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Petrography and Geochemical Classification of the Saigbe Granites, North Central Nigeria

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Abstract

This work involves detailed field, petrographic and geochemical studies of Saigbe granites to bring forth their possible petrogenesis. Geological field mapping reveals the basement rocks of the Saigbe area consist of schist, amphibolite, and granite with minor intrusion of pegmatitic veins. Structural features were also discerned with principal joint direction as plotted on rose diagrams showing NWW – SEE for the granites. A total of ten granitic rock samples were collected and described based on their field relationships. Three fresh representative rock samples were subjected to petrographic analysis while five others were later subjected to geochemical analysis using the X-ray Fluorescence (XRF) technique. Petrography of the investigated rock samples showed an average mineralogical composition of plagioclase feldspar, quartz, biotite, microcline, muscovite and a trace of opaque minerals for the granites. The result of the geochemical analysis revealed the average percentage composition of major oxides as follows; SiO_2 (71.30 wt.%), Al_2O_3 (11.13 wt.%), Fe_2O_3 (3.37 wt.%), CaO (4.44 wt.%), K_2O (2.18 wt.%), Na_2O (1.58 wt.%), MgO (2.09 wt.%), P_2O_5 (0.003 wt.%), TiO_2 (1.04 wt.%) and MnO (0.62 wt.%). The geochemical classification of the granitic rocks revealed that the rocks fall within the Calc-alkaline/Tholeiitic series (AFM Plot), which supports a mixed and evolved magma origin during the evolution of the granitic rock. They were also classified into both I-Type and S-Type granite based on the $Al_2O_3/(Na_2O+K_2O+CaO)$ versus SiO_2 plot. Ternary plot of the granitic samples sho.ws continent.al setting for the granitic rocks in the area. Therefore, the granitic rocks in the Saigbe area can then be said to have been formed from the fractionation of magma within the continental setting as the granitic rocks range in composition from Diorite and Granodiorite to Granite.

Keywords: Petrographic Characteristic, Classification, Saigbe Granites, Nigeria

1. Introduction

Granites are deep-seated intrusive igneous rocks composed of mica, quartz, feldspars and ferro-magnesian mineral such as amphibole. Granite *sensu stricto* is rich in potassium feldspar (up to 65% of feldspars) relative to plagioclase, and has a high content of quartz (20 – 60%).

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However, with increasing plagioclase feldspar ratio, granite grades into rocks called granodiorite (plagioclase constituting 65 - 90 % of feldspars) and tonalite (plagioclase constituting 90 - 100% of feldspars). In addition, with decreasing quartz (less than 20%) content granites grade into (potassium feldspar - rich) syenite or monzonite (Myers, 1997).

Granite is one of the most prominent topographic entities of the Nigerian basement complex due to their enormous sizes outcrop prominently above the general peneplain (Oluwatoyin *et al.*, 2021). These granitic rocks are referred to as the Older Granites or the Precambrian Granites, consisting of biotite granite, hornblende biotite granite, diorite, hypersthene granite, porphyritic or porphyroblastic muscovite granite, quartz-hypersthene granite, syenite, quartz diorite, non-porphyroblastic or non-porphyritic granite and aplite granodiorite (Oyawoye, 1964). Kroner *et al.* (2001) described the evolution of the complex as an extension of the craton of West Africa in the Western portion and that of Congo craton in the Southeast. These cratons were further reported to be of Archean to Lower Proterozoic age. Older granites are the plutonic rocks and are the most prominent evidence of late Precambrian tectono-magmatic activiies during which significant materials are added to the cust. They are of Pan-African orogeny (600 Ma) and cover a lage areal of rocks whose composition varies and consisted of granodiorite, syenite, granite, tonalite and charnockite (Truswell and Cope, 1963). The origin of these massive bodies has been linked with orgenic activities finalizing in wide-spread plutonism across the entire Pan-African countries.

Early studies regarded the granitoids as having composition ranging from granite, granodiorite, tonalite and adamellite. The granitoids are of calc-alkaline affinity due to the significant amounts of potassium they possess and often contain traces of normatve corundum (Rahaman, 1988). The magmas that gave rise to these masses were thought to have been derived from low-Rb/Sr protoliths characterized by crustal contaminations. The available geochronologic data across major granite terrains in Nigeria revealed that the granitic masses and the pegmatite associated have ages ranging between 620 and 580 Ma (Goodenough *et al.*, 2014). Despite their common occurrences, studies have not ascertained the true origin of these rocks. This research presents petrographic features and a geochemical study of one of such rocks within the Saigbe area.

1.1 Study Area

Saigbe area is part of North central Nigeria lying within the coordinates of Latitudes 9°42' N and 9°45' N and Longitudes 6°33'30" E and 6°36'30" E, and located on the outskirt of Minna metropolis, Bosso Local Government Area (LGA) of Niger State (Figure 1). It is approxmately 32 km^2 in terms of areal coverage.

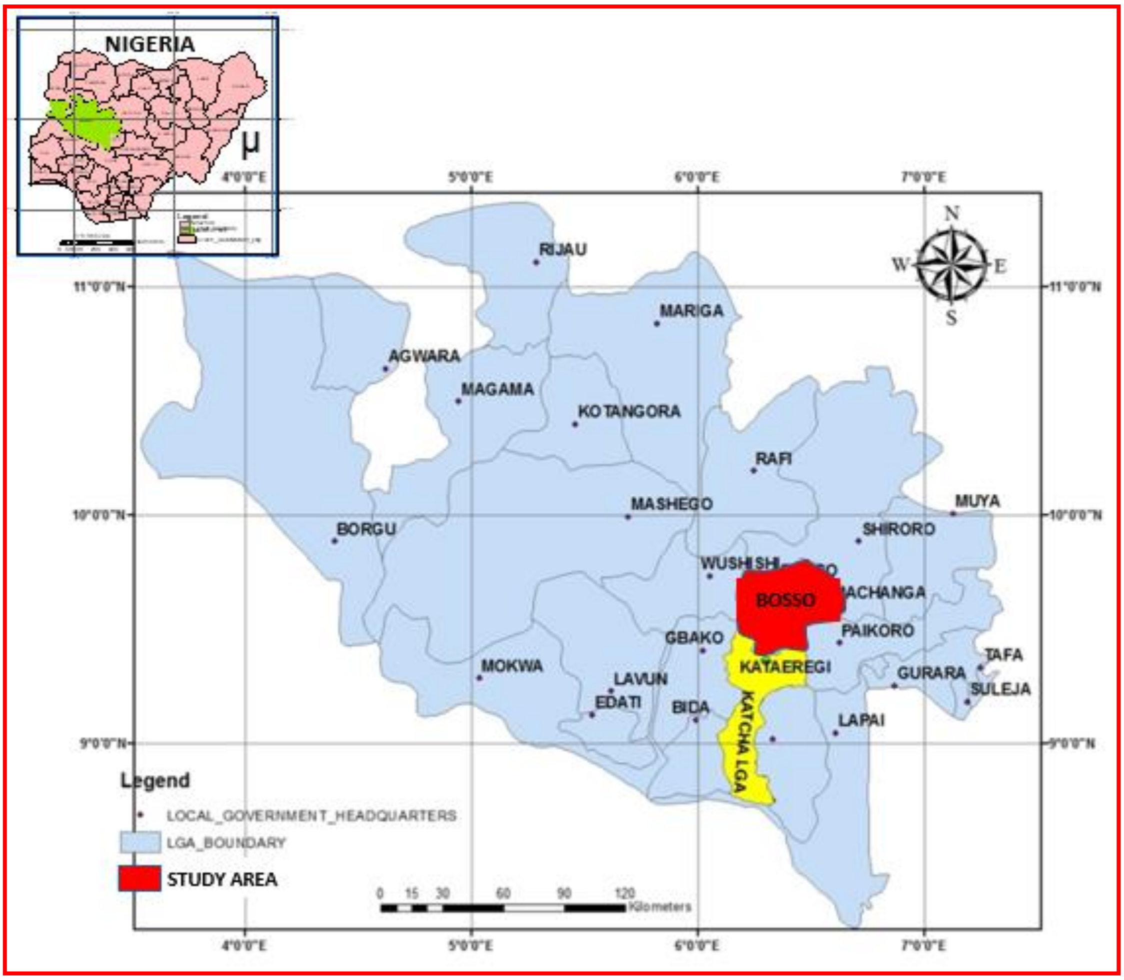

Figure 1: Location of Saigbe in Bosso Local Government Area, Niger State, Nigeria (After Omanayin *et al.,* 2016)

The Saigbe area is mainly accessible by the new Maitunbi - Maikunkele bye-pass, while several minor roads and footpaths are also linked to it. The area is drained by River Saigbe which flows in southward direction and is fed by many other smaller streams or tributaries (Omanayin *et al.*, 2023a).

2. Materials and Methods

This research adopted both field and laboratory methods. The field method involved reconnaissance survey and detailed geological mapping. Reconnaissance survey helped to establish the boundaries of the study area, and it was followed by a detailed geological mapping on a scale of 1: 25,000. The mapping was conducted with the aid of a base map extracted from the topographic map of Minna Sheet 164 SW (1: 100,000). During the geological mapping, each outcrop located was plotted on the base map using the global positioning system (GPS); hand lens aided the study of mineral compositions in hand specimen; structural information was measured using compass-clinometer and tape-rule; fresh samples measuring between 1 – 1.5 kg each were collected within the study area with a geological hammer. Important features observed in the field were captured with the aid of a digital Camera. All the observations and measurements taken in the field were recorded on the field notebook. The samples collected were properly labelled, packaged and conveyed using sample bags to the laboratory.

At the laboratory, three (3) representative granitic rock samples were subjected to petrographic study. Thin sections of these rocks were prepared in accordance with the method by (Rowland, 1953). These prepared slides were examined using a petrological microscopic (model NP-107B) under plane-polarized light (PPL) and crossed polarized light (XPL) with the aid of transmitted light and photomicrographs of the thin sections produced. Major oxide geochemical analysis was conducted on five (5) representative samples. These samples were pulverized using an agate pulverizing machine to ensure homogeneity and it was made to pass through a 150µm (micro mesh) sieve. The pulverized sample was then pelletized, labelled, and analysed using Minipal 4 model of Energy Dispesive X-ray Fluorescence (EDX-RF) spectrometer. The laboratory analyses were conducted at the National Geosciences Research Laboratories, Nigerian Geological Survey Agency (NGSA), Kaduna state.

3. Results and Discusion

The result from the field mapping exercise of the area revealed three main lithologic units which occur at low to moderately high topographic levels; schists, granitic rocks with the minor intrusion of pegmtitic veins occurring mostly in the wesern half of the stuy area, and amphibolites. The amphibolite extensively intruded the schist along the main River Saigbe. These rock units are adequately represented from which the geological map was produced (Figure 2). The geological map shows the lithological boundaries. These observed lithologic units are similar to those reported by Sambo *et al.* (2020) from adjacent studied area with the exclusion of amphibolites. It is imperative to note here that this research work was strictly focused on the granitc rocks from the stuy area.

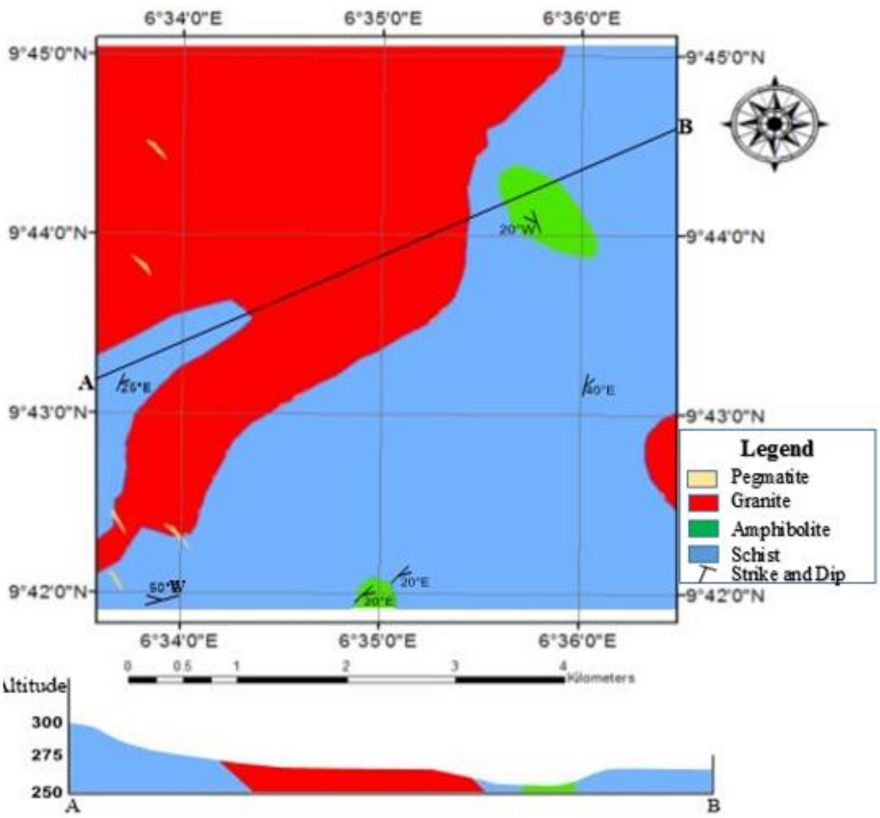

Figure 2: Geologic map and cross-section of the Saigbe area

3.1 Petrography of the Granitic Rocks

The granitic rocks intruded into the schist, mostly appearing as batholiths and some boulders. It covers about 38%, occupying the northwest mostly, and southwest of the study area. It shows some effect of weathering with a medium to coarse-grained texture (Plate I). They consist of mica, quartz, feldspar and some darker minerals which can be assessed in the hand specimen. They are light to darkish in colour and exhibit structural features like faults, joints, and veins. In view of the authors this granite is younger having intruded the schist as observed on the field.

Plate I: Photograph of a granitic rock with quartz veins

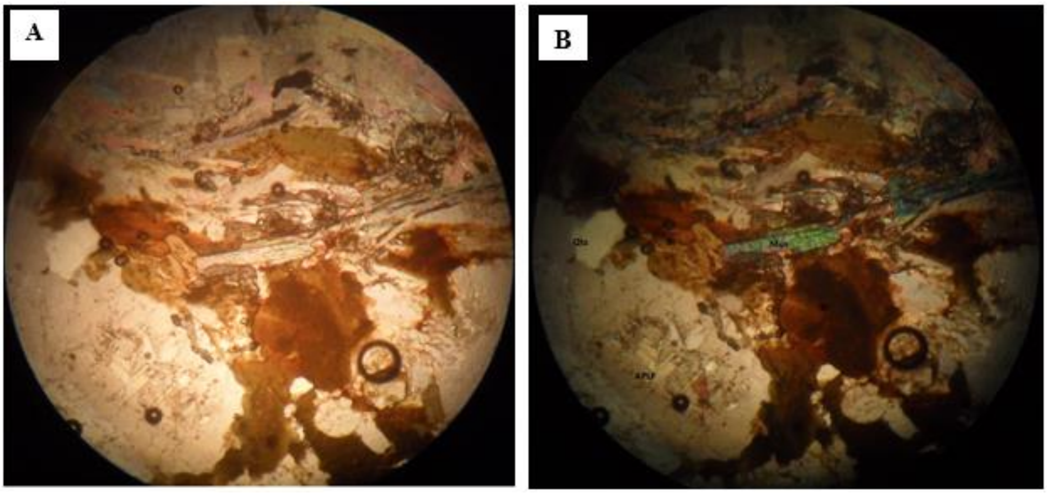

Plate II: Phtomicrograph of sample L4 (a) under PPL; (b) Under XPL. MG x 10

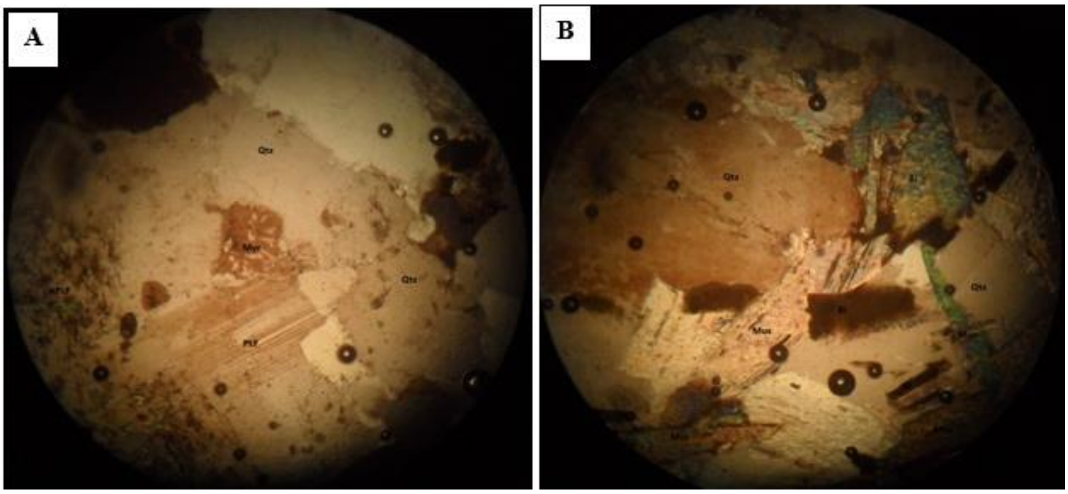

Plate III: Photomicrograph of sample L8 (a) under PPL; (b) Under XPL. MG x 10

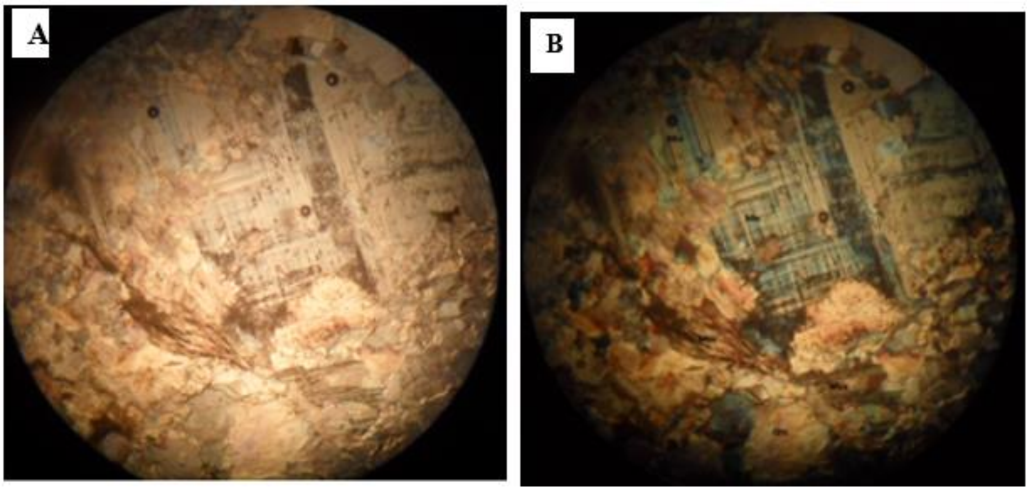

Plate IV: Photomicrgraph of sample L16 (a) under PPL; (b) under XPL, MG x 10

Three (3) representative samples (L4, L8, and L16) out of ten granitic rock samples collected from the field were analysed under the petrographic microscope. Their thin-section slides prepared from each samples were viewed under both plane polar (PPL) and cross polar (XPL) light microscope. Their respective photomicrographs are shown above (Plates II, III, and IV). The modal composition (in percentage) of the major mineral components forming the granitic rocks is presented in Table 1 below.

Table 1: Modal composition in percentage (%) for the Saigbe granites

Minerals/Samples	L4	L8	L16	Average
Quartz	40	45	45	43.33
Plagioclase feldspar	20	25	10	18.33
Microcline	15	-	25	13.33
Biotite	15	20	-	11.67
Muscovite	10	10	15	11.67
Opaque minerals	-	-	5	1.67
Total	100	100	100	100

The detailed petrographic study (mineralogical composition) of samples L4, L8, and L16 in thin sections are presented below (Tables 2, 3, and 4).

Table 2: Petrographic description of minerals in sample L4 under a microscope

Optical Properties	Sample L4				
	Quartz	Plagioclase feldspar	Microcline	Biotite	Muscovite
Under PPL					
Colour	Colourless	Colourless to cloudy	Colourless	Reddish brown	Light pink
Pleochroism	-	-	-	Reddish brown – dark brown	Light pink to light green
Relief	Low	-	-	-	-
Shape	Anhedral	-	Anhedral	Euhedral	Euhedral
Fracture	Slightly	-	No fracture	-	-
Alteration	Not altered	Altered	Not altered	-	-
Cleavage	No cleavage	Not clear but shows inclusions of muscovite and quartz	No cleavage seen	Perfect	Perfect
Under XPL					
Interference colour	Grey to white	Grey to white alternating line	Grey to white	Brownish green to dark green	Lemon green to pink
Birefringence	1^{st} order	1^{st} order	1^{st} order	2^{nd} order	3^{rd} order
Twinning	No twinning	Polysynthetic	Cross hatched	No twinning	No twinning
Extinction	Undulose	Angular of 49°	Oblique	Parallel	Oblique

PPL = plane-polarized light; XPL = cross-polarized light

Table 3: Petrographic description of minerals in sample L8 under a microscope

Optical Properties	Sample L8			
	Quartz	Plagioclase feldspar	Biotite	Muscovite
Under PPL				
Colour	Colourless	Colourless to cloudy	Brown	Light pink
Pleochroism	-	-	Pleochroic to dark brown	To light green
Relief	High	Low and presence of inclusions of muscovite flakes	High	Moderate
Shape	Anhedral	-	-	Euhedral
Fracture	-	-	-	-
Alteration	-	-	-	-
Cleavage	-	Unidirectional along twinning	Perfect, not oriented	Perfect and as inclusion in plagioclase and biotite
Under XPL				
Interference colour	Grey to white	White to cloudy grey	Brown to dark green	Pink to purple green
Birefringence	1^{st} order	1^{st} order	2^{nd} order	3^{rd} order
Twinning	-	polysynthetic	-	No twinning
Extinction	Undulose	Angular at 29°	Straight	Oblique

PPL = plane-polarized light; XPL = cross-polarized light

Table 4: Petrographic description of minerals in sample L16 under a microscope

Optical Properties	Sample L16				
	Quartz	Plagioclase feldspar	Microcline	Opaque mineral	Muscovite
Under PPL					
Colour	Colourless	Colourless to cloudy	Colourless to cloudy		Light pink
Pleochroism	-	-	-	-	Pleochroic to light green
Relief	-	low	low	-	moderate
Shape	Anhedral to sub-hedral	Sub-hedral to anhedral	Sub-hedral to anhedral	-	Euhedral
Fracture	No fracture	No fracture	No fracture	-	-
Alteration	Not altered	Slight	Slight	-	-
Cleavage	No cleavage	Unidirectional	No cleavage	-	Perfect, not oriented
Under XPL					
Interference colour	Grey to white	Alternation of grey and white lines	Grey to white		Pink to light green
Birefringence	1st order	1st order	1st order	-	3rd order
Twinning	No twinning	Polysynthetic	Cross hatched	-	No twnning
Extinction	Undulose	Angular at 40°- 42°	Oblique	-	Obique

PPL = plane-polarized light; XPL = cross-polarized light

From the modal composition (Table 1), quartz which is a common rock forming mineral has the highest percentage (43.33%) on the average in all the rock samples. This implied the rocks may have occurred and crystallized from melt rich in crustal materials (Adamu *et al.*, 2021). Quartz in all the rock samples analysed displayed undulose extinction which is an indication of deformation or straining. Feldspar is the second most abundant mineral in the samples; plagioclase contents averaged 18.33%, with slightly elevated values in samples L4 and L8 compared to L16; and microcline (alkali feldspar) been more pronounced in sample L16 making it leucocratic compared to other samples. The mica (biotite and muscovite) contents in these samples are relatively moderate making them a good to excellent material for construction work.

3.2 Structures

3.2.1 Faults

A fault is a fracture with a relative displacement either to the left (sinistral) or right (dextral) and such displacements are often measurable. It is a sign of weakness in the rock where it did occur. Dextral fault pattern characterised the study area (Plate V). This fault pattern had been reported by several researchers to be common within the basement complex rocks in Nigeria (Omanayin *et al.*, 2023b).

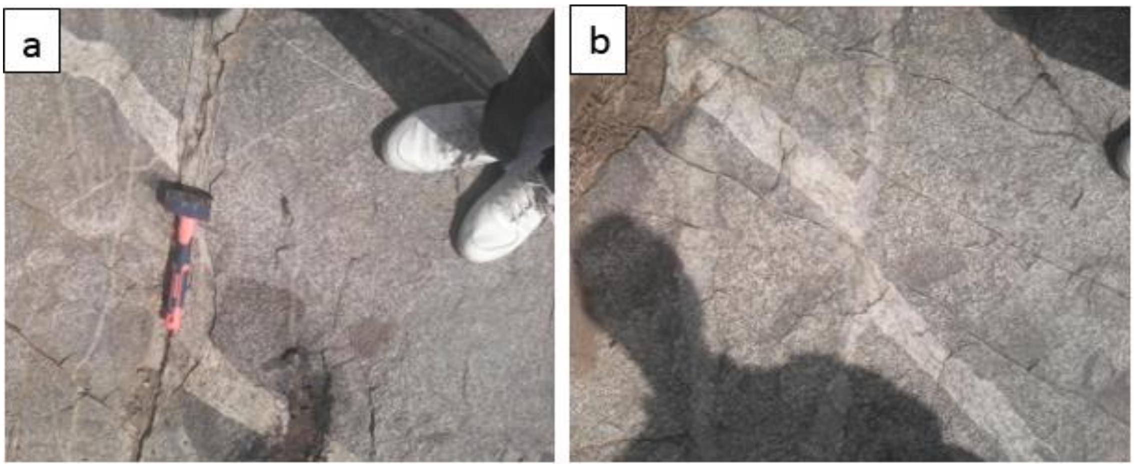

Plate V: Photographs of (a) Fault in a granitic outcrop with a considerable width along the fault line and crosscutting veins; (b) A set of joints in a granitic outcrop with a lesser displacement (fault)

3.2.2 Joints

Joints can be set or system; and are common structures observed on almost all the outcrop in the area (Plate Vb). Joint values recorded on the granites reveals a NWW - SEE direction (Table 5). The common joints recorded within the Nigeria basement complex are mainly in the N-S, NE-SW, NW-SE, and minors in the NNE-SSW and NWW-SEE directions; and have been considered as imprint of Pan-African orogeny (Adamu *et al.*, 2021, and Omanayin *et al.*, 2023a). The distributions of joint directions were inputted into the Rockwork 15 to generate the rose plots for granitic rock in the Saigbe area (Figure 3). The importance of joints can never be over emphasized to mineral explorationists, hydrogeologists and structural engineers.

Table 5: Joint values recorded on granitic outcrops

Lithology	Joint Values (Degrees)
Granitic rocks	320, 308, 310, 320, 330, 327, 280, 138, 315, 310, 314, 310, 145, 170, 150, 300, 285, 280, 285, 293, 104, 122, 126, 185, 113, 078, 126, 090, 085, 075, 112, 116, 276, 043, 028, 110, 285, 293, 115, 270, 256, 306, 318, 307, 340, 028, 045, 070, 215, 300, 335, 330, 270, 320, 300, 268, 270, 260, 285, 297, 290, 280

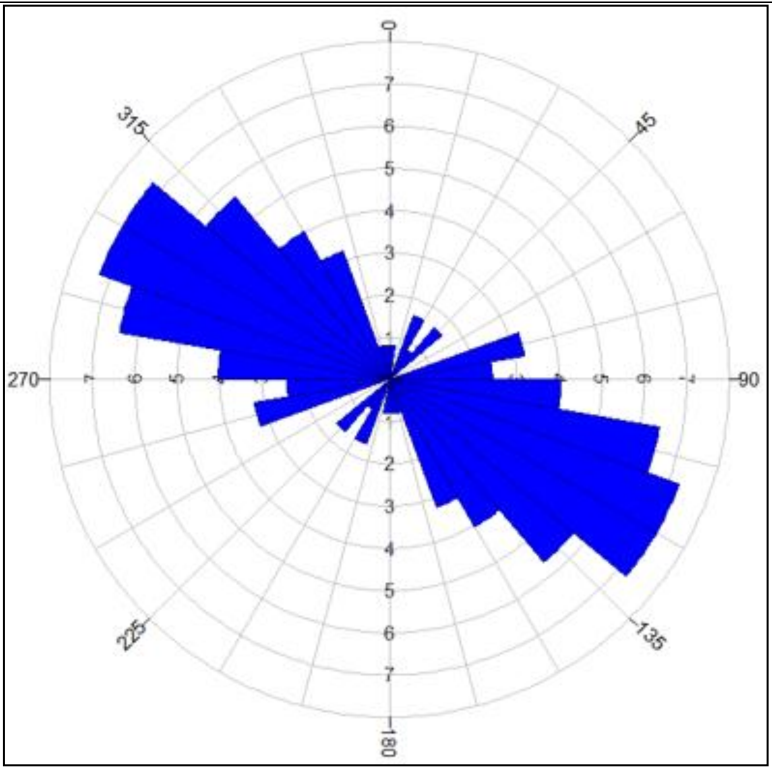

Figure 3: Rose plot of the joint readings on the granitic outcrops

3.3 Geochemitry of the Granitic Rocks

The geochemical results of the five (5) representative granitic rocks samples out of the ten collected from the Saigbe area are presented in Table 6. They were analysed for major oxides composition and the result was presented in percentages. These major oxides include SiO_2, Al_2O_3, TiO_2, MgO, MnO, Fe_2O_3, CaO, P_2O_5, K_2O, Na_2O, and LOI.

From Table 6, SiO_2 content ranges from 59.80 wt.% to 77.01 wt.% with an average of 71.30 wt.%; TiO_2 ranges from 0.51 wt.% to 1.78 wt.% with an average of 1.04; Al_2O_3 ranges from 8.27 wt.% to 13.37 wt.% with an average of 11.13 wt.%; MnO ranges from 0.46 wt.% to 0.85 wt.% with an average of 0.62 wt.%; MgO ranges from 0.53 wt.% to 6.38 wt.% with an average of 2.09; Fe_2O_3 ranges from 0.88 wt.% to 6.99 wt.% with an average of 3.37wt%; CaO ranges from 0.90 wt.% to 8.72 wt.% with an average of 4.44 wt.%; K_2O ranges from 0.52 wt.% to 6.90 wt.% with an average of 2.18 wt.%; Na_2O ranges from 0.09 to 2.62 wt.% with an average of 1.58 wt.%; P_2O_5 ranges from 0.001 w% to 0.004 wt.% with an average of 0.003 wt.%; LOI ranges from 1.20 wt.% to 4.00 wt.% with an average of 2.34 wt.% respectively.

Table 6: Major oxides compositon of the granitic rocks from Saigbe area (wt.%)

	L4	L8	L16	L17	L20	Range	Mean
SiO_2	73.11	71.40	77.01	59.80	75.20	59.80 – 77.01	71.30
TiO_2	0.91	1.42	0.51	1.78	0.59	0.51 - 1.78	1.04
Al_2O_3	12.34	12.68	9.00	8.27	13.37	8.27 – 13.37	11.13
MnO	0.46	0.85	0.69	0.60	0.50	0.46 – 0.85	0.62
MgO	1.41	1.27	0.53	6.33	0.92	0.53 – 6.33	2.09
Fe_2O_3	3.21	3.10	0.88	6.99	2.68	0.88 – 6.99	3.37
CaO	4.31	4.68	0.90	8.72	3.58	0.90 – 8.72	4.44
K_2O	1.15	1.32	6.90	1.02	0.52	0.52 – 6.90	2.18
Na_2O	1.71	1.76	2.62	1.74	0.09	0.09 – 2.62	1.58
P_2O_5	0.004	0.001	0.003	0.002	0.003	0.001 – 0.003	0.003
LOI	2.00	2.10	1.20	4.00	2.40	1.20 – 4.00	2.34
Total	100.61	100.58	100.24	99.25	99.85	99.25 – 100.61	100.11

The high value recorded by the SiO_2 in these granitic rocks is an affirmation of their acidic character and enrichment in common rock forming minerals (quartz and feldspar) as indicated in the petrography.

3.3.1 Geochemical Classififcation

From the geochemical analyses in Table 6, and subsequently inputting the data into the geochemical data (GCD) Toolkit 3.0, different discrimination diagrams have been generated (Figures 4 – 8) to classify the granites in the Saigbe area using their major oxides composition. Most of the granitic rock samples fall within the calc-alkaline series except one sample with tholeiitic characteristics on Alumina-Ferro-Magnesia (AFM) plot (after Irvine and Baragar, 1971) (Figure 4). This calc-alkaline character of the samples suggests that they are rich in lime while the tholeiitic nature of the few samples points to their richness in iron content. These characteristics support a mixed and evolved magma source during the evolution of the granite.

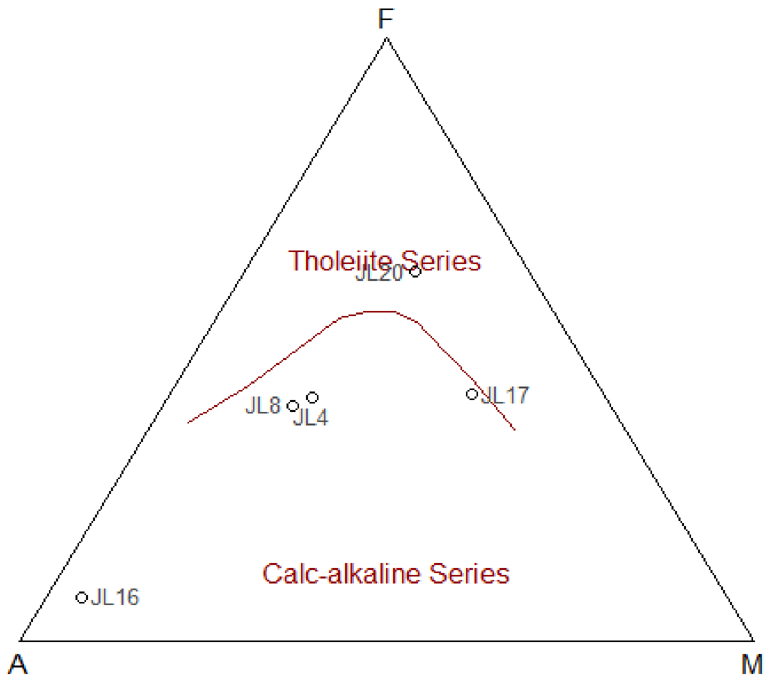

Figure 4: AFM plot for the granites (Irvine and Baragar, 1971)

Also, the samples are grouped into both S-Type and I-Type granite on the $Al_2O_3/(Na_2O+K_2O+CaO)$ versus SiO_2 plot (after White and Chapell, 1977) (Figure 5). This type of grouping is based on the presumed protolith of sedimentary (pelitic) and igneous (mafic) that influence unique composition on the granitic rocks. This implies that I-Types have SiO_2 in the range of 53-76 wt.% while the S-Types have SiO_2 in the range of 65-79 wt.%, for I-type and S-type, the $Al_2O_3/(Na_2O+K_2O+CaO)$ is <1.1 and >1.1 respectively (White and Chapell, 1977). This also affirmed the mixed and evolved magmatic source for granitic rocks from the Saigbe area.

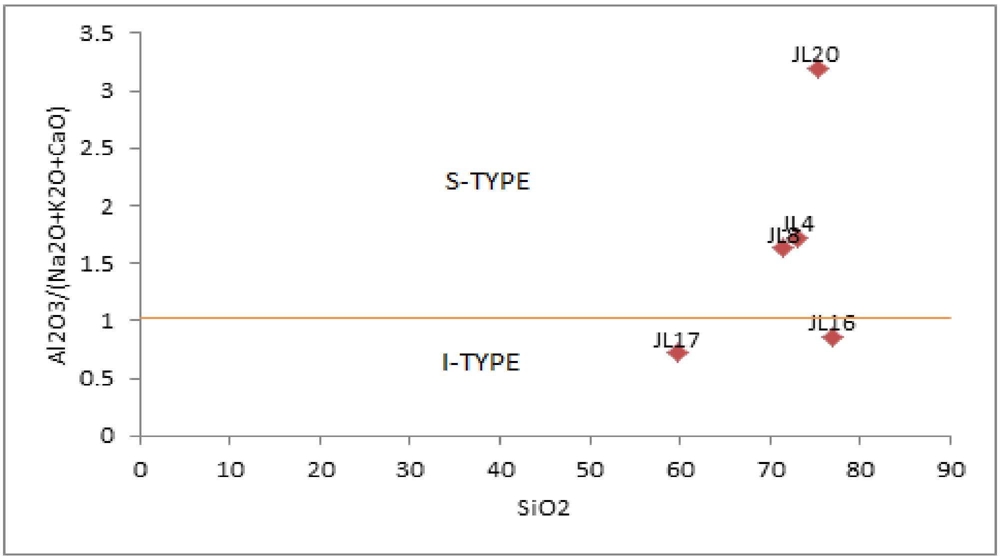

Figure 5: $Al_2O_3/(Na_2O+K_2O+CaO)$ against SiO_2 diagram of the granites (White and Chappell, 1977)

Furthermore, the plot of total alkali versus silica (Figure 6) content grouped the rocks into Diorite, Granodiorite, and Granite respectively. These rocks are believed to be genetically related by fractional crystallization and to be at least partly derived from magmas of basalt composition formed in the Earth's mantle.

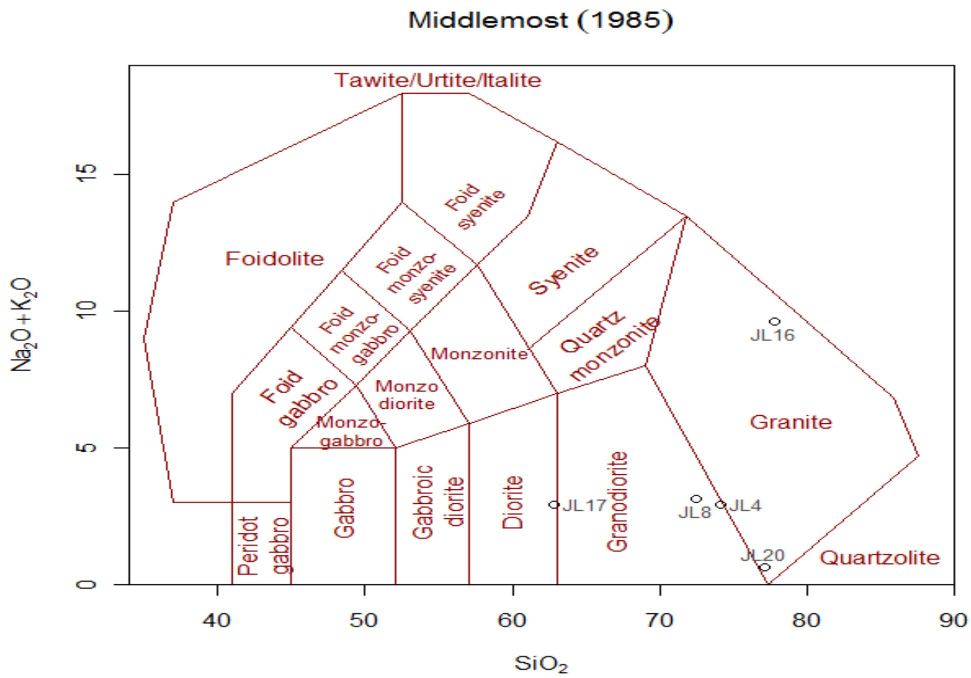

Figure 6: Total alkali versus Silica plot for the granitic rocks (after Middlemost, 1985)

Ternary plot of the granitic samples shows continental setting for the granites in the area (Figure 7). The QAPF diagram after Streckeisen (1974) further shows that the analysed rocks from the Saigbe area are quartzolite to quartz – rich granitoid (Figure 8).

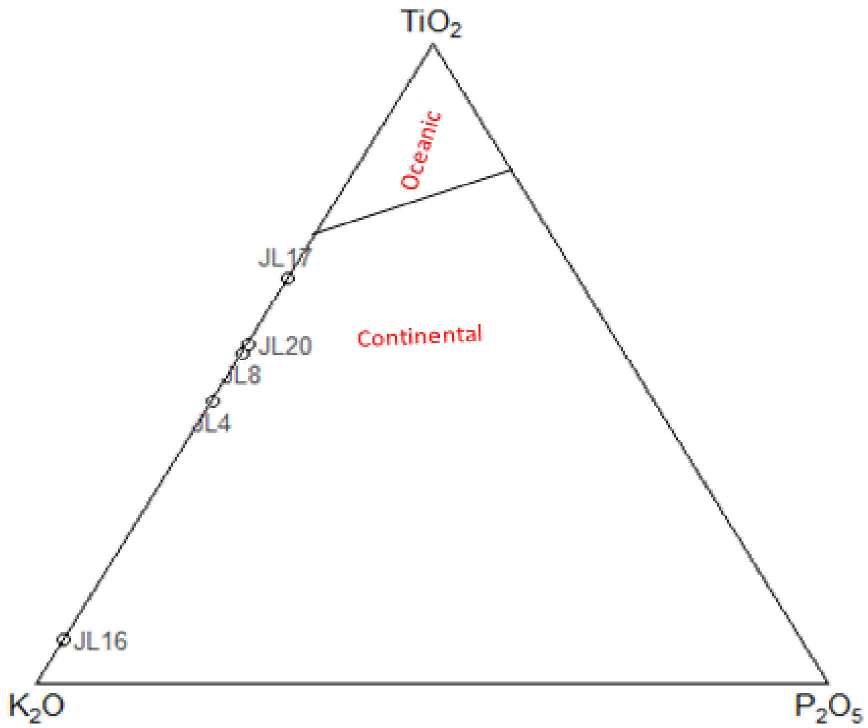

Figure 7: Ternary plot of the granitic rocks (after Pearce,1975)

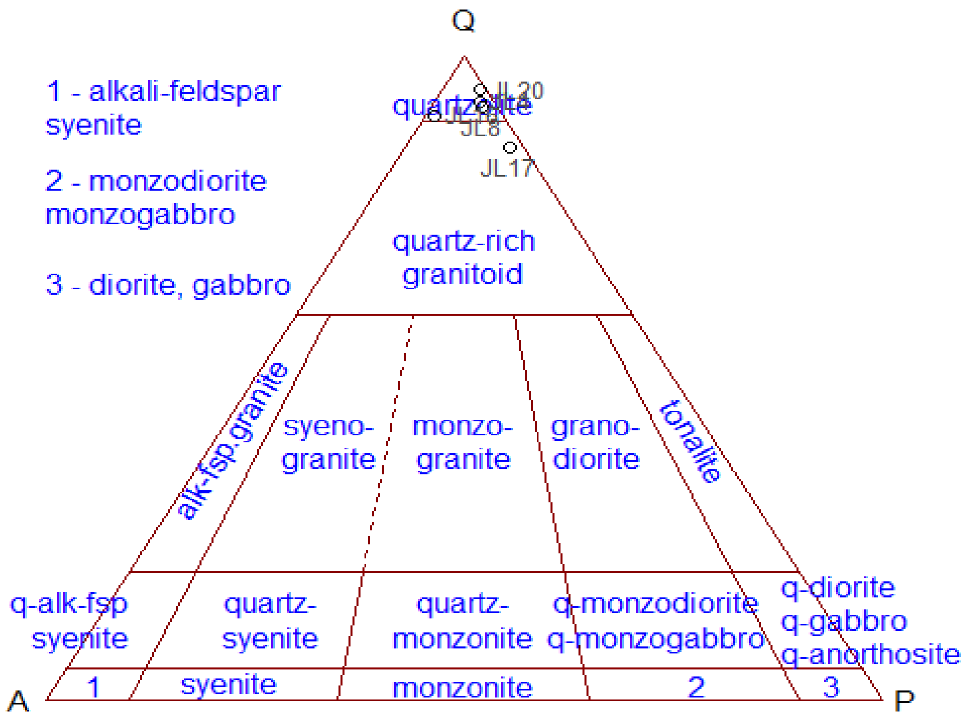

Figure 8: QAPF plot for the granitic rocks (after Streckeisen, 1974)

4. Conclusion

Geologically, the Saigbe area is underlain by three major lithologic units; schist, amphibolite and granitic rock representing 54%, 8% and 38% respectively in terms of areal coverage. The granitic rock occupies mostly the north-western part, intruding into the dominant rock type schist in the study area. The rock showed intense deformation, indicated by the presence of minor structural features such as joints, faults and veins. Grain sizes in the granitic rocks varied from medium to coarse and the mineralogy in the hand specimen is characterized by feldspar, quartz, and mica with minor darker minerals. The dominant structural trend of the granitic rocks is NWW-SEE direction. This trend most probably represents imprint of the Pan-African orogeny.

The petrographic analyses of these representative rock samples showed average mineralogical composition of quartz, plagioclase feldspar, microcline, biotite, microcline, and a trace of opaque mineral which may be iron oxide in the granites in descending order of abundance.

Geochemical results showed the most abundant oxide is SiO_2 contents in these granites with the highest percentage being (77.01 wt.%) and the lowest (59.8 wt.%), while P_2O_5 is the least abundant oxide with an average composition of less than (0.1 wt.%) in all the rock samples. In addition, ferromagnesian (Fe_2O_3 and MgO) have varying abundances across the rock samples. The research then concluded from the various discrimination plots that Saigbe granites are formed from the fractionation of magma having ranged in composition from Diorite, Granodiorite to Granite. Thus, these rocks are from mixed and evolved magmatic melt within continental setting.

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