direction while the ductile structures trend in the NNE/NE direction.

Table 3: Summary of strike azimuth frequency data of structures (foliations, joints/fractures and veins) in the study area

Structural Elements Azimuth (Degree)	FOLIATIONS		BRITTLE STRUCTURES (JOINTS AND FRACTURES)		BRITTLE STRUCTURES (PEGMATITES AND QUARTZ VEINS)		TOTAL BRITTILE STRUCTURES	
	Number	% freq-uency	Number	%freq-uency	Number	%frequency	Number	%freq-uency
N0-30 E	45	45	14	14	17	24.64	31	18.34
N31-60 E	25	25	7	7	6	8.70	13	7.69
61-90 (E-W)	3	3	12	12	2	2.90	14	8.28
91-120	5	5	18	18	7	10.14	25	14.79
121-150	12	12	20	20	10	14.49	30	17.75
331-360 (N0-31 W)	10	10	29	29	27	39.13	56	33.14
Total	**100**	**100**	**100**	**100**	**69**	**100**	**169**	**100.00**

3.2.1 Foliations

Foliations in the rocks in the area is defined by alignment and orientation of mineral grains as a result of metamorphism or deformation of the rocks and are parallel to the plane of the folds and fold limbs. Foliation is the earliest penetrative structure of the area, mapped as planar metamorphic fabric of the migmatitic gneiss and quartz-mica schist. The first and most prominent deformation produced the penetrative foliation, and the development of concordant quartzo-feldspathic segregations in both the migmatitic gneiss and migmatized schist. Foliation is strong in the migmatitic gneiss, and is marked by alternating bands of dark and light minerals. Schistosity in the quartz-mica schist is well-developed, due to parallel orientation of the micas. Foliation in amphibolite is strong, marked by persistent quartzo-feldspathic layers and aligned amphibole prisms that appear as a fine differentiation lamination (Plate 3). In some areas, granite deformation is locally exhibited and defined by weak foliation of aligned and elongated porphyroclast of feldspar and quartz aggregate.

The density plot of the azimuth of foliation planes on an equal area lower hemisphere (Schmidt's net) stereographic projection of poles (∏-diagrams) shows that the data plotted majorly in the NW- SE portion of the net (Fig. 3) which confirms majorly the NE-SW trend. This is in conformity with the regional strike of foliation on the Rose diagram which is roughly constant and trend in the NE-SW direction with variation between NNE-SSW, NNW-SSE and N-S directions (fig 4a).

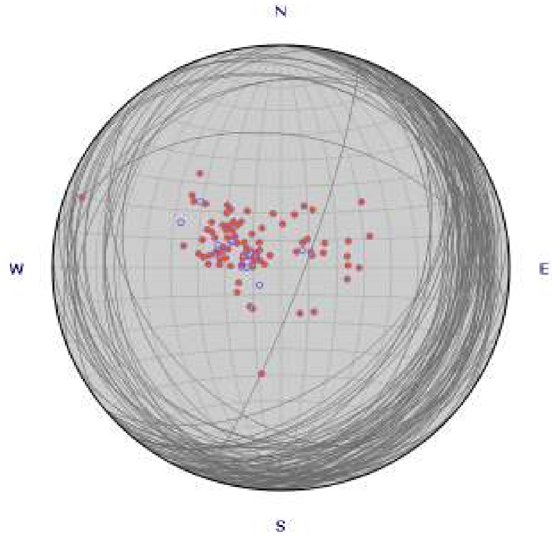

Fig. 3: Lower hemisphere (Schmidt's net) stereographic projection of poles (∏-diagrams) of foliation planes.

The northerly trends are predominant, while the obscure earlier E-W trend is still largely preserved. In some places in the quartz-mica schist, there is corrugation of the foliation by minor folds resulting in the formation of crenulation cleavage. This is the most common linear structure observed in the schist. In some locations within the gneiss and schist, lineation was observed to be a result of the intersection of two foliation surfaces. Boudinage, pinch and swell structures also occur usually in quartz veins that intrude the granite gneiss and are parallel to fold axes (Plate 6a).

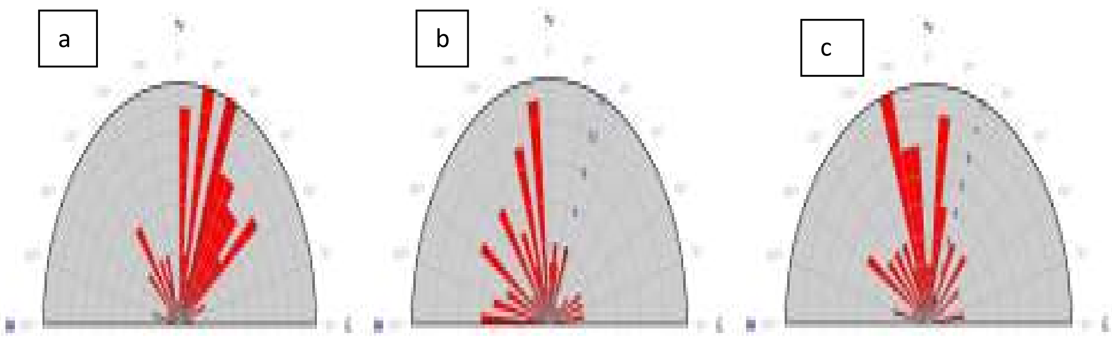

Fig. 4: Rose diagrams of trends of **(a)** foliations and mineral lineations and **(b)** joints, fractures and **(c)** veins of pegmatites, aplites, dolerite and lamprophyres of Bunu Precambrian rocks.

Field mapping reveals three deformational episodes that occurred in two phases and which have led to the generation of three major foliation trends namely: E-W, NE-SW and NW-SE and near vertical N-S as observed in the adjacent Egbe-Isanlu belt by Dada, *et al.,* (2003). It is believed that the latter and more prominent N-S shears served as conduits within which quartz stringers and pegmatite dykes were emplaced. This also appears to agree with the N-S, NE-SW structural model for western schist belts of the basement complex (Oyawoye, 1972; Wright, *et al.,* 1985; Woakes, *et al.,* 1989) and described as ductile deformational phase by Goki, *et al*., (2010).

3.1.1.2 Folds

Folds are the major structural features of the rocks in the area. They are generally tight-isoclinal folds, with series of open to close asymmetric folds having vertical axial planes trending northwest-southeast. These folds are common in the migmatitic gneiss and migmatized schist and to a lesser extent in the quartz-mica schist, and they are defined by quartzo-feldspathic layers or veins within the rocks. These veins could also display more complex disharmonic, ptygmatitic and dragged folding (Plate 6b). They locally exhibit well-formed M-and Z-shape drag folds where the axial plane of drag folds strike at 050º and dip 70º SE; the fold axis plunges 34º SW on the average (Plates 6c and d).

Folding is also well developed within the quartz-mica schists and quartzite at Ofere-Kiri and Suku-Kiri NE of the area, where they are gently folded with fold axis plunging 30^0 SE. The Aiyegunle-Iluke-Olle quartzite ridge has been gently folded into an anticlinorium with a northeast striking axial plane 50^0 to 60^0 SW. From the field disposition of the competent quartzite bands, the study area has suffered at least two thermotectonic orogenic events: one with E-W fold axis produced by N-S compressional forces assumed to be probably Eburnian in age and the other with N-S fold axis produced by E-W compressional stress usually associated with the Pan-African event (fig 2).The folding pattern is similar to one in Isanlu- Egbe area adjacent to the study area which Olobaniyi (1997) and Dada, *et al.,* (2003) divided into two sets according to their orientation: (i) folds whose axial planes are parallel to the regional foliation with general east-west trends and (ii) northerly or southerly dips, but whose fold axis vary in direction within these planes.

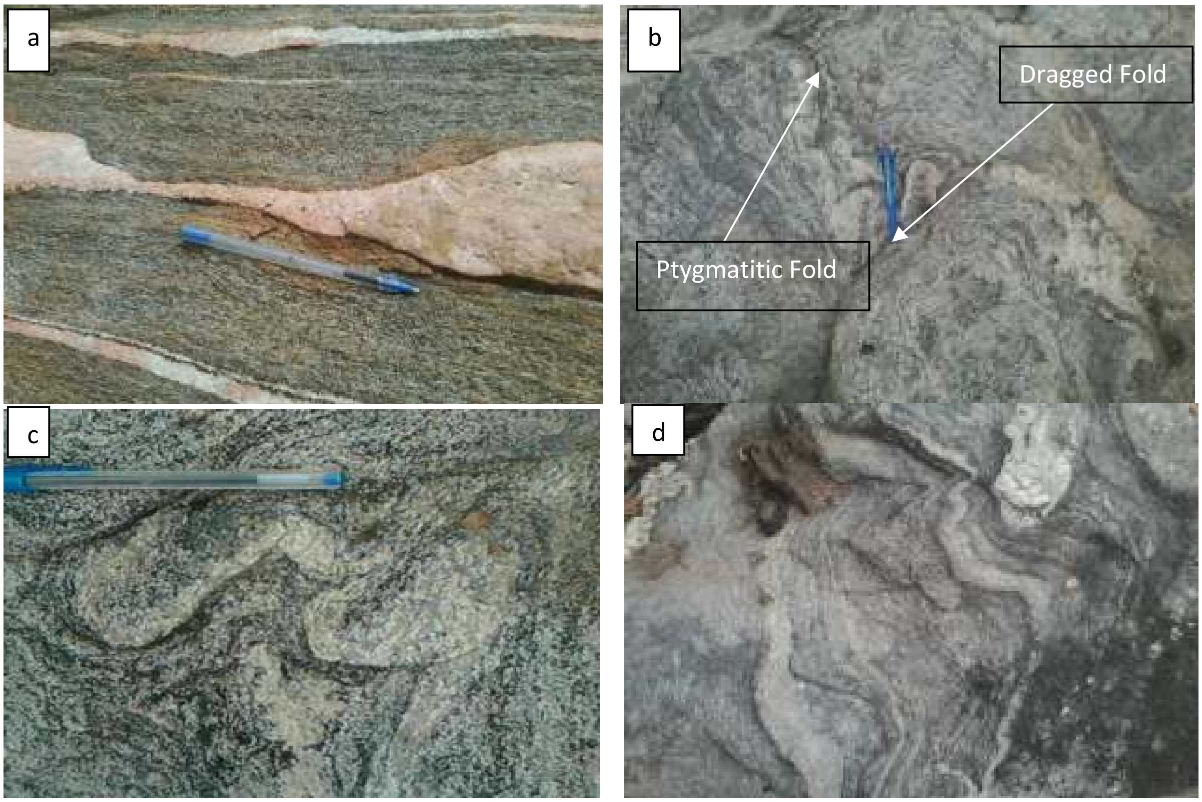

Plate 6: (a) Pinch-swell and boundinage on outcrop of banded gneiss, **(b)** dragged and ptygmatic folds, **(c)** M and **(d)** Z-asymmetrically folded quartz veins in high-strain zone on outcrops of migmatite-gneiss mapped in the area.

3.1.1.3 Joints, Fractures and faults

Two major lineaments, indicated in the map area by rectilinear drainage pattern, suggest the presence of two sub-parallel fractures trending approximately north-south in the area. These faults and conjugate fracture systems cut all the rocks in the area and are therefore assumed to be late-tectonic (Akintola and Adekeye, 2008). Minor faults trending in NE-SW direction and characterised by dextral displacement of quartz vein are seen on the migmatitic and granite gneisses outcrop while they trend NW-SE with sinistral displacements on the granitic rocks (Plates 7a and b). This agrees with the observation that the end of the Pan-African event is marked by a conjugate fracture system of strike-slip faults having consistent trend of dextral and sinistral sense of movements that cut-cross all the main Pan-African structures including older N-S trending shear zones and late orogenic granites (McCurry 1971; Wright, 1976).

The brittle structures especially joints occur in all the rock types, although they are more pronounced in the quartzites and granites (Plate 7c). Joint spacing was within the range of a few millimetres to 10cm in areas where they occur as a joint set. In some places, they cross-cut the rocks horizontally while in others vertically. Rose diagram generated from field measurements show that the rocks in the area have more than one generation of joints (fig 4b). The orientation of the joints in the field does not follow any particular trend or direction as they trend in all directions. The joints and fracture readings in the field generally range from N0^0 - N35^0W. In some places, the fractures have been filled with quartzo-feldspathic material resulting in the cross-cutting relationship which enables one to determine their order of formation. In the area, joints and fractures generally have N-S and NW-SE trends conforming in some places with the foliation trends (fig 4b).

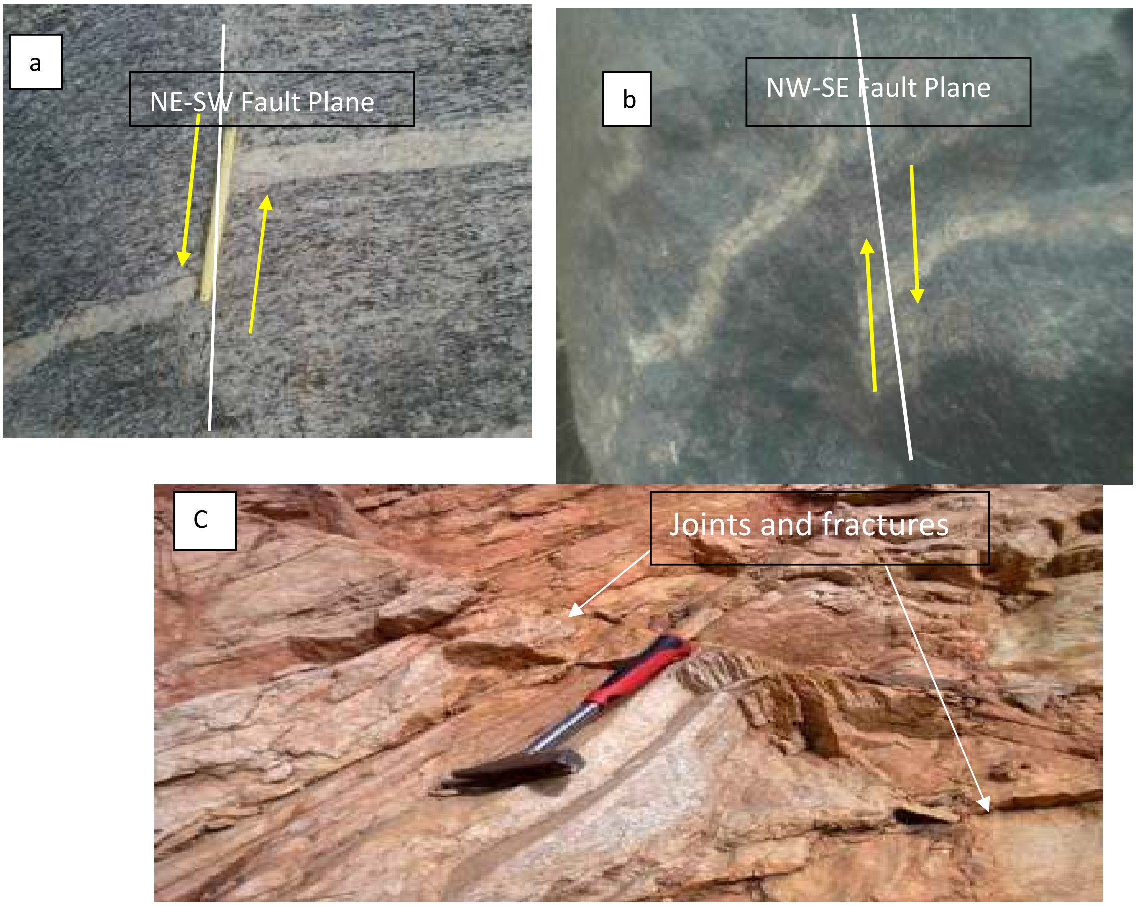

Plate 7: Minor **(a)** right lateral (dextral) and **(b)** left lateral (sinistral) strike-slip faults that displaced quartz veins in granite gniess and biotite granite and **(c)** series of fractures and joints on sheared foliated quartzite in the area.

3.1.1.4 Dykes and Veins

Pegmatite and quartzo-feldsphatic veins are common within the rock units of the study area. The pegmatites are simple pegmatites with quartz in the centre and feldspar at the border. They trend dominantly in the NE-SW, NNE-SSW and NW-SE directions (fig 4c). This prominent N-S brittle shear fracture serves as conduits for the emplacement of the gold- bearing quartz veins. The mineralizing hydrothermal solution have a tendency to migrate towards open fractures and shears to eventually form vein and fissure deposits of gold, cassiterite, tantalite, base metals and associated minerals of economic potential (Dada *et al.,* 2003). The rose diagrams (figs. 3b and c) for the brittle structures show three principal directions: (i) a major NW-SE trends for joints, fractures, quartz veins, dolerite and pegmatite dykes, (ii) Minor NE-SW directions for veins and dykes and (iii) E-W directions for fractures and joints. Field relationship shows that these brittle fractures are younger and cut all the rocks in the area.

CONCLUSION

Field and stucural mapping of the study area shows that the rocks belong to two main suites: the gneiss-schist suite that includes migmatite/migmatized schist, quartzites, mica schist with subordinate bands of metaigneous body and granitic suite comprising fine-medium grained granite, medium-coarse grained granodiorite and porphyritic granite. From field disposition of the granitic rocks, fine-medium grained granite are assumed to be the youngest and intruded into the biotite granite and the medium to coarse grained granodiorite. The two suites are locally associated with pegmatitic and mafic dykes. The final geological map of the area shows that the area has been affected by at least two orogenic cycles as evident by two generations of folded, massive and foliated quartzites in the area. The rocks of the area show majorly N-S and NE-SW planar structures and minor NW and E-W structural trend defined by gneissose foliation. The N-S, NE-SW and E-W represent ductile metamorphic deformations that are probably pre- or syn- Pan African event that led to the wide spread emplacement of gneissose structures in the rocks of the basement while the NW-SE brittle deformational structures in- filled by pegmatites and quartz veins are probably post- or syn- Pan-African.

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