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Petrographic and Geochemical Classification of Rocks in Garze Areas of Akwanga Sheet 210 NE, Central Nigeria

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Abstract: This study aims to provide petrographic and geochemical classification of rocks in Garze and its surrounding areas, to serve as a guide for further scientific or exploratory studies. The study area is located within Latitude 8°53'00" N to 8°56'00"N and Longitude 8°25'00"E to 8°28'00"E on the Akwanga Sheet 210 NE which falls within the North Central portion of the Basement Complex of Nigeria. To achieve the aim of this study, field geological mapping, thin section analysis and X-ray florescence geochemical analytical techniques were deployed. Results indicated that the area is underlain by medium grained granite gneiss and medium grained granites, intruded by pegmatite veins and basaltic dykes. Macro and micro joints display a NNE-SSW principal trend in the medium grained gneiss, and a WNW- ESE trend in the medium grained granite gneiss, while veins show a preferred NE-SW principal orientation. Petrographic studies revealed that the medium grained granite exhibits 45% quartz, 20% orthoclase, 15%, biotite, 10% plagioclase, 5% perthite and 5% microcline while the medium grained granite gneiss contains 34% orthoclase, 30% quartz, 15% plagioclase, 6% biotite, and 15% of accessory minerals. Pegmatite sample contains 40% quartz, 30%, plagioclase, 20% microcline, and 10% biotite. Geochemical analysis results of four representative rock samples indicated the following average elemental compositions: SiO2 (73.781), Fe2O3 (3.169), CaO (1.844), K2O (5.964), Al2O3 (13.896), SO3 (0.770), TiO2 (0.374), and SnO2 (0.155). The concentration of Al, Si, Fe and K are generally high, while Ba, Ca, Fe, Ti, and S show low concentrations in the rock samples. Based on Total Alkali Silica (TAS) binary plot, the medium grained granite falls in the Rhyolite field, whilst the medium grained granite gneiss plotted in the granitic and quartz diorite field. AFM ternary plot reveals the medium grained granite gneiss (LR2), medium grained granite (LR3) falls between tholeiitic series and Calc-alkaline series while the pegmatite (LR6), falls within the Calc-alkaline series demarcating it from the tholeiitic series. High amounts of silica, potassium and alumina oxides in pegmatite depict possible lithium mineralization and could also be linked to feldspar mineralization; hence the need for further intensive exploration studies in the study area. Key wards: granite, gneiss, exploration

Keyword: *housing quality, occupants' satisfaction, occupants' willingness to stay.*

1. Introduction

The study area falls within the Basement Complex of Nigeria, comprising mainly of igneous and metamorphicrock suits. Gneisses from North-Central Nigeria have been suggested to be the oldest basement rocks in Nigeria (Oyawoye, 1972; Dada *et al*., 1998) while Akintola *et al*., (2012) elucidate that, most of the economically viable mineral deposits like gemstones and rare metals such as tantalum, niobium, tin and lithium are mostly hosted in pegmatite. They further stated that the pegmatites of Nigeria mostly occur as discordant intrusions (dykes) and vary from few meters to several kilometers in length and few centimeters to meters in width. It is believed that the mineralized pegmatites are confined to a broad 400km long NW-SE trending belt stretching from Wamba area in North-Central part of Nigeria to Abeokuta area in the South-Western part of Nigeria.

In Akwanga and Wamba area, Kuster (1990) documented that the emplacement of Late Pan African granites with similar geochemical characteristics as the mineralized pegmatites are fracture-controlled and mylonitized along a conjugate set of NE-SW and NW-SE to NNW-SSE striking faults.The studies carried out by Garba (2003) and Okunlola (2005) shows that the Precambrian pegmatite zones are not restricted onlyto these precincts. Matheis and Caen-Vachete (1983) explained that the pegmatite evolved during the time span of about 600 Ma to 530 Ma, thus indicating that they were formed during the latter periods of Pan African magmatism. Recently, there has been more interest in the study of these pegmatite occurrences because of its associated economic rare metal and gem mineralization. This has resulted in the classification of the pegmatite into the rare metal mineralized and barren ones, in order to reveal their modes of occurrence and mineralization (Kuster, 1990; Garba, 2003).

2. Regional Geology

Nigeria is part of Africa that forms the continental crust and lies in an extensive Pan- African mobile belt that has been affected by Pan-African events during the ages of orogenic, epeiorogenetic, tectonic and metamorphic cycles (Rahaman, 1976). The geology of the study area falls within the framework of the North-Central Basement Complex of Nigeria, which is underlain by Basement Complex rocks only (Wuyep and Tanko, 2012). These Basement Complex rocks were emplaced duringthe Pan African Orogeny before the Jurassic Younger Granites intruded through peripheral ring structures (Aga *et al*., 2012). Geochemical evidence indicates that the Basement Complex of Nigeria is polycyclic in nature and has been reactivated during the Liberian (2,700±200Ma), Eburnean (2000±170 Ma), Pan-African (600±150Ma) orogenesis (McCurry and Wright, 1977; Ogezi, 1977; Annor and Freeth, 1998 ; Dada, 2006; Ibrahim, 2008).

3. Previous work

The structural and tectonic framework of the Nigerian Basement Complex has been documented by several researchers (Annor and Freeth, 1985; Kuster, 1990; Annor*et al*., 1990; Olasehinde *et al*., 1990) to consist of northeast – southwesterly and northwest – southeasterly lineaments that are superimposed over a prevailing north-southerly pattern (Olasehinde *et al*., 1990), and northwest – southeasterly and northeast – southwesterly pair superimposed on a north - south set of joints (Annor *et al*., 1990; Annor and Freeth, 1985).Goki *et al*., (2011) stated that, field relations as well as regional tectonics seem to favour the gneisses as the primarybasement that was in part intruded by basic dykes that were subsequently sheared and deformed. This complex tectonic history has not only resulted in a complex rock composition but a complex structural pattern. Such structural patterns are a major control to mineral resources in Nigeria.

Okunlola (2005) subdivided the metallogeny of the rare metal Ta-Nb pegmatites of Nigeria into seven (7) broad fields namely Kabba-Isanlu, Ijero-Aramoko, Keffi-Nasarawa, Lema-Ndeji, Oke Ogun, Ibadan-Osogbo, Kushaka-BirninGwari Okunlola and Ocan (2009) envisaged that the pegmatite bodies of Nigeria intrude generally discordantly, older lithologies of the schist belt, the gneiss-migmatite complex and the Older Granite Suites.

Pegmatite study of North-Central Nigeria has been documented by several researchers. Pollard (1989) documented on the geochemistry of the granites associated with tantalum and niobium mineralization with examples of the Ring-complexes of Northern Nigeria. Kinniard (1984) discussed on the contrasting styles of pegmatite of this area with respect to Sn-Nb-Ta-Zn mineralization. Kuster (1990) observed that the Late Pan African tectonic granites at Wamba (about 100km northeast of Nasarawa) are all sub-alkaline, peraluminous, and highly siliceous rocks with their peraluminosity more pronouncedwith increasing differentiation. They envisaged that the major elements that include Si, Al, K, and Na show only slight variations; only Na is enhanced toward the end of granite evolution. Prior to evolution from the biotite granites through biotite-muscovite granites, muscovite granites to the apo-granites, there is a pronounced enrichment of Rb, Li, Cs, Sn, Nb, Mn, and P whereas B is only slightly enhanced. Strong depletion is evident for Ba, Sr, Zr, Y, La, and Ce together with Ti, Mg, Ca, and Fe. These results support the observation that the rare-metals are related to highly differentiated granitic magmas and represent strongly fractionated residual melts rich in silica, alumina, alkali elements, water and other volatiles, lithophile elements and rare metals (Cerny, 1991b and London,1990).

Agunleti *et al*., (2014) documented that the pegmatites of Angwan Rimi are hosted by the biotite gneiss, schist, and amphibole schist. Petrographic analysis of these rocks shows that it contains mainly quartz, plagioclase, biotite, microcline and muscovite. Whole rock geochemical studies indicate that the pegmatites are siliceous, with a paper a luminous composition. Trace elements analysis reveals that the pegmatites are fair Agunleti *et al*., (2014) documented that the pegmatites of Angwan Rimi are hosted by the biotite gneiss, schist, and amphibole schist. Petrographic analysis of these rocks shows that it contains mainly quartz, plagioclase, biotite, microcline and muscovite. Whole rock geochemical studies indicate that the pegmatites are siliceous, with a paper a luminous composition. Trace elements analysis reveals that the pegmatites are fairly rich in Ta and Sn mineralization. Variation plots of Ta vs Cs, K/Rbvs Cs and K/RbvsRb showed that Angwan Rimi pegmatites can be merged with those of Ijero south-western Nigeria in term of mineralization. Wright (1970) and Jacobson and Webb (1946) were among the first researchers to document on the pegmatites of Wamba area in Nasarawa State, Central Nigeria. Akintola and Adekeye (2008) stated that the pegmatites of Nasarawa area occur in the central part of Nigeria and that they are mainly hosted by phyllonites in a NNE-SSW trending shear zone lying east of some foliated Pan-African and west of Jurassic Afu Complex Younger Granites. Akintola *et al*., (2012) carried out a petrochemical evaluations of the Pan African pegmatites of Apomu Area in the south- western Nigeria and they documented that the pegmatite which occur as near vertical dyke and strike mainly in the NNW-SSE direction, intrude into the older lithology of granite around Apomu area, south-western Nigeria. Petrographic determinations show they are enriched in microcline, quartz and to a lesser extent in plagioclase albite with interstitial muscovite, biotite and accessory minerals.

Geochemical studies carried out by Akintola *et al*., (2012) reveals that the pegmatites are poorly fractionated which shows nearness, to their parental melt sources. They further explained that rare metal indicative elements like Ta, Nb, Rb, Cs and Sn are depleted in the rock unit while elemental ratio, K/Rb, Ba/Rb suggest low index of differentiation, poor fractionation and barren mineralization. Poor albitization is demonstrated in low Na/K ratio, whilst Ta vs Cs, Ta vs Rb and Ta vs K/Cs confirms its apparently poor or barren mineralization compared to other pegmatites bodies in Nigeria and around the world. The geochemical analysis (major element distribution) shows that the pegmatites are siliceous; with SiO_2 content ranging between 46.03% and 73.54% with an average value of 69.31%;. (Akintola *et al*.,2012). This is marginally lower than average values of rare metal Ta-Nb pegmatite of Nigeria (Okunlola,2005), but comparable.

4. METHODOLOGY

The study involved systematic data collection, processing, analysis and interpretation

approach. Several operations were carried out, which include: desktop study or literature review, field work, laboratory analysis, interpretation and discussion of results.

Existing literatures were consulted in order to have an overview of the geology of the area, geologic structures and the economic potential of the area. Prior to field work, a base map of the study area was used for reconnaissance survey and later follow-up with a detailed mapping using the grid system. Figure 3.1 indicates a step by step approach employed for the study.

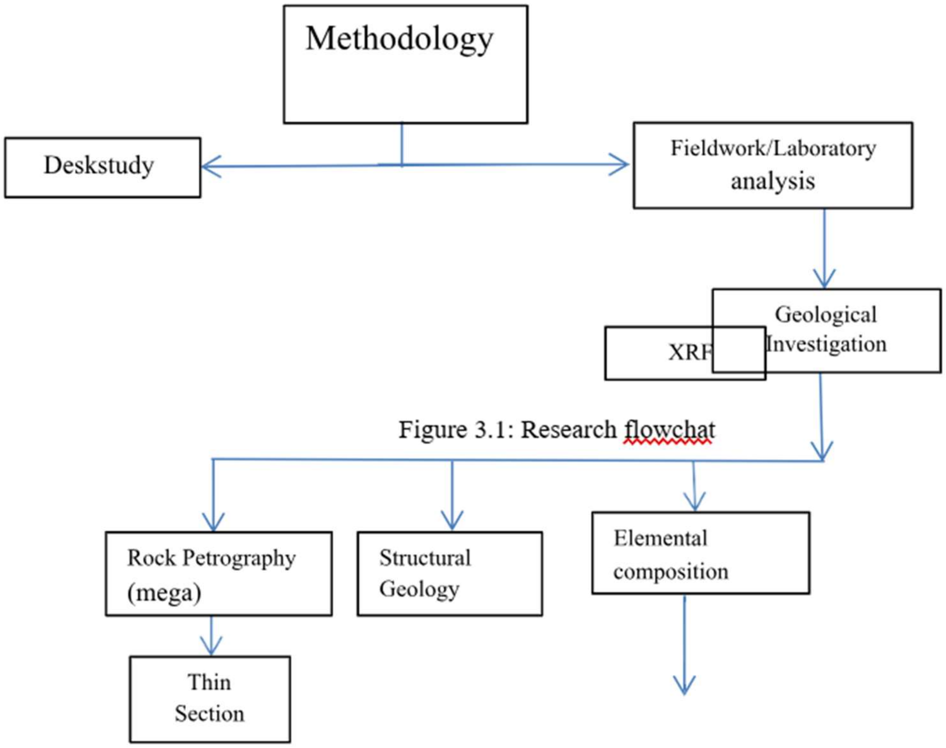

Figure 3.1: Research flowchat

4. Geology of the Study Area

The study area falls within the framework of the North-Central Basement Complex of Nigeria. Four main lithologic units were mapped during geologic field mapping of the area; these units are Medium grained Granite, Medium grained granite gneiss, pegmatites and basalts. The medium grained Granite occupied about 60 % of the rocks in the study area. The Medium grained granite gneiss occupied about 40 % of the rocks, the basalts and pegmatite occur as dyke outcropping in the study area. The pegmatites vein intruded theunder lain rock types in the area but are occasionally seen in contact with basalt inthe eastern part of the map.

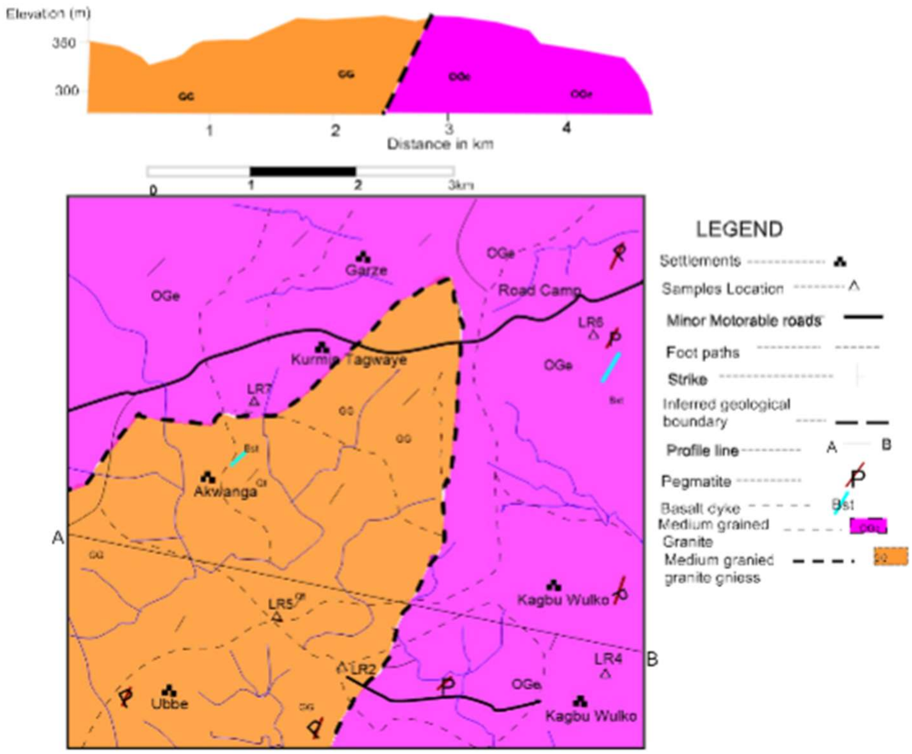

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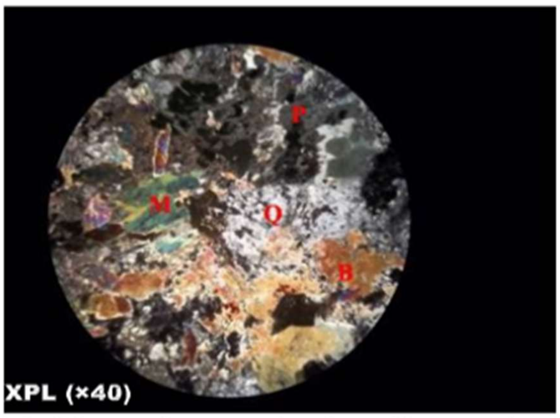
Figure 4.1: Geology and Samples Location map of the Study Area.

1. Petrography and structural geology of the Study area

Petrographic studies were conducted under plane polarized light (PPL) and cross polarized light (XPL) on the prepared thin sections of rock samples varying from medium grained granite, medium granite gneiss and pegmatite vein in the study area.

Noticeable structures encountered in the area include; veins (pegmatite and quartz veins) and joints. The predominant structures trend N-S to NE-SW and this conforms to Pan- African structural pattern. Shear fractures observed on the medium grained gneiss are either filled by late pegmatitic veins or display evidence of free aperture.

Plate:4.1: Medium-grained Granite (08°53’24.3”N and 08°27’07.3”E)



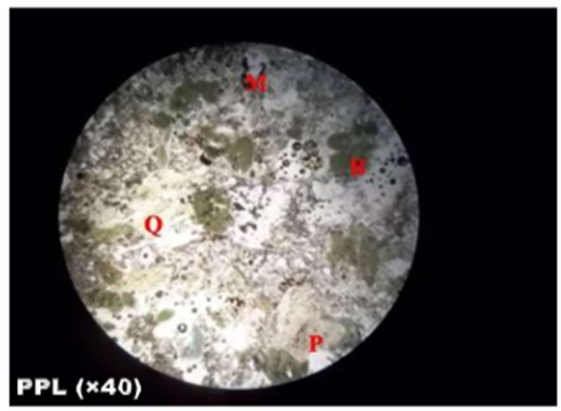


Plate 4.2**:** Photomicrograph of medium grained grainedunder cross-polarized light(XPL)*Mag. ×40*

Plate4:3:Photomicrographofmedium grainedGraniteunderplane-polarized light(PPL)*Mag. ×40*

(B=Biotite;Q=Quartz;P=Plagioclase;M=Microcline)

Table4.1: Estimated modal composition of medium grained Granite

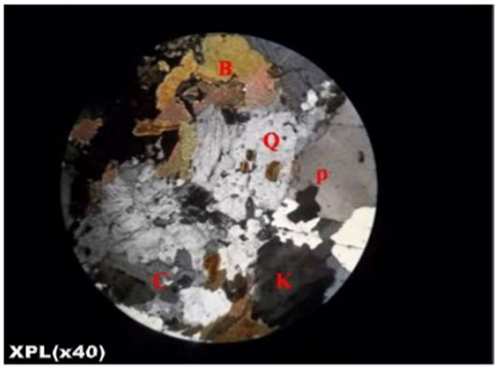
S/N	**Mineral Composition**
Quartz	45%
Orthoclase	20%
Biotite	15%
Plagioclase	10%

Perthite	5%
Microcline	5%
TOTAL	100

Plate4.4: Medium grained Granite gneiss (08º53'13ˈˈN;008º26ˈ47ˈˈE).

Table4.2: Modal composition of minerals in the medium granite gneiss.

Mineral	**Composition(%)**
Orthoclase	34%
Quartz	30%
Plagioclase	15%
Biotite	6%
Accessoryminerals	15%
Total	100%



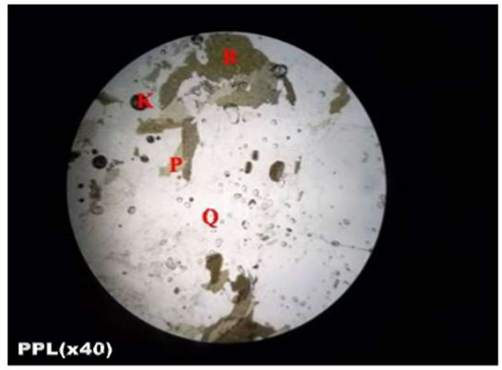


Plate 4.5: Photomicrograph of medium granite **gneiss** Plate 4:6: Photomicrograph of mediumgraniticgneissundercross-polarizedpolarizedlight(PPL)*mag.×40* Light (XPL) *mag. × 40*

(B=Biotite;Q=Quartz;P=Plagioclase;K=K-feldspar;C=Chloride)

Plate4.7:Pegmatite intrusion (8°53’42.9’’E;8°27’26.6’’N)

Table4.3:modal mineral composition of pegmatitevein

Mineral	**Approximate Quantity(%)**
Quartz	40%
Plagioclase	30%
Microcline	20%
Biotite	10%

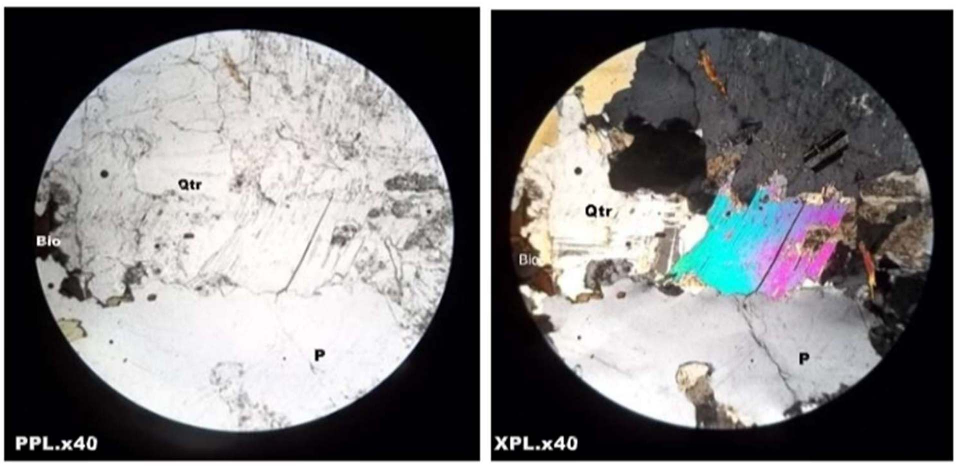


Figure 4.8 and 4.9: Photomicrograph of Pegmatite for LR5 (under plane (PPL) and cross polarized light(XPL)showing quartz(Qtr), plagioclase feldspar(P),and biotite (Bio)

Table4.4: Measured orientations of medium grained granite gneiss joints in the study area

080	010	20	088	028	066	110	022	048	012
060	028	108	102	320	208	305	282	110	012
190	310	084	285	028	066	028	140	066	150
020	030	150	038	020	022	028	028	030	022

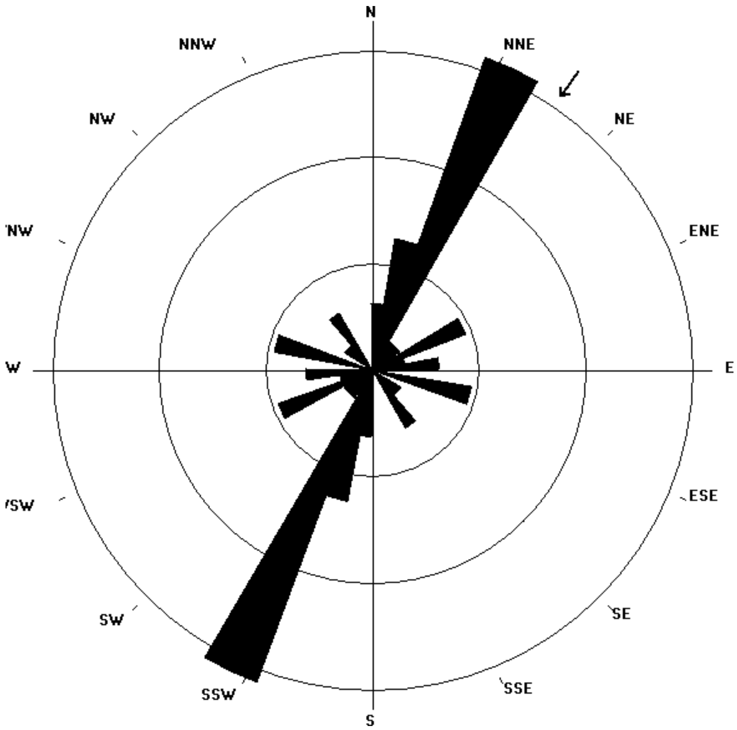


Figure 4.2: Rose diagram of Joint showing the major NNE-SSW, WNW- ESE

Plate4.10: Joints

In the medium granite gneiss of the study area (8°33’23.5’’E; 9°01’06.2’’N)

Table 4.5: Measured orientation of quartzo-feldspathic vein in the medium grained granite of the study area

068	025	050	062	050	030	025	058	064	044
036	078	075	052	030	048	066	060	080	048
068	022	046	050	048	036	042	050	080	050

Plate4.11: Pegmatite intrusion in medium grained granite (8°31’58.8’’E;9°02’34’’N).

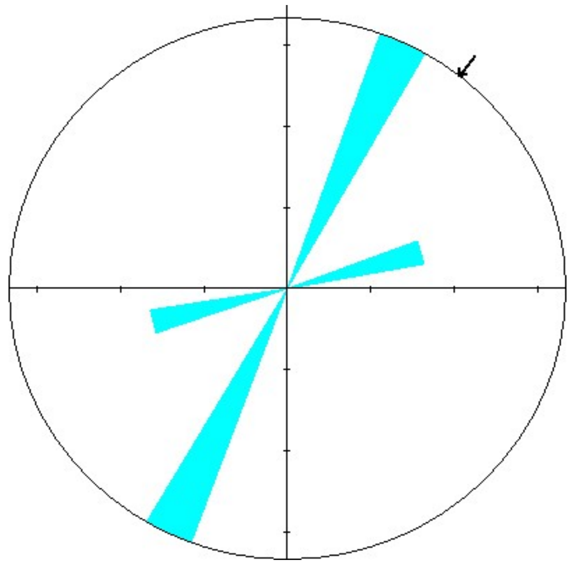


Figure4.3: **Rose diagram of pegmatite veins showing the NE-SW dominant trend in** the Medium grained granite of the study area.

2. : Geochemistry

Geochemical analysis of all the four rock samples collected from the study area were carried out to study the dispersion of elements in the area. The analytical method used is X- ray fluorescence techniques which were prepared and analyzed at the geochemical laboratory of National Steel Raw Materials Exploration Agency, Kaduna. The analysis of minor and trace elements concentration was used to determine the distribution of elements in the rock during their formation process. The elemental compositional data of the rocks in the study area are presented on table 4.6 and 4.7.

Table4.6: Major Element Geochemistry

S/No	SampleID	SiO_2	$Fe_2 0_3$	CaO	K_2O	Al_2O_3	So_3	TiO_2	Cl	SnO_2
1	**LR2**	70.907	8.421	1.614	4.818	11.385	0.181	1.261	0.641	0.417
2	**LR3**	70.172	1.835	3.168	7.843	15.363	0.431	0.203	0.482	0.081
3	**LR5**	73.418	1.137	1.499	7.363	14.149	0.903	0.002	0.519	0.122
4	**LR6**	80.628	1.281	1.095	3.833	14.688	1.563	0.028	0.541	0.000
	Average	**73.781**	**3.169**	**1.844**	**5.964**	**13.896**	**0.770**	**0.374**	**0.546**	**0.155**

The SiO_2 concentration in the rock sample in the study ranges from 83.628wt.% in LR6 to 70.172wt.% in LR3 (Table 4.6), for Potassium amount 2.4wt.%, The content of calcium oxide ranges from 3.168wt.% in granite (LR3) to 1.095wt.% in pegmatite (LR6), (Table

4.6) while calcium oxide in granite range from 3.168wt.%in medium grained granite (LR3) to 1.499wt.%, in medium grained granite (LR5), The iron oxide concentration ranges from 8.421wt% in granite gneiss (LR2) to 1.137wt.% in medium grained granite (LR5) (Table 4.6), The medium grained granite has alumina content ranges from 15.363wt.% in (LR3) and 14.149wt.% in (LR5), Alumina concentration of 14.149wt.% is recorded in pegmatite sample (LR6) and 11.385wt.% is detected in medium grained granite gneiss (LR2) sample. Titanium concentration in the samples analysis range from 1.261wt.% in medium grained granite gneiss (LR2) to 0.002wt.% in pegmatite (LR6) in the study area(Table 4.6).

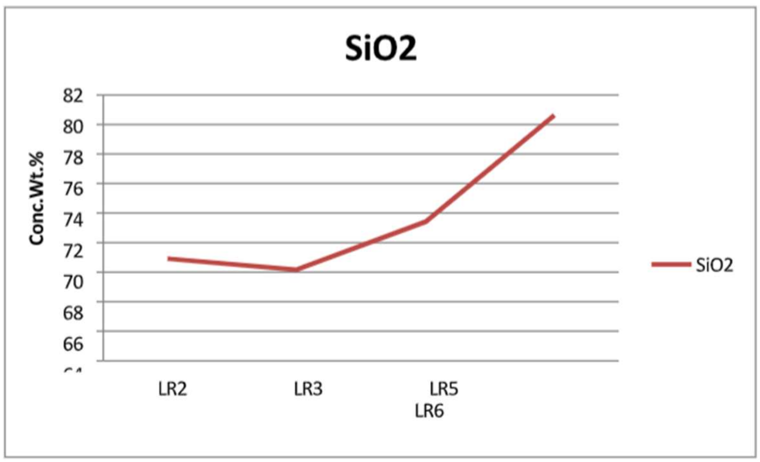


Figure 4.4: SiO2 concentration in rock samples

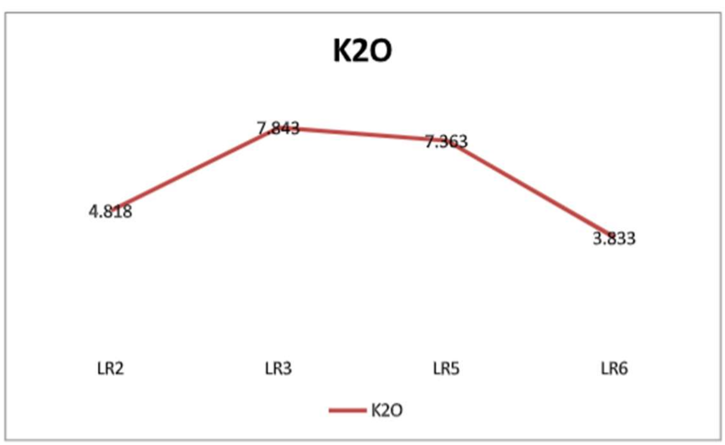


Figure 4.5: Showing K_2O concentration in rock samples

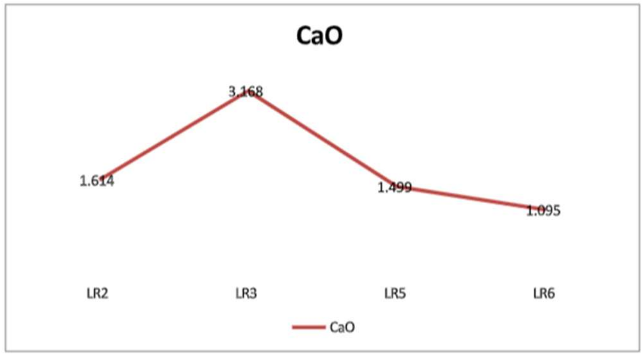


Figure 4.6: Calcium concentration in rock samples

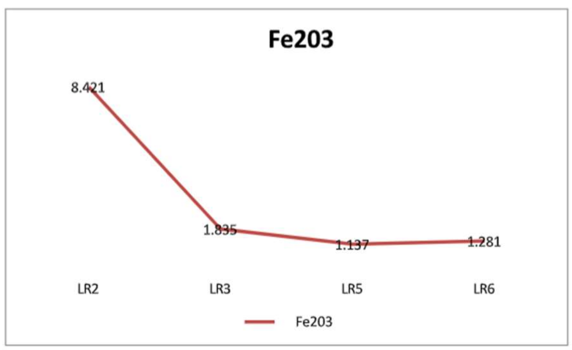


Figure4.7: Fe_2O_3 concentration in rock samples.

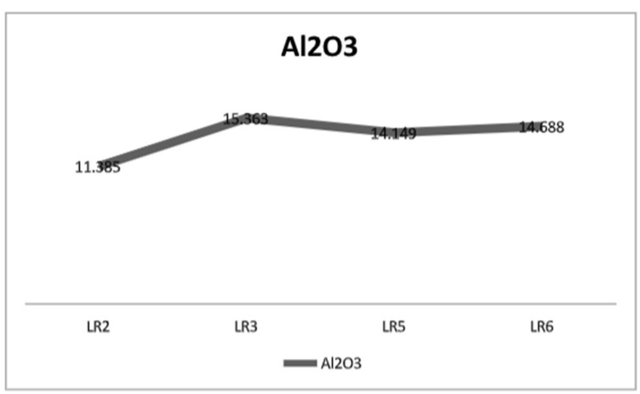


Figure 4.8: Alumina concentration in rock samples

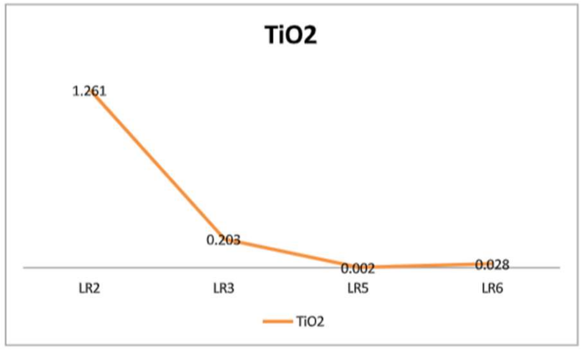


Figure 4.9:Titanium oxide concentration in rock samples

5. Trace Element Geochemistry

Table4.7: Trace element data of whole rock samples (Wt.%).

S/No	Sample ID	O_2	Al	SI	S	K	Ca	Fe	Ba	Ti
1	LR2	47.728	6.025	33.145	0.072	3.999	1.153	5.890	0.086	0.756
2	LR3	47.827	8.131	32.801	0.172	6.511	2.264	1.283	0.59	0.122
3	LR5	48.683	7.631	34.319	0.362	6.113	1.071	0.786	0.049	0.001
4	LR6	50.112	7.774	35.837	0.626	3.182	0.782	0.896	0.023	0.017

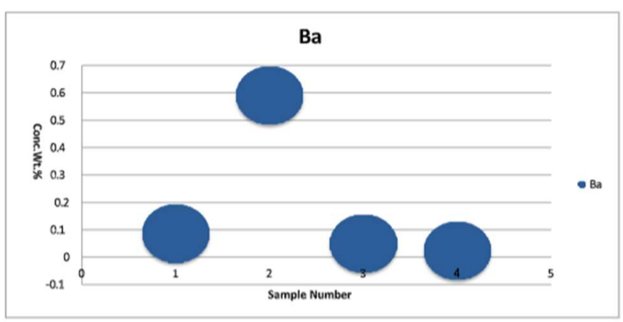


Figure4.10: Barium concentration in rock samples

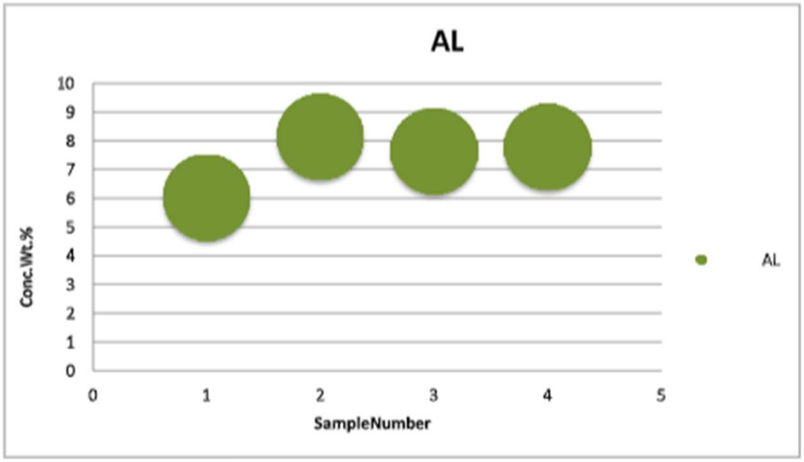


Figure4.11: Aluminium Concentration in Rock Samples.

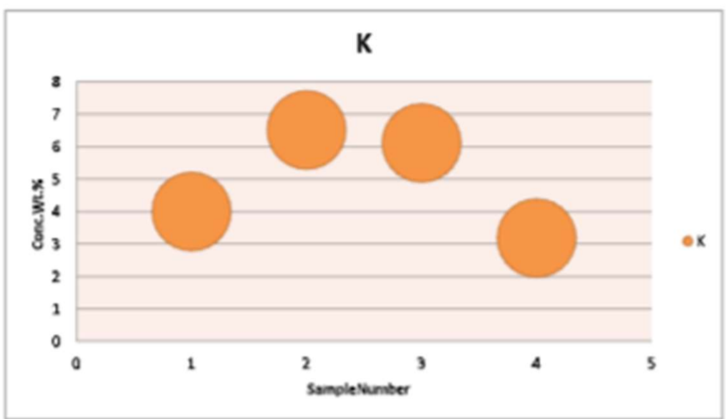


Figure4.13: Potassium concentration in rock sample

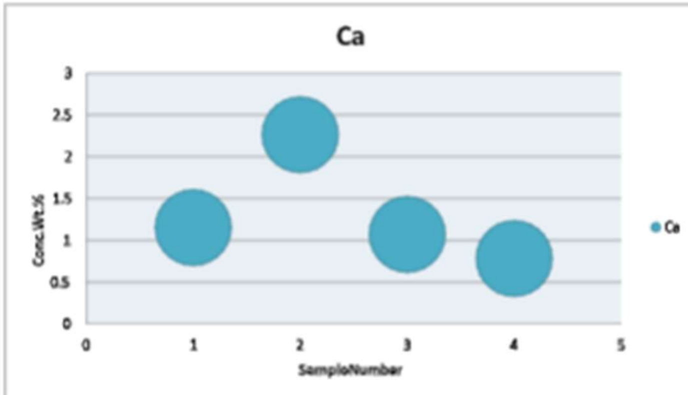


Figure 4.14: Calcium concentration in rock sample

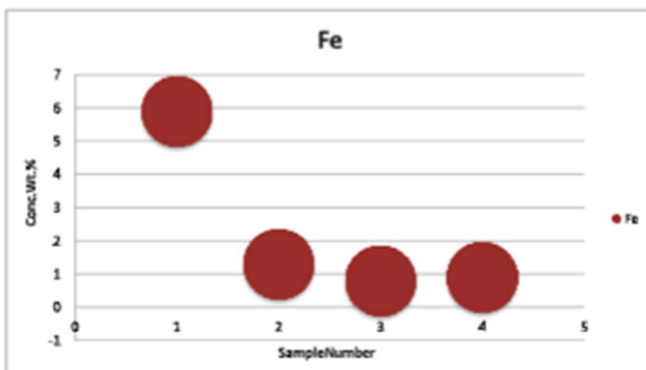


Figure4.15 :Iron concentration in rock sample

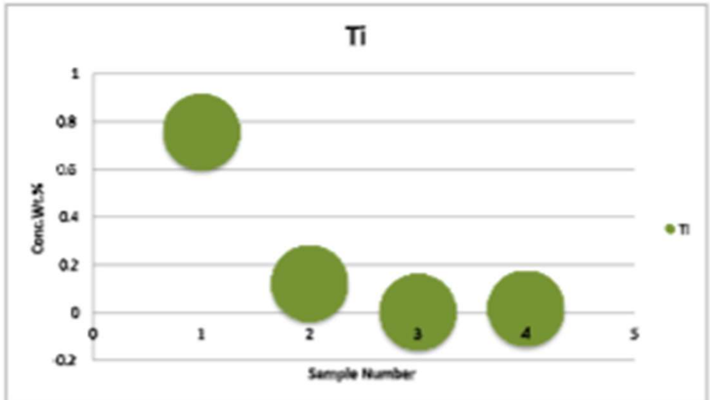


Figure4.16:Titanium concentration Chart

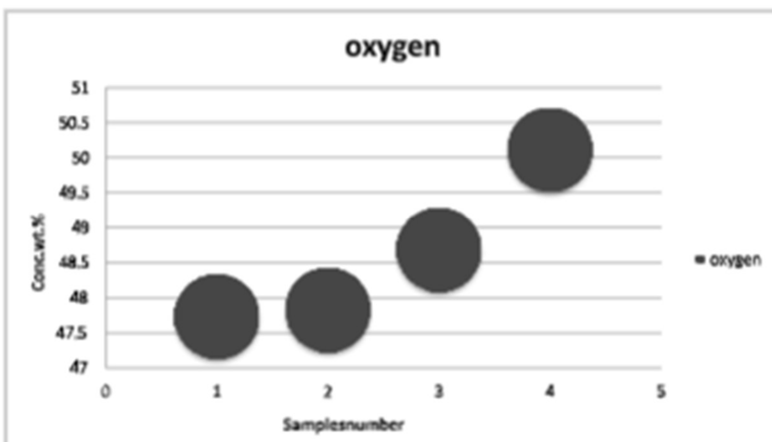


Figure4.17: Oxygen concentration in rock sample.

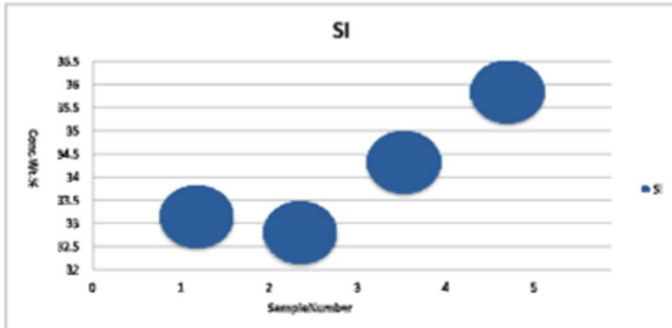


Figure4.18: Silicon concentration in rock sample

6. **Discussion**

The TAS binary plot (Figure4.19 and figure 4.20) shows that the medium grained granite falls in the Rhyolite field, whilst the medium grained granite and medium gneiss plotted in the granitic amdquartz diorite field. AFM ternary plot (Fig. 4.20) reveals that the medium grained granite gneiss (LR2), medium granied granite (LR3) and medium grained granite (LR5) falls within the line demarcating tholeiiticseries from calc-alkaline series. AFMternaryplot(Figure4.21)revealsthatthemediumgrainedgranite(LR5 fallswithin the line demarcating tholeiitic series from calc-alkaline series while the pegmatite (LR6),medium grained granite gnesiss and medium granied granite falls within the calc- alkaline series demarcating from the tholeiitic series.

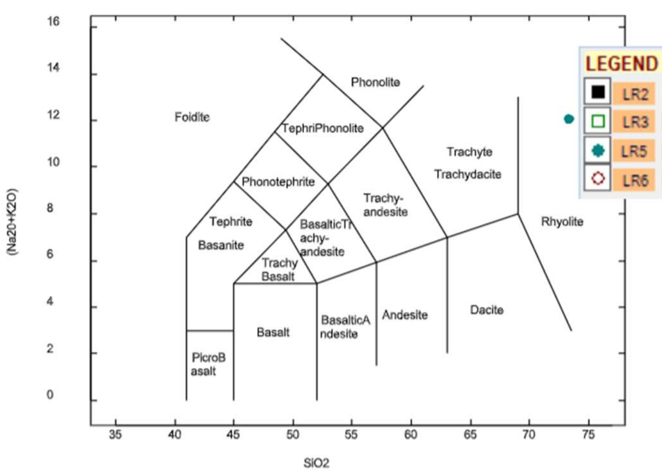


Figure4.19:Binary plot of TAS Alkali-Silica (AfterLe Basetal., 1986).

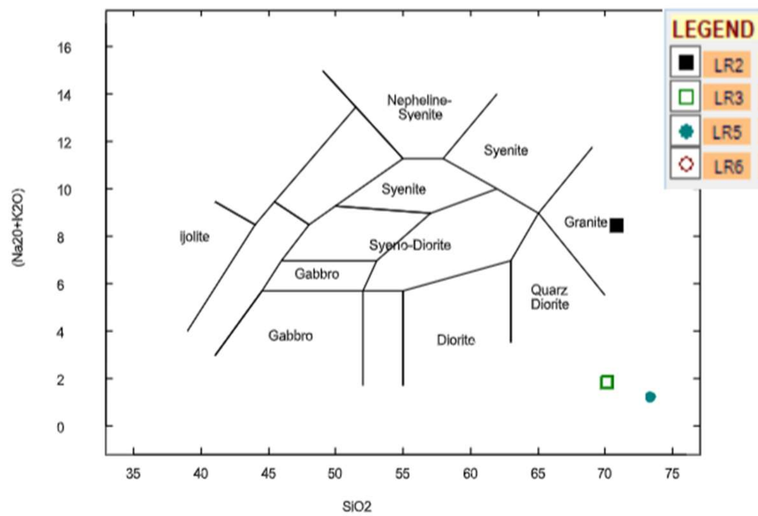


Figure4.20: Binary plo tof TAS Alkali-Silica (AfterCox-Bell-Pank, 1979).

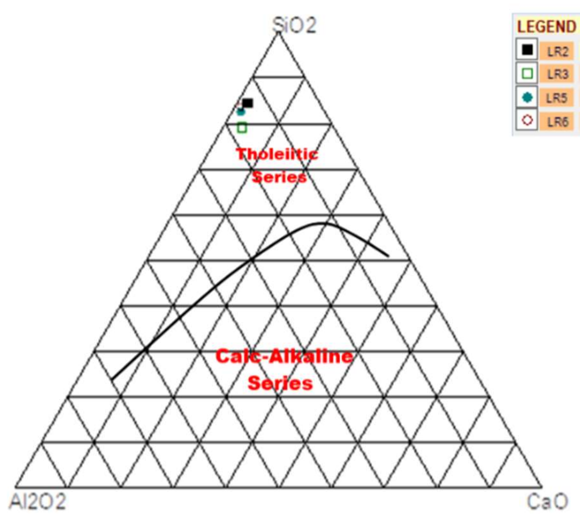


Figure4.21:AFM ternary plot (AfterKuno, 1968).

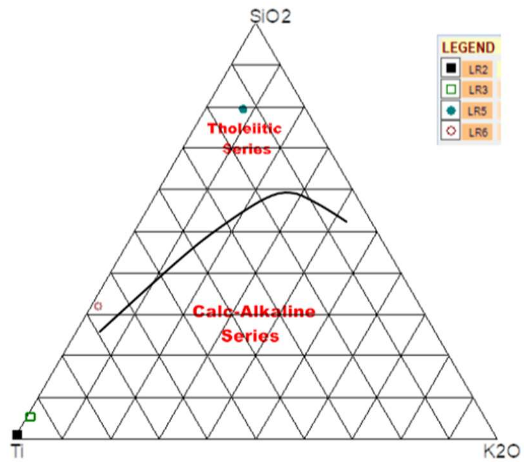


Figure4.22: AFM ternary plot(After Kuno, 1968).

1. Conclusion

The study area is underlain by the Basement Complex rocks that comprises of granite gneiss and granite. These host rocks are intruded by veins, which are pegmatitic and quartz veins and occur as discordant low lying dykes. Petrographic studies conducted under plane polarized light (PPL) and cross polarized light (XPL) on rock samples show that the gneisses exhibit variable mineral grains closely packed with preferred orientation. The granite and granite gneiss revealed that quartz, plagioclase feldspar, biotite, muscovite, microcline and hornblende are the dominant minerals. Meanwhile the pegmatites veins which trend majorly in a NE-SW contain mainly quartz, plagioclase, microcline and muscovite with little trace of lithium mineralization The concentration of metals like O_2, Al, Si, Fe and K are generally high and Ba, Ca, Fe, Ti, and S shows low concentration in the granite, granite gneiss and the pegmatite samples analysis in the study area. The high concentration or present of silica, potassium oxide and alumina in the rock sample (pegmatite) depicts the present of lithium mineralization in the veins as seen during the geological mapping within the study area and could be linked feldspar mineralization in the area.

The TAS binary plot (Figure4.18 and figure 4.19) shows that the medium grained granite falls in the Rhyolite field, whilst the medium grained granite and medium gneiss plotted in the granitic and quartz diorite field. AFM ternary plot (Figure 4.20) reveals that the medium grained granite gneiss (LR2), medium granied granite(LR3) and medium grained granite (LR5) falls within the line demarcating tholeiitic series from calc-alkaline series. AFM ternary plot (Figure 4.21) reveals that the medium grained granite (LR5 falls within the line demarcating tholeiitic series from calc-alkaline series while the pegmatite (LR6),medium grained granite gnesiss and medium granied granite falls within the calc-alkaline series demarcating from the tholeiitic series.

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