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Petrographic Studies of Rocks around Arum and Its Environs, North Central Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author MMI designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors UMM and IU managed the analyses of the study. Authors MMI and UMM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A detailed geological mapping of the area around Arum and environs part of Kurra sheet 189 SW was carried out on the scale of 1: 12, 500. Geologic field mapping and petrographic study (both megascopic and microscopic) were the methodology used. The geologic mapping of the area identified four rock units which are; granite, porphyritic granite, granitic gneiss and Porphyroblastic gneiss. These rock types were distributed such that the granite at the north-eastern part covered about 25%, the north –western portion was occupied by the porphyritic granite which occupied the largest portion of about 30% of the area. The third rock unit is the granitic gneiss which covered only about 20%. The fourth (last) and the oldest rock unit is the Porphyroblastic gneiss covering about 25% of the total area at the south-eastern corner. Megascopic and microscopic study revealed that the rocks in the area comprised of minerals such as; quartz, biotite, muscovite, microcline, feldspar, hornblende, garnet, etc. Structures that were clearly evident in the area included fault, foliation, joints, and veins. Structural analysis showed that their rose diagrams proved a NW-SE, NNE-SSW and NE-SW trends to be dominant.

Keywords: Petrography; structures; mapping; arum.

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1. INTRODUCTION

The study area is around Arum and environs lies within longitude 08^0 39'33"- 08^0 41'57" E and Latitude 09^0 00' 00"- 09^0 02' 21" N Fig. 1. It is part of the Basement Complex which is made up of Precambrian rocks [1]. These rocks within the study area are part of the Precambrian Basement Complex of Nigeria which is made up of the Migmatite Gneiss Complex, the Schist Belts and the Granitoids. The main lithologic units found within the area are; Granites, Porphyritic granites, Granitic Gneisses and Porphyroblastic Gneisses in order of their ages, with well delineated boundaries. These rocks have undergone polycyclic deformations which are characteristic of rocks affected by Pan African Orogeny. This is evident in the micro and macro structures displayed on the rocks exposed in the study area. Geologic structures in the rocks have been used to reconstruct the geologic history of the area. These include joints, faults, foliations and lineation, veins, etc.). The major structural orientations are in the NE- SW and NW-SE direction which are indicative of the structural trend of the Basement Complex of Nigeria. Representative rock types were sampled and analyzed for petrographic studies. The mineral suites identified include feldspars, quartz, biotite, muscovite, hornblende, and opaque minerals. The feldspars include plagioclase, orthoclase, and microcline.

There is not much record of detailed work carried out on the various areas of the Basement Complex. In this paper, a detailed and comprehensive petrographic study of the rock types both on hand specimen and under the microscope is carried out. Some Recent works carried out in the basement complex of the Wamba area include: Anudu *et al.* [2] carried out an analysis of aeromagnetic data over Wamba and adjoining areas to delineate structures and map mineral deposits within the basement rocks.

Ekeleme et al. [3-4] in their studies of Angwan Madaki and environs discovered basement rocks such as gneisses, migmatites and granites which are part of the older granite suite.

Ekeleme et al. [3-4], in another study of an area located North West of Wamba sheet 210NW recorded the presence of basement rocks such as migmatites and gneisses with dolerite and pegmatite dykes.

1.1 Regional Geologic Setting

Most of the researches that have been carried out on the basement complex of Nigeria are on a regional scale [5] Mc Curry [6] Oyawoye [7]. According Fitches and Ajibade [8] the basement complex comprises three major lithological group, namely;

- The Migmatite Gneiss Complex which is wide spread throughout the country;
- Metasedimentary and Metavolcanic rocks which form schist belt and tend to be dominantly restricted to the western half of the country;
- The Older Granites which intruded both the Migmatite Gneiss Complex and the Schist belts and have consistently yielded Pan-African ages

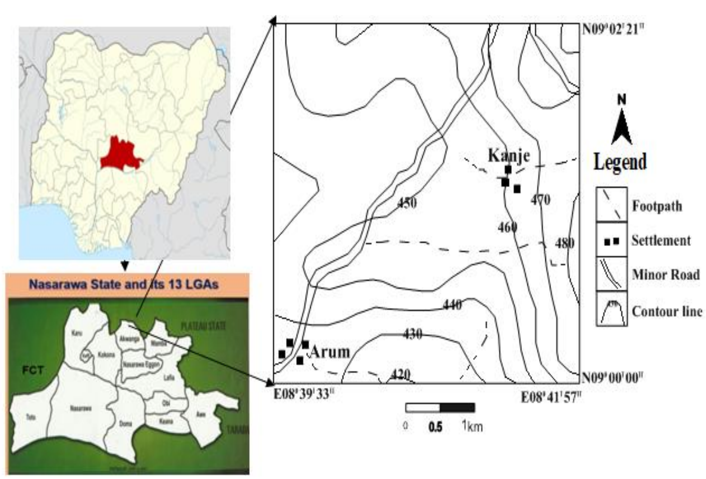


Fig. 1. Location, extent and accessibility map

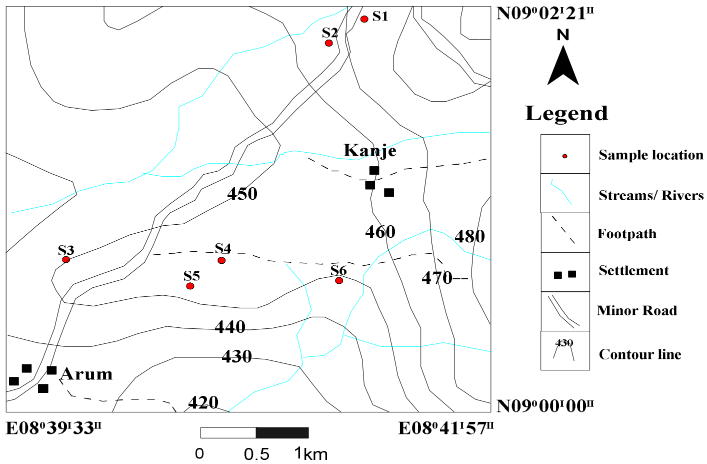


Fig. 2. Sample location map

The Basement Complex is intruded by Younger Granites and is unconformably overlain by the Cretaceous and Tertiary sediments. The Precambrian Basement Complex of Nigeria lies within the internal region of the reactivated part of the Trans-Saharan Belt, east of the West African Craton and northwest of the Congo Craton. Reactivation of this plate margin is believed to be due to the collision of these two cratons. The Basement Complex is characterized by synclinorial belts of low grade metasediments down folded into high grade gneisses and migmatites, the whole intruded by batholitic granites. It is characterized by a process of several phases of deformation, recrystallization and intrusion, the last of which is the Pan African Orogeny [6].

Four major Orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2700Ma), the Eburnean (2000Ma), the Kibaran (1100Ma) and the Pan African cycles (600Ma), formed the Basement Complex [9] Ajibade [10], Rahaman [1]. These Precambrian Basement rocks are found in five main areas in the country around: Northeastern zone, Southwestern zone, Southeastern zone (extension of the Bamenda Massif into Nigeria), Northeastern zone (the Hawal massif) and South southeastern (the Oban Massif) [11].

2. MATERIALS AND METHODS

The materials used to carry this study were topographic map, compass, GPS, sledge hammer, sampling bag, chisel etc. The methods used included geologic field mapping and sample collection: This involves detailed field mapping of the area. A systematic procedure of mapping was used. This involved mapping using footpaths, cattle tracks, stream and river channels. Rock samples were collected evenly from the available outcrops so as to check for any variation in the lithologies Fig. 3. Field photographs of the rock types were taken. These rock samples were taken to the laboratory for thin-section and petrographic studies with the aid of a polarizing microscope (N7066B). The petrographic analyses of these representative rock samples (thin sections) were done in the laboratory of the Department of Geology and Mining, Nasarawa State University, Keffi.

3. RESULTS AND DISCUSSION

3.1 Megascopic and Microscopic Study

It is the description of the different rock types of the study area in hand specimen which was facilitated by the use of outcrop photographs. The lithologic units, mineralogy, texture, structures, mode of occurrence and field relationships, were all considered in the field mapping to enhance both megascopic and microscopic studies. Combinations of megascopic and microscopic descriptions were used to produce a geologic map of delineated rock units within the study area Fig 3.

3.2 Result of Petrographic Studies

3.2.1 Granite (field/megascopic description)

The granite in the study area is fine-medium grained intrusive outcrop Fig 4. It occurs as low lying and covers one third of the portion of the study area. In hand specimen the rock consists of quartz, feldspar and mica. The color index of the granite is leucocratic. It is predominantly composed of feldspar and quartz; while hornblende and biotite are comparatively minute. These rocks are highly fractured. Associated structures include joint, quartz vein, and faults, with most of its geologic structures having a dominantly NE-SW trending direction.

3.2.2 Microscopic description

Quartz: Under Plane Polarized Light (PPL), quartz is colorless, non-pleochroic, subhedral crystals which have very low relief relative to other minerals in the field of view. Under Cross Polarized Light (XPL), quartz showed white to pale-yellow interference, no sign of alteration and goes extinct 4 times on 360^0 rotation of the microscope stage.

Biotite: Under PPL, biotite appeared as subhedral, brown crystals which are slightly pleochroic and has a moderate relief. The crystal showed no distinctive cleavage and no fracture. Under XPL, biotite displays brown colour, untwined, not altered and goes extinct at same points in 360^0 rotation of microscope stage.

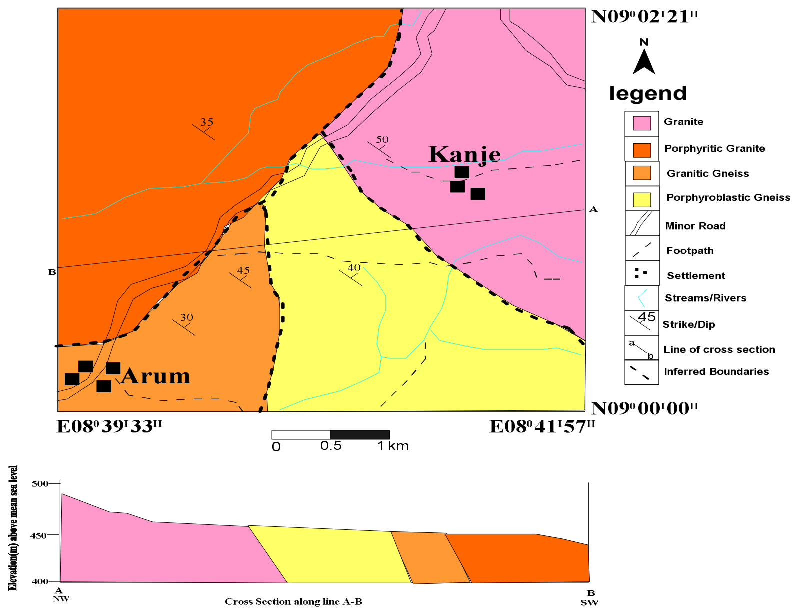


Fig. 3. Geological map of the study area

Fig. 4. field Photograph of granite in the study area

Plagioclase: Under PPL it appeared as colourless, subhedral crystals which are slightly pleochroic with low relief. The crystals also show two cleavages not perpendicular to each other. Under XPL, plagioclase showed grey interference colour, displays albite polysynthetic twinning, and does go into extinction at same points in 360 rotation of the microscope stage.

Microcline: Under PPL, the microcline crystals appeared as subhedral, colourless non-pleochroic crystals that has a low relief and two cleavages which are not perpendicular to each other. Under XPL, the microcline crystals displayed grey interference colour, showed cross-hatch twinning (this is a distinctive optical property of microcline). It also does not show any sign of alteration.

3.2.3 Porphyritic granite (field description)

The porphyritic granite in the study area is medium to fine grained intrusive outcrop. It is a low-lying outcrop and covers a small portion of the study area. In hand specimen the rock consists of quartz, feldspar and biotite. It is leucocratic in colour. Associated structures include joint, and pegmatite veins.

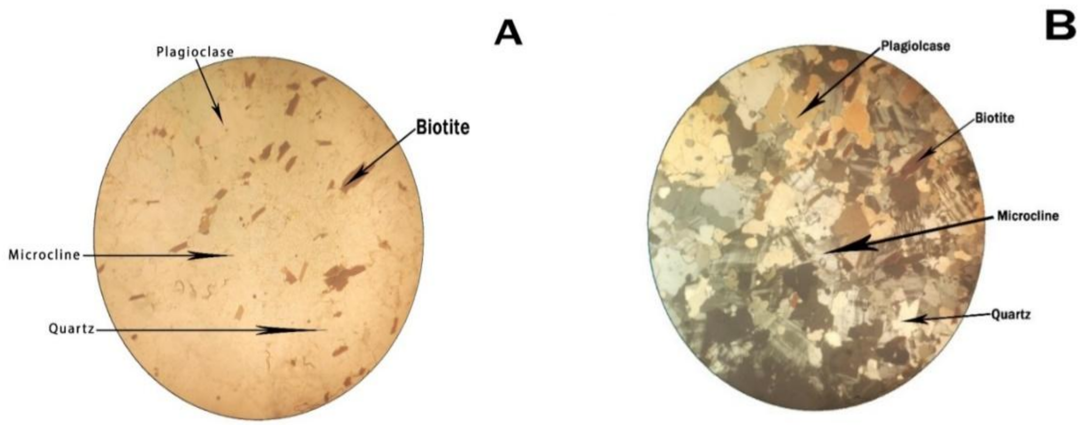


Fig. 5a. Photomicrograph of granite under PPL (quartz, biotite, microcline, and plagioclase)
Fig. 5b. Photomicrograph of granite under XPL. (quartz, biotite, plagioclase, and microcline)

Fig. 6. Field Photograph of Porphyritic granite in the study area

3.2.4 Microscopic description

Quartz: In PPL, it appeared as colourless subhedral, non-pleochroic crystals which have low relief and no cleavage, no fracture. Under XPL, it displays white pale-yellow interference colour not twinned and goes extinct 4 times in 360^0 rotation of the microscope stage.

Plagioclase: Under PPL, plagioclase appeared colourless, non-pleochroic, subhedral crystals which has low relief and distinctive cleavage was observed on the field of view. Under XPL, plagioclase displayed grey interference colour, showed polysynthetic twinning and appeared to have pockets of other mineral grains within one crystal.

Biotite: In PPL, biotite appeared as lath-like, brown, slightly pleochroic crystal which shows no distinctive cleavage. Under XPL, it displays brown colour not twinned and goes extinct at some points in a complete rotation of the microscope stage.

Hornblende: In XPL, the hornblende crystal appears as bluish-green, subhedral, non-pleochroic crystal which shows a moderate relief. Under XPL, hornblende display and does not go into extinction on complete rotation of microscope stage.

3.2.5 Porphyroblastic gneiss (field description)

The Porphyroblastic gneiss in the study area is a coarse-grained outcrop. It occurs as massive outcrop. In hand specimen the rock consists of quartz, feldspar and biotite. It exhibits an alternation of light and dark colored bands. It also contains prominent feldspar porphyroblasts. Associated structures include joint, folds and fault.

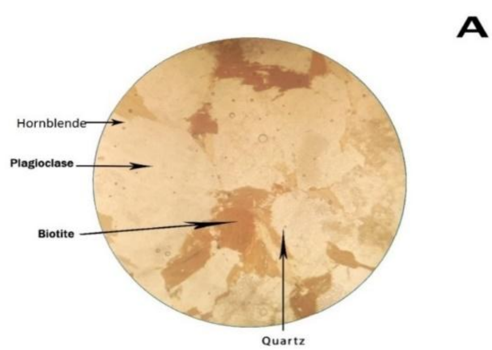
3.2.6 Microscopic description

Quartz: Under PPL, quartz is colorless, non-pleochroic, subhedral crystals which have low relief it has no cleavage. Under XPL, it displays grey interference color no twinning and goes extinct four times on 360^0 rotation of the microscope stage.

Muscovite: The crystals of muscovite on PPL, appeared as pale-green crystals which gradually changes to colorless on rotation of the microscope stage. The crystals are also lath-like and have a moderate relief. In XPL, the crystals of muscovite showed pink interference color and slightly greenish at the edge of the crystals which is a sign that the mineral grains have started undergoing alteration, It goes into extinction at some point in 360^0 rotation of microscope stage.

Plagioclase: In PPL, the crystals of plagioclase are colourless, non-pleochroic, subhedral crystals that have low relief. Under XPL, the crystal displays grey interference colour and polysynthetic twinning (this is a distinctive optical property of plagioclase).

Biotite: This appears as the lath-like known minerals which are slightly pleochroic and has a moderate relief in PPL. In XPL, biotite is brown, untwined crystals which goes extinct at some point in 360^0 rotation of the microscope stage.



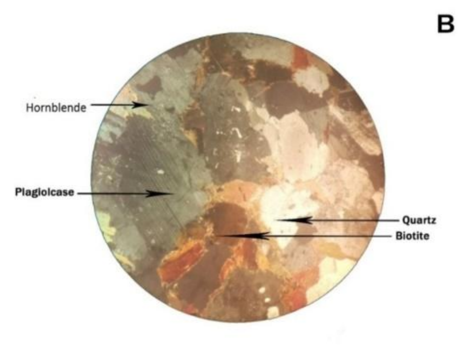


Fig. 7a. Photomicrograph of Porphyritic granite under PPL (quartz, biotite, plagioclase, and hornblende)
Fig. 7b. Photomicrograph of porphyritic granite under XPL (quartz, biotite, plagioclase, and hornblende)

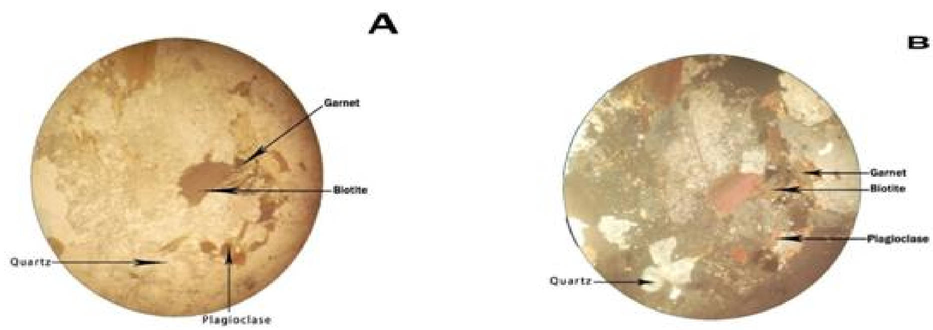


Fig. 8a. Photomicrograph of Porphyroblastic gneiss under PPL (quartz, biotite, plagioclase, and garnet)
Fig. 8b. Photomicrograph of Porphyroblastic gneiss under XPL (quartz, biotite, plagioclase, and garnet)

3.2.7 Granitic gneiss. (field description)

The granitic gneiss in the study area is coarse-medium grained extrusive outcrop. It occurs at lower elevations as compared to the large granitic outcrops. These rocks were observed to be highly fractured, contain quartz veins and empty joints with a dominantly NE-SW trending direction. In hand specimen the rock consists of hornblende, quartz, feldspar and biotite. The gneiss exhibits a leucocratic-mesocratic color index, while exhibiting a gneissose foliation (segregation of light and dark bands). The degree of foliation is low making it appear as granite gneiss. The rock is fine- medium grained. Associated structures include joint, folds and faults.

3.2.8 Microscopic description

Plagioclase: Plagioclase under PPL, is colorless, non-pleochroic, subhedral crystal with low relief and shows fractures in some grains. Cleavage are not visible under XPL, it displays grey interference color, and polysynthetic twinning (this is a distinctive optical property of a plagioclase). It also shows inclusion of some other mineral grains.

Quartz: Under PPL, quartz is colorless, non-pleochroic, subhedral crystals which are mostly having low relief and fractures but without cleavage. In XPL, quartz display white-grey interference color, no twinning and goes extinct four times on 360^0 rotation of the microscope stage.

Biotite: Under PPL, biotite is brown lath-like, slightly pleochroic minerals which shows moderate relief and no distinctive cleavage. Under cross XPL, biotite is brown, untwined crystal which goes extinct at some pints in 360^0 rotation of the microscope stage.

Garnet: The photograph shows a number of subhedral garnet crystals, of the almandine series, inter-grown with quartz and mica in a metamorphic rock. Under PPL garnet stands out quite clearly from the other minerals because of its high relief and brownish color. It shows inclusions of the groundmass minerals and this is a very common feature. Under XPL, garnets are seen to be isotropic (some garnets are birefringent and may show zoning and twinning revealed in the low birefringence colours.

3.3 STRUCTURAL STUDIES

Foliations: Foliation of rocks is tectonically controlled, and was observed in some of the outcrops within the study area. Foliations in the Porphyroblastic Gneiss are characterized by alignment of mafic and felsic minerals in direction parallel to the strike of the rocks Fig. 11. The foliation are often sheet-like planes with altered mineral composition, can often indicate the direction of increased strain and inform regional stress and plate tectonic analysis.

Joints: Joint is a fracture dividing rock into two sections that moved away from each other, Or It is a break (fracture) of natural origin in the continuity of either a layer or body of rock that lack any visible or measurable movement parallel to the surface (plane) of the fracture [10] [1]. Although they occur singly, they most frequently occur as joint sets and system. Joints occur in most of the outcrops in the study area although very pronounced in the Porphyroblastic gneisses. The joints in the area are both closed and opened. The orientation of the joints in the field does not follow any particular trend (direction), as they trend in all directions but the dominant trend is in NE-SW direction Fig. 12.

Fig. 9. Photograph of granitic gneiss in the study area

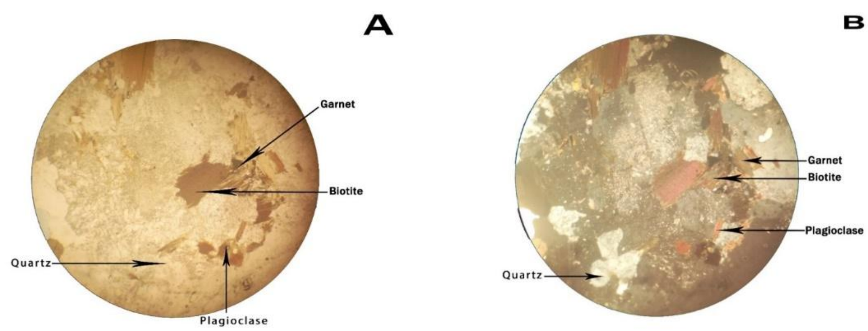


Fig. 10a. Photomicrograph of granitic gneiss under PPL (quartz, biotite, opaque mineral, and garnet)
Fig. 10b. Photomicrograph of granitic gneiss under XPL (quartz, biotite, opaque mineral, and garnet)

Table 1. Summary of estimated modal composition for minerals in the rocks

	Mineral / Sample	Granite	Porphyritic Granite	Granitic Gneiss	Porphyroblastic Gneiss
1	Quartz	33.33	26.67	23.53	25.00
2	Biotite	12.52	13.33	5.88	15.00
3	Plagioclase	29.17	40.00	41.18	35.00
4	Microcline	16.65	-	-	-
5	Hornblende	-	10.00	-	25.00
6	Garnet	-	-	17.65	-
7	Opaque minerals	-	-	11.76	--
8	Others	8.33	10.00	-	--
9	Total	100	100	100	100

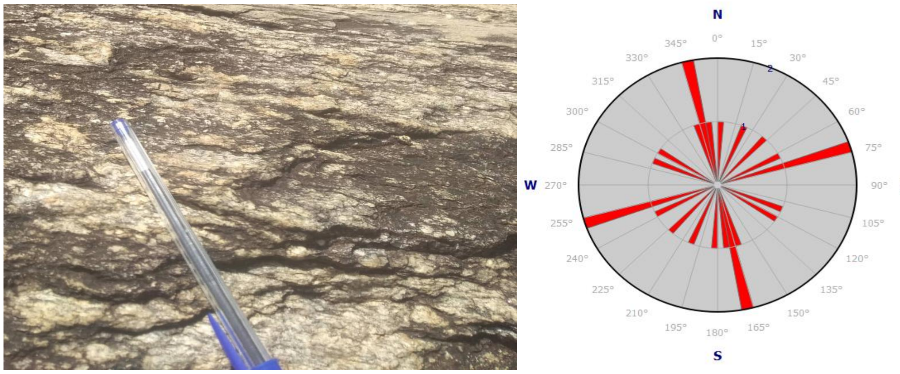


Fig. 11. Foliation displayed on gneiss in the study area and rose plot for foliation number of data = 31, dorminant trend= NNE-SSW, NNW-SSE

Fig. 12. Joint displayed in Porphyroblastic Gneiss in the study area and Rose plot for Joints Number of data = 31, Dorminant trend= NE-SW

Fig. 13. Photographs showing quartz vein and pegmatite vein in the study Area

Veins: Veins are formed when there is recrystallization of silicate grains in the rock crevices or joints which are being filled up with hydrothermal fluid which is rich in quartz, feldspar and muscovite. Some of these veins may be discordant to foliation planes. This structure is mapped on almost all the outcrop visited in the study area. Quartz veins and pegmatite veins are the major vein occurrence in the study area. The quartz veins composed completely of quartz crystals. The rosette diagram of the quartz veins also indicates an orientation predominantly trending in a NE-SW direction Fig.14.

3.4 Sinistral Fault

When stresses in rocks build up, and become greater than the strength of the rock, the rock breaks and a fault form. The fault in the rocks in the study area are dominantly trending NE-SW and NW-SE directions. The structure is found on the porphyritic granite with relative displacement of the intruding quartzo-feldsparthic vein Fig. 15 is a Sinistral fault.

4. DISCUSSION

Mineral assemblages from thin-section and field observations of the rocks as described above were used for the classification of the rock in the geologic map of the area produced as presented in Fig 3.Comparing our classification with earlier workers (for example Jones and Hockey [12] Rahaman [1] reveals the area studied is part of the Basement complex of Nigeria. The Older Granite has high proportion of quartz mineral as seen in the modal analysis from thin section. The extent of the gneisses was also not reported in the earlier geologic map, probably due to the regional nature of the work. The structures in

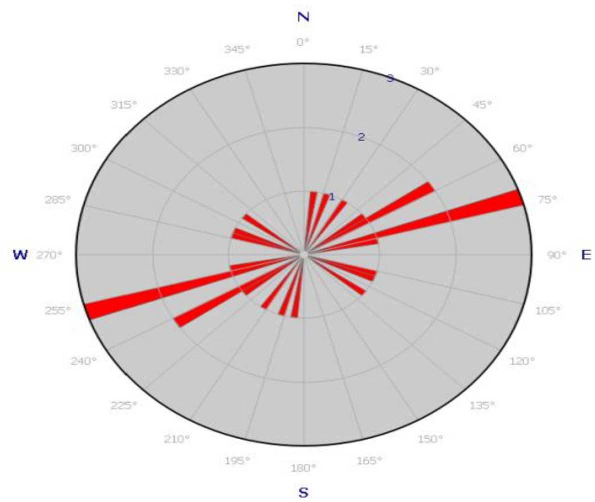


Fig. 14. Rose plot for quartz veins number of data = 31, dorminant trend= NE-SW

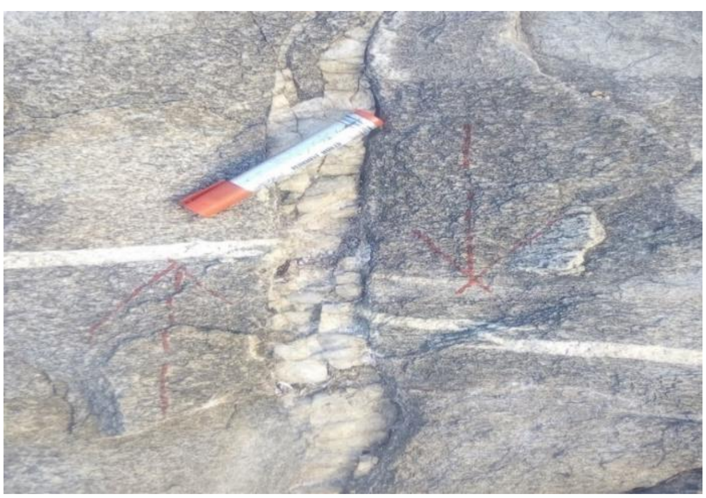


Fig. 15. Sinistral fault observed on the granite

some of the rocks in the study area bear the imprint of evolution and or paleotectonic activities as shown in the granitic-gneiss and Porphyroblastic gneiss which exhibit mineral lineation of the background felsic and mafic minerals (feldspar and biotite) in a preferred orientation suggests the re-adjustment of mineral compositions of the rock during metamorphism. Faulting and fracturing (jointing) in the rocks within the study area is an evidence of paleo-tectonic magmatic cycle associated with the Pan-African orogeny (Obaje, 2009). On the structural measurements, the resultant orientation of foliations and vein shows a NE-SW, NW-SE, NNE-SSW trending analogous to the direction of tectonic event.

5. CONCLUSION

Based on field and microscopic studies, four distinct rock units which are granite, porphyritic granite, Porphyroblastic gneiss, and gneiss were found in the study area. The rock types are the members of the Basement Complex of Nigeria. The major mineralogical assemblages of these rocks are quartz, biotite, plagioclase, hornblende, muscovite, microcline and other opaque minerals. Most mineral components of the rock show evidence of metamorphism. Major structures such as, joints, faults, foliation and veins with NW-SE, NNE-SSW and NE-SW trends indicate that these rocks have been affected by three major cycles of deformation. Metamorphism and remobilization including the Liberian, Eburnean and Pan-African orogeny may have affected the rocks as recorded in the literature.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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