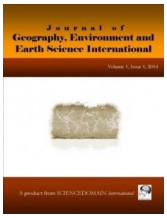

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Petrology and Structural Geology of Lankpeshi Area of Igarra Schist Belt, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration between authors VIM and NE. Author VIM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NE managed the analyses of the study. Author NE also managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Field study of the area shows that the major rock groups are migmatites, gneisses, schists, quartzites and calc-silicate rocks which have been intruded by a series of granites and pegmatites. The gneisses are sandwiched by the migmatites while the schists are highly weathered. Petrographic analysis reveals the presence of quartz, biotite, plagioclase, K-feldspar and accessory minerals in many of the rock samples. Migmatites in the study area range in textural characteristics from medium to coarse-grained with mafic bands defined by biotite and hornblende while feldspar with quartz forms the granular lighter coloured layers. Structural evidence shows that the area is a typical metamorphic terrain with rocks of diverse nature, complexly deformed with development of foliations and lineations and the presence of both planar and linear structures. Structural evidence also shows that most structures in the area include joints, strike-slip faults, quartz veins, asymmetric folds, drag folds. The fracture trends show that the dominant trend is in the N-S and NNW-SSE direction. The plot of foliation trend of the area shows NW-SE and NE-SW, indicating imprint of Pan-African and relict of pre-Pan African structural pattern. The nature of the minerals contain in the rocks, together with their geometry reveal that the rocks have undergone more than one deformational, metamorphic and magmatism event.

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1. INTRODUCTION

Lankpeshi area lies within the Igarra Schist Belt of the Southwestern Nigerian Basement Complex Fig. 1. The area is made up of Basement Complex rocks which include migmatites, gneisses, schists, calc-gneisses, quartzites which have been intruded by granites and pegmatites. The schist (metasediments) occurs as a supracrustal cover on the basement and consists of biotite schist, quartzites and mica schist, calc-gneiss and marble [1], [2] and [3]. The Nigerian Basement Complex has undergone polyphase deformation and polycyclic metamorphism during the Proterozoic and early Phanerozoic periods [4]. [5] noted that the rocks in the area show evidence of polyphase deformation. [6] grouped the rocks in this region as migmatite-gneiss complex comprising metasedimentary rocks, which have been altered by migmatitic and granitic processes.

Deformational and tectonic events that accompanied Pan African orogeny in the area resulted to the development of structural elements such as joints, strike-slip faults, veins, asymmetric folds, drag folds, mineral lineations and foliations. The Pan-African orogeny is the last tectono-thermal event (600 ± 150Ma) to affect the Nigerian Basement Complex, and it is very complex that [1] proposed not less than two episodes of deformation during the orogeny.

It is quite significant because it led to the strong deformation of both Pan-African and pre-Pan African rocks. This study involves the study of the rocks and the various structural elements present in the rocks in the study area with the view to understanding the deformational and structural history of the rocks in the context of the geology of Nigeria.

2. GEOLOGY OF THE AREA

The study area is located geographically within latitudes 7°24′N-7°30′N and longitudes 6°05′E-6°15′E. It is situated at the northern part of Akoko Edo Local Government of Edo State, Southwest Nigeria, within the topographical map of [7], (Fig. 1) on a scale of 1:50,000. The major highway in the area runs from Auchi through Ikpeshi, Sobe Ogbe, Igarra, Ibillo to Lankpeshi. There is also another route from Okene, Magongo to Lankpeshi. Both the old, new roads and foot paths were used as access for the exercise.

The Igarra region is part of the Precambrian Southwestern Basement Complex of Nigeria and it host a series of rock types with Pan-African granites which contain joints and mineral veins [8]. Southwestern Nigeria is made up of rocks which are mainly Precambrian in age. The Nigerian Basement Complex comprises of migmatites, gneisses and supracrustal sequences. Pan-African orogenic imprints in the Nigerian Basement Complex were characterized by high grade metamorphism, folding, faulting and widespread granite plutonism. [9,10,11] are of the view that the Pan-African event achieved the status of an orogeny and that the Basement Complex was affected by two isoclinal foldings during this orogeny. The region around Igarra is mostly underlain by crystalline rocks ranging from Precambrian to Paleozoic age and generally strongly folded rocks assigned to the Nigerian Basement Complex [6].

The migmatitie-gneiss complex also termed “migmatite-gneiss-quartzite complex” is generally considered as the Basement Complex [6,12] and it is the most widespread of the component units in the Nigerian Basement. The migmatite–gneiss complex has ages ranging from Pan-African to Eburnean. It has a heterogeneous assemblage comprising migmatites, orthogneises, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. The schist belt is a supracrustal sedimentary succession and has undergone deformation. The most easterly schist belts in south-western Nigeria are distributed around the Okene area. [13] reported occurance of pelitic schists, gneisses, marble, migmatites and older granites around Igarra near Okene. Biotite, garnet, muscovite were identified in the pelitic schists. Chanockitic rocks form subordinate but important group in the Precambrian Basement Complex and they are mainly found in the western, northern and eastern parts of Nigeria. The charnockitic dyke recognized by [14] has been re-mapped and corrected as a syenite dyke by [15]. [16] identified earlier charnockites within the migmatite-gneiss complex and considered them to have crystallized in granulite facies

condition and another type he believed formed during the Pan-African plutonism by crystallization from magma or metasomatism of pre-existing rocks. Metasomatism is a widespread process in the basement rocks of Nigeria.

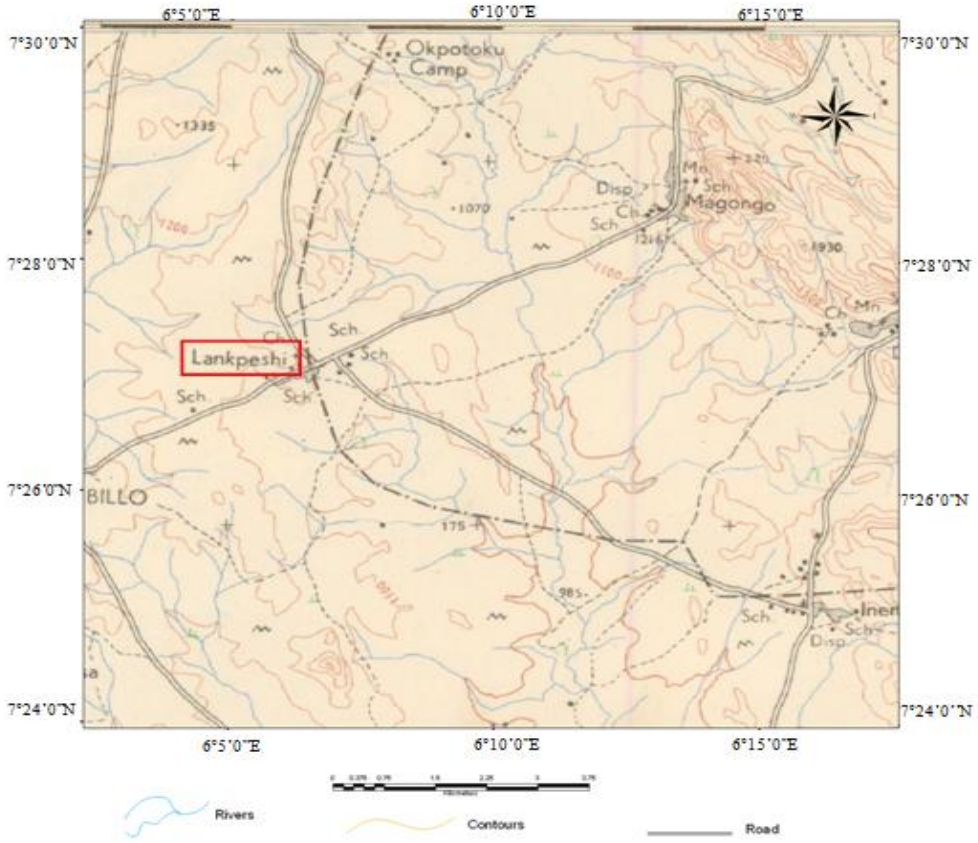

Fig. 1. Topographic map of the study area
[Adapted from 6]

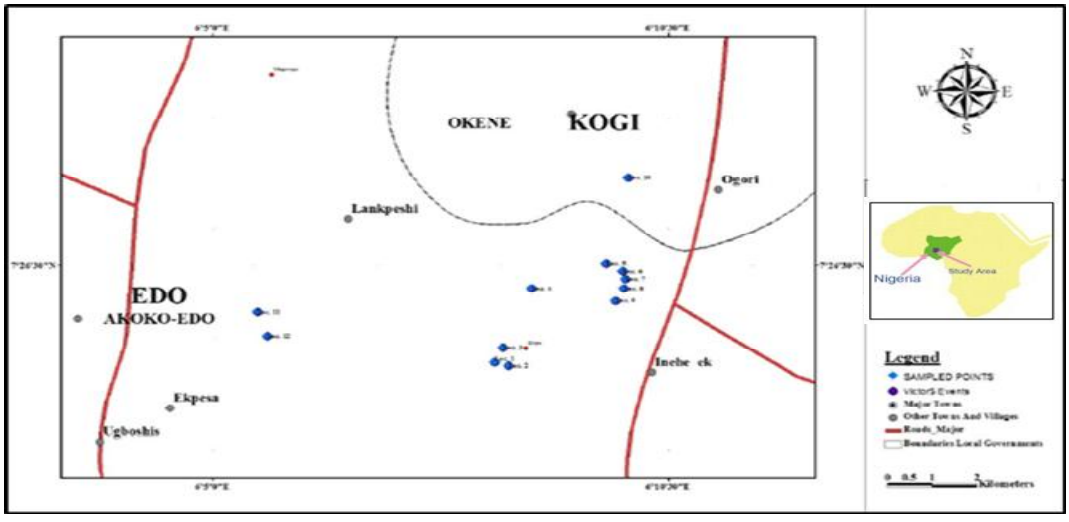

Fig. 2. Map showing the rock sample collection points

3. METHODOLOGY

The methods adopted for the research is field operations and laboratory techniques. In the field, each outcrop was observed and described based on macroscopic characteristics, structural elements and field relation. Hand specimens were described based on the following macroscopic features: colour, texture, mineralogy and carefully labeled. Macroscopic structures are relevant to the study of regional structures and events. Sample points were plotted on the base map at the appropriate locations where the samples were collected with the use of a global positioning system (GPS) and the geographic coordinates of the base map (Fig. 2). The rock samples collected were taken to the laboratory for further analysis. In the laboratory, petrographic analysis was done on selected representative rock samples for microscopic study. Strike and dips of foliations and fracture trends identified in the field were measured using the compass clinometer. A plot of rose diagram and stereonet was made to determine the trend and geologic event that led to the deformation in the area.

4. RESULTS

Field study of the area shows that the major rock groups are migmatites, gneisses, schists, calc-gneisses, quartzites which have been intruded by a series of granites of Precambrian age (Fig. 3). The migmatites occur in association with the gneisses in a N-S direction and are marked by the development of foliations and lineations. The schists are highly weathered and exfoliated, resulting in the peeling of the surface layers.

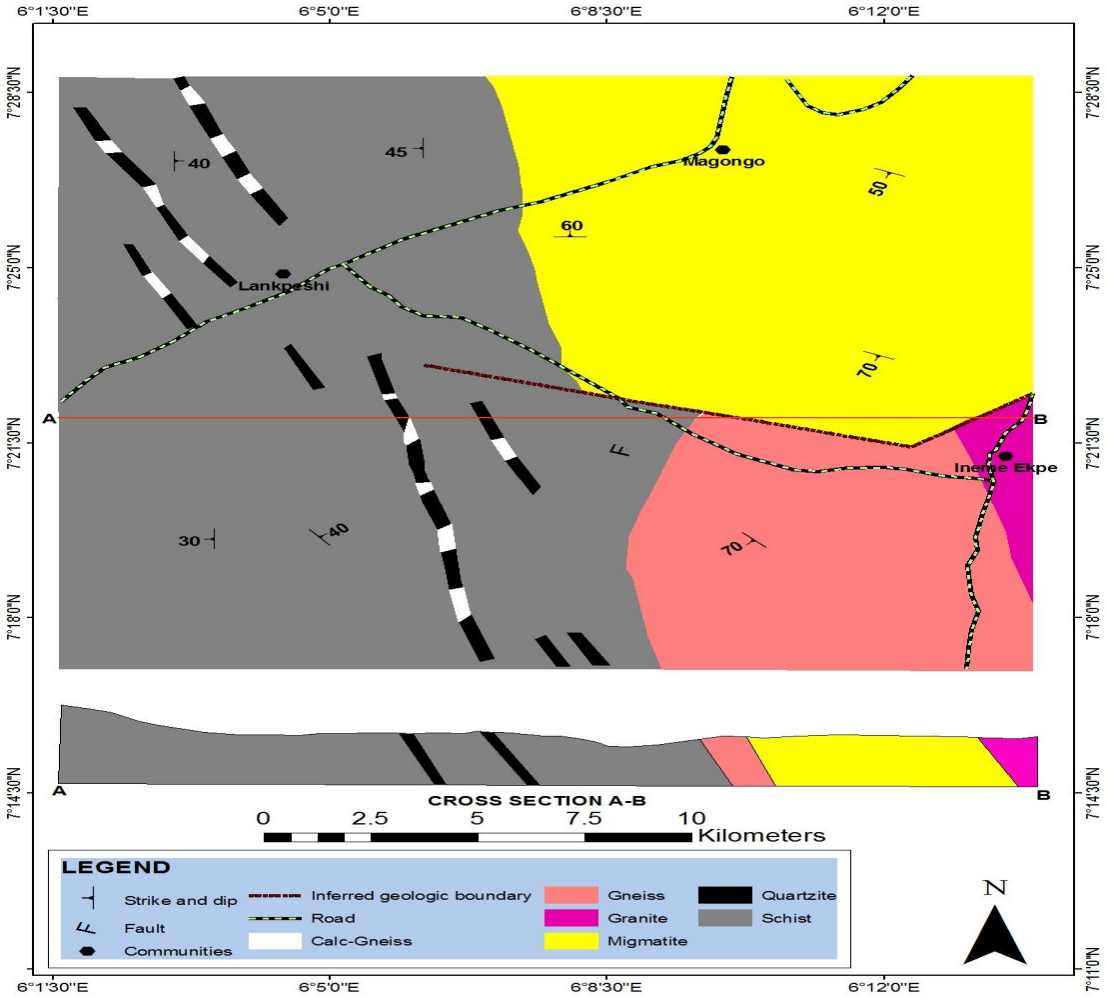

Fig. 3. Geologic map of Lankpeshi area

5. PETROGRAPHY

The Migmatites in the study area are mixture of dark and light coloured rock. The textural characteristics of migmatites in the study area range from medium to coarse-grained with mafic bands defined by biotite and hornblende while feldspar and quartz forms the granular lighter coloured layers (Plates 1a, 1b, 1c). The rocks display migmatitic texture marked by the development of foliations and lineations. The orientation of the dark and light coloured minerals defines the foliations and lineations in the rock. Average modal analysis of the migmatites shows that the dominant minerals observed includes quartz (32%), K-feldspar (22%), plagioclase (10%), biotite (16%), hornblende (18%) and accessory mineral (2%).

Gneisses shows varying textural characteristics trending from the northwest to southeast in the area. The gneisses are generally dark-grey in colour and occurs as a medium to coarse-gained foliated rocks with bands of light and dark colored minerals. The mineralogy of the outcrop is characterized by felsic minerals such as quartz, feldspar and mica with some accessory minerals. The intensity of metamorphism on the outcrop shows an alternation and mineralogical alteration of the mafic and felsic minerals in the rock. It is highly banded with ferromagnesian minerals representing the dark bands. The dark bands contain hornblende and biotite while the light bands are made up of quartz and feldspar. Under the microscope, the rock shows variable grains of minerals closely packed showing preferred orientation. The following minerals can be distinguished quartz (32%), K-feldspar (20%), plagioclase (30%), biotite (10%), muscovite (2%) hornblende (4%) and accessory mineral (2%) (Plates 2a, 2b, 2c).

Schists are among the largest rock unit in the area. Schists is a medium-grade metamorphic rock with medium to large grains of mica flakes in a preferred orientation. Schists in the area have been intensely weathered. The weathered schists are brownish in appearance and cover much of the study area. The schists are probably the oldest rocks in the area and have been intruded by Pan-African granite in some places. They are foliated and folded. The foliation is represented by the ferromagnesian minerals and quartzo-feldspathic minerals. The schists are largely pelitic and contain very little feldspathic minerals. The rocks display well-defined schistosity that makes it split easily and contains mica flakes distributed in wavy lines which alternately meet and separate into sheets. In hand specimen the rocks are light in colour, fine-to-medium grained and consist of percentage mineral composition of quartz (24%), plagioclase (20%), muscovite (8%), K-feldspar (18%), biotite (22%), hornblende (4%), epidote (1%), chlorite (1%) and opaque minerals (2%) (Plates 3a, 3b and 3c).

Calc-gneiss and marble make up an important part of the supracrustal sequence. Igarra and Ikpeshi are important marble producing areas of Southwestern Nigeria [17]. Marble occurs prominently in Lankpeshi area of Igarra schist belt and is associated with calc-gneiss

Plate 1a. Hand specimen of migmatite at Lankpeshi- Magongo Okene road showing mixture of dark and light colour

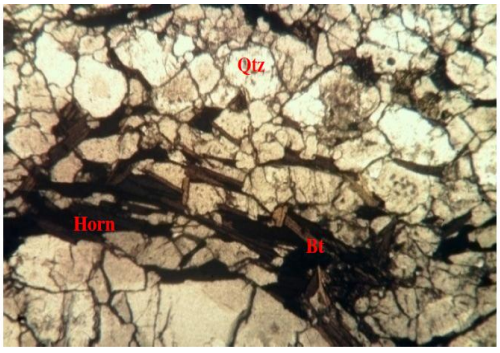

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Plate 1b. Photomicrograph of migmatite under plane polarized light (PPL) at Lankpeshi-Magongo Okene road showing biotite (Bt), hornblende (Horn) and quartz (Qtz)

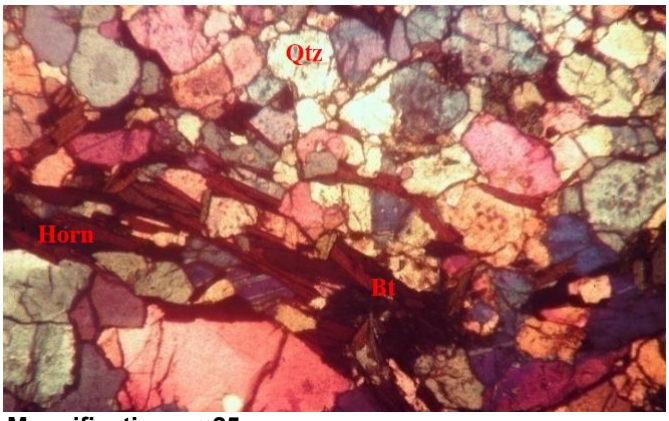

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Plate 1c. Photomicrograph of migmatite under crossed polarized light (XPL) at Lankpeshi-Magongo Okene road showing biotite (Bt), hornblende (Horn) and quartz (Qtz)

within the schist rock unit. Outcrops of marble in the study area were mapped at Bekuma mining site along Ossoso road, northwest of Igarra. The colour of the mapped rock in the area varies from light grey to white as shown in plate 4a. It is medium to coarse-grained; it tends to be granular, often sugary in appearance. The lithological banding of the greenish and light grey bands, define its gneissic fabric. Structurally, marble is commonly massive but may have a layering or banding which is usually a primary bedding structure. Thin section study of the marble in the study area shows an average modal composition of calcite (40%), quartz (10%), biotite (26%), and accessory mineral (2%). The modal composition shows that the marble is impure, and is a calc-gneiss. Calc-gneiss is mainly composed of calcite, quartz with biotite. Most of the minerals show evidence of strain and are altered. Calcite, quartz and biotite are the dominant minerals accounting for 90% of the modal composition. It is the presence of minerals that produces the attractive range of colours and structures found in marble. Calcite also occurs as parallel or fibrous aggregates, or as granular or massive aggregates.

Quartzites are found in association with other metamorphosed sedimentary rocks such as phyllites, schist and marble. This rock type is widely distributed. It is seen at Bekuma mining site along Ossoso road (Plate 5a). It is a light coloured rock and contains over 90% quartz (Table 1). It is medium-grained, usually of a granoblastic texture. Quartzites are essentially composed of tightly interlocking grains of quartz. Quartz is one of the mostly distributed minerals. It is abundant in clastic sediments and it is virtually the sole constituent of quartzite.

Plate 2a. Hand specimen of gneiss at Lankpeshi-Magongo Okene road showing variable colours of mineral grains

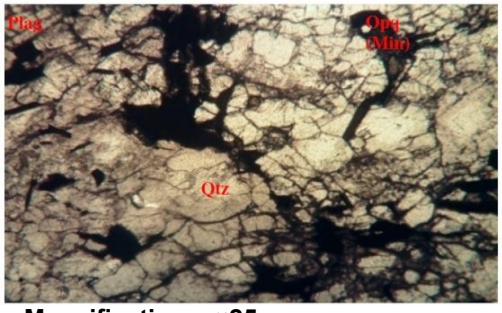

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Plate 2b. Photomicrograph of gneiss under plane polarized light (PPL) at Lankpeshi-Magongo Okene road showing quartz (Qtz) sub-hedral in shape with no cleavage, plagioclase (Plag) and opaque mineral (Opq)

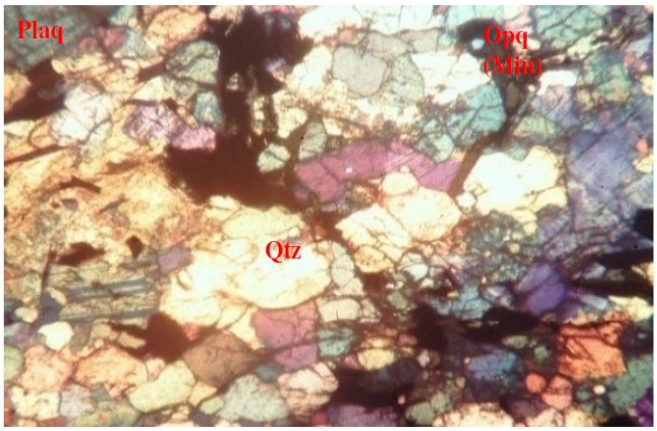

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Plate 2c. Photomicrograph of gneiss under cross polarized light (XPL) at Lankpeshi-Magongo Okene road showing quartz (Qtz) sub-hedral in shape with no cleavage, plagioclase (Plag) andopaque mineral (Opq)

6. STRUCTURAL GEOLOGY

Structural elements in the study area include those formed due to brittle deformation (brittle structures) and ductile deformation (ductile structures). Deformation of the area occurred in two phases, a ductile phase, which is responsible for the formation of planar structures (foliations) and a brittle phase resulting in fractures (joints and faults), many of which have been filled with quartz veins and pegmatite veins. The major structures in Lankpeshi area include joints, strike-slip faults, veins, foliations, lineations, asymmetric folds and drag folds.

Joints characterize most outcrops in the area. Joints are frequently observed in schists (Plate 6), quartzites and gneisses and to lesser extent in the granites. Structures occur in the rock encountered and the joint spacing was within the range of a few millimeters in the study area. In some places, they cross-cut the rocks horizontally while in others vertically. The major set of joint in the area trends in NNW-SSE direction. In some places, the joints have been filled with quartz resulting in the crosscutting relationship which enables one to determine their order of formation (Plate 7). Both quartz veins and pegmatite veins (Plate 8) are found in the rocks of the studied area. The veins

Plate 3a. Hand specimen of schist at Lankpeshi- Magongo Okene road showing grey colour and medium to coarse-grained texture

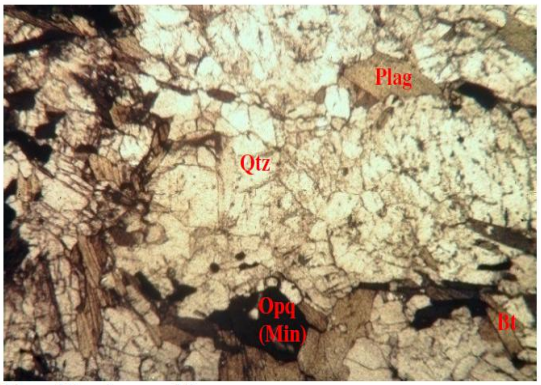

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Plate 3b. Photomicrograph of schist under planepolarized light (PPL) at Lankpeshi-MagongoOkene road showing quartz (Qtz), biotite (Bt)plagioclase (Plag) with some opaque mineral(Opq)

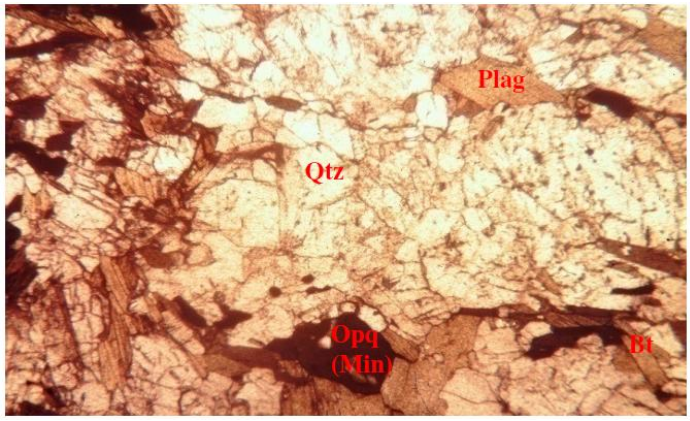

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Plate 3c. Photomicrograph of schist under crossedpolarized light (XPL) at Lankpeshi-Magongo Okene road showing quartz (Qtz), biotite (Bt) plagioclase (Plag) with some opaque mineral (Opq)

are irregular; some of them run parallel to the general structural NW-SE trend, while others crosscut especially the quartz veins. Joint values plotted on a rose diagram show that the principal joints values in the area are in the N-S, NNW-SSE direction (Fig. 4).

The faults encountered in the area were mainly minor faults with small displacements. Two types of faults occur in the area. They are the normal and strike-slip faults. Strike-slip faults occur in the migmatitic-gneiss of the area. The sense of displacement of these faults is dextral. In the area, fracture trend shows N-S and NNW-SSW trending veins crosscut and displace the E-W trending veins with slips of about 1.7 cm long (Plate 9). A strike-slip fault indicates horizontal motion parallel to the strike of the fault surface. Structural imprints are more in the migmatitic-gneiss than in any other rock type in the area. The structures exhibited by the migmatitic-gneiss are parallel to the bedding and faulting in the basement rocks is mainly strike-slip. Faults show local cataclasis and the cataclasis which principally defined in the fault zones confirm that the faults are dextral transcurrent faults.

Foliations and lineations occur in most of the rocks encountered in the study area. They probably developed as a result of tectonic differentiation. Foliation is well developed in most of the rock types, but is indistinct in some. One foliation trend is dominant throughout the area and this is consistent with the regional strike of foliation, which is essentially north-south with some variations. Foliations which are common in the migmatites, gneisses and schists occur as simple mineralogical banding. Foliation is strong in the migmatitic-gneiss, and is marked by alternating bands of dark and light minerals. Schist mapped in the study area display foliation planes (Plate 10). The schistosity of the quartz-biotite-muscovite schist is well-developed, due to parallel orientation of the micas. Foliation is weak in the granitic gneiss of the area. The stereonet plot of foliation trend of the area shows NW-SE and NE-SW trending and this indicate imprint of Pan-African structural pattern (Fig. 5). Lineations in the rocks are displayed by the parallel alignment or preferred orientation of dark and light coloured minerals. The dark coloured minerals are hornblende and biotite while the light coloured minerals are quartz and feldspar.

Minor folds occur as asymmetric folds in gneissic rock around Lankpeshi-Magongo Okene road (Plate 11). The asymmetric folds are of unequal limbs and the axial planes are not equidistant from the limbs. The crests of which measures 1.3 m vary considerably with various crest lines. This may be due to compressional forces to which these rocks have been subjected overtime. The limbs of some of the folds are asymmetrical, and exhibit open fold with vertical axial planes, trending northwest-southeast. The dominant axial trends of the folds in the area are E-W with few trending NNW-SSE direction along the southern segment of the outcrop. Drag folds were also encountered in the area (Plate 12).

Plate 4a. Hand specimen of calc-gneiss at Lankpeshi mining site showing granular mineral texture

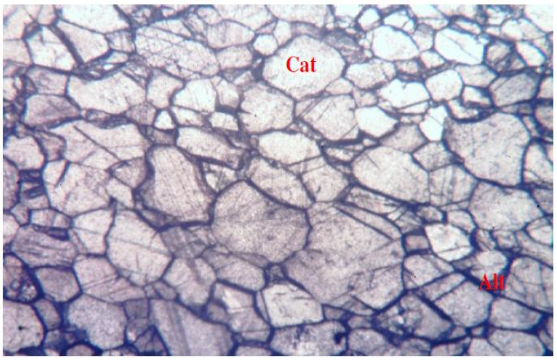

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Plate 4b. Photomicrograph of calc-gneiss under plane polarized light (PPL) at Bekuma mining site showing calcite (Cat) mineral, alteration (Alt), a curved grain boundaries and granular mineral texture

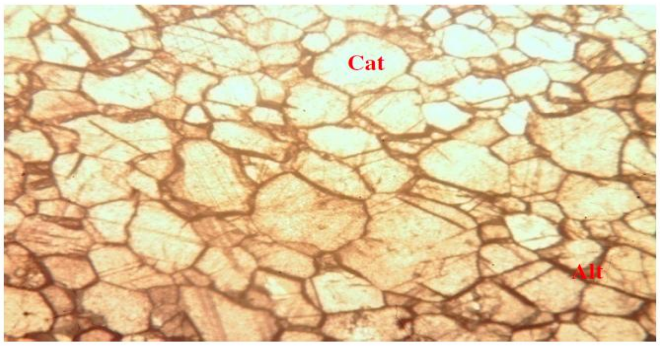

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Plate 4c. Photomicrograph of calc-gneiss under crossed polarized light (XPL) at Bekuma mining site showing calcite (Cat) mineral, aegurine (Aeg), alteration (Alt), a curved grain boundaries and granular mineral texture

Plate 5a. Hand specimen of quartzite at Lankpeshi mining site showing quartz crystals with variable interference colours

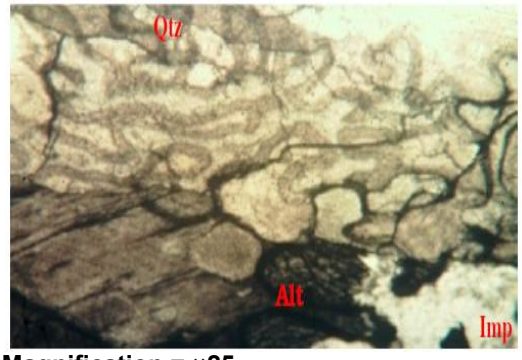

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Plate 5b. Photomicrograph of quartzite under plane polarized light (PPL) at Lankpeshi mining site showing anhedral crystals of quartz (Qtz) with an interlocking texture,alteration (Alt) and impurities (Imp)

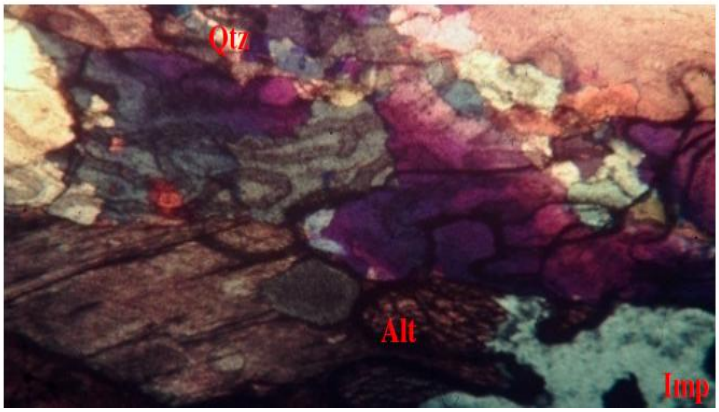

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Plate 5c. Photomicrograph of quartzite under crossed polarized light (XPL) at Lankpeshi mining site showing anhedral crystals of quartz (Qtz) with an interlocking texture, alteration (Alt) and impurities (Imp)

Table 1. Average modal composition of rocks around Lankpeshi area of Igarra schist belt (%)

Minerals	Percentage (%) mineral composition of the rocks					Minerals average
	Migmatite	Gneiss	Schist	Calc-gneiss	Quartzite	
Quartz	32	32	24	10	96	38.8
K-feldspar	22	20	18	8	-	13.6
Plagioclase	10	30	20	12	-	14.4
Biotite	16	10	22	26	-	14.8
Muscovite	-	2	8	1	-	2.2
Hornblende	18	4	4	1	-	5.4
Pyroxenes	-	-	-	-	-	0
Olivines	-	-	-	-	-	0
Calcite	-	-	-	40	-	8
Accessory mineral	2	2	4	2	4	2.8

Plate 6. Field photograph of joints on schist at Lankpeshi mining site

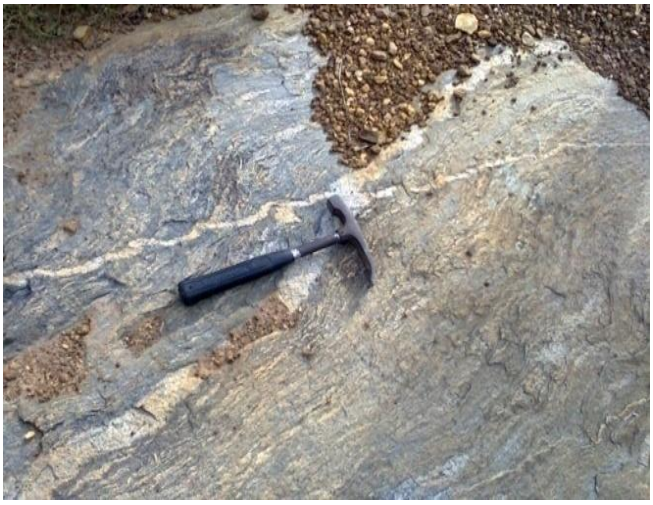

Plate 7. Field photograph of crosscutting quartz veins showing drag folds in gneissic rockaround Lankpeshi-Magongo Okene road

Plate 8. Field photograph of pegmatite veins in gneissic rock around Lankpeshi-Magongo Okene road

Plate 9. Field photograph of dextral strike-slip fault along Lankpeshi-Magongo Okene road

Plate 10. Field photograph showing foliated weathered schist along foot path to mining site at Lankpeshi

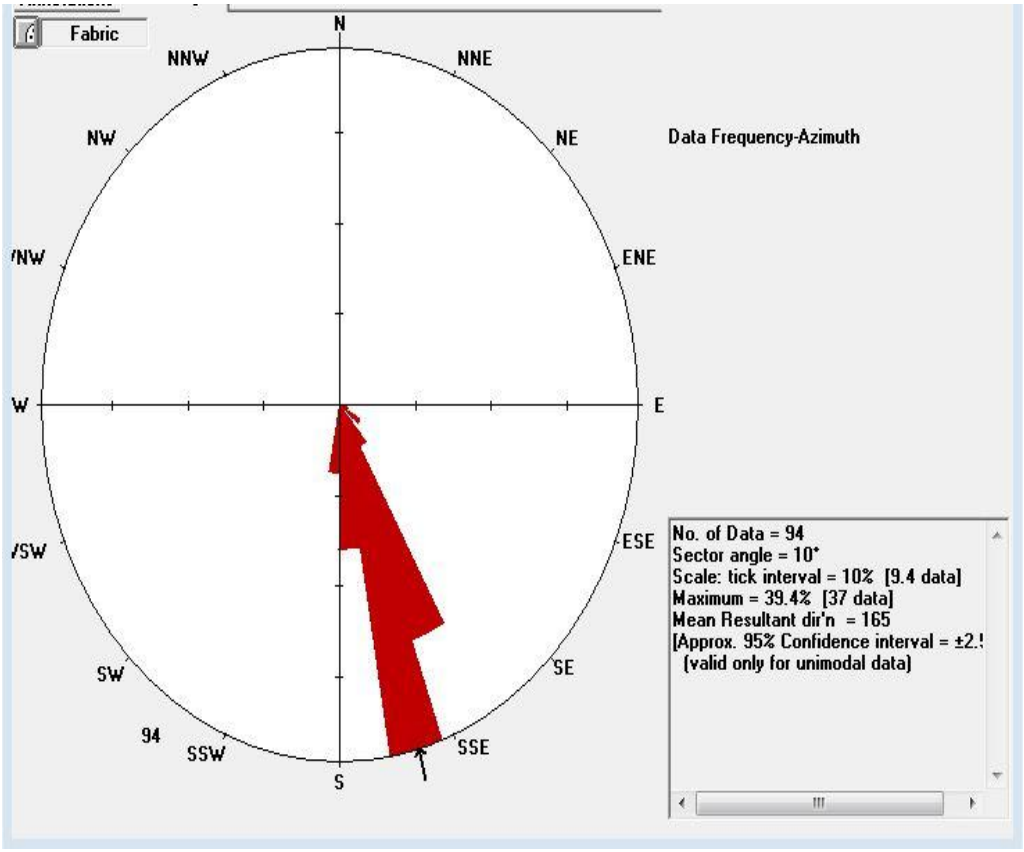

Fig. 4. A rose diagram of fracture trend at Lankpeshi area showing orientation of joints and structural trend of N-S and NNW-SSE direction

Plate 11. Field photograph showing asymmetric folds in gneissic rock around Lankpeshi-Magongo Okene road

Plate 12. Field photograph showing drag folds on the schist outcrop at Lankpeshi mining site

7. DISCUSSION

Petrographic and structural studies of Lankpeshi area of Igarra Schist Belt shows that the area is part of the Basement Complex of Nigeria and is characterized by hilly and undulating rocks which consists of migmatites, gneisses, schists, calc-gneisses and quartzites which have been intruded by granites and pegmatites. Petrographic examination of rocks in the area shows quartz (38.8%), k-feldspar (13.6%), plagioclase (14.4%), biotite (14.8%), muscovite (2.2%), and hornblende (5.4%) as the common mineral constituents occurring in the basement rocks of the area. However, calc-gneiss is mainly composed of calcite (40%) quartz (10%) and biotite (26%). Calcite, quartz and biotite are the dominant minerals accounting for 90% of the modal composition of the calc-gneiss. The occurrence of biotite, plagioclase, K-feldspar and quartz in many of the rock samples further show a metamorphic terrain with rocks of diverse nature, complexly deformed with the presence of both planar and linear structures.

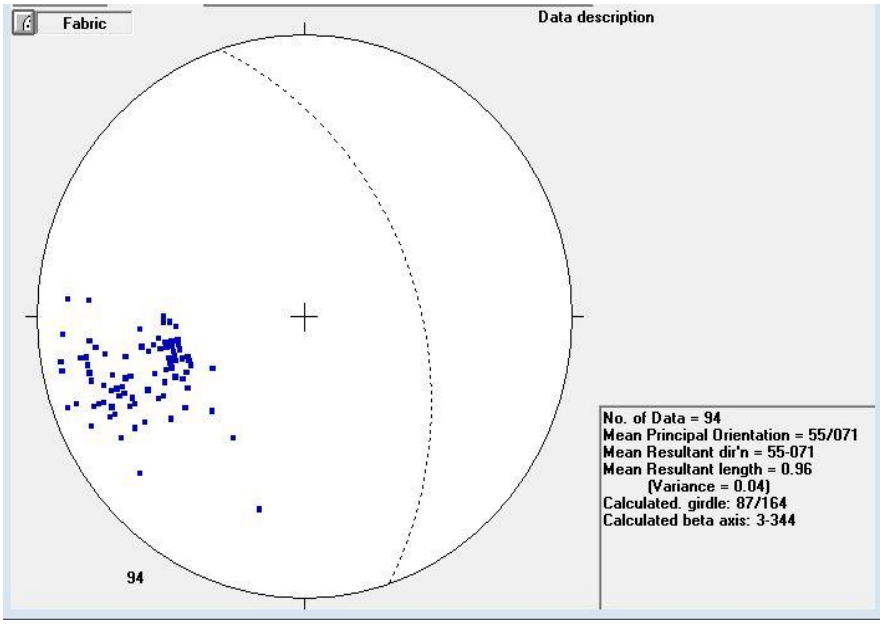

Fig. 5. Stereonet plot of foliation trend at Lankpeshi area showing SW cluster and NW-SE trending of the foliation planes

The lithologic units revealed that the area has witnessed several episodes of deformation leading to re-orientation of the pre-existing structural framework. Results show that structures such as joints, strike-slip faults, veins, asymmetric folds, drag folds, mineral lineations and foliations in the mapped area have resulted from processes of tectonism and metamorphism. The faults encountered in the area were mainly minor faults with small displacements. This fault type is similar to the faults reported by [18] in the north western part of Nigeria. The existence of minor asymmetric folds in the area has been documented from other parts of southwestern Nigeria; Oke-Awun area, Southwestern Nigeria [19] and the Jebba areas [20]. There are evidences of weathering on the outcrop. The plot of foliation trend of the area shows NW-SE and NE-SW, indicating imprint of Pan-African structural pattern. The most dominant structural trend is in the N-S to NNW-SSE directions.

The foliations in the area are characterized by mineralogical banding which is defined by alternating light and dark minerals. The abundance of foliations and lineations suggest that the rocks have been subjected to many deformational events.

8. CONCLUSIONS

Lankpeshi area consists of metamorphic rocks which are similar to rocks distributed in the Basement Complex of Nigeria and are mostly migmatites, gneisses, schists, calc-gneisses, quartzites with the intrusion of granites and pegmatites. Metamorphic rocks of the area have been folded into anticlines and synclines. Generally, N-S to NNW-SSE structural trends characterize the basement rocks of Lankpeshi area of Igarra Schist Belt. The area has undergone deformational events, resulting in the development of both brittle and ductile structures. The brittle structure resulting in fractures (joints and faults), many of which have been filled with quartz veins and pegmatite veins. The ductile structures mapped in the area include asymmetrical folds, drag folds, foliations and lineations. Minor folds occur as asymmetric folds in gneissic rock around Lankpeshi-Magongo-Okene road. The type and nature of minerals the rocks contain together with the geometry reveal that the rocks have undergone more than one deformational event since the time of their formation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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