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Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around Jimgbe, Northcentral Nigeria

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Abstract
The field geological mapping of the area around South-Eastern part of Jimgbe, in Ajaokuta Local Government of Kogi State has been carried out, it lies 07°41' ?07°42'N and 06°44' ?06°45'E and has an extent of 3.42 Km^2. Four (3) dominant rock units were revealed which are: Porphyritic granite, Migmatitic gneiss, Granite gneiss and Biotite gneiss. The minor rocks include quartzo-feldspartic intrusion and quartz vein. The area has different structures such as fold, fracture and foliation which trends NW-SE and NE-SW direction, this is allotted to the Pan-African Orogeny imprints. The petrographic analysis result shows that the four rock types are granitic in origin due to their high quartz and feldspar contents. The major mineral composition are quartz, plagioclase, microcline and biotite. Geochemical analysis result shows that SiO_2 is the most abundant major oxide. The average oxide percentages are; SiO_2 (69.25%), Al_2O_3 (12.41%), CaO (5.72%), Na_2O (3.25%), K_2O (3.76%), MgO (2.76%), Fe_2O_3 (1.79%), TiO_2 (0.28%), MnO (0.33%) and P_2O_5 (0.47%). These results shows that the rocks are calcic, and is also of high K-Calc alkaline in nature, the rocks majorly plot in the eugeosynclinal field except for sample T4 of the biotite gneiss which plot in the sedimentary field. They are mostly S-type peraluminous rocks except for the biotite gneiss (T11) which is an I-type peraluminous rock, these rocks are obtained from the upper mantle and lower crustal regions. They all plot in the magmatic field and also in the Granodioritic field.

Keywords: *Precambrian; Basement Rocks; Geochemistry; Pan-African Orogeny; Jimgbe; Ajaokuta*

Introduction

The study encompasses specialties such as petrology, geochemistry and Petrogenesis. Petrology is the branch of geology that studies the conditions under which rocks are being formed. It deals with origin and formation of rocks and therefore involves the laboratory synthesis of rocks for purpose of ascertaining the physical and chemical conditions (geochemistry) under which rock formation occurs. Petrographic study involves detailed descriptions of rocks with respect to its mineral content and its textural relationships within the rock. The petrographic analysis of any given rock(s) sample aid in the classification of that particular rock sample.

Most Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around the Southwestern Basement Complex were carried out by workers such as Oyinloye (2011), Akindele and Oyinloye (2011), Akindele (2011), Akintola *et al.* (2011), Goki *et al.* (2011), Onimisi *et al.*(2013), Folorunso *et al*. (2013), Olatunji *et al*. (2013), Olusiji (2015), Ogunleye *et al.* (2015), Adegbuyi *et al.* (2018) and Gideon (2019) on a regional scale.

Akindele and Oyinloye, (2011) revealed that of all the tectonic episodes, the Eburnean and the Pan-African Orogeny are the major events which modified the study area and the Precambrian geology of Nigeria. His geological and geochemical results unraveled that all these crystalline rocks are genetically related and had evolved by progressive differentiation of a parent basaltic magma to give rise to the protoliths of the amphibolites. He concluded a back arc tectonic setting as the environment of emplacement of these rocks. Onimisi *et al.*, (2013) revealed occurrence of two outcrops of marble (described as Mass I and Mass II) around Itobe. Also that the Itobe marble body and the host rocks of mica/quartz schist and quartzite trend in NNE-SSW direction; parallel to dominant foliation trend of the associated basement rocks. XRD analysis of the marble reveals an average mineralogical composition of Dolomites (33.3%, Calcite (64.9%) and Quartz (1.8%) for mass I and dolomite (1.7%), Calcite (92.5%) and Quartz (6.3%) for mass II.

Folorunso *et al.*, (2013) revealed four different rocktypes: porphyroblastic (augen) gneiss, hornblende-biotite gneiss, banded gneiss and quartz schist with mineralogical assemblages ranging from quartz, micas (biotite and muscovite), hornblende, feldspars (plagioclase and microcline) feldspars to accessory and opaque minerals (iron oxide) in part of Ago-Iwoye Southwestern Nigeria and also revealed NW-SE trending of foliations and mineral lineation, which conforms to the direction of stream flow as an indication of the streams being structurally controlled. Olatunji *et al.*, (2013) revealed that the basement rocks around Ganaja, Kogi State, Nigeria belongs to the Migmatite-gneiss complex of the southwestern basement complex and that the area is underlain predominantly by migmatite, augen gneiss, biotite gneiss, as well as minor occurrences of quartzo-feldspathic veins.

Adegbuyi *et al.*, (2018) revealed petrologic units around Oka-Akoko, Southwestern Nigeria include grey gneiss, granite gneiss, older granite, Charnokite and minor felsic and basic rocks. Petrographic results revealed that the granite gneiss is more enriched in Quartz and alkali feldspar than the grey gneiss while the grey gneiss is richer in plagioclase feldspar, hornblende, and opaques compared to the granite gneiss. They revealed igneous protoliths of granitic and granodioritic compositions respectively for the Oka-Akoko granite gneiss and grey gneiss and further draw that the grey gneiss is ferroan, alkali to alkali-calcic and metaluminous suggesting that it is igneous protoliths(s) is a M-type granitoid derived from melting of rocks from upper mantle to lower crustal regions under conditions of limited availability of water and a low oxygen fugacity while the granite gneiss is magnessian, alkali-calc and slightly peraluminous suggesting that its igneous protoliths(s) is an I-type granitoid derived from the partial melting of crustal igneous rocks. Gideon, (2019) revealed the lithologies within Okene Metropolis, North Central Nigeria to include Migmatite, granite, charnockite, hornblende biotite gneiss, melanocratic banded gneiss, and leucocratic biotite gneiss, quartzo-feldspartic gneiss and pegmatite dyke all of igneous origin and high alumina, alkaline and tholeitic composition.

Nevertheless, this study is aimed at determining the petrology, geochemical compositions and Petrogenetic characteristics of the basement rocks around Jimgbe area. Hence, it will document the petrographical and geochemical study of the study area which include descriptions, identification and measurement of geologic structures in-situ rock outcrop, identification of various rock units, production of a detailed geologic map of the study area and delineate an inferred rock boundary between these rock types. The study will disclose the major rock forming minerals, the elemental composition of the different rock types as well as the textural relationships within the rock. The findings of this work will help in the understanding of the origin of the differing lithologic units in the study area and genesis of the Basement Complex of the southwester Nigeria at large.

Location and Accessibility

The study area is located in the Southeastern Jimgbe area, part of Lokoja Sheet 247 SW of Kogi State, Nigeria. It is located between the latitude 07°41' – 07° 43' N, and longitude 06°43' – 06°45' E (Fig. 1). The extent of the study area is 13.69 km^2. The area is accessible through the Ajaokuta - Ganaja-Lokoja road which cuts across the North-Western part of the mapped area. Other minor roads are footpaths that links the settlements and the two dry stream channels running west to east of the study area to the Niger River. The footpaths helped in designing a suitable closed transverse method during mapping and also the dry stream channels helped in exposing the low lying outcrops for further field studies.

Regional Geology and Geochronology of Southwestern Basement Complex of Nigeria

The area covered by the southwestern Nigeria basement complex lies between latitudes 7°N and 10°N and longitudes 3°E and 6°E right in the equatorial rain forest region of Africa (Fig. 1). The main lithologies includes; Amphibolites, Migmatite gneisses, Granites and Pegmatites. Other important rock units are the schists, made up of biotite schist, quartzite schist talk-tremolite schist, and the muscovite schists. The crystalline rocks intruded into these schistose rocks. It has been established that the Precambrian basement complex of Nigeria including Southwestern Nigeria is polycyclic in nature, (Ajibade and Fitches 1988). The southwestern Nigeria basement complex had undergone 4 major orogenesis in;

1. Liberian (Archaean) 2500Ma-2750± 25Ma
2. Eburnean orogeny (Early Proterozoic), 2000Ma-2500Ma
3. Kibaran orogeny (Mid Proterozoic), 1100Ma - 2000Ma and
4. The Pan African Orogeny, 450Ma-750Ma.

Of all the above orogeny, the Eburnean and the Pan-African are major events which modified the Precambrian Geology of Nigeria including the Southwestern Nigerian basement complex. The Eburnean event is marked by the emplacement of the Ibadan granite gneiss in Southwestern Nigeria which has been dated 2500 ± 200Ma (Rahaman, 1988) and a pink granite gneiss at Ile-Ife Southwestern Nigeria dated 1875Ma using U-Pb on Zircon. Thus Archaean to Pan African ages had been suggested for the basement rocks of the Southwestern Nigeria.

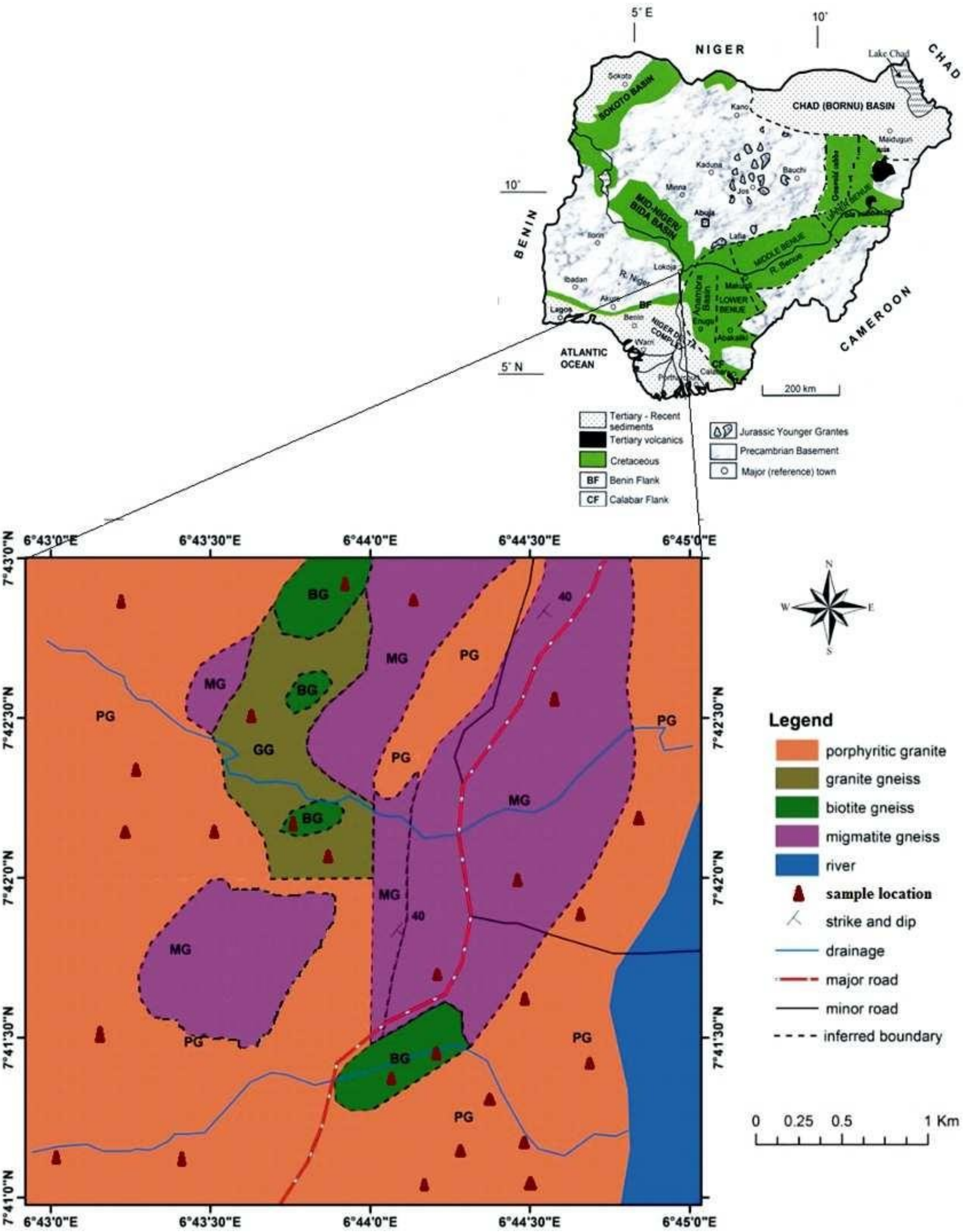

Fig. 1: Geology and Sample Location Map of the study Area.

Materials and Method

Field Methods

The field methods include choosing a suitable open traverse method of mapping which involved traversing along routes and mapping out the outcrops megascopically. Structural features on the outcrops and demarcating geological boundaries. The field work was carried out over a period of three weeks. This involved reconnaissance mapping, detailed geological mapping which include collection of representative rock samples from outcrops, from along river channels and road cuts. These rock were identified and studied on the field and the information such as the trend, extent, colour, structural characteristics and the location using the Global Positioning System (GPS) are all recorded in the field notebook. The mapping also involved recognition of contact relationship between the different rock types within the study area and the representation of each of the rock unit on the base map (Fig. 1). Each of the samples collected are well labelled using masking tape taking note of the locations and structures such as joints, folds, veins, foliations etc. About thirty (30) rock samples were collected during the mapping. Rocks were systematically sampled to represent the outcrops and to avoid weathered sample. At each sampling point, weathered surfaces were avoided, fresh representative rock samples were taken, packaged in new polythene sample bag and labelled.

Petrographic (Thin Section) Analysis

Fourteen (14) rock samples from the study area was systematically selected and were cut for thin section preparation. The cutting was across the foliations so that all the minerals present in the rock will surface on the rock slide. The cut section of these rocks were frosted and placed on a glass slide with Canada balsam. The excess thickness of the rock was then grinded from the Frosting section of the Thin Section machine and then manually frosted on a flat surface using Carborundum so as to get a perfect and the required thickness of 0.003µm for a rock slide. The petrographic analysis was carried out in the Petrology laboratory, Department of Earth Sciences, Kogi State University, Anyigba, Nigeria.

Geochemical Analysis (X-Ray Fluorescence X.R.F)

Twenty four (24) rock samples were subjected to geochemical analysis. The Geochemical analysis involved taking the selected samples firstly to the sample preparation laboratory for pulverization. The pulverizing machine grinds or mill the rock sample into fine grain form with crystals not more than 60 µm. this is important so as to homogenize the rock sample and to make sure that every part of the rock sample is partaking in the geochemical analysis it will be subjected to. The pulverized sample is measured and further made into pellets using deionized water. The pellet is then air-dried and introduced into the vacuum chamber of Energy Dispersion X-ray Fluorescence Spectrometer machine. The result is usually presented in form of Oxides.

Results and Discussion

Petrology, Mineralogy and Field Relationships

The study area is made up of porphyritic granite, migmatitic gneiss, granite gneiss and biotite gneiss and minor lithological units which include pegmatite, quartz vein and aplite dykes (Fig. 1). The structural feature of the study area comprises joints, fold, joints and foliation.

Porphyritic Granite

The rock is light in colour and covers about 75% of the study area. The outcrop in most cases are characterized by low lying outcrop and extend towards the River Niger to form the base of the river (Fig. 1). The rock has a porphyritic texture, Phenocrysts of this rock is composed of white to pink prismatic microcline (30 mm and sometimes up to 40 mm in length) (Fig. 2). These porphyritic textures are randomly oriented in a medium to fine grained granitic groundmass. The minor rock include cross cutting quartzo-feldspartic intrusions and quartz vein intrusions which is majorly composed of feldspar, quartz and biotite mica. The dominant mineral assemblages found in the porphyritic granite include Quartz (39.91%), Plagioclase (13.2%), Microcline (14.3%), biotite (11.6%), Muscovite (8.0%), Hornblende (7.4%), and Opaque Mineral (5.5%) (Fig. 3) and the structures found on the outcrop are microfolds, joints, faults, veinlets and exfoliation.

Fig. 2: Photograph showing Porphyritic Granite rocks showing (A) A NE-SW trending Quartz vein intrusion (Location 2: GPS; N 07o 41' 20"; E 0060 44’ 15.4’’). (B) A domed shape Porphyritic Granite (Location 1: N 07o 41’ 10.8’’; E 006 44' 5.4"). (C) An isolated porphyritic granite (Location 5: N 07o 41’4” E 006 44’30.5”).

Migmatitic Gneiss

The migmatite gneiss occurs as ridges and low lying outcrops towards the Northwestern part of the study area. It is variable in colour due to the alternating light (quartzo-feldspartic) and dark (Ferro-magnessian) minerals that are in lit-par-lit and some of these

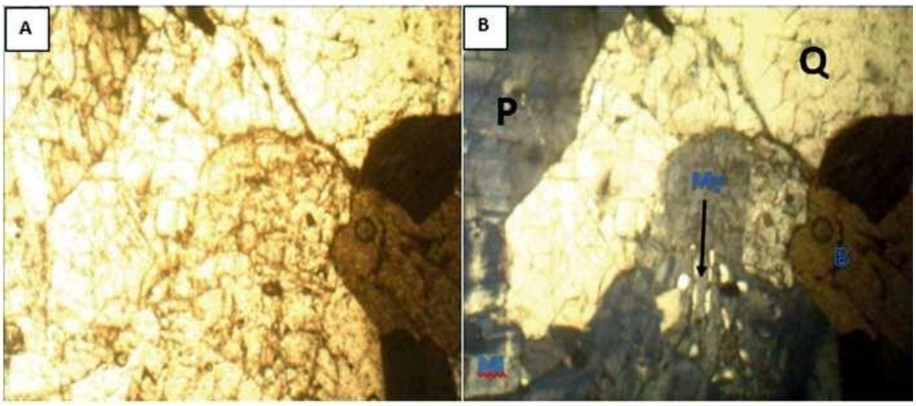

Fig. 3: (Slide T2). A photomicrograph of porphyritic granite (a) under a Plain Polarized Light. (b) Essential mineral composition under XPL. Q=quartz, My=Myrmekitic texture, P=plagioclase, B=Biotite and Mi=Microcline. (x20)

alternations are thick while some are thin (Fig. 4). The thin alternations are highly folded into ptygmatic folds. The rocks are highly exfoliated which suggests the action of mechanical weathering processes. The migmatite gneiss rock is presumed as the oldest rock type in the study area owing to the mixing of the older metamorphic rock and the younger granitic materials. The texture of the rock varies from fine grained to medium grained while the structures observed on the outcrop include folds, joints, cracks and veins. Mineralogically the dominant mineral assemblage of the rock include Quartz (43.1%), Plagioclase (14.05%), Microcline (11.85%), biotite (14.8%), Muscovite (7.45%), Hornblende (5%), Orthoclase (0.6%), Sanidine (0.3%) and Opaque Minerals (2.85%) (Fig. 5 and 6).

Fig. 4: A photograph showing (a) ptygmatic folds and quartz vein intrusion (Location 6: N 07° 41’ 47.8’’ and E 006o 44’ 04.3’’), (b) Low lying Migmatitic gneiss rock with deformed quartz vein in different direction (Location 9: N 07° 41’ 43.0’’ and E 006°44'20’’).

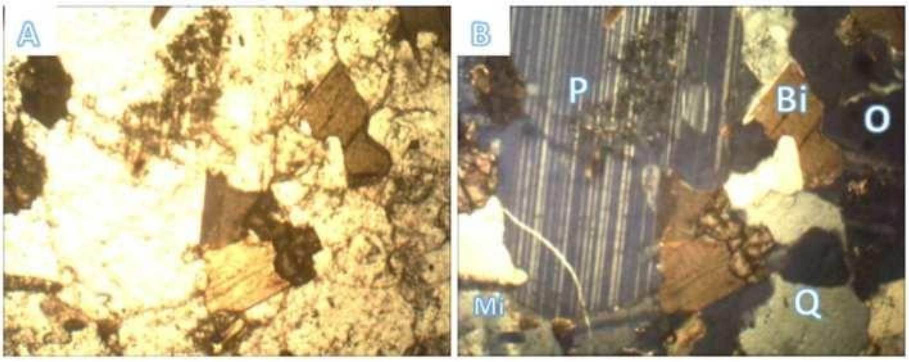

Fig. 5: (Slide T9). A photomicrograph of Migmatitic Gneiss (a) Under PPL. (b) Essential mineral composition under XPL include; Q=quartz, P=plagioclase, Bi=Biotite, O=Opaque minerals and Mi=Microcline. (x20).

Biotite Gneiss

This rock type occurred as an isolated outcrop in the western part of the study area (Fig. 1). The outcrop is trending 120^0 ESE and 30^0 NNE. The rock has a range of joints (09^0 - 15^0 NNE) which are almost parallel to the strike of the rock (46^0 NE – 226^0 SSW). The rock is very dark in colour. The high biotite composition of the rock makes it easily susceptible to weathering due to the high rate at which the rock absorbs heat from the sun. It has a medium to fine grain size. The rock is highly foliated and these folds forms a sharp contact with the porphyritic granite rock bordering it (Fig. 7a and 7b). The structures observed on the outcrop include quartzo-feldspartic intrusions, folds, joints, foliations and veins. From hand specimen, 60% of the rock is leucocratic while the remaining 40% is melanocratic. The dominant mineral assemblage of the rock include quartz (41.9%), Sanidine (0.4%), Microcline (3.4%), biotite (30.8%), Muscovite (7.7%), Hornblende (2.6%), Plagioclase (8.5%) and Opaque Minerals (4.7%) (Fig. 8).

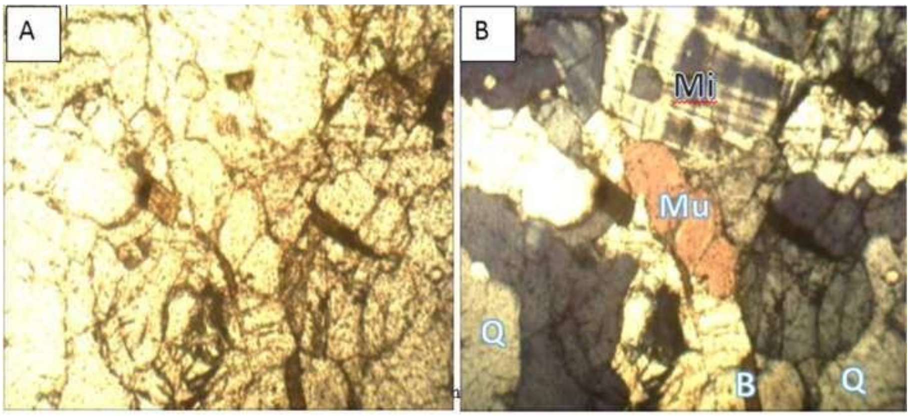

Fig. 6: (Slide T6). A photomicrograph of Migmatitic Gneiss (A) under PPL. (B)Photomicrograph of Migmatitic Gneiss showing essential mineral composition under XPL. Q=quartz, Bi=Biotite, Mu= Muscovite and Mi=Microcline. (x20).

Fig. 7: A photograph of (A) A folded Biotite Gneiss rock forming a boundary with a porphyritic granite (Location 8a: N 07° 41' 30.1'' and E 006° 44' 14.5''), (B) A foliated Biotite Gneiss (Location 8b: N 07° 41' 31.1'' and E 006° 44' 15''), (C) A foliated and more felsic biotite gneiss rock forming boundary with the Migmatite Gneiss (Location 7: N 07° 41' 26.1'' and E 006° 44' 5.4'').

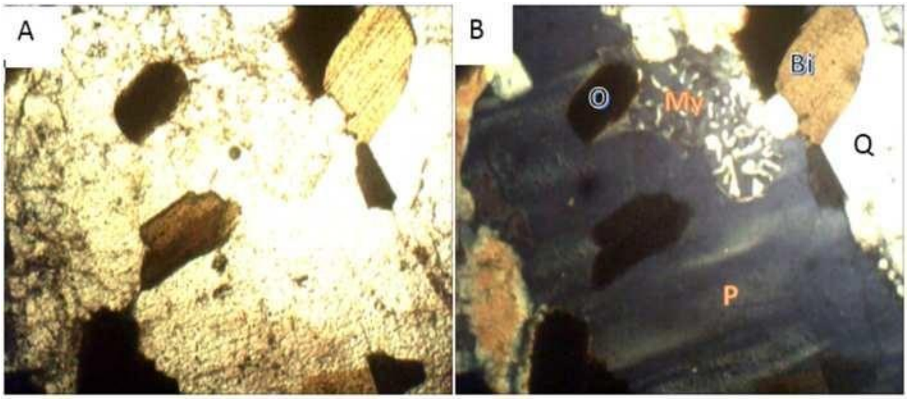

Fig. 8: A photomicrograph of Biotite Gneiss (A) under PPL. (B) Showing mineral composition under XPL. Q=quartz, Bi=Biotite, O=Opaque Minerals, My= Myrmekitic texture and P=Plagioclase. (x20).

Granite Gneiss

The granite gneiss occurs in areas along Salem University Lokoja, Ajaokuta Road and the rocks trending in 32NE-SW direction (Fig. 1). The texture of these rocks varies from medium to coarse grains and foliated with thin-bands of light to dark colour minerals (Fig. 9). The dominant mineral assemblages found in the granite-gneiss include quartz (57.9%), plagioclase (20%), biotite (14.7%), microcline (15%) and others (10%) (Fig. 10) and the structures observed on the outcrop are folds, joints, veinlets and quartz veins.

Fig. 9: ***Aand B:*** Are photographs of the Banded Gneisses found within Salem University. (A) Location B3: N07° 41' 51" E006° 43' 50" (B) Location N07° 41' 42" E006° 43' 50").

and therefore, it will be more resistant to weathering. The plagioclase all together is averagely 11.44%, on the porphyritic granite (Table 1), calcium dominates the plagioclase in the porphyritic granite and thus validate the QAP plot where the sample plots in the granodioritic field of the QAP diagram (Fig. 11) while Sodium dominates the plagioclase in the migmatitic gneiss and the biotite gneiss as it shows a thin band in Figure 5. Generally the biotite content of each of these rock samples are relatively moderate except in the biotite gneiss where it hits an average of about 31% (Table 1). This gives the rock a higher susceptibility to weathering and it also makes the rock less useful for construction works. The rocks having the moderately low percentage of ferromagnesian i.e. biotite, hornblende makes it a good to excellent material for construction work. Based on the rock types we have within the study area, the porphyritic granite and the migmatitic gneiss are good for construction but the migmatitic gneiss is the best for construction because of its fine to medium grain size. The smaller the grain size of any rock, the less susceptible it is to weathering.

Structural imprints (Fig. 4, 7, 9) on the rocks shows a lot about the tectonic episodes that the rocks have been subjected to. The common fault types are dextral strike-slip faults and Normal faults, this reveals that there has been an extensional force that led to the breakage thus displacing the rocks relative to each other. The strike slip faults indicate a trans-current tectonic regime. The

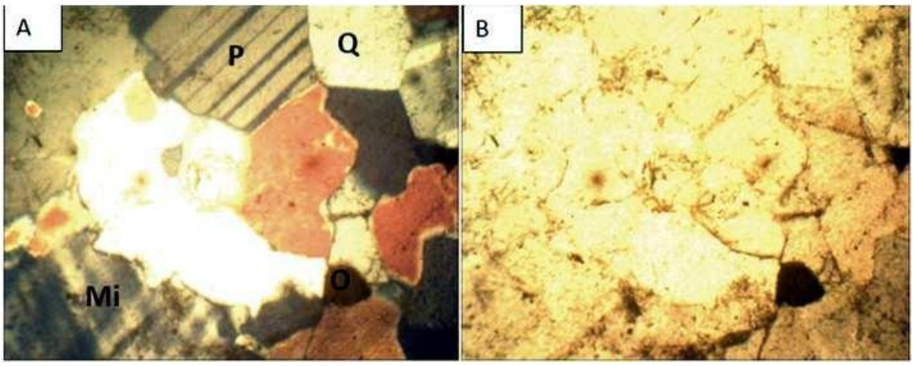

Fig. 10: ***Aand B:*** (A) A photomicrograph of a Banded Gneiss showing some common rock forming minerals under XPL, Q= Quartz, P=Plagioclase, Mi=Microcline, O=Opaque minerals. (B) A photomicrograph of a Banded Gneiss showing 85% felsic minerals and 15% mafic minerals under PPL.

From the modal composition of each of the samples of the rock analyzed, quartz which is a common rock forming mineral has the highest percentage with an average of 45.68% (Table 1). This shows that the rocks are extrusive and must have occurred from melting of crustal rocks. The quartz in all the rock samples analyzed are polysynthetic. The quartz content of the migmatitic gneiss increases towards the northern part of the study area, this gives a more felsic migmatitic gneiss

complex folds encountered on the migmatitic gneiss rocks shows compressional forces coming from the limbs of these folds. The ptygmatic folds occur due to flowage in different directions, the flow of these partially melted rocks was in response to gravity. The joints are also trending NE-SW and NW-SE directions, the joints that is parallel to the rock trend can be said to be syntectonic while the joints that are perpendicular to the rock trend must have occurred after the rock was

Table 1: Average mineral modal compositions of rocks from area abound Jimgne

Rock Types/Minerals	Porphyritic (%)	Migmatite Gneiss (%)	Biotite Gneiss (%)	Granite Gneiss (%)	Average (%)
Quartz	39.91	43.10	41.90	57.80	45.68
Plagioclase	13.20	14.05	8.50	10.00	11.44
Orthoclase	-	0.60	-	-	0.15
Microcline	14.30	11.85	3.40	8.10	9.41
Sanidine	-	0.30	0.40	0.10	0.20
Biotite	11.69	14.80	30.80	14.00	17.82
Muscovite	8.00	7.45	7.70	6.10	7.31
Hornblende	7.40	5.00	2.60	2.70	4.43
Opaque	5.50	2.85	4.70	1.20	3.56
Total Average	100	100	100	100	100

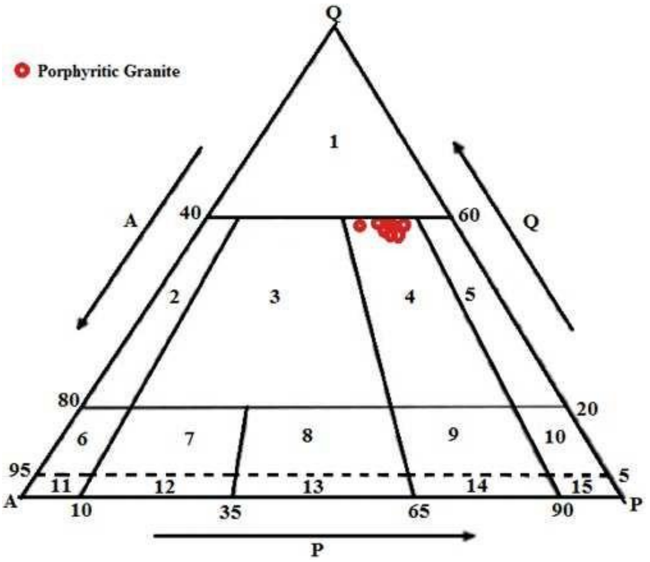

Fig. 11: The QAP diagram for the granitic rocks in aera around SE of Jimgbe (Streckeisen *et al.* 1976). 1=Quartzolite; 2=Alkali Granite; 3=Granite; 4=Granodiorite; 5=Tonalite; 6=Alkali Quartz Syenite; 7=Quartz Syenite; 8=Quartz Monzonite; 9=Quartz Monzodiorite; 10=Quartz Diorite; 11=Alkali Syenite; 12=Syenite; 13=Monzonite; 14=Monzodiorite; 15=Diorite.

emplaced. The minor rocks include pegmatite which occur in form of quartzo-feldspartic intrusion and quartz vein. The quartzo-feldspartic intrusions are majorly trending 285° to 300° (NW- SE) direction while the quartz vein also trends NE-SW direction, they are mostly crosscutting the rocks trend. These characteristics as evident on the rocks in the study area indicate imprints of the Pan-African orogeny.

Geochemical Characterization

The geochemical results for the major oxides is presented in Table 2. The SiO_2 content in porphyritic granite is 69 wt.%, Al_2O_3 14% wt.%, CaO 5.6% wt.%, Na_2O is 2.70 wt.%, while MgO content is 2.20 wt.%. The k_2O content is 4.20 wt. %, Fe_2O_3 is 1.80 wt. %, P_2O_5 is 0.50 wt. %, while MnO and TiO_2 are 0.10 wt. % each while the SiO_2 content of the biotite gneisses ranges from 68 to 71.3 wt.%, Al_2O_3 10.9 to 14% wt.%, CaO 5.0 to 5.4% wt.%, Na_2O is 3.1 to 3.9 wt.%, while MgO content 2.80 to 3.1 wt.%. The k_2O content ranges 2.7 to

Table 2: Average percentage oxide values of Major Element compositions of the rock types around Jimgbe.

Major Oxides	Porphyritic Granite T2 N = 4	Porphyritic Granite B3 N = 4	Biotite Gneiss T4 N = 4	Biotite Gneiss T11 N = 4	Granite Gneiss B9 N = 4	Migmatitic Gneiss B6 N = 4	Average (%)
SiO_2	69.00	69.12	68.00	71.30	66.75	71.34	69.25
Al_2O_3	14.00	12.63	14.00	10.89	11.60	11.34	12.41
CaO	5.50	5.16	5.40	5.00	7.49	5.74	5.72
Na_2O	2.700	3.79	3.80	3.10	3.63	2.53	3.25
MgO	2.20	1.89	3.10	2.80	3.23	3.42	2.76
K_2O	4.20	4.21	2.70	4.10	4.21	3.15	3.76
Fe_2O_3	1.80	1.84	1.70	1.70	1.66	1.94	1.77
P_2O_5	0.50	0.54	0.30	0.60	0.49	0.37	0.47
MnO	0.10	0.29	0.50	0.20	0.41	0.50	0.33
TiO_2	0.10	0.38	0.35	0.30	0.26	0.26	0.28
Total Average							**100.00**
Na_2O/Al_2O_3	0.20	0.30	0.28	0.28	0.31	0.22	
K_2O/Al_2O_3	0.31	0.35	0.19	0.38	0.36	0.28	
K_2O/Na_2O	1.56	1.56	0.69	1.32	0.69	1.32	
$Al_2O_3/(Na_2O+K_2O)$	2.03	13.30	2.12	1.51	13.00	14.1	
$Al_2O_3/(CaO+Na_2O+K_2O)$	1.20	10.40	1.17	0.89	9.30	7.70	
K_2O+NaO-CaO	1.30	1.30	1.20	2.20	1.20	2.20	
K_2O+NaO	6.90	8.00	6.60	7.20	7.80	5.70	

4.10 wt. %, Fe_2O_3 is 1.70 wt. % each, P_2O_5 is 0.30 to 0.60 wt. %, MnO 0.2 to 0.5 wt. % and TiO_2 ranges from 0.30 to 0.40 wt. % (Table 2). The high content of the SiO_2 in the granite is an indication of the acidic nature and enrichment in common rock forming minerals such as quartz and feldspar.

The variation diagram of SiO_2 against other major oxides according to Harkar, (1909) shows a strong negative correlation between SiO_2 versus Al_2O_3, CaO, MgO and K_2O (Fig. 12). This means that as the SiO_2 content increases, Al_2O_3, CaO, MgO, and K_2O decreases. P_2O_5 and N_2O against SiO_2 plot indicates a positive correlation while Fe_2O_3 shows no correlations at all.

The discrimination diagram of Na_2O/Al_2O_3 against K_2O/Al_2O_3 (Fig. 13) shows that the porphyritic granite and sample T4 of the biotite gneiss are of igneous origin while sample T11 of the biotite gneiss plots in the metasedimentary field (Garrel and McKenzie, 1971). The TiO_2-K_2O-P_2O_5 diagram shows that the granite and the gneisses were emplaced in a continental environment, this must have been the reason that accounts for the high SiO_2 and Al_2O_3 contents (pierce *et al.* 1975) (Fig. 14). CaO-N_2O-K_2O diagram shows that the porphyritic granite is quartz diorite to granodiorite which is in agreement with the result from the QAP diagram (Fig. 11) (Condie, 1967) (Fig. 15).

The molecular plot of Al_2O_3/ (Na_2O+K_2O) against Al_2O_3/ (CaO+Na_2O+K_2O) (Fig. 16) shows that the porphyritic granite and sample T4 of the biotite gneiss are peraluminous rocks, this means that that Al_2O_3> (CaO+Na_2O+K_2O) thus indicating the high content of Alumina in the rocks, Slide T11 plots in the metaluminous field Al_2O_3< (CaO+Na_2O+K_2O). The peraluminous and slightly metaluminous nature of the

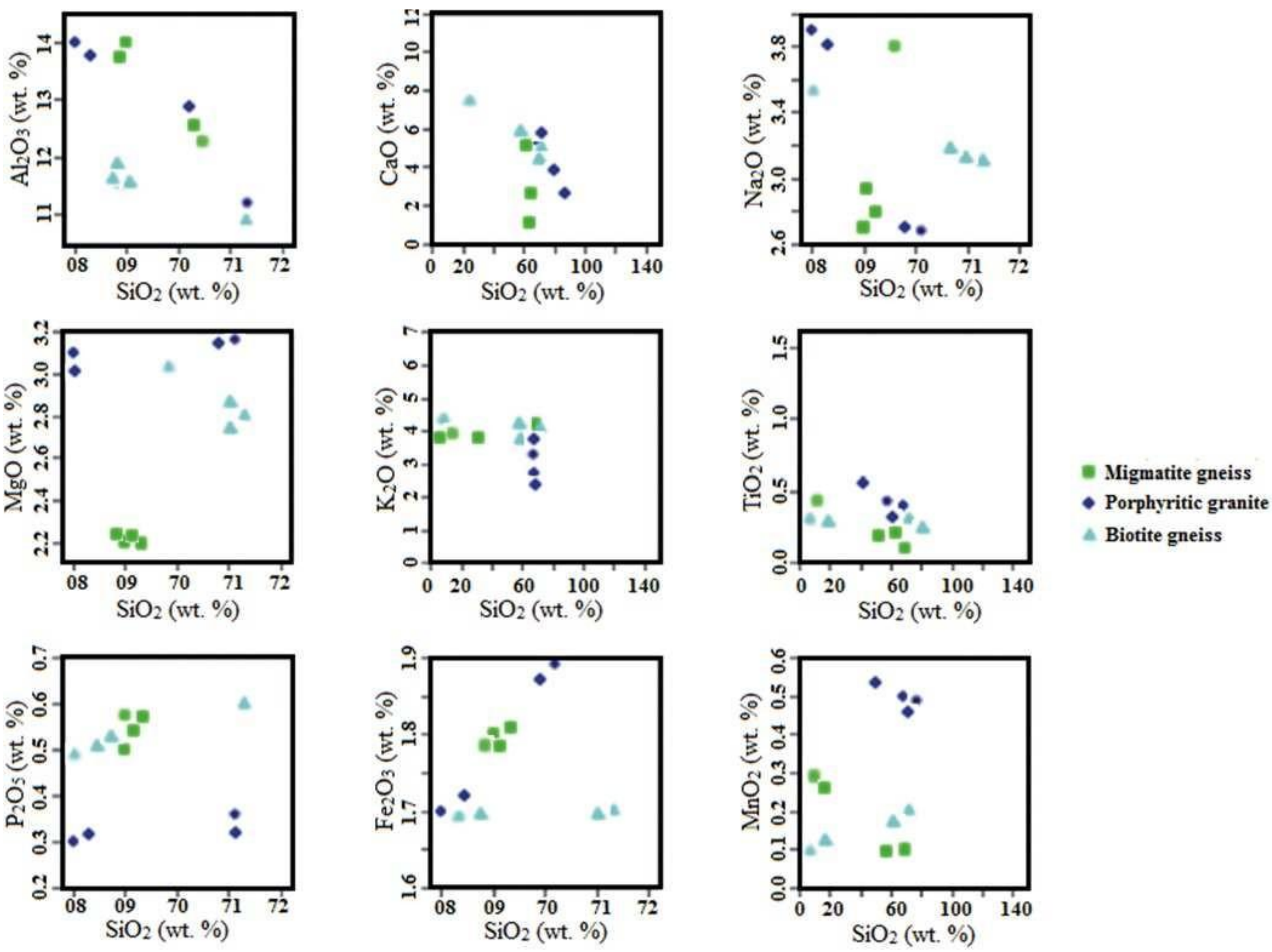

Fig. 12: A variation diagram of SiO_2 against the other major oxides within the study area.

rocks are indications of an igneous protolith (Maniar *et al*. 1989) (Fig. 16). The plot of Al_2O_3/ (CaO+Na_2O+K_2O) against SiO_2 further classify the porphyritic granite and sample T4 of the biotite gneiss to be an S-type peraluminous rock (Dombrowski *et al.* 1995) (Fig. 17).

The MgO-CaO-Al_2O_3 diagram of Leyleroup *et al.* (1977) shows that the porphyritic granite and the biotite gneisses are magmatic rocks (Fig. 18). K_2O versus N_2O discrimination diagram shows that the porphyritic granite and sample T11 of the biotite gneiss plots in the eugeosynclinal field which indicates that their protolith are sedimentary rocks while sample T4 of the biotite gneiss plots outside the eugeosynclinal field indicating a magmatic protolith (Middleton, 1960) (Fig 19). Plot Na_2O+K_2O against SiO_2 indicates that the porphyritic granite and the biotite gneisses are Sub-alkaline rocks (Irvine and Baragar, 1971*)* (Fig. 20). Finally, K_2O versus SiO_2 plot shows that the porphyritic granite is medium K-Calc Alkaline rock while the biotite gneisses are high K-Calc Alkaline rocks (Rickwood, 1989) (Fig. 21).

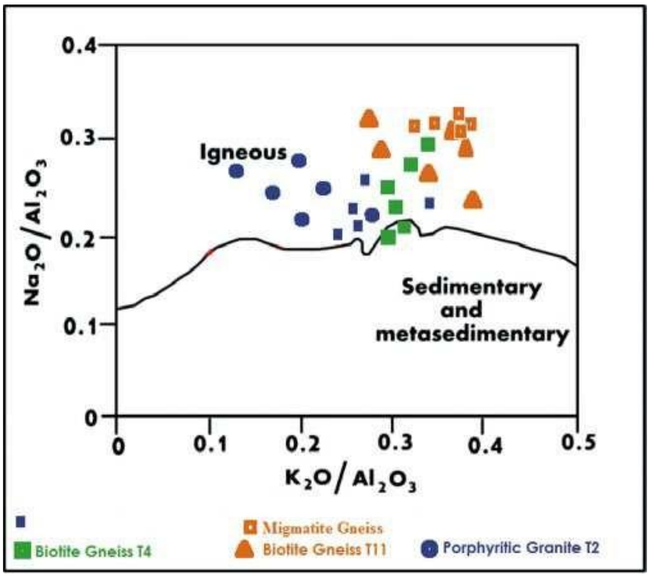

Fig. 13: Na_2O/Al_2O_3 versus K_2O/Al_2O_3 discrimination diagram for SE Jimgbe basement rocks (After Garrels and McKenzie, 1971).

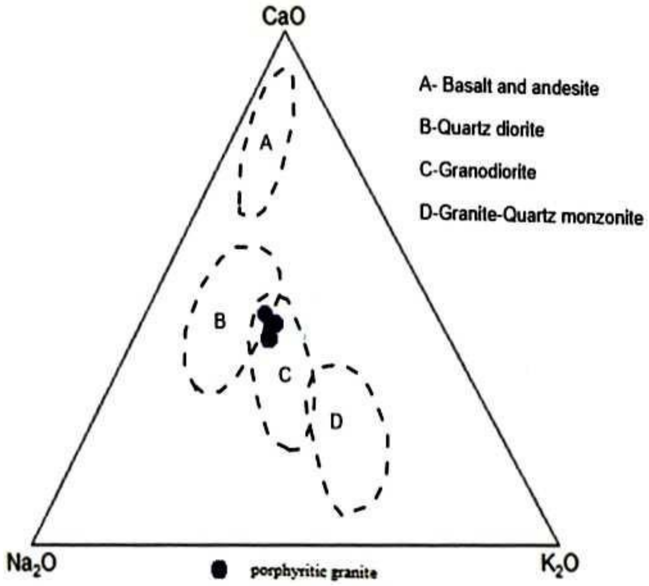

Fig. 15: CaO –Na_2O –K_2O ternary diagram of the rocks in SE Jimgbe area (After Condie, 1967).

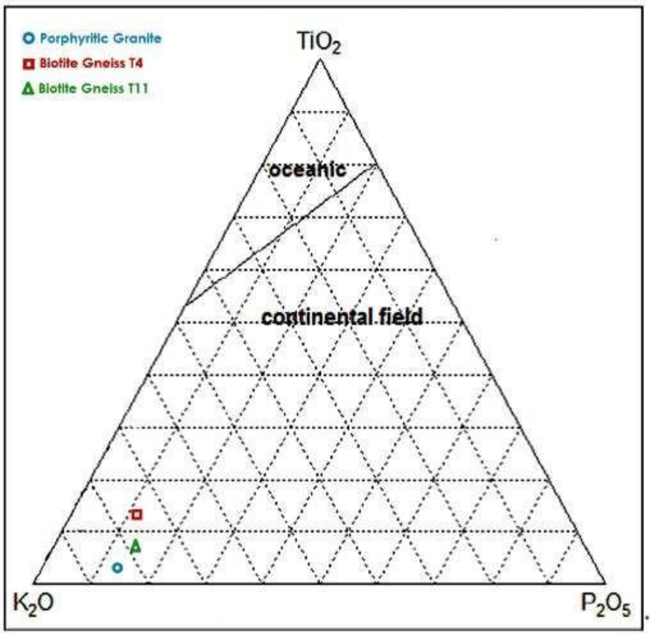

Fig. 14: TiO_2 K_2O P_2O_5 diagram of rocks from South Eastern Jimgbe area (After Pierce *et al.*, 1975).

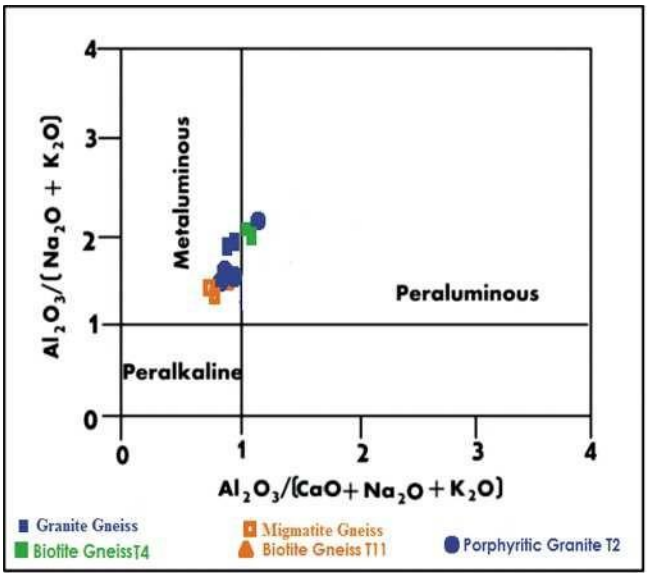

Fig. 16: Al_2O_3/ (Na_2O + K_2O) versus Al_2O_3/ (CaO + Na_2O + K_2O) molecular plot for rocks in SE Jimgbe area (After Maniar and Piccoli, 1989).

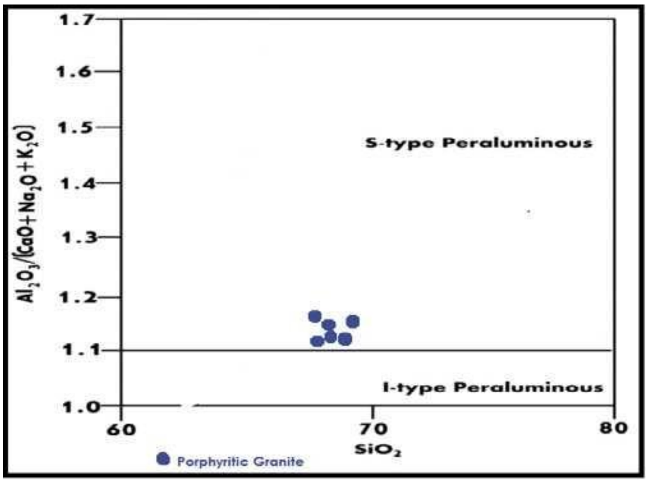

Fig. 17: Al_2O_3/ (CaO+Na_2O+K_2O) versus SiO_2 plot of rocks within SE Jimgbe area (Dombrowski et al., 1995).

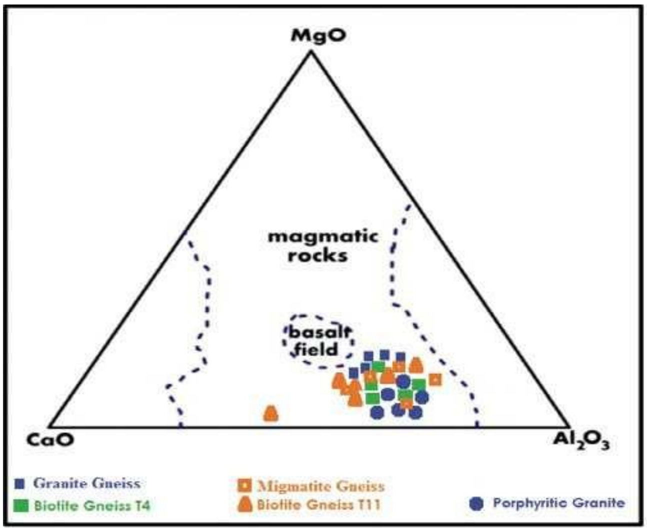

Fig. 18: MgO –CaO –Al_2O_3 diagram for rocks in SE Jimgbe area (After Leylercoup *et al.*, 1977).

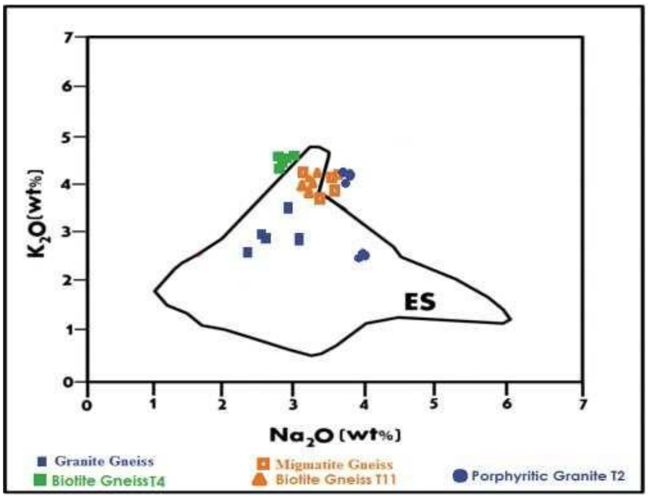

Fig. 19: K_2O versus Na_2O discrimination diagram for rocks in SE Jimgbe area (After Middleton, 1960).

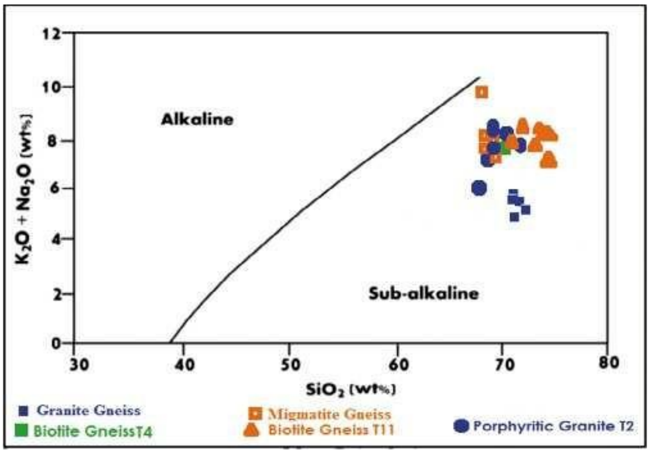

Fig. 20: $Na_2O + K_2O$ against SiO_2 Plot for SE Jimgbe area (After Irvine and Baragar, 1971).

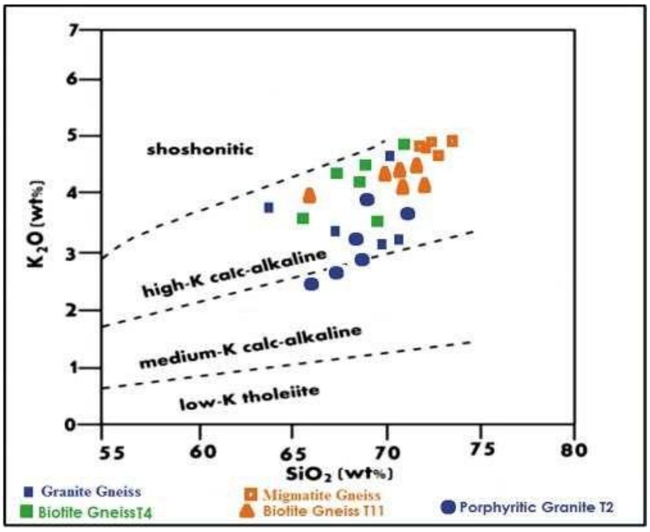

Fig. 21: K_2O versus SiO_2 plot for rocks in SE Jimgbe area (Rickwood, 1989).

Conclusion

The geochemical and geological studies of the basement complex rocks in SE Jimgbe area has been studied and from the results acquired from the analyses, it was concluded that the rocks belong to the Southwestern Basement Complex rock of Nigeria. Correlation between the petrographic study, field relationship records and the geochemical results give a good match and shows that the rocks are granitic in origin. The tectonic imprints on the major and minor rocks shows signatures of the Pan-African Orogeny. These studies in totality confirms that the rocks are part of the Pan-African South western Basement Complex of Nigeria. Finally, intrusions such as quartzo-feldspartic intrusions which occurred as fracture fillings and quartz vein imprints on these rocks are events which terminated the Pan-African Orogeny.

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