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Geology, Geochemistry and Structural Analysis of the Basement Rocks of Gora Area, Part of Keffi Sheet 208 NE, Northcentral Nigeria

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ABSTRACT

The basement complex rock that underlies Gora and its surroundings consists primarily of banded and porphyroblastic gneisses, biotite schist, and the minor rocks being pegmatites and quartzo-feldspatic veins. This study aims to characterize, at a 1:25,000 scale, the geology, structure, and geochemistry of the rock units in the Gora region. To attain this aim, field research, petrographic, and geochemical studies were conducted. Quartz, feldspars, biotite, and hornblende were identified as major minerals in petrographic analyses of the gneiss, with muscovite and apatite present in trace amounts. X-ray fluorescence (XRF) analytical methods were used to determine the rocks' geochemical compositions. Fold, fault, pinch, and swell, and vein sizes were all quantified. Major fractures, joints, and veins all run NW-SE, while smaller ones run NE-SW. The structural NW-SE and NE-SW trends are also reflected in the data that has been linearly analysed (SRTM DEM). The geochemical results obtained revealed that the gneisses and biotite schist are high-K calc-alkaline and orthogneiss derived from igneous protoliths. The gneisses and biotite schist were further classified on the SiO_2 vs. FeOt /MgO binary diagram in calc-alkaline series. The gneisses and biotite schist are peraluminous in nature. The gneisses and biotite schist were formed in a passive continental margin tectonic setting.

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1. Introduction

The study area Gora and its environs falls within the Basement Complex of Nigeria that forms part of the Pan-African mobile belt which lies between the West African Craton and the Congo Craton south of the active margin of the Taureg shield (Black, 1980) of the Precambrian orogenesis. The Basement Complex is made up of Precambrian rocks and these rocks consist of the Migmatite-Gneiss Complex, the Schist Belts and the Granitoids (Rahaman, 1988).

Falconer (1911), who first studied the Nigerian Basement Complex and distinguished the Younger Granite from the Older Granites. Oyawoye (1964) classified the Basement rocks as Older Meta-sediments, which includes Gneiss, Migmatites and Older Granites and Younger Meta-sediments. In reviewing the Basement geology of the Precambrian to Lower Paleozoic rock of Northern Nigeria.

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Structural pattern in the Basement Complex has been pointed to have resulted from polyphase metamorphism which has affected the Basement Complex leaving imprints of at least three plutonic events during the Eburnean, Kibaran and the Pan-African orogenic episodes (Grant, 1970).

Rahaman (1976, 1988) and Rahaman and Ocan (1978) presented a more classical description of the rocks. Some of the Basement Complex rocks are related to the orogenic cycles of deformation, metamorphism and remobilisation corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), whilst others are affiliated to the Pan African Orogeny (600±150 Ma) and linked to the rare metal pegmatites. These varied propositions for the origin of gneisses of the Basement Complex of Nigeria suggest that two different locations may have different sources.

Rahaman (1988) had described the rocks of the Schist belt as composed of predominantly metamorphosed pelitic to semi-pelitic rocks, granites, sandstones, polymeta- conglomerates, calcareous rocks, mafic to ultramafic rocks with minor amounts of greywacke and acid to intermediate volcanic rocks. Rahaman (1988) classified the rocks of the Basement Complex revealing that the north central Basement Complex is made up of migmatite, Older Granite, minor felsic and mafic intrusive. Dada (2006) revealed that the basement rocks resulted from at least four orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2800 ± 200Ma), the Eburnean (2000 ± 200Ma), the Kibaran (1100 ± 200Ma) and the Pan African Orogeny (600 ± 150Ma).

Tanko *et al*, (2015) worked on the geochemical investigation of gneisses of Keffi area on a large scale with a view to determine their characteristics and petrogenesis, he noted that a different parental melt source for the granodiorite gneisses, probably from a different episode of magma phase. Okunlola, and Ocan, (2009), worked on the rare metal (Ta-Sn-Li-Be) distribution in Precambrian pegmatites

Previously Dada (2006) and Tank *et al*, (2015) worked in the study area on a regional scale of 1:100,000 and identified gneiss, schist, andesite, and pegmatites as the underlying rocks observed with well delineated boundaries. Jonah (2019), stated that the presence of high B, Be, Ta and Ta content in the Saura pegmatite field is an indication of the presence of tourmaline, beryl, tantalite and niobium**.** However there appears scanty works on detailed geological, structural and geochemical characterization of the rock units on a scale of 1:12,500.

2. LOCATION AND ACCESSIBILTY OF THE STUDY AREA

The study area is in Keffi Sheet 208 NE in Nasarawa State of Nigeria and is located in Gora and Environs. The area lies between latitude 8° 51' 31" and 8°54' 21" N and longitude 7°45' E and 7° 47' 44" E (Fig.1). It is accessible by a major road that links Abuja to Keffi. Apart from the major road, there are minor roads that cut – across the study area, making access very easy most especially in the dry season.

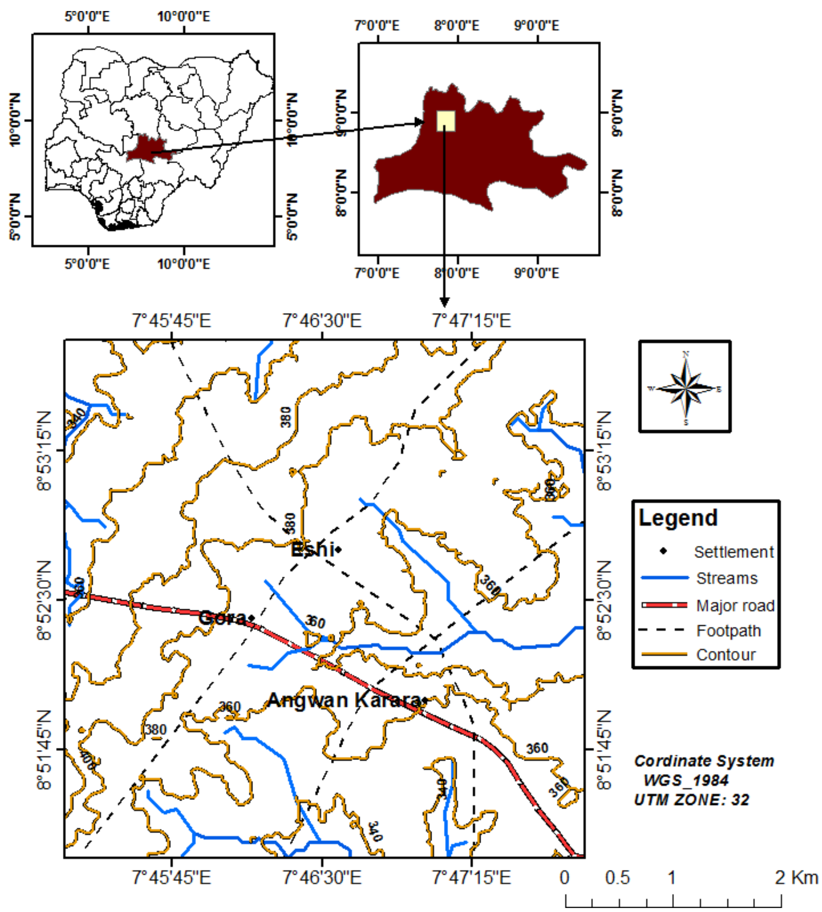

Fig. 1: Location map of the study area

3. METHODOLOGY

In order to obtain accurate field result and for successful completion of this research work, various methods and procedures were used in carrying out this work. This was carried out in stages; fieldwork which involves traversing or mapping on a scale of 1:12,500 was used to map the study area. Representative rock samples were collected from all available rock exposure in the study area. Laboratory studies involving petrographic and geochemical studies were carried out.

Geochemical analysis comprising of samples from the biotite schist and gneisses were analyzed for major elements using X-ray fluorescence spectrometer (XRF) at the National steel raw materials exploration agency Kaduna, Nigeria. The data gotten were analyzed using GCD2kits. Remote sensing data such as DEM (digital elevation model) were analyzed using Arc-GIS, PC Geomatic, and global mapper in order study the structural pattern of the rocks in the area.

4. RESULTS AND DISCUSSIONS

4.1 FIELD GEOLOGY AND PETROGRAPHY

The major rock units of the study area comprise of gneisses, biotite schist and the minor rocks are pegmatites, and quartzo-feldspatic veins (Fig.2). Contact relationship between the various rocks is mostly gradational with lit-per-lit structures.

The gneisses (banded and porphyroblastic gneisses) are medium to coarse grained and foliated (Plate I). It is made up of alternating light and dark bands with different mineral compositions. The lighter bands are predominantly quartz and feldspar, whilst the darker bands are mostly mica and hornblende.

Gneisses exist as low-lying outcrops in the study region. They can be found along stream channels and have foliation texture. Minerals are typically formed as a result of deformation, recovery, and recrystallization. Gidan Zakara and neighbouring places have biotite schist ridges (Plate II). This rock is partly weathered and is aligned in the N-S direction. The rock is generally medium grained with a ferruginized laterite capping. It is intruded by quartz veins as well as pegmatites

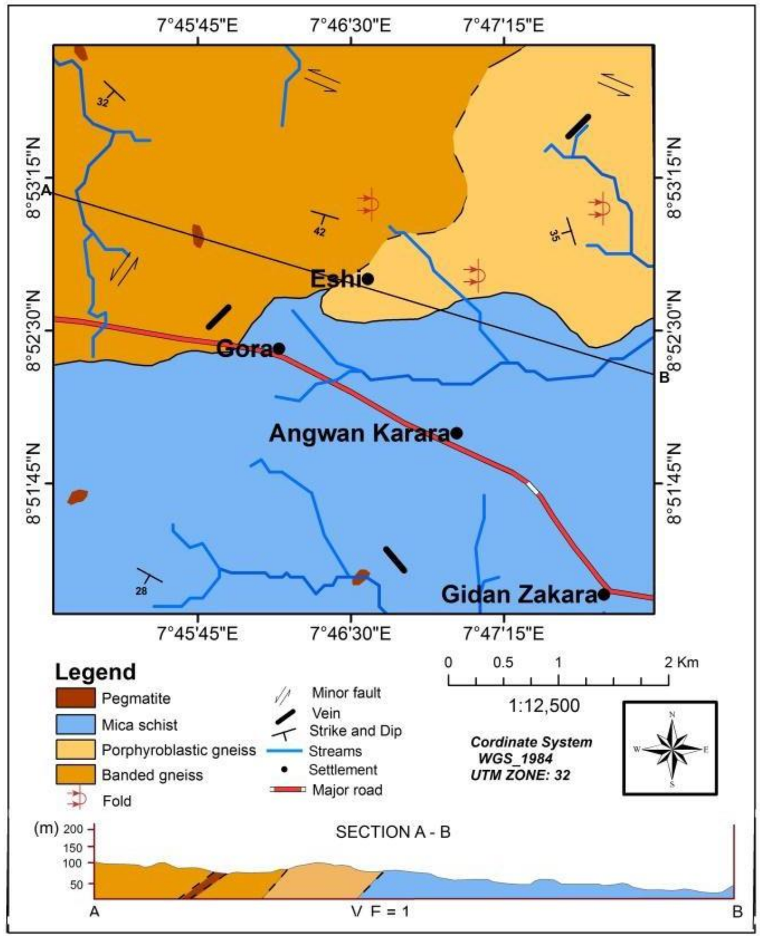

Fig. 2: Geological map of the study area

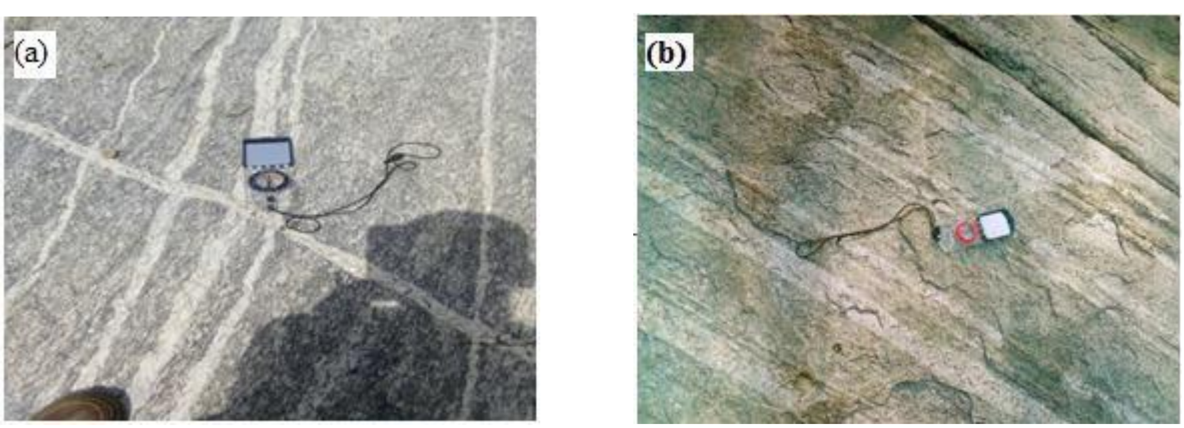

Plate I: (a) Porphyroblastic gneiss at east of Eshi village, (N 008˚ 53' 08.45", E 007˚ 47' 35.82"), (b) banded gneiss Northeast offset of Eshi village (N 008˚ 53' 14.77", E 007˚ 46' 16.35"),

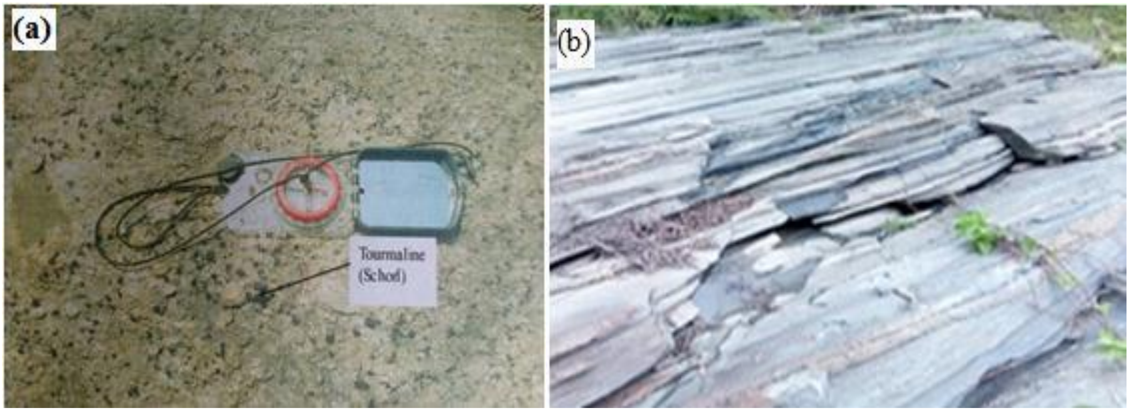

Plate II: (a) Pegmatite vein with Schorl tourmaline at southwest of Gora area (N 008˚ 52′ 23.80″, E 007˚ 45′ 59.92″) (b) Biotite schist at Angwan Karara area (N 008˚ 52′ 23.80″, E 007˚ 45′ 59.92″)

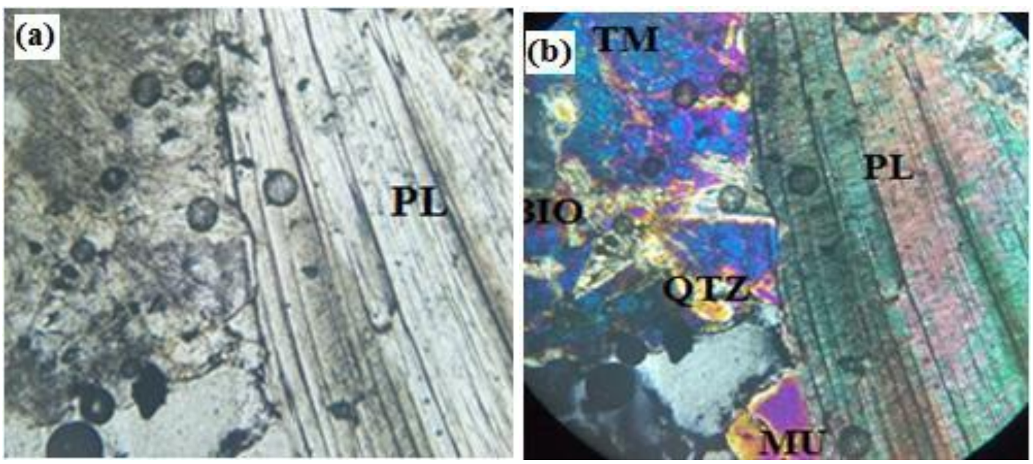

Plate III: Photomicrograph of coarse grained pegmatite, under Plane polarized light (XPL) and Crossed polarized light (PPL) showing BIO = biotite, MU = muscovite, QTZ = quartz, TM = tourmaline and PL = plagioclase feldspar, Diameter of view= 4.0mm. Mag. =X40

The coarse-grained pegmatite contains quartz 22%, plagioclase feldspar 36%, biotite 13, muscovite 5% and tourmaline 23% (Plate III). Quartz occurs as colourless crystals in PPL and XPL. It has small to medium grain size and the shape of the crystals is anhedral. The mineral has low relief and exhibits undulose extinction. Biotite appears brown colour and it is strongly pleochroism. Biotite has anhedral to subhedral crystal habit with moderate relief. Plagioclase is white to colourless under plane polarized light and grey colour in cross polarized light. It shows clear plagioclase phenocryst crystals of euhedral shape, the plagioclase is zoned due to deformation. Plagioclase has an inclusion clay matrix. It has low extinction angle and moderate relief. Tourmaline (schorl) appears pale green to blue colour in XPL, it displays blocky subhedral crystal shape and have intergrowth of quartz within it crystal. Muscovite displays pink colour in XPL with subhedral crystals shape and exhibit cleavage.

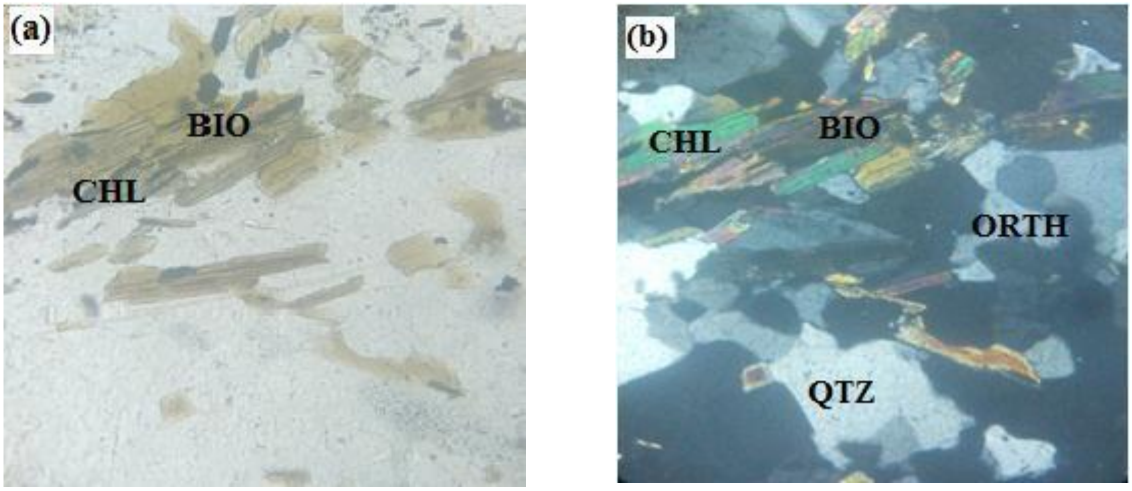

Plate IV: Photomicrograph of porphyroblastic gneiss, under (a) Plane polarized light (PPL) and (b) Crossed polarized light (XPL), (QTZ) =Quartz (BIO) =Biotite, (ORTH) =Orthoclase, and (CHL) =Chlorite, Mag. =X40.

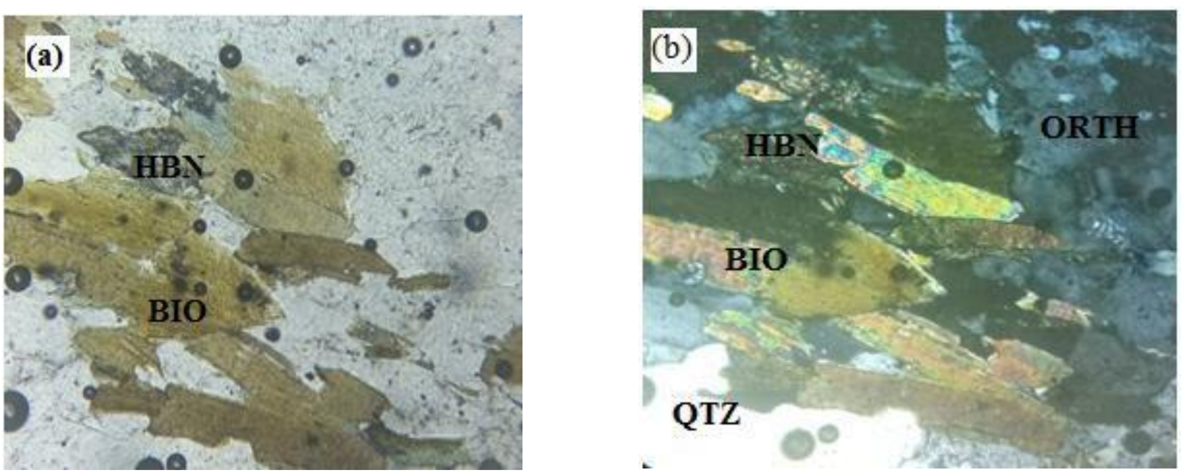

Plate V: Photomicrograph of banded gneiss, under (a) Plane polarized light (PPL) and (b) Crossed polarized light (XPL), (QTZ) =Quartz (BIO) =Biotite, (ORTH) =Orthoclase, and (HBN)=Hornblende, Mag. =X40.

The porphyroblastic gneiss consists of the following minerals; Biotite 29%, orthoclase 38%, quartz 20%, and chlorite 13%, (Plate IV). Quartz is colourless PPL and XPL, anhedral in form, low relief, displays no pleochroism in plane polarized light and exhibit a characteristics undulose extinction in cross polarized light, it about 2.3cm in size. Biotite is brown to dark-green colour in PPL and XPL. Its exhibits sub-hedral prismatic crystals with one direction of cleavage parallel to the prismatic section and the size of the mineral crystal is about 0.2mm in width and 2.0 cm in lenght. It has straight boundaries with preferential orientation. Orthoclase is a colourless mineral with low relief under PPL. It has subhedral crystal form and it shows weak cleavage. It exhibits interference colour of grey to black, and exhibit Carlsbad twinning in XPL. It also has irregular extinction with the crystal size ranging from 0.4mm to 2.3cm. Chlorite is colourless in PPL but green with blue rim in XPL view. It was formed by the alteration of biotite. It occurs as minor mineral in the petrographic studies. It also exhibits basal cleavage and as flakes with mottled extinction. Chlorite is the only accessory mineral identif

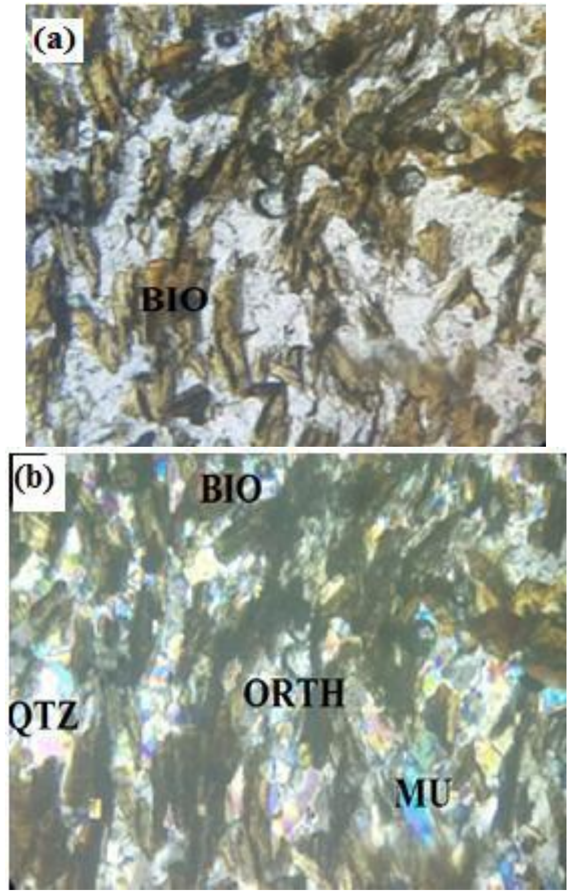

Plate VI: Photomicrograph of Biotite Schist, under (a) Plane polarized light (PPL) and (b) Crossed polarized light (XPL) (BIO) =Biotite, (M) =Muscovite, and (ORTH) =Orthoclase, Mag. =X40

Petrographic studies of Biotite Schist consist of the following; Orthoclase, biotite, quartz and muscovite. Biotite constitutes about 37%, quartz 25%, muscovite 9%, and orthoclase feldspar 29%, (Plate VI). Biotite is brown in PPL and dark-brown in XPL. It has straight boundaries, highly pleochroism, it has cleavages and subhedral in shape. Biotites are aligned in the same preferential direction and exhibit foliations. Quartz is colourless in PPL and XPL with moderate relief, quartz depict subhedral crystals habit which exhibits undulose extinction. Orthoclase appears ash grey colour under XPL and light ash under PPL. It’s has anhedral crystal form with some inclusions of biotite grains. Orthoclase displays low relief, no cleavage was observed and also cloudy with microcrystalline mineral crystals dispersed within the slide. Muscovite display’s pale brown to blue colour in XPL, moderate relief, anhedral crystal habit, crystals with a rough surface outline. Muscovite also exhibits low relief in PPL.

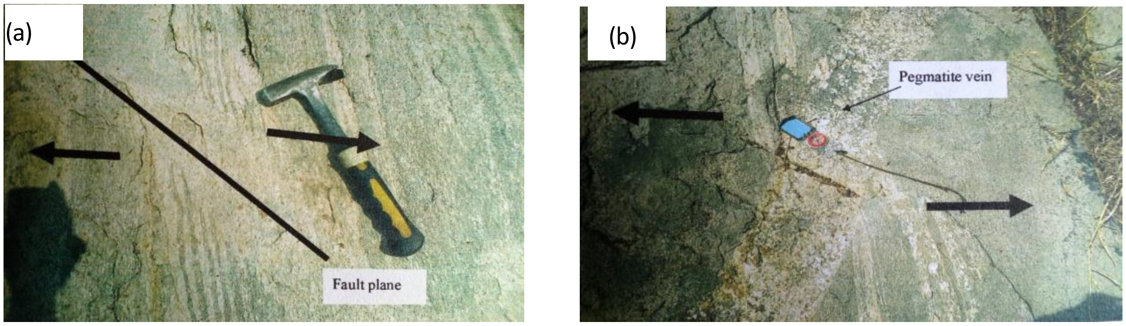

Plate VII: (a) Field Photograph of dextral fault on the gneiss east of Eshi village (N 8° 53′ 54.46″, E 007° 47′ 07.65″), (b) Field Photograph of sinistral fault on the gneiss (N 8° 53′ 54.46″, E 007° 47′ 07.65″)

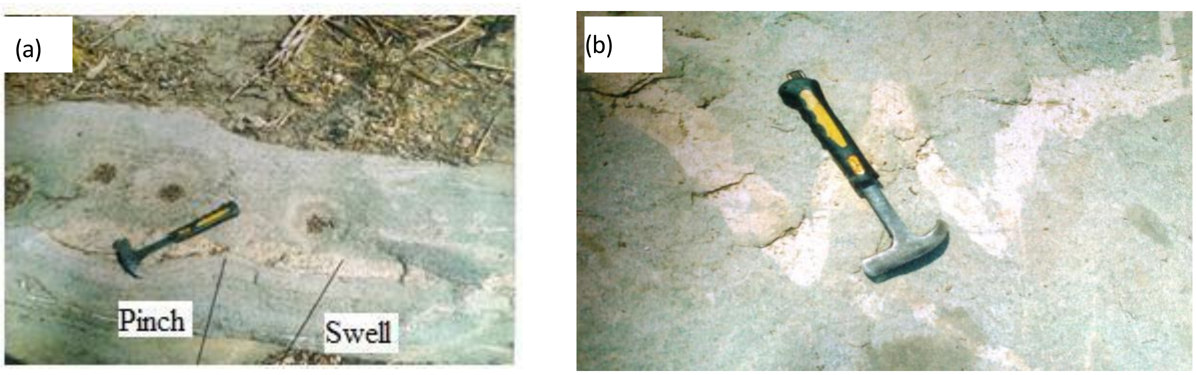

Plate VIII: Field Photograph of pinch and swell on the gneiss north of Gora (N 8° 52′ 57.82″, E 007° 45′ 48″), (b) Field Photograph of chevron fold on the gneiss at Eshi (N 8° 53′ 04.11″, E 007° 46′ 39.58″)

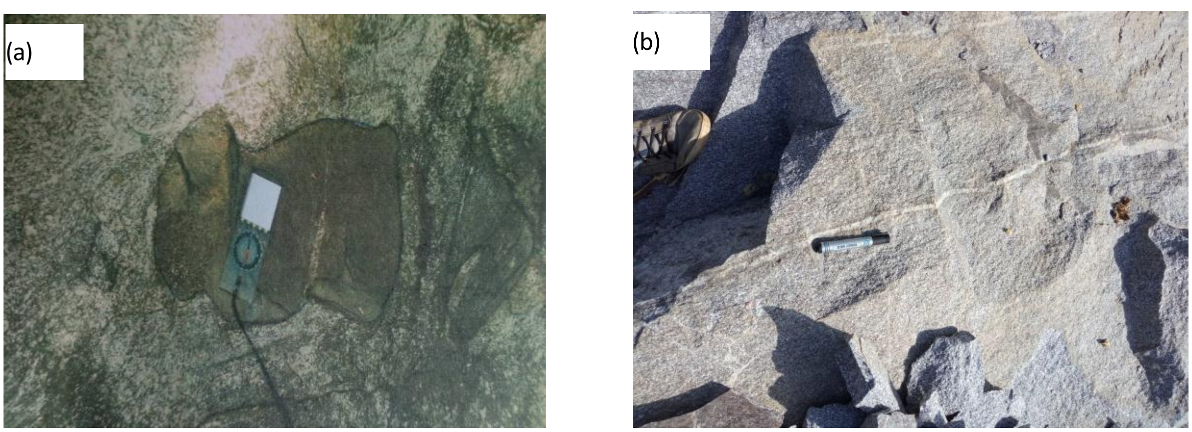

Plate IX: (a) Field Photograph of xenoliths on the gneiss north of Gora (N 8° 53′ 08.45″, E 007° 47′ 35.82″), (b) Field Photograph of quartz vein on the gneiss north of Gora (N 8° 53′ 08.45″, E 007° 47′ 35.82″)

5 STRUCTURAL GEOLOGY

The geological structures in the study area comprises of joints, pinch and swell, folds and faults. The dominant geological structures in the area are most probably associated with later deformation episode, which resulted in the N-S trending, steeply dipping structural features that are common in the basement complex terrain of Nigeria. The NW-SE and NE-SW trends of these structural features have also been documented in the study area. The lineaments map (Fig. 3) shows a significant NW-SE trend and a minor NE-SW trend, with relatively few lineaments overlapping one another. The generated lineament map demonstrates that the strikes of economically important structures are parallel and controlled by the NW-SE trending lineaments in the study area. The lineament frequency/rose diagram reveals that the prominent strike direction is NE-SW, N-S, NNE-SSW trend and others are subordinate direction (Fig. 4). The results of the lineament analysis and the rose plot based on manually recorded field readings are consistent.

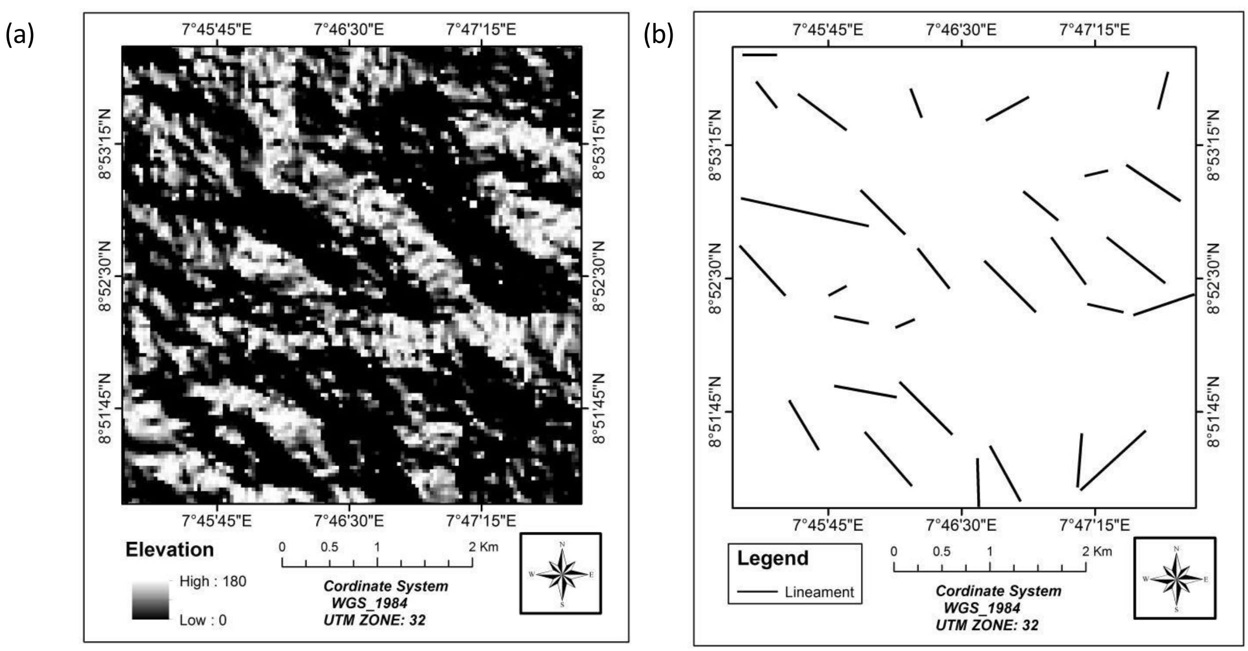

Fig. 3: (a) Hillshade digital elevation model (DEM) of the study area (b) Lineament map of the study area deduced from DEM

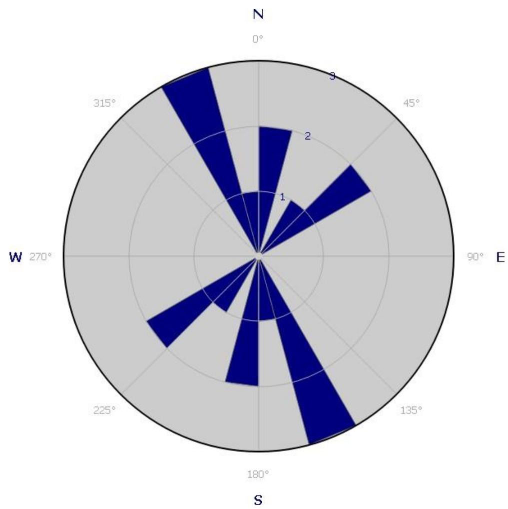

Fig. 4: Rose diagram (azimuth frequency) of lineament and veins of the study area

6 GEOCHEMISTRY

The analytical data from the lithological units comprises of major oxides, presented in Tables 1. The gneisses contain relative enrichment of SiO_2 ranging 61.737 - 63.419 wt %, Al_2O_3 (14.932 – 16.214 wt %), K_2O (1.996 – 3.095 wt %), Fe_2O_3 (5.533 – 6.368 wt %), and low enrichment of MgO (0.536 – 4.785 wt %), TiO_2 (0.615 – 0.823 wt %), and CaO (0.618 – 4.444 wt %). While

the biotite schist also are generally enriched in SiO_2 66.819 wt %, Al_2O_3 15.495 wt %, Fe_2O_3

6.304 wt %, Na_2O 2.563 wt %, and low concentration of MgO 1.376 wt %, TiO_2 0.667 wt %.

Table 1: Major elements content in rocks in the study area

Oxides	Biotite Schist K1	Banded gneiss K2	Banded gneiss K3	Porphyroblastic gneiss K4
SiO2	66.819	63.479	61.737	61.988
Al2O3	15.495	14.932	16.214	15.533
Fe2O3(T)	6.304	6.368	5.533	5.722
MgO	1.376	0.536	4.785	2.351
CaO	2.869	0.618	2.411	4.444
Na2O	2.563	2.4	2.258	1.945
Na2O+CaO	5.432	3.018	4.6691	6.389
K2O	3.564	1.996	2.72	3.095
TiO2	0.667	0.615	0.823	0.807
P2O5	0.001	1.321	1.407	1.248

Using Middlemost's (1985) total alkali (Na2O+K2O) against SiO2 (TAS) diagram for the chemical categorization and nomenclature of volcanic rocks, the gneiss plots primarily inside the granite and granodiorite field, while biotite schist plots in the granodiorite field (Fig. 5a).The Al_2O_3 versus MgO after Marc (1992), shows that gneisses all plotted mainly in the orthogneiss field. This suggests that the gneisses in the study area have igneous protolith. While the biotite schist falls within the paragneiss (Fig. 5b). The discrimination diagram of Shand (1943), reveals that the gneisses and biotite schist plot in the peraluminous field (Fig.8b). On SiO_2 versus K_2O diagram was used to distinguish various series of tholeiitic, calc-alkaline and shoshonitic rocks. The rocks of the study area plot mainly within High-K to calc-alkaline series (Fig. 6a) using Peccerillo and Taylor (1976), discrimination diagram. The Diagram of Miyashiro (1974) distinguishing between tholeiitic and calc-alkaline. On SiO_2 vs. FeOt /MgO binary diagram the gneisses and biotite schist plots in calc-alkaline series (Fig. 6b). The A–CN–K ternary diagram (Fig. 7) after Nesbitt and Young (1984), reveals the rocks samples are lower in CaO + Na_2O but richer in Al_2O_3, which largely indicates an igneous protholith. On the K_2O/Na_2O versus SiO_2 discrimination diagram, the gneisses and biotite schist plotted in the field passive continental margin (Fig. 8a). The geochemical interpretation reveals that the gneisses in the study area are orthogneiss (derivative from igneous source), peraluminous, and calc-alkaline in nature and it’s in consistence with the works of Rahaman (1988).

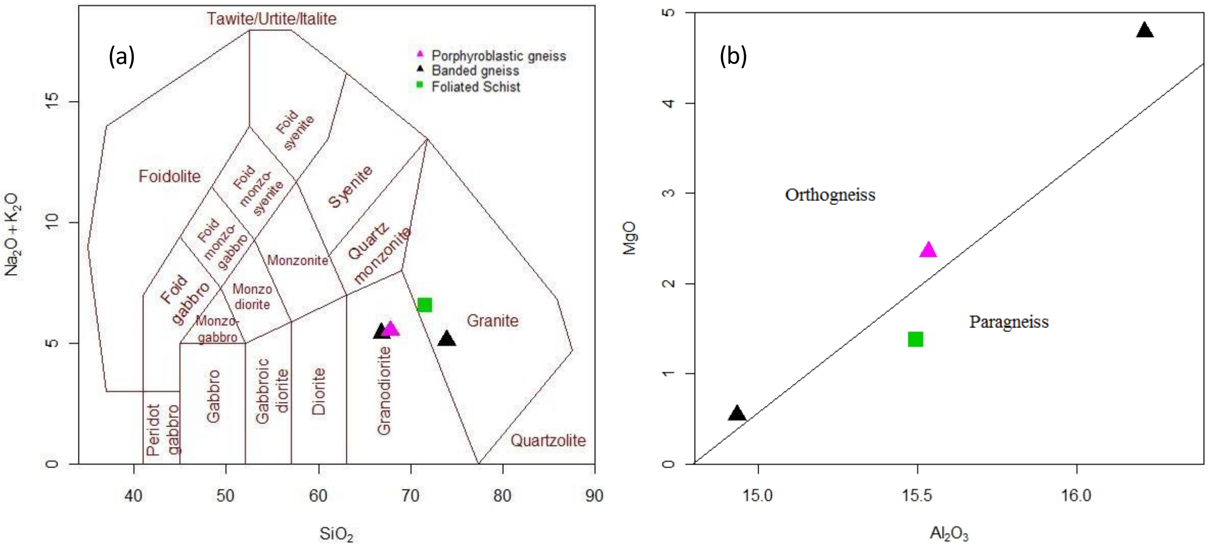

Fig. 5: (a) Chemical classification of the gneisses in the study area adopting TAS diagram (SiO_2 versus ($Na_2O + K_2O$) Showing the granitic protolith of gneisses using Middlemost diagram (1985) discrimination diagram. (b) Discrimination diagrams (Al_2O_3 versus MgO), using Marc (1992) discrimination diagram.

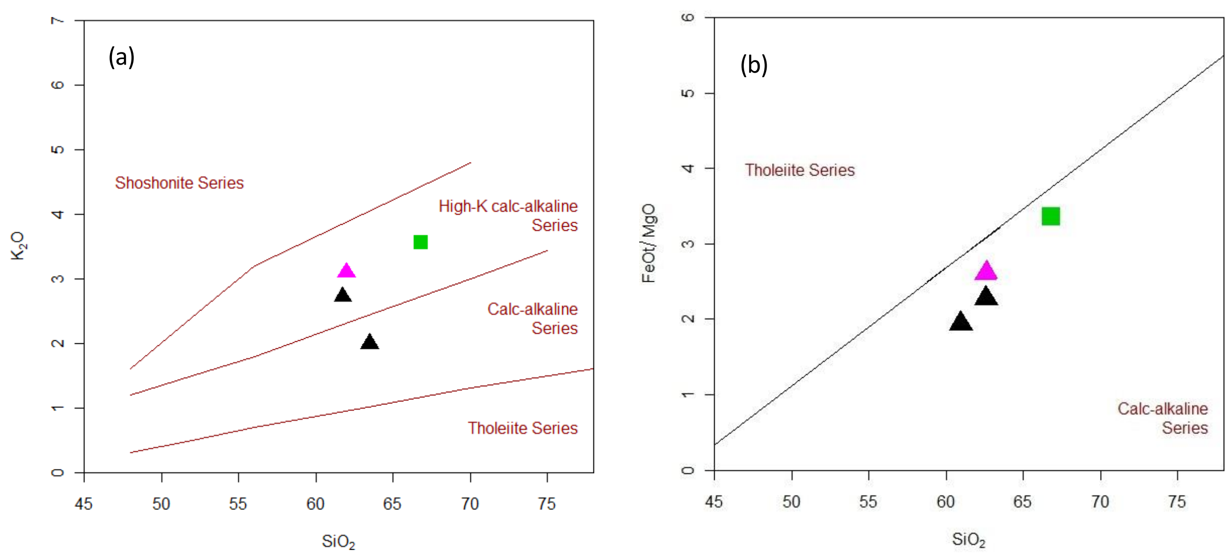

Fig. 6: (a) K_2O versus SiO_2 diagram of the rocks in the study area (using Peccerillo and Taylor, 1976). (b) SiO_2 vs. FeOt /MgO binary diagram of the gneiss in the study area using Miyashiro (1974) diagram

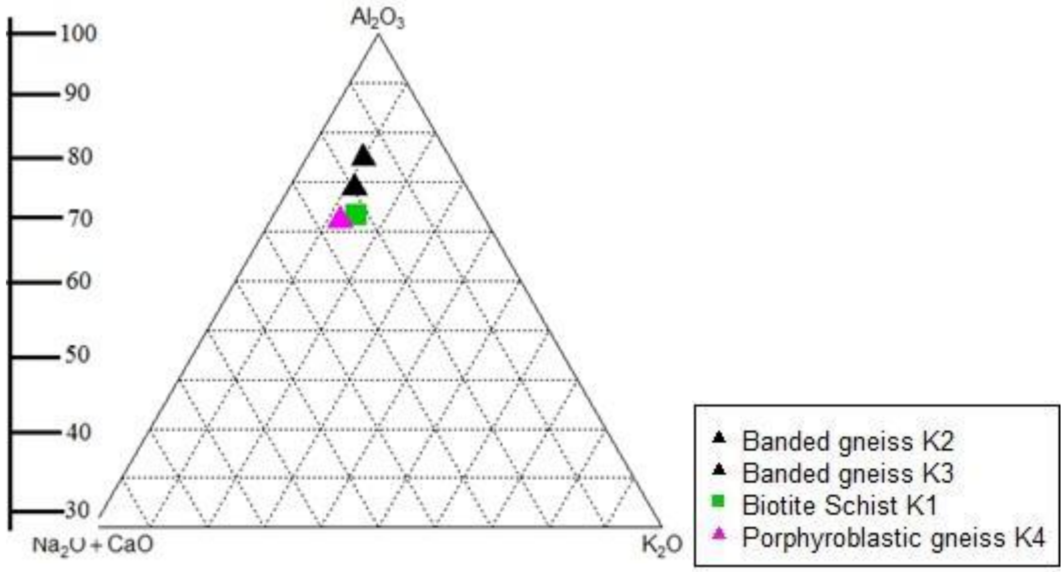

Fig. 7: A–CN–K ternary diagram of the gneisses and schist of the study area adapted from Nesbitt and Young (1984) discrimination diagram

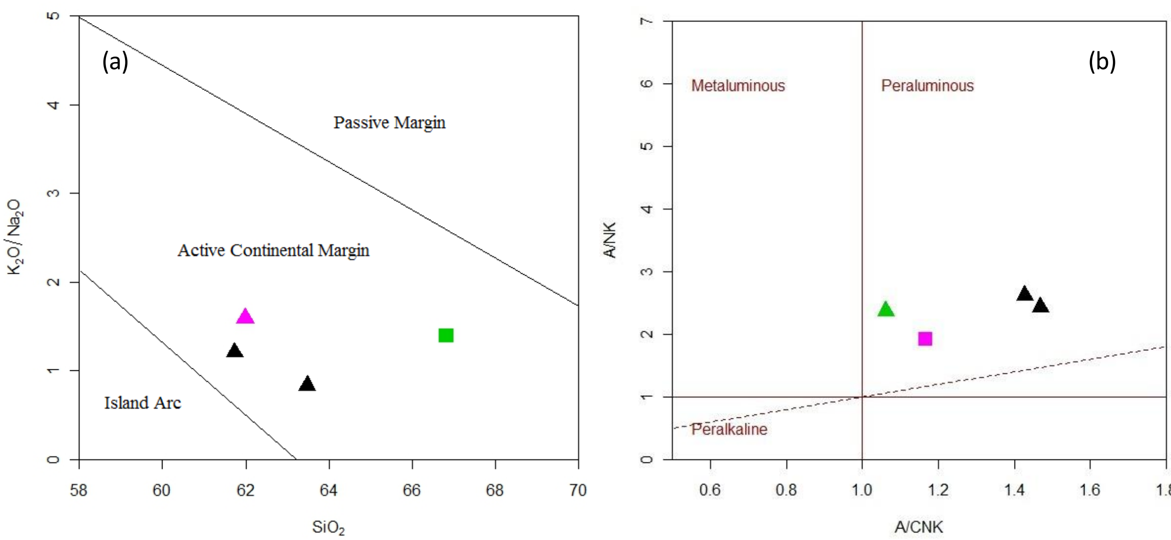

Fig: 8: (a) K_2O/Na_2O versus SiO_2 discrimination plot of the rocks in the study area, after Roser and Korsch, (1986). (b) Molecular Al_2O_3/ (Na_2O+K_2O) vs Al_2O_3/ ($Cao+Na_2O+K_2O$) diagram, plots of the granite rocks in the study area showing a dominant Peraluminous nature using Shand (1943) diagram

7 CONCLUSIONS

Geological mapping of the study area has revealed banded and porphyroblastic gneiss, biotite schist, pegmatite, quartz vein, while laterites are superficial material mapped in the study area. The medium to coarse grained leucocratic gneiss and medium grained melanocratic gneiss revealed that quartz, plagioclase feldspar, biotite, and muscovite are the dominant minerals. Petrographic studies have shown that the rocks in the study area consist mainly of quartz, feldspars, hornblende, muscovite and biotite. Both ductile and brittle deformational structures were mapped and these include; folds, joints, faults, pinch and swell, and veins. The lineaments map reveals a major NW-SE trend and NE-SW minor trend which conformed the rose diagram of the structures indicating NW-SE and NE-SW trends.

Major element analysis of the gneisses and biotite schist has revealed a peraluminous nature of the rocks. The petrogenetic discrimination (Al_2O_3 vs MgO) plot of Marc (1992) suggested the gneisses are orthogneisses (derived from igneous sources). The peraluminous, calc-alkaline character of the gneisses in this study area is consistent with the findings of other researchers of the Nigerian Basement Complex. Rahman *et al*. (1988) reported that gneisses around Oban Massif, southeastern Nigeria are peraluminous and calc-alkaline. Major elements composition has revealed that the gneiss is orthogneiss, i.e. were derived from igneous source using Al_2O_3 vs MgO discriminative diagram, after Marc (1992). In SiO_2 vs. FeO_2/MgO diagram the gneisses and biotite schist plot in high-K and calc-alkaline field using Miyashiro. The tectonic analytical setting of the gneisses of the study area on the K_2O/Na_2O versus SiO_2 discrimination diagram, the gneisses and biotite schist plotted in the field passive continental margin

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