Geological Mapping, Petrological Study and Structural Analysis of Complex Rocks in Ife-South Local Government Area of Osun State South Western Nigeria

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***Abstract*: - Geologic map is an important planning tool for the economic growth of a nation, it displays the arrangement of geologic features of a particular area. It has been observed that the available geologic map of Nigeria omits some local geology of interest which is the reason local geological mapping must be encouraged. Mapping of the Study area was carried out by traversing along dip direction i.e west east direction from one location to another with the aid of a base map, compass clinometer and a geographic positioning system. Samples were taken across various locations where there was an outcrop, these samples were taken to the laboratory for further analysis. The result shows that the study area consist of gneiss, granite gneiss and amphibolite. Gneiss which shows metamorphic grade up to the amphibolite facies. Compositionally, they are predominantly granodiorite but vary from diorite through tonalite to granite. Metamorphosed basaltic dykes also occur in the area as sheet of amphibolite. Two phases of deformation was recognized; the first phase attained granulite facies while the second phase was associated with cataclastic and probably retrogression to the amphibolite facies. Systematic structural mapping and study of the area also confirmed different types of structures such as fractures, quartzo-feldspathic veins, joints and quartz-veins. The overall results showed the study area is a manifestation of Precambrian deformation which was revealed by the several structural features found in the area.**

I. INTRODUCTION

Several work from various researchers on the geology of Nigeria have provided a great depth of knowledge about the countries geological settings. Similarly, a number of geologists have done extensive work and research in the study area which lies between latitude 7^0 12 and 7^0 15 and longitude 4^0 30 and 4^0 32 of Ife-Ilesa Schist belt ,the Older granites and Charnockitic rocks in Akure Ondo state, (Rahaman, 1988; Dada, 2006 ;Odeyemi, 1977; Obaje, 2009).Although considerable work has been carried out around the geology of south western Nigeria to include some part of the studied area (Odeyemi, 1977 and Oyawoye, 1964), however, there is still need for detailed studies and mapping to enable a better understanding of the local geology of the area to enhance the sustainable management of the resources in the area which the general work done would not provide. Detailed, concentrated and localized mapping will help to solve problems link between the major rock types of the basement complex and their associated rocks which have been difficult to resolve even though dating methods have been employed. These solutions might only be achieved when considering the structures and rock attitudes of every small detailed area. Apart from the regional geologic data which is already in existence, more detailed localized knowledge is needed to complement the previous works and also help geologist have a better view of the past events and how they can initiate new and better ideas subsequent to the known ideologies. This geologic mapping report attempts to identify the rock types and analyse the various structural elements present on the rocks in the study area, relates their occurrence to the geology of the area with a view to understanding the geologic and structural history of the rocks and the deformational episodes that pervaded them.

II. MATERIALS AND METHODS

Description of the study area

The study area is Amusan village, a remote community in Ife south local government area of Osun State southwestern Nigeria. Other communities in the vicinity of Amusan are Ajebandele, Aluti-erin, Sanmi, amongst others. The area is approximately $25km^2$ and two rock units namely; Gneiss and Granite were differentiated. Rahaman (1976) and Odeyemi (1977) noted that the rocks in the southwestern areas shows evidences of polyphase deformation with the plutonic episode of the Pan African event being the most pervasive. Rahaman (1988) noted that the south western basement complex of Nigeria lies within the rest of the Precambrian rocks in Nigeria. He grouped the rocks in this region as migmatite-gneiss complex comprising largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes. Odeyemi (1999) suggested that almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusives are tectonic in origin, because pre-existing primary structures have been obliterated by subsequent deformation.

Geologic structures present in rocks can serves as clues in the determination of the geologic history of an area.

Anifowose (2004) also noted that joints ranging from minor to major ones in all the rock types, some of which are filled with quartz, feldspars or a combination of both lie generally in the NE-SW direction, while Boesse and Ocan (1992) reported that the south western basement complex of Nigeria has been affected by two phases of deformation namely D1, D2, the first phase (D1) produced tight to isoclinals folds while the second phase (D2) is characterized by more open folds of variable style and large vertical NNE-SSW trending fault. Oluyide (1988) gave evidence that within the basement complex, tectonic deformation has completely obliterated primary structures except in a few places where they survived deformation (Okonkwo, 1992) and this was similar in the rocks of the study area.

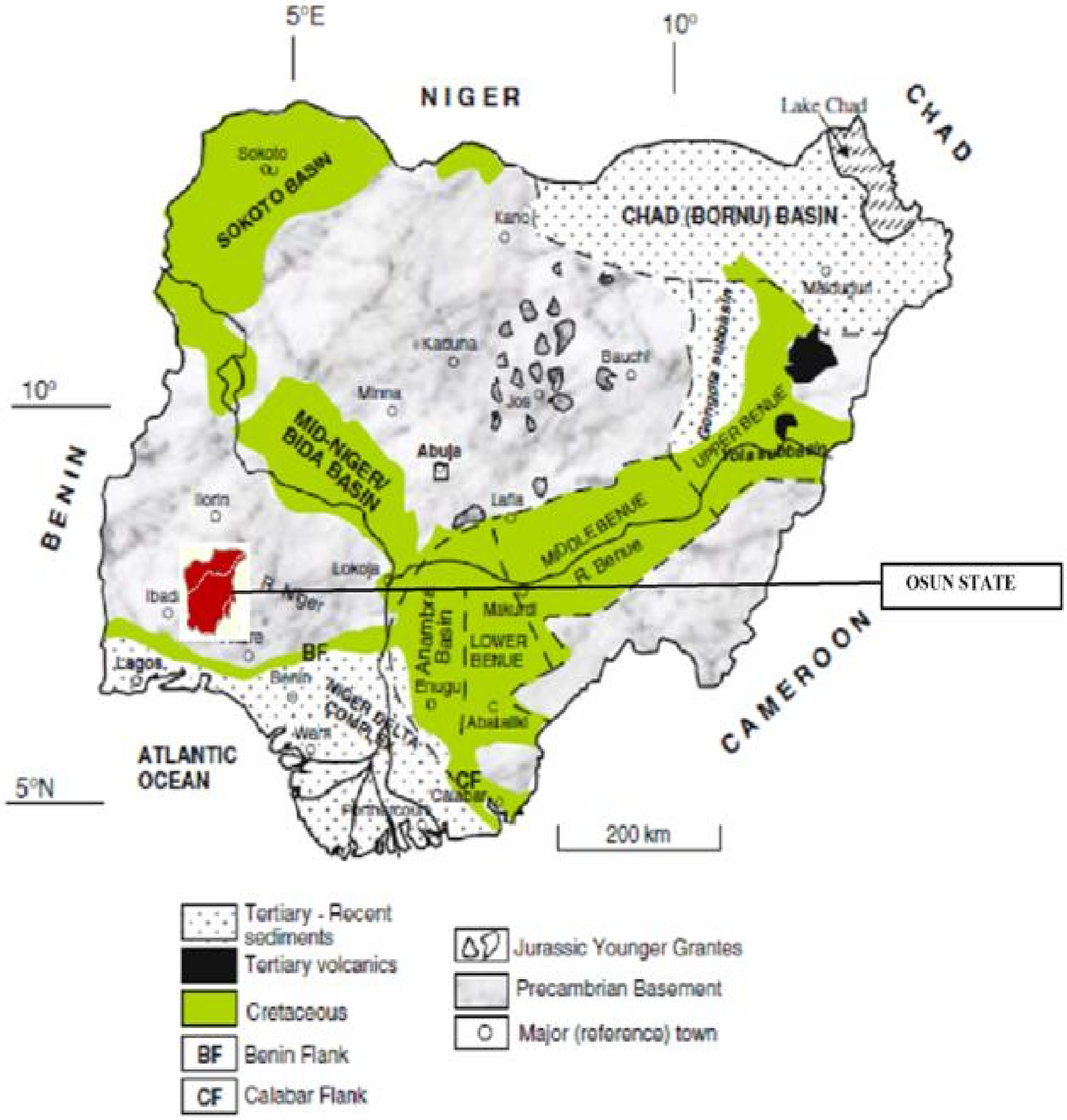


Figure 1: Map of Nigeria showing the three major litho-petrological units (modified after Obaje, 2009)

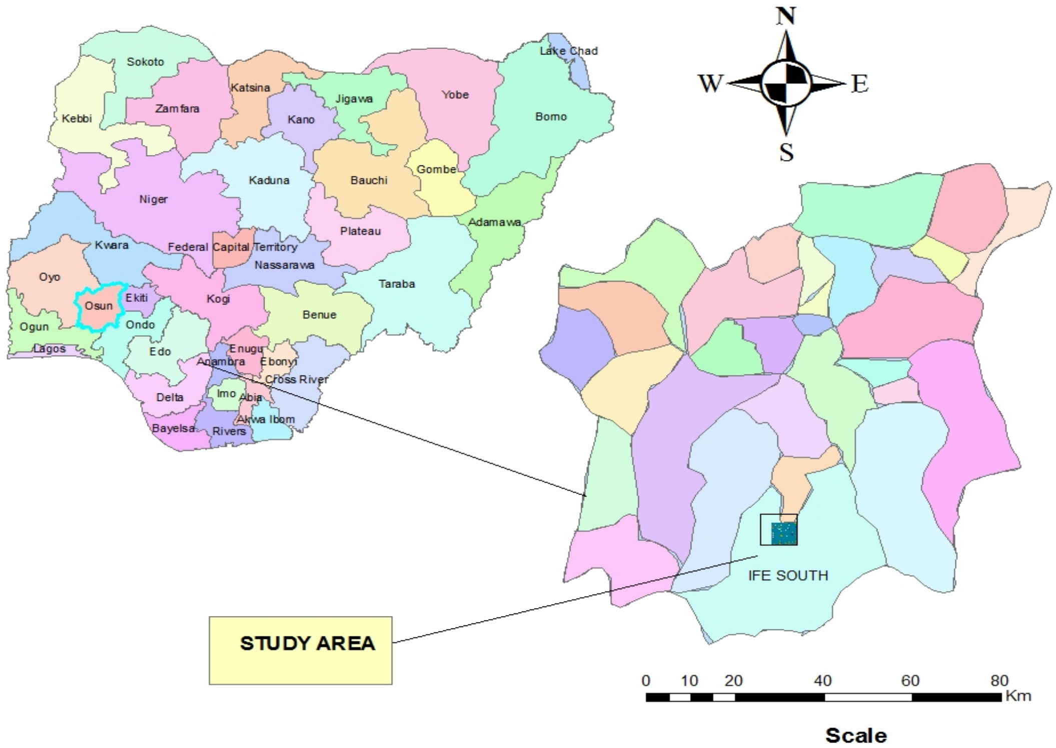


Figure 2: Map of Nigeria and Osun State showing the study area

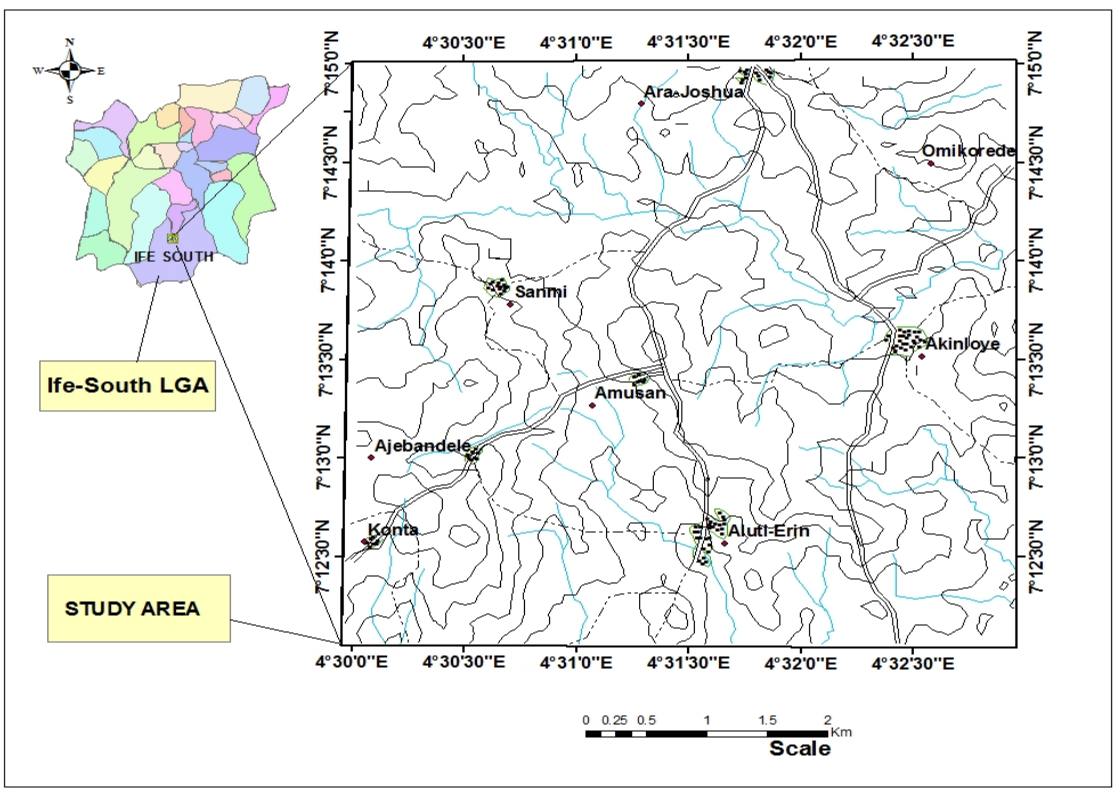


Figure 3: Digitized Map of the study area

III. METHODOLOGY

Detailed mapping was done on the study area. Traversing by foot across the strike directions within the study area with adequate pace-length and compass bearing, paths as indicated on the topographical map were followed with some that are available with river channels. A total of 12 different localities were visited and 12 GPS reading were obtained from these localities, observed outcrops were properly located on the field map, observations were recorded in the field notebook and samples were only collected from unweathered /fresh deposits.

The outcrops were described in detail noting their field relationships, mode of occurrence, mineralogy, structures as well as their attitude i.e. dip and strike are measured where necessary. Mineral alignments, vein orientations and structural features of the outcrops also the photographs and sketches of important features were taken. Such important features were quartz-feldspathic veins, folds, faults, foliation and fractures etc (Figure 4a-d).

Figure 4a A pegmatite vein seen on gneiss at Aluti-erin

Figure 4b Quartzofelspathic veins on the gneiss at Akinloye

Figure 4c Joint present on the gneissic rock

Figure 4d fold on a gneiss body at omikorede

Optical study

The laboratory work can be discussed on the basis of thin section preparation for microscopic study and also how the microscopic study was carried out. The petrographic study of the prepared thin section was carried out in the Petrological laboratory of the Department of Geology Federal University of Technology, Akure with the aid of the Polarizing microscope. The mineral constituents of the individual thin sections were identified using the optical properties of the minerals under plane polarized light and cross-nicols. Such properties include colour, pleochroism, cleavage, habit and relief.

IV. RESULTS, INTERPRETATIONS AND DISCUSSIONS

Petrographic studies

The study involves studying prepared thin sections under polarizing microscope by using certain optical properties in identifying the minerals present. Such properties like colour, pleiochroism, extinction, cleavage, form and relief, birefringence, and twinning. Microstructures observed on the slides were also studied. Four (4) samples were carefully selected and studied to obtain the mineralogical and structural information where possible.

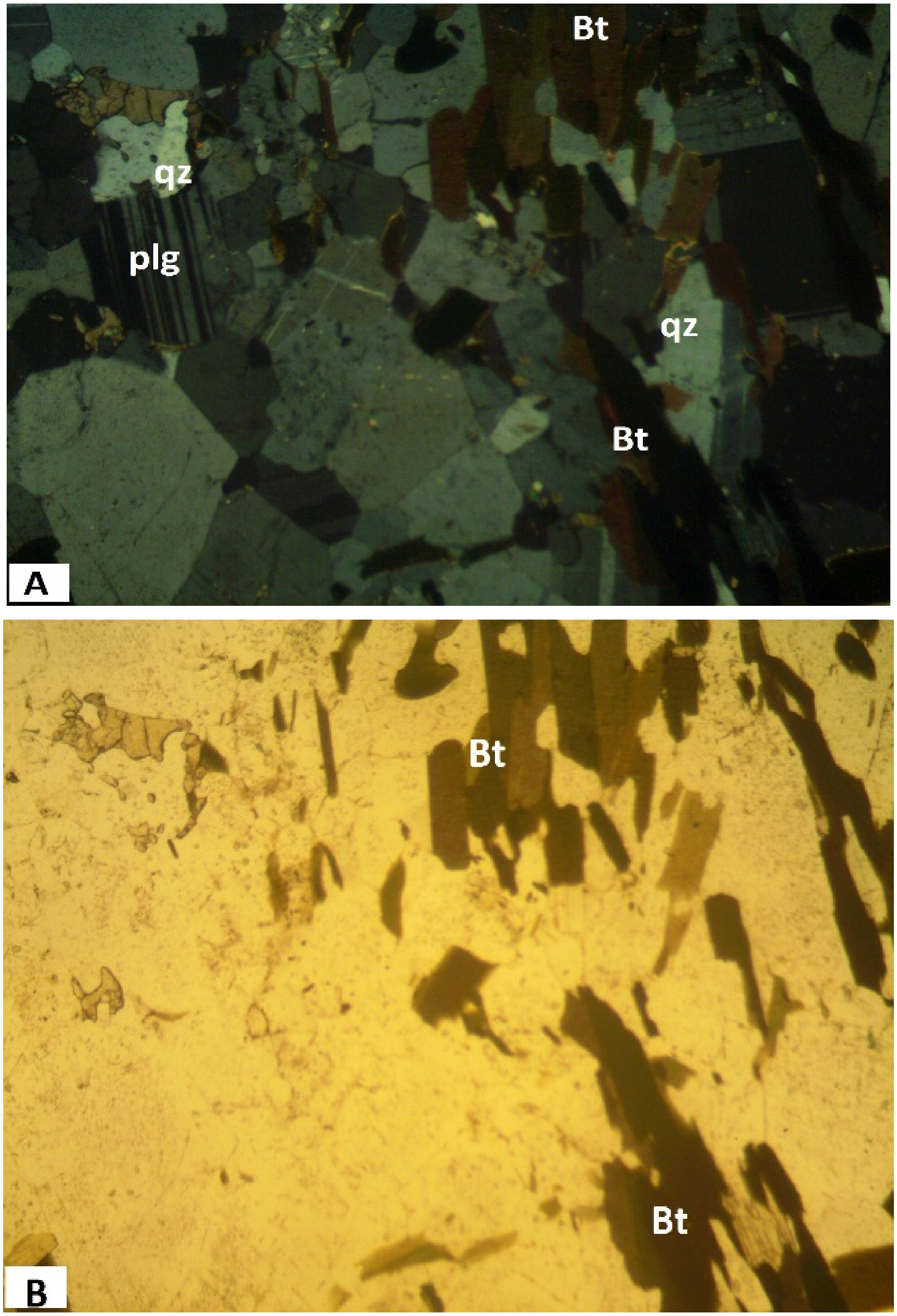


Plate 1: Photomicrographs of gneiss in thin section showing quartz, plagioclase feldspar, altered Biotite (Note: bt-biotite, qz-quartz, plg-Plagioclase feldspar, A- cross nicol, B- plane polarized light)) Magnification is x 100.

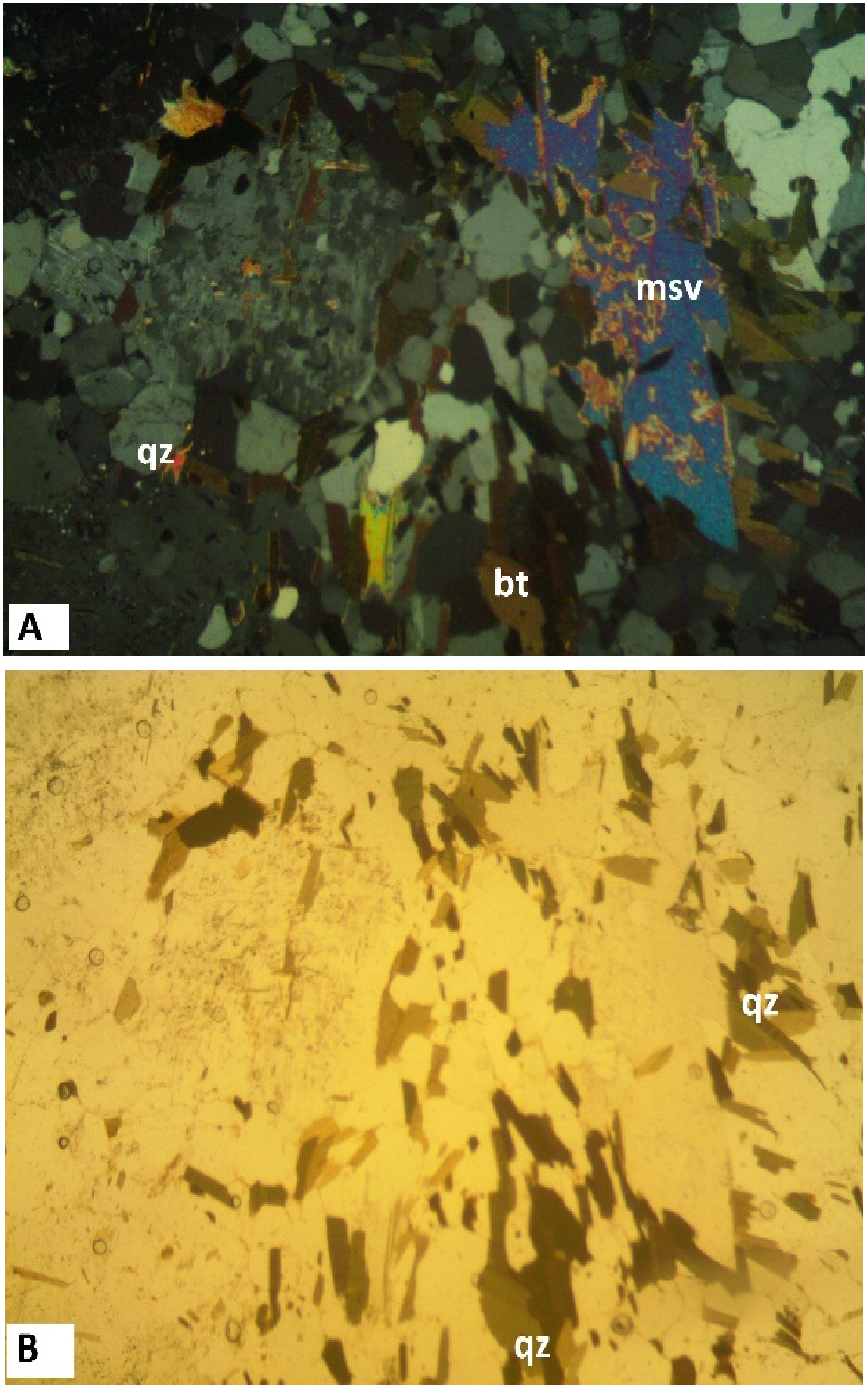


Plate 2: Photomicrographs of gneiss in thin section showing overgrowth quartz, muscovite, biotite (Note: bt-biotite, qz-quartz, msv- muscovite, A-cross nicol, B-plane polarized light)) Magnification is x 100.

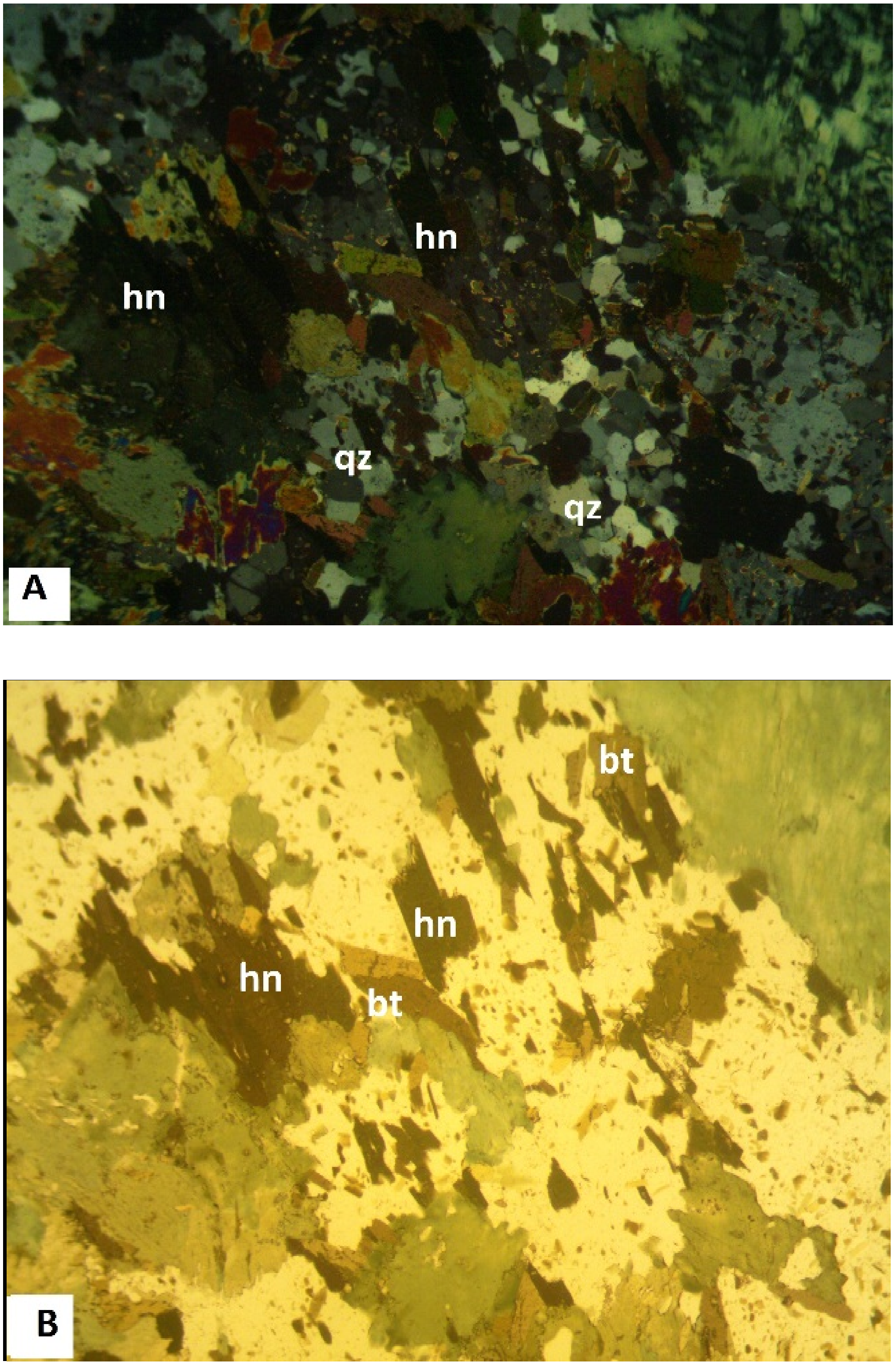


Plate 3: Photomicrographs of amphibolite in thin section showing quartz, biotite, hornblende (Note: bt-biotite, qz-quartz, hn-hornblende A-cross nicol, B- plane polarized light) Magnification is x 100.

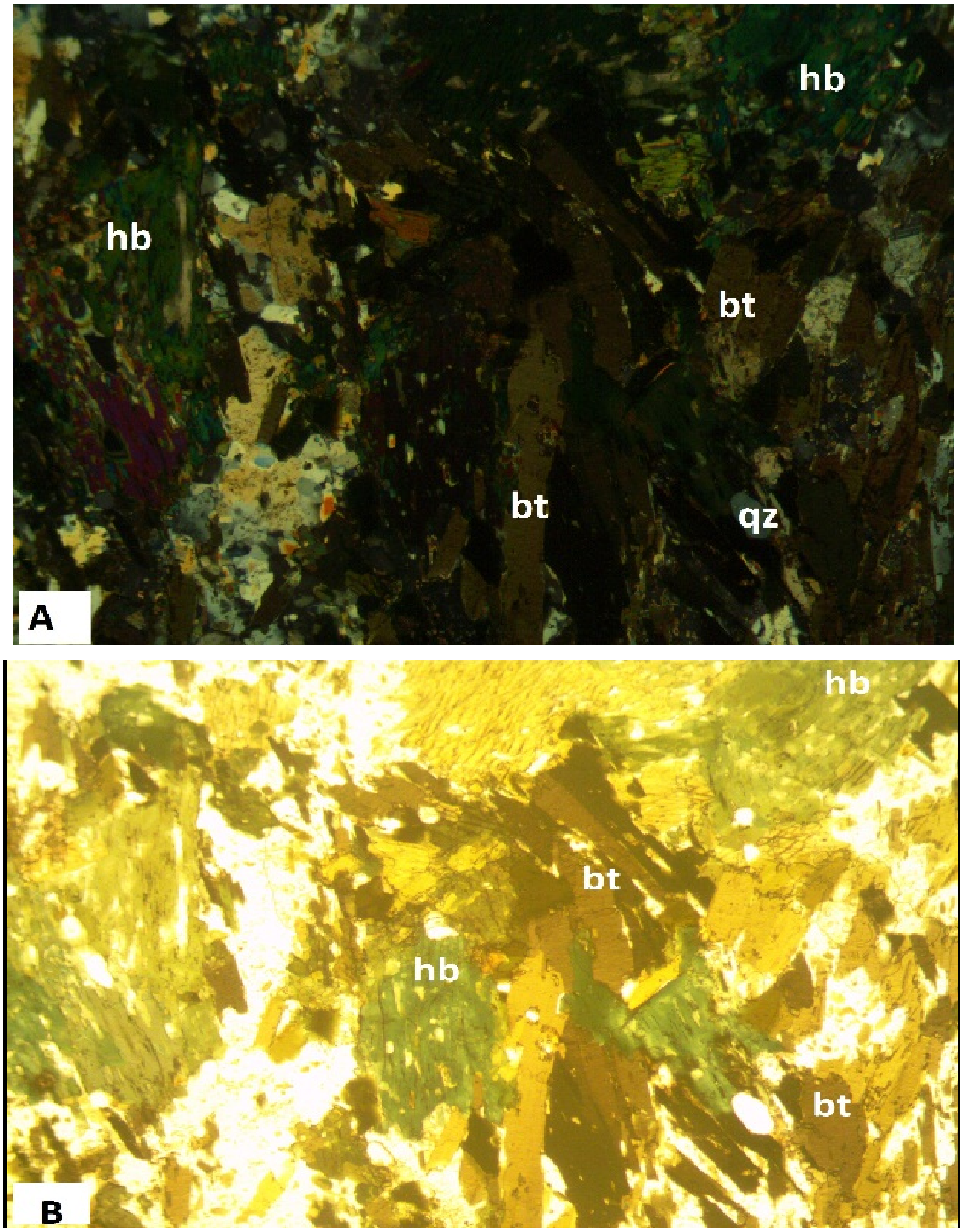


Plate 4: Photomicrographs of granite gneiss in thin section showing Quartz mineral with microfractures (cracks) which is a reflection of deformation on the observed outcrop. A-cross nicol, B- plane polarized light) Magnification is x 100.

Gneiss

Biotite, feldspars (plagioclase and microcline), quartz, garnet and opaque minerals were observed on Plates 1, 2 and 4. Quartz mineral grains were tabular in shape, showed conspicuously in plates where present. Microstructures such as cracks were observed on the quartz mineral which is a reflection of the deformation from the observed outcrop. Quartz minerals in some plates occur as overgrowth on the feldspar minerals in the background.

The feldspar minerals observed are plagioclase feldspar evidently from the albite twinning characteristic (Plate 1) and microcline feldspar on the other hand evidently from the cross hatch twinning characteristic feature (Plate 2), microcline feldspar was observed to be altered and weathered which is also a reflection of the intense weathering from the observed outcrop. Biotite mineral grain occurs in almost all of the slides, in some plates, biotite occur as stretched, preferred orientation, zoned and highly altered when rotated and viewed (Plates 1, 2, 4). The structures evident on the biotite are a manifestation of the deformation observed on the outcrop. The preferred orientation of biotite and quartz minerals as observed under the thin section also confirmed the metamorphic nature (segregation and alternation) of the rock.

Amphibolite

The thin section when observed under cross-polars shows that the sample contains plagioclase which exhibits Albite twinning and quartz (plate 3). However, it contains biotite, hornblende and opaque minerals under plane-polarized light. Hornblende is dark greenish under plane-polarized light.

Geological interpretation of section

This is based on the geologic section drawn from the relationships between three different petrologic units as observed on the geological map. The geological map was drawn from the field observation and thin section studies of the rocks in the study area. The three lithological units differentiated in the study area are biotite gneiss, granite gneiss, amphibolite.

Gneiss occurs as the most widespread lithological unit in the study area and the imprints of the Pan-African deformation were evident by a regional metamorphism, migmatization and extensive granitization and gneissification which produced syntectonic granites and homogeneous gneisses (Abaa, 1983).

The general trend of the gneiss in the study is in NW-SE direction and they are strongly foliated. The manifestation of the Pan African Orogeny was also believed to have resulted in the development of structural elements such as mineral lineation, foliation, jointing and veins which were evident on these rocks.

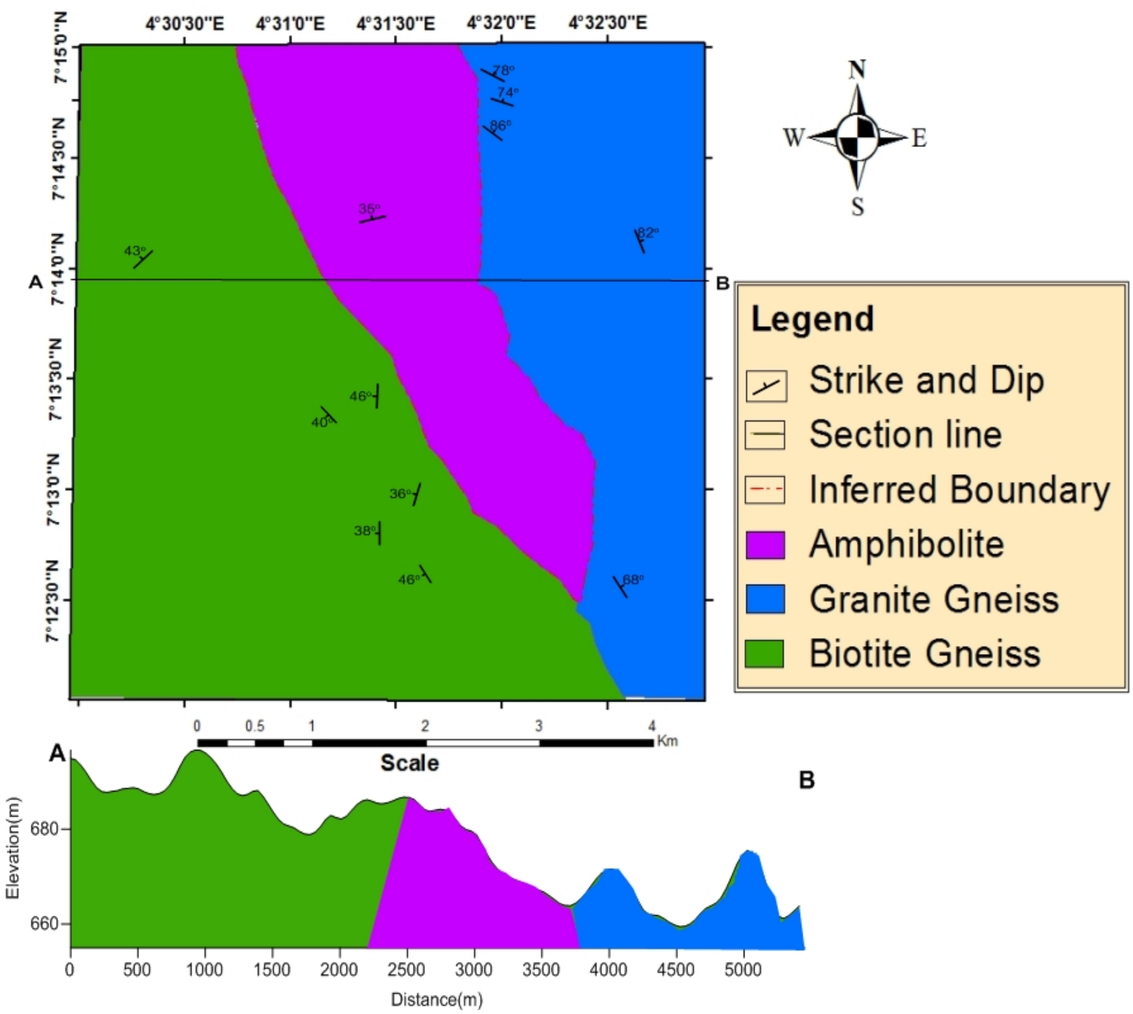


Figure 5: Geologic map of Amusan and its environs

Statistical treatment and analysis of structural data

The study area is part of the Nigerian Basement Complex, a polycyclic terrain that has responded to various tectonic events within the Pan African Orogeny. The Pan African orogeny comes with deformation (Obaje, 2009), with imprint that has been widely reported in Precambrian rocks of Southwestern Nigeria (Rahaman, 1989). Regional metamorphism was one of these events that accompanied the Pan-African deformation (Abaa, 1983).

This has resulted in the formation of structures such as fracturing (Olayinka, 1992), folding, jointing, veins, intrusions, foliation and mineral lineation which were all found in the study area. The structures occur mainly on the gneissic rock and where pictures could not be taken sketches were drawn and are discussed in detail.

Description, spatial representation, and analysis of foliations, joints and veins structures measured on the field were documented. The measured field data are presented in Table 1. The different ways of presenting such information are Rose diagram, line diagram, point diagram and stereographic plotting. Rose plots and stereographical plot were used to evaluate the portion of the tectonic forces that affected rocks in the study area and characterize the extent of the deformation based on the available data obtained on the field.

Table 1: Table showing the summary of field data

LOCATION	LONGITUDE	LATITUDE	STRIKE	DIP	DIP DIRECTION	FOLD	ROCK NAME
P19A1	004 °31'36.1"	07°12'26.1"	158 °	46°	WEST	Similar	Gneiss
P19A2	004°31'20.6"	07°12'37.3 "	14°	38°	WEST		Gneiss
P19A3	004°31'34"	07°12'45.4"	178°	36°	WEST		Gneiss
P19A4	004°30'09.8"	07°12'36.2"	-	-	-	-	Pegmatite
P19A5	004°30'45.1"	07°12'6.8"	-	-	-	-	Gneiss
P19A6	004°31'32.5"	07°12'44.4"	-	-	-	-	Gneiss
P19A7	004°31'09.3"	07°13'15.2"	-	-	-	-	Gneiss
P19A8	004°31'06.1"	07°13'07.5 "	145°	56°	WEST	-	Gneiss
P19A9	004°30'51.2"	07°13'15.1"	-	-	-	-	Gneiss
P19A10	004°30'52.7"	07°13'27.0"	-	-	-	-	pegmatite
P19A11	004°31'19.7"	07°13'23.5"	-	-	-	-	Gneiss?
P19A12	004°31'19.8"	07°13'28.5"	10	46°	WEST	-	Gneiss
P19A13	004°31'00"	07°14'0.9"	-	-	-	-	Pegmatitic Granite?
P19A14	004°30'13.8"	07°14'0.3"	56°	43°	WEST	-	Gneiss
P19A15	004°31'25.2 "	07°14'11.7"	65°	35°	-	-	Amphibolite
P19A16	004°31'47.1"	07°13'40"	-	-	-	-	Granite Gneiss
P19A17	004°32'09.3 "	07°13'15.9"	-	-	-	-	Granite Gneiss
P19A18	004°32'10.1"	07°12'52.1"	-	-	-	-	Amphibolite
P19A19	004°32'12.4"	07°12'34.5"	-	-	-	-	Granite Gneiss
P19A20	004°32'12.4"	07°12'34.5"	-	-	-	-	Granite Gneiss
P19A21	004°32'10.0"	07°12'46.4"	126°	68°	EAST	-	Granite Gneiss
P19A22	004°31'50.1"	07°15'2.6"	134°	78°	EAST	similar	Granite Gneiss
P19A23	004°31'49.5"	07°14'58.5"	144°	74°	EAST	-	Granite Gneiss
P19A24	004°31'56.0"	07°14'42.1	130°	176°	EAST	-	Granite Gneiss
P19A25	004°31'56.1"	07°14'41.7"	128°	88°	EAST	-	Granite Gneiss
P19A26	004°32'20.8"	07°13'41.7"	-	-	-	-	Granite Gneiss?
P19A27	004°32'37.5"	07°14'06.2"	174°	82°	EAST	-	Granite Gneiss

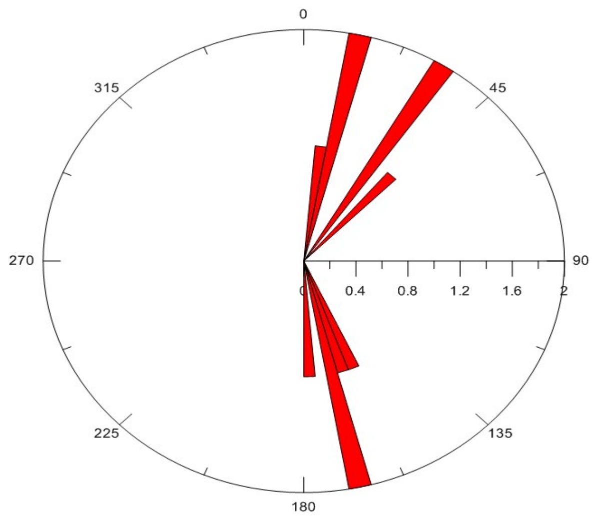


Figure 6: Rose diagram of foliations

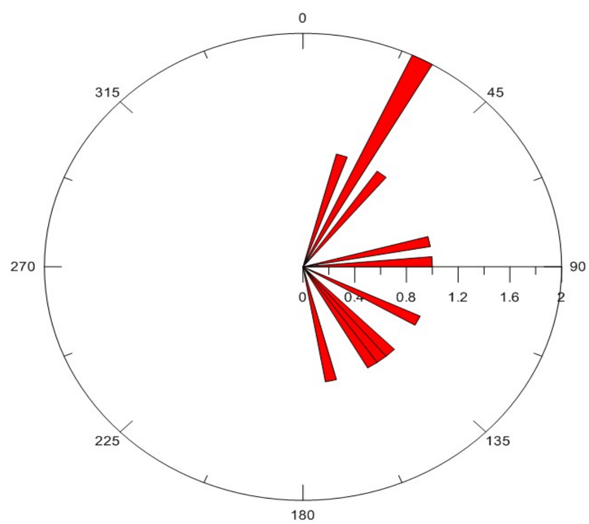


Figure 7: Rose diagrams of veins

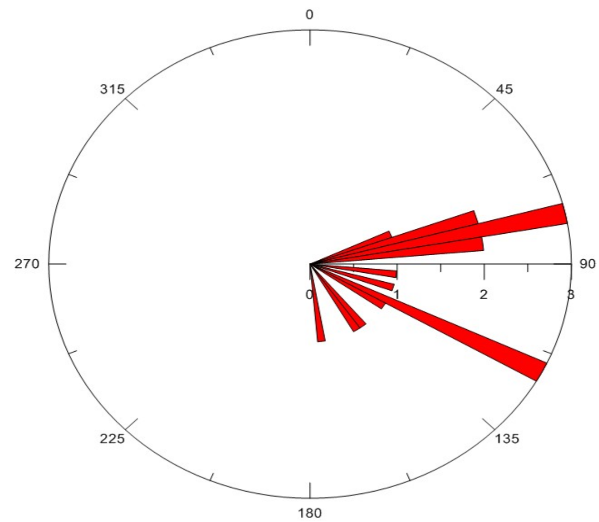
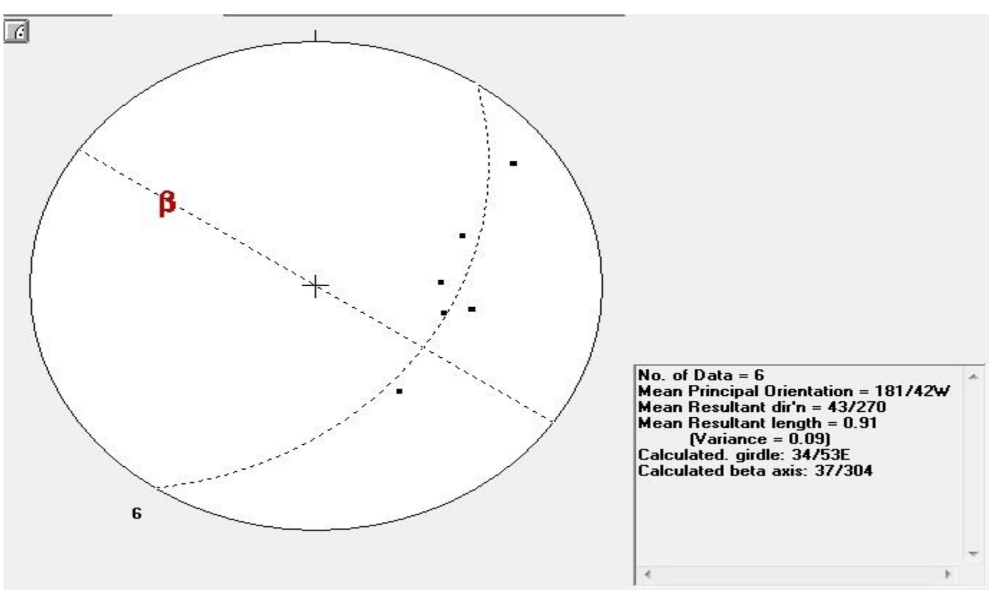


Figure 8: Rose diagrams of joints

Table 2: Statistical table of strikes of foliation, veins, joints and lineation measured on the rock outcrops in the study area.

Degree	Foliation	Vein	Joints	Lineation
01-20	2	0	0	1
21-40	2	1	1	0
41-60	1	0	0	0
61-80	0	3	4	0
81-100	0	4	2	0
101-120	0	4	0	0
121-140	0	4	0	0
141-160	1	1	4	0
161-180	4	2	0	0
Total	10	19	11	1



Stereographic plot of foliations in the study area

This field mapping will not be complete if the age relationship of the lithologies encountered is not established. From the study area, the oldest rocks are the Gneisses of the Migmatite-Gneiss-Quartzite complex group of ages almost about Late Archean-Paleoproterozoic, 2500 Ma to 1900 Ma (Rahman and Lancelot, 1984; Rahman, 1988). These rocks were intruded and affected during the emplacement of the Pan African Granites. The Pan African orogeny (650$^{+/}_{-}$ 150 Ma) was responsible for the emplacement of 50% of the rock units in the area. During the late stages of the Pan African orogeny, pegmatites crystallized as late intrusives into the granites, migmatites and quartzites. The reason for these intrusions were due to fissures created by the tectonic effects bringing about joints, faults and folds. However, quartz veins and quartzo-feldspathic veins are not necessarily syn-tectonic with Pan African events. Some of the veins are pre-tectonic while some might be post-tectonic. These veins either cross-cut each other or are cut-crossed by pegmatites. According to the principle of cross-cutting relationship, "a rock is older than the rock which cross-cuts it", it can be said that at instances where pegmatites veins cross cuts the quartz and quartzo-feldspathic veins, they are undoubtedly younger indicating that the quartz and quartzo-feldspathic veins were either intruded into the gneisses before Pan African or that they came at the very stages of Pan African much before Pegmatites intruded. The reason for the quartz and quartzo-feldspathic veins cross-cutting each other cannot be farfetched, similar to what has been discussed. It simply indicates that the quartz and quartzo-feldspathic veins are of different ages. The pegmatite veins and quartz/quartz-feldspathic veins are not always concordant.

V. CONCLUSION

In conclusion, the study area Amusan and environs of southwestern Nigeria is part of the basement complex of Nigeria. The lithologies encountered shows that study are although has been previously categorized as part of the Ife/Ilesa schist belt. This work has confirmed the existing works done supporting the already known geochronology on the regional scale, placing the Migmatite-Gneiss-Quartzite complex as the oldest rock unit while the Pan African granites are younger. Pegmatite veins are associated with the late stage of Pan African while the quartz and quartzo-feldspathic veins have disparity in their ages as some are older than the Pan African while some are younger.

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