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Research Article

Petrographic Study and Geochemical Analysis of Basement Rocks in Federal University Gusau and Its Environs, Zamfara State, Northwestern Nigeria

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ABSTRACT

Petrographic and geochemical analysis of basement rocks in Federal University Gusau and its environs, Zamfara State, Northwestern Nigeria were carried out in order to unveil the major rock forming minerals as well as the textural relationships composition within the rock. The identified rock unit is granite and they are mainly whitish-grey in colour, with the majority of them having porphyritic-coarse-grained texture and minor with fine-grained texture. The light coloured crystals in hand specimens are the felsic minerals mainly quartz, and feldspars while the grey-dark crystals are the mafic minerals like the biotite-mica. The result of the thin section analysis depicts that the minerals present within the rock samples in the area: quartz (40%), orthoclase (40%) and biotite (20%). These identified minerals are classified as the major rock forming silicate minerals. The geochemical analysis result shows that the rocks are characterized by high percentage of quartz (SiO_2) in the range of 77.4-98.2 wt% with an average of 84.87 wt%; subordinate amounts of hematite (Fe_2O_3) with an average concentration of 4.08 wt% as well as low concentration of K_2O, CaO, TiO_2, V_2O_5, MnO, NiO, CuO, ZnO, RuO_2, In_2O_3 and other minor constituent oxides. The variation diagram of SiO_2 and other oxides within the study area reveals a very strong negative correlation of SiO_2 against CaO, TiO_2, V_2O_5, MnO, Fe_2O_3, CUO, PbO, and Eu_2O_3 respectively, with the average correlation value of -0.91. The geochemical analysis results also reveal minor alteration of modal composition amongst the samples analysed which suggest the similarities in composition of all the samples within the study area.

Keywords: Granite; Mineral; Quartz-vein; Older Granites; Oxides

INTRODUCTION

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. Danbatta and Garba [1] revealed that the Precambrian amphibolites outcrops within the Zuru Schist Belt of Northwestern Nigeria are bounded to the east by the Anka Fault Zone, suggesting a tectonic control. The result also depicts that the Zuru amphibolites have extremely low K_2O; high Al_2O_3; and low TiO_2, Nb, Zr, Y, Ni and Cr contents, signifying an island-arc or back-arc settings. They also deduced that the geological mapping in conjunction with geochemical characterisation of the area depict that the protoliths of the amphibolites were igneous tholeiitic basalts. Based on the geochemical analysis of data acquired from the study area, the researchers concluded that the obtained results are in accordance with the orogenic nature of the Pan-African event.

Opara et al. [2] conducted a study on the petrology and geochemistry of basement complex rocks in Okom-Ita area, Oban Massif, Southeastern Nigeriain in order to determine the mineralogical composition of rocks that underlie the area, in order to aid in the interpretation of the petrogenesis of the protoliths rocks in the area. The study revealed that the major intrusive rocks in the area are pegmatites, quartz veins and dolerites emplaced within gneisses, schists and phyllites host rocks. They deduced that the quartz veins and pegmatites are leucocratic in nature. The study revealed that the dolerite were dark grey, fine to medium grained and texturally ophitic and consists dominantly of pyroxenes, olivine and opaques. Also, the study recognized three (3) types of gneisses: feldspathic, banded and biotite gneisses. The percentage

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concentrations of SiO_2 in gneisses, schists, and phyllites range from 60-75%. The study revealed that the rocks in the study area exhibit higher molecular concentration {Al_2O_3>(CaO + Na_2O + K_2O)}, high alkali concentration with Na_2O>K_2O, high Al_2O_3 to alkali ratios along with little TiO_2, CaO and MgO concentrations. The researchers concluded that these results suggest a granitic protolith for the pegmatites and their host gneisses and/or schists. In addition, Obiora and Ukaegbu established that the Precambrian basement rocks in the southernmost part of northcentral Nigeria is underlain by migmatitic banded gneisses, granitic intrusions, dykes of dolerite, rhyolite porphyry and pegmatite. The study also showed that the rocks are generally felsic, containing modal and normative hypersthene, as well as normative corundum. The basement complex has undergone high-grade regional metamorphism as shown by the occurrence of hypersthene along with plagioclase of andesine composition. According to the researchers, the basement rocks contain magnesian, calc-alkalic and robustly peraluminous characteristics which suggest origin from pelitic rocks during high-grade regional metamorphism.

However, this study will document the petrographical study and geochemical analysis of the study area which include in-situ rock outcrop descriptions, identification and measurement of geologic structures, and identification of various rock units. Hence, our study aims at describing the petrographic characteristics as well as the geochemical analysis of some collected rock samples in the study area. The study will unveil the major rock forming minerals as well as the textural relationships within the rock. It is worthy to note that, the Basement terrain in Zamfara State host variety of lithological units and in a comple geological setting like the Basement Complex of southwestern Nigeria. The findings of this work will be help in the understanding of the genesis the Basememnt Complex of the northwester Nigeria.

Regional geologic setting

Federal University Gusau, Zamfara State main Campus is located along Zaria-Sokoto Road of Gusau precisely at Kotokoroshi Community, Zamfara State, Nigeria (Figure 1). The study area falls within Basement Complex of Northwestern Nigeria [3]. Previous workers by Danbatta and Garba, Opara et al., Obaje et al., Black, Ajibade and Fitches Obaje, Nwachukwu et al.,Folorunso et al., Saleh and Maunde, Ekeleme et al., etc [1-10]. Have done extensive work on the Basement Complex of Nigeria. The Nigerian Basement Complex is a part of the Pan-African mobile belt which lies among the West African and Congo Cratons as well as south of the Tuareg Shield [4].

According to Burke and Dewey [11] alongside Dada [12], the Nigerian basement occupies the reactivated region as a result of the plate collision between the passive continental margin of the West African Craton and the active Pharusian continental margins which was affected by Pan-African Orogeny. In addition, Condie revealed that the Kibaran and Pan African events affected mostly the Godwana continent and did not seem to have strong counterparts in other continents [13]. Thus, the tectonic activities between the tectono-thermal events were limited mostly to anorogenic magmatism and rifting.

Geological field mapping by various geologists signify that the Older Granites are composite bodies, frequently consist of more than one intrusions. Previous researchers such as Trustwell and Cope [14], and Mccurry and Wright [15] studied a detailed work in Northwestern Nigeria and they classified the Older Granites into syntectonic granites. These researchers assumed that the granites were to some extent intrusive and fairly metasomatic. They also established that the late tectonic granites are fine grained, aplitic or dioritic which obviously cross-cut the syntectonic granite.

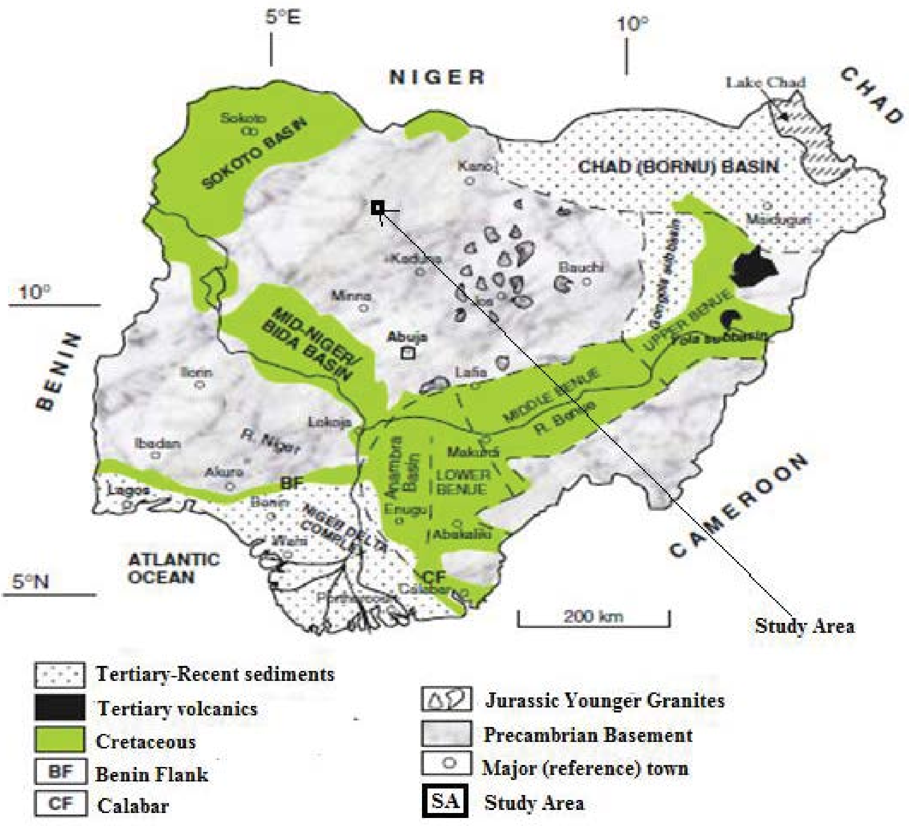

Figure 1: Geological map of Nigeria showing the study area [9].

The basement is characterised by synclinorial belts of low grade metasediments down-folded into high grade gneisses and migmatites, the whole intruded by batholitic granites. It is characterised by process of several phases of deformation, recrystallization and intrusion, the last of which is the Pan African orogeny McCurry and Wright, [16]. Ajibade and Fitches [5] reported that the basement comprises three major lithological groups: (i) the migmatite gneiss complex which is widespread throughout the country; (ii) metasedimentary and metavolcanic rocks which form schist belts and appear to be dominantly restricted to the western half of the country; (iii) the Older Granites which intrude both the migmatite gneiss complex and the schist belts and have consistently yielded Pan-African ages. Thus, the study area is underlain by Old-Granites.

METHODOLOGY

The fieldwork equipment and materials used during the mapping period are clinometers-compass, geological hammer, global positioning system (GPS), fieldwork note, base map and sample bag(s) and topographic and geologic maps. The study involved five main stages namely; desk study, reconnaissance survey, detailed study (field work), laboratory work and analysis and interpretations. The execution of these steps was done in accordance with the geological principles. A summary of the procedure and methods used in this study are illustrated in Figure 2 in a form flowchart. The desk study involved extensive and careful literature reviews of relevant reports, review of existing geological materials or works and topographic maps covering the study area. Meanwhile, the reconnaissance study or preliminary survey was carried out with a mission to obtain, by visual observation, some necessary information about the human activities and mineral resources data concerning the study area. The activities carried out under detailed study include detailed geological mapping using compass-traverse method of mapping, outcrop logging, taking field measurement, pre-mining studies and collection of samples for petrographic analysis. Seventeen (17) outcrops were studied altogether within the study area.

Consequently, the laboratory analysis was carried out on some of the samples collected from the study area during the field mapping. The samples were collected from the open-cast mine site, on outcrops and along the river channels at different location within the study area. The samples were adequately protected against pre-test deterioration. Due to the uniformity of the geology of the area and cost implications, representative samples of six (6) were taken to the National Steel Raw Materials Exploration Agency (NSRMEA), Kaduna Nigeria for petrographical analysis namely; thin section analysis and optical observations. During the preparation of thin sections analysis for all the six samples, a thickness of 1.0 cm of a square shape of the rock sample was cut with the cutting machine. Applying emery cloth and caborundum powder, the specimen is further flattening to a thickness of about 0.04 mm. This flattened specimen is overlaid by the boiled Canada balsam and it is covered with a cover slip and left for about a day, then it is washed, rinsed with spirit and later with water. A total of 12 thin sections (2 slides from each rock sample) were prepared from the samples for effective analysis and control. The analyses were subjected to microscopic examinations. Petrographic studies of the selected samples were made with the aid of a polarizing microscope. Some of the major minerals were observed under the microscopic examinations. On the other hand, the geochemical analysis was carried out on the six (6) selected bulk rock sample using Energy Dispersive-X-Ray-Fluorescence (EDXRF) equipment. Each of the specimens was crushed into powdery form and was oven-dried for 24 hours at both 105 °C and 800 °C respectively to determine their natural moisture contents as well as Loss on Ignition in readiness for the major and minor element analyses. This was followed by the compilation and processing of accumulated field data and the analysis of the petrographic and geochemical data. The results were then interpreted.

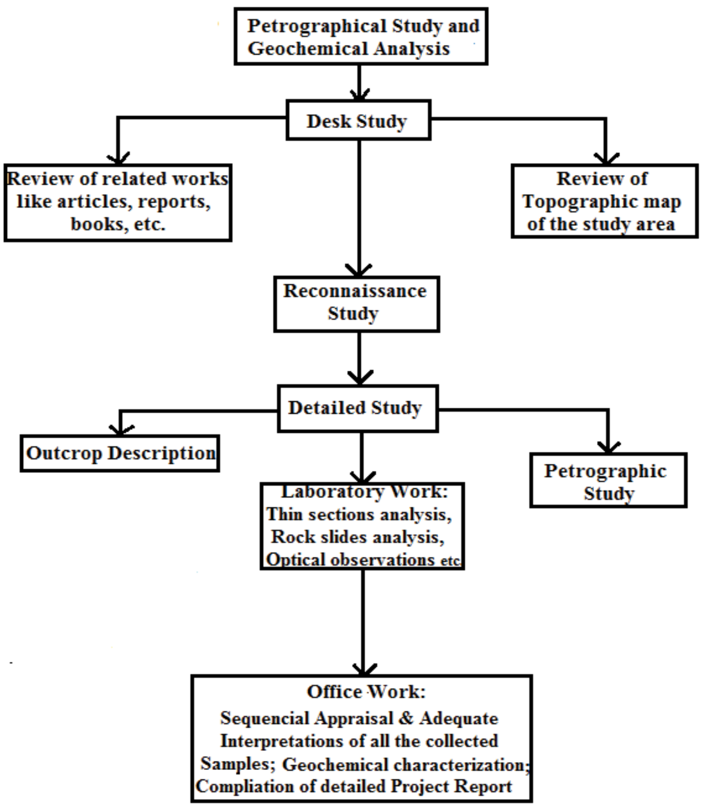

Figure 2: Research workflow.

RESULT AND DISCUSSION

Megascopic description

The fresh sample of granites obtained from the study area shows a grey to white with small traces of black to dark brown in colour (Figures 3-5). The textural compositions of granites within the study area are phaneritic, porphyritic and fine-grained structures (Figure 4). The megascopic observation made indicates that the rock sample is composed of minerals including quartz, feldspar and biotite. Visual identification of the minerals observed in the sample shows that quartz and feldspar are the major minerals that make up the rock and constitute about 80% of the total volume of the rock, whereas mica minerals account for only 20% of the rock (Figure 5).

Thin section analysis

The twelve thin sections analyses indicate that the rock samples within the study area are coarse-grained in texture with individual mineral grains being well-developed. In general, the minerals present include Quartz (40%), Orthoclase (40%) and Biotite (20%). The Figure 6 below shows the minerals observed both in PPL and XPL. Quartz and orthoclase are the most abundant minerals observed in the slide (Table 1). Quartz constitutes about 40% of the mineral content of the prepared slide and its morphology rarely forms euhedral crystals except in some veins which are anhedral. Quartz is an extremely common mineral in continental crustal rocks. It is the most common vein-forming mineral. More so, Orthoclase feldspar or K-feldspar is also the most dominant mineral observed in the slide and constitute about (40%) of the total volume of the rock (Table 1 and Figure 7). In hand sample, the feldspars are white, gray, pink, or black in colour, distinguishable from quartz, which is glassy and gray. Its morphology is mostly form anhedral crystals in most granite. Alkali feldspars are colourless in thin section, but they may appear a cloudy grey or brown due to alteration to clay minerals. They may form euhedral rectangular crystals especially as phenocrysts in igneous rocks. They also occur as anhedral grains in many granites and high grade metamorphic rocks. However, biotite is brown, cleaved, occurs as platy crystals and has moderate relief under PPL (Figure 6 and Table 1). It is brownish to reddish brown under XPL. It displays no pleochroism. It constitutes about (20%) of the total volume of the rock sample (Figure 7). It commonly occurs as well-formed tabular crystals in pelitic metamorphic rocks and in granites. In many gabbroic rocks it crystallizes late and is anhedral. Biotite is one of the most common of the rock-forming minerals. It is a major constituent of rocks of intermediate composition, such as granodiorites, diorites, monzonites, and some nepheline syenites.

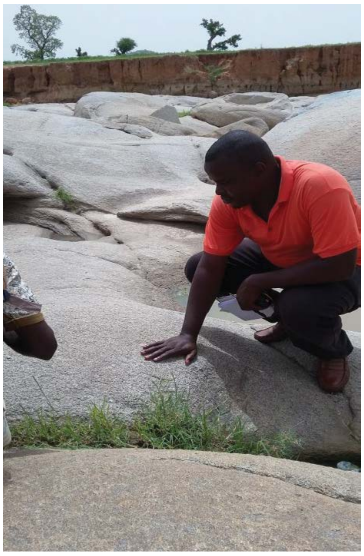

Figure 3: Porphyritic texture [Lat: 12°08'34.7"N & Long: 006°45'36.6"E].

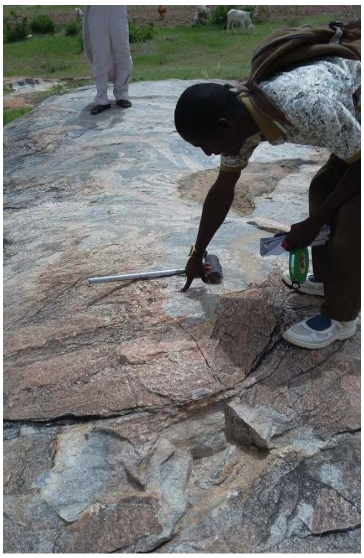

Figure 4: Fine-grained structure [Lat: 12°07'45.0"N & Long: 006°46'50.6"E].

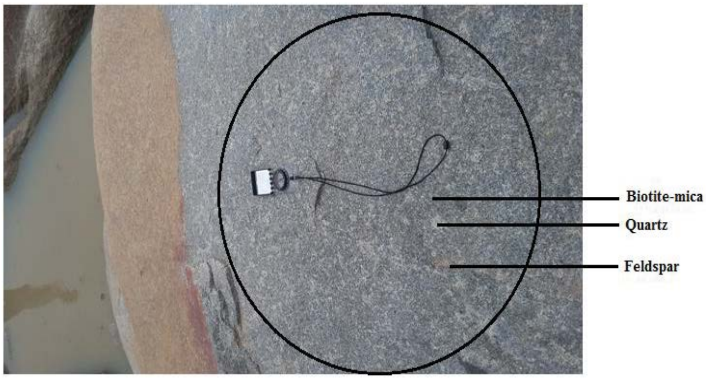

Figure 5: Spot mineral identification from the major rock in the study area.

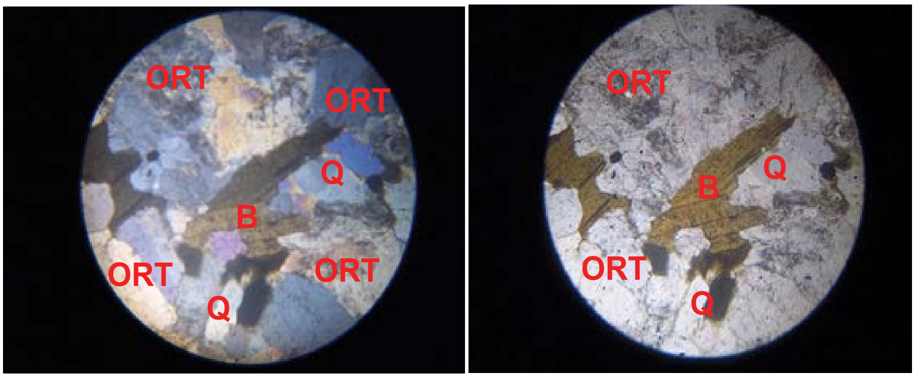

Figure 6: Photomicrograph of granite showing its mineralogical composition in XPL and PPL (B =Biotite, Q=Quartz and ORT=Orthoclase) (a) SM1 PP M40 (b) SM1 XP M40.

Table 1: Petrographical analysis of sample 1.

Minerals	Optical Properties	Cross Polarized (Xpl)	Plane Polarize (ppl)	Percentage in Thin Section	Rock Name
Quartz	Color	Bluish to milky	Colourless	40%	Granite
	Relief:	Low relief			
	Form/size	Anhedral			
	Inclusion	Absent			
	Cleavage	Absent			
	Extinction	absent			
	interference	Absent			
	pleochroism	Moderately pleochroic			
Orthoclase	Color	Light Blue to Milky Colour	Colourless	40%	
	Relief:	Medium			
	Form/size	Anhedral			
	Inclusion	Absent			
	Cleavage	Absent			
	Extinction	Absent			
	Pleochroism	Moderately pleochroic			
	Twining	Tready (albite)/Polysynthetic twins			
Biotite	Color	Brown	Brown	20%	
	Relief:	Low			
	Form/size	Euhedral			
	Inclusion	Absent			
	Cleavage	Two(2) cleavage direction			
	Extinction	Absent			
	Pleochroism	Absent			
Total	-	-	-	100%	-

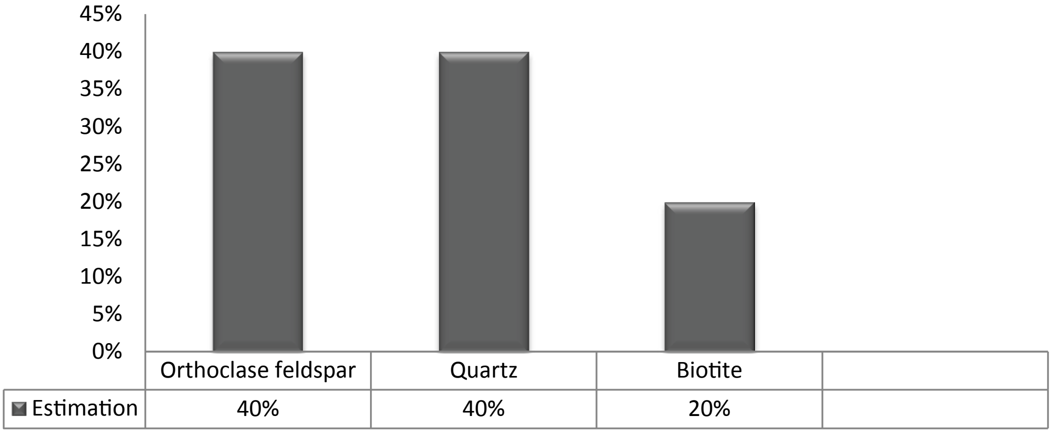

Figure 7: Bar chart showing estimated modal mineralogical composition of granite under the microscope.

Table 2: Result of geochemical analysis of samples within the study.

Compound	Concentration Unit (%)							
	L1	L2A	L2B	L9	L10	L17	Total	Average
SiO_2	79.8	96.8	98.2	70.5	77.4	86.5	509.2	84.87
K_2O	4.1	-	0.3	4.72	5.37	6.61	21.1	4.22
CaO	4.95	0.087	0.017	9.87	5.96	1.21	22.094	3.682
TiO_2	0.995	-	0.053	1.41	0.887	0.211	3.556	0.711
V_2O_5	0.005	-	0.005	0.02	0.01	-	0.04	0.01
MnO	0.055	0.027	0	0.13	0.076	0.04	0.328	0.0547
Fe_2O_3	6.961	0.262	0.285	9.76	6.123	1.06	24.452	4.0753
NiO	0.054	0.003	0.004	-	-	-	0.061	0.0203
CuO	0.031	0.02	0.023	0.03	0.032	0.031	0.166	0.0277
ZnO	0.03	0.01	-	0.04	0.028	0.097	0.2034	0.0407
Ga_2O_3	0.006	-	-	0.02	-	0.004	0.027	0.009
Rb_2O	0.097	-	-	0.1	0.09	0.09	0.377	0.0943
SrO	0.254	-	-	0.22	0.328	0.035	0.833	0.2083
Y_2O_3	0.01	-	-	0.01	0.01	0.005	0.033	0.0083
ZrO_2	0.14	-	-	0.09	0.074	0.062	0.37	0.0925
RuO_2	0.53	0.3	0.3		0.54	0.42	2.09	0.418
In_2O_3	1.7		0.7	2.6	2.6	3.5	11.1	2.22
CeO_2	0.04	-	-	0.02	0		0.06	0.02
Eu_2O_3	0.18		0.058	0.23	0.16	0.088	0.716	0.1432
Re_2O_7	0.01	0.043		0.04	0.02	0.027	0.139	0.0278
IrO_2	0.024	-	-	0.02		0.026	0.07	0.0233
Au	0.021	0.024		0.03	-	-	0.073	0.0243
PbO	0.045	0.022	0.018	0.05	0.035	0.037	0.202	0.0337
$S0_3$	-	0.96	-	-	-	-	0.96	0.96
Cl	-	1.2	-	-	-	-	1.2	1.2
As_2O_3	-	0.005	0.003		0.006	0.004	0.018	0.0045
BaO	-	0.059	-	0.04	0.2	-	0.299	0.0997
Pr_20_3	-	0.12	-	-	-	-	0.12	0.12
Sm_2O_3	-	0.058	-	-	-	-	0.058	0.058
Yb203	-	0.008	0.012	-	-	-	0.02	0.01
HgO	-	0.004	-	-	-	-	0.004	0.004
Cr_2O_3	-	-	0.011	-	-	-	0.011	0.011
CeO_2	-	-	0.025	-	-	-	0.025	0.025
Bi_2O_3	-	-	0.021	-	-	-	0.021	0.021
Total	100	100	100	99.9	99.95	100.1	-	-

Geochemical characterization

The result of the geochemical analysis in the study area shows that the rocks are characterized by high percentage of quartz (SiO_2) in the range of 77.4 - 98.2 wt% with an average of 84.87 wt% (Table 2 and Figure 8). Also, the rocks are characterized by subordinate amounts of hematite (Fe_2O_3) in the range of 0.26-9.76 wt% with an average of 4.08 wt% (Table 2). They are characterised by low potassium oxide (K_2O), quicklime (CaO), titanium di oxide (TiO_2), divanadium pentaoxide (V_2O_5), manganese(II)oxide (MnO), nitric oxide (NiO), copper(II)oxide (CuO), zinc oxide (ZnO), ruthenium(IV)oxide (RuO_2), indium trioxide (in range of 0.7-3.5%) and other minor constituents (Table 2). These geochemical concentrations values obtained within the study area aligned with that obtained by Danbatta and Garba [1] for Precambrian amphibolites in the Zuru schist belt, northwestern Nigeria. Their study revealed that the Zuru amphibolites have extremely low K_2O; high Al_2O_3; and low TiO_2, Nb, Zr, Y, Ni and Cr contents which were in accordance with the orogenic nature of the Pan-African event.

The results of the geochemical analysis show that sample L1, L2A, L2B, L9, L10 and L17 contains 79.8%, 96.8%, 98.2%, 70.5%, 77.4% and 86.5% of SiO_2 with low concentration of K_2O, CaO, Fe_2O_3 and In_2O_3 as well as traces of other compounds respectively (Table 2 and Figure 8). These geochemical distribution values suggest that the study area possess high silica concentrations and these support the granitic origin of the analyzed rock samples. These geochemical concentrations values obtained within the study area also aligned with that obtained by Opara et al. [2] on the petrology and geochemistry of basement complex rocks in Okom-Ita area, Oban Massif, Southeastern Nigeriain.; where they depicted that the percentage concentrations of SiO_2 in gneisses, schists, and phyllites range from 60-75%.

Applying Harker [17] diagram method to study the element relationships within the study area, a very strong negative correlation is observed in the generated plots of SiO_2 against CaO, TiO2, V_2O_5, MnO, Fe_2O_3, CUO, PbO, and Eu_2O_3 respectively, with the average correlation value of -0.91 (Figure 9). Also, the generated plots of SiO_2 against K_2O and In_2O_3 show moderate negative correlation with the average of -0.59, whereas ZnO did not correlate with SiO_2 (Figure 8). More so, rhenium (VII) oxide (Re_2O_7) has a correlation value of 0.28 and this simply means that Re_2O_7 has a weak positive correlation with SiO_2 (Figure 9). This signifies that with increase in silica content within the study area, the following trends are evident: TiO_2, FeO, MgO and CaO increase in abundance; K_2O and In_2O_3 decrease in abundance and ZnO does not exhibit a strong variation. According to Okonkwo and Folorunsho [18], the strong negative correlation between SiO_2 and Fe_2O_3 as well as SiO_2 and MnO in the analysed granite suggests olivine, pyroxene and hornblende as the major mineral within the study area.

CONCLUSION

The result of the petrographic study reveals that the granites in the study area are predominantly whitish-grey in colour with the textural compositions of porphyritic to fine-grained structures. Petrographically, the granitic rocks in the study area are composed of major rock forming silicate minerals such as quartz, biotite-mica, and feldspars. The result also reveals that the light coloured crystals are the felsic minerals mostly quartz, and feldspars while the grey and dark crystals are the mafic minerals mostly biotite-mica. The geochemical analysis on the rocks in the study area shows that the rocks are characterized by high percentage of quartz (SiO_2) in the range of 77.4-98.2 wt% with an average of 84.87 wt% and subordinate amounts of hematite (Fe_2O_3) with an average concentration of 4.08 wt% as well as low concentration of K_2O, CaO, TiO_2, V_2O_5, MnO, NiO, CuO, ZnO, RuO_2, In_2O_3 and other minor constituents. The variation diagram of SiO_2 and other oxides within the study area reveals a very strong negative correlation of SiO_2 against CaO, TiO2, V_2O_5, MnO, Fe_2O_3, CUO, PbO, and Eu_2O_3 respectively, with the average correlation value of

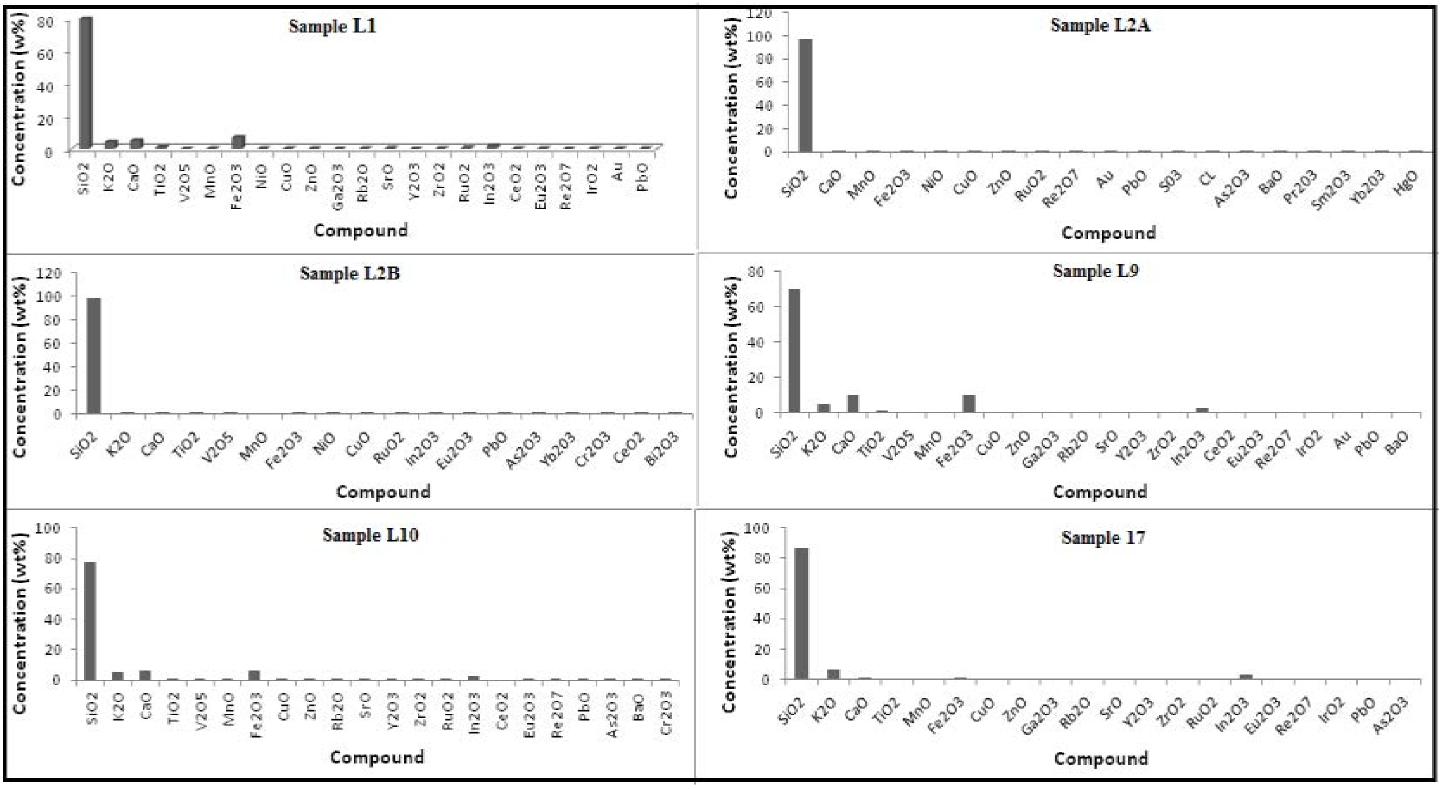

Figure 8: Geochemical chart showing concentration of different compound.

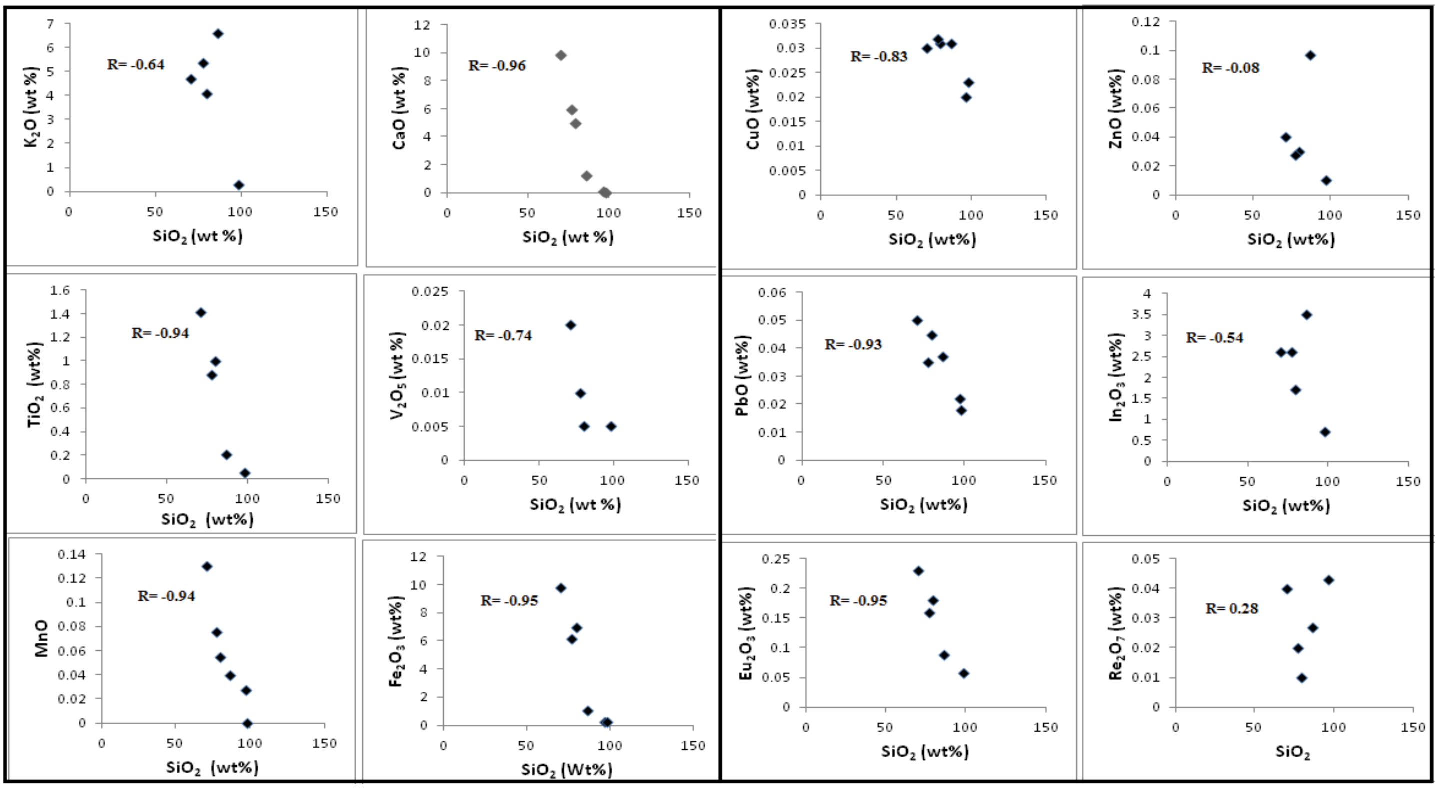

Figure 9: Variation diagram of SiO_2 and other oxides within the study area.

-0.91. Based on the petrographical and geochemical analysis obtained, the results suggest that the study area possess high silica concentrations and these support the granitic origin of the analyzed rock samples.

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