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Geology, Petrography and Geochemical Evaluation of Basement Rocks In Bakomba–Kabba Junction Area, Sheet 247 Lokoja SW, North Central, Nigeria

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Abstract: *Geologic mapping provides many types of information in the exploration for new mineral deposits, including the lithology, morphology, age relationships and structural information. Field geological mapping of basement rocks around the Bakomba-Kabba junction was carried out on a scale of 1:30,000 to establish the petrogenesis of rocks that underlain the area. The study area covers 30.80 km^2 and falls at the eastern flank of the southwestern Basement Complex of Nigeria. Migmatite, banded gneiss, aplite and charnockite rock types were encountered during the mapping exercise. Predominant trends of joints, veins and lineation are indicative of imprints of the Pan-African thermotectonic Orogeny. Five different representative rock samples were subjected to both petrographic and geochemical analyses. Migmatite is composed of 62.12 % quartz, 24.50 % potash-feldspar, 6.60 % biotite, 5.82 % muscovite and 0.96 % opaque. The banded gneiss near Zariagi has 51.83 % quartz, 21.65 % potash-feldspar, 18.90 % biotite, 4.88 % muscovite and 2.74 % myrmekite minerals; whereas, the banded gneiss close to Oyi-Apataoworo has 58.63 % quartz, 21.58 % plagioclase, 6.47 % biotite, 7.19 % muscovite and 2.88 % opaque minerals. The aplite is dominated by 57.40 % potash-feldspar and 23.14 % quartz, 6.10 % biotite, 5.25 % perthite, 5.38 % muscovite, while the charnockite consists of 50.00 % quartz, 25.26% pyroxene, 12.89 % biotite, 8.76 % plagioclase and 3.09 % opaque minerals. The geochemical composition of these rocks indicate 69.90 % SiO_2, 12.71 % Al_2O_3, 4.50 % Fe_2O_3, 0.48 % MgO, 6.62 % K_2O, 3.09 % CaO, 1.32 % Na_2O, 0.96 % TiO_2, 0.07 % MnO and 0.34 % SO_3 on the average. Harker diagram indicated a high fractionation of mafic minerals in the rocks. Other discriminating diagrams revealed that all the rock types have igneous origin and crystallized from magmas that are strongly alkaline. However, the migmatite, aplite, and banded gneiss from Zariagi crystallized from the high-K alkaline magma series; the banded gneiss close to Oyi-Apataoworo originated from medium-K alkaline magma series; while the charnockite evolved from low-K alkaline series. This implied that rocks from the study area were derived from heterogeneous alkaline magma series.*

Keywords: *petrography, geochemical, basement rock, petrogenesis, Lokoja*

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1.0 Introduction

The study area is at the eastern flank of the South Western Nigeria Basement Complex of Nigeria. The geology and geochemistry of the southwestern Nigerian Basement Complex have been reported by many researchers such as Jones and Hockey (1964), Rahaman (1976), Dada (1998), Obiora (2005), Anifowose and Borode (2007), Omada *et al.*, (2009), Olatunji *et al.* (2013), Ayodele (2015), Ngozi-Chika (2016), Gideon (2019) and many others. These Researchers have mapped on regional scales and classified the rocks from southwestern Nigeria to include granite, migmatitic complex, metasedimentary series of schists, amphibolites, marble and calc-silicates, charnockite, diorite, potassic-syenites and dolerite. However, detailed geological mapping of basement rocks in Bakomba area, needed to evaluate its petrogenesis and economic potential is not available in the literature. This study aims to establish the petrogenesis of rocks in the Bakomba-Kabba junction area. To achieve this, the study area will be geologically mapped on a scale of 1:30,000, host rock samples shall be collected, analysed, and characterised. Also, an updated map of the study area will be produced.

2.0 Materials and Methods

2.1 The Study Area

The study area is located within latitudes 7^{O} 50′ to 7^{O} 53′N and longitudes 6^{O} 32′ to 6^{O} 35′ E (Fig. 1). It is situated on a topographic map of Sheet 247 Lokoja NW and falls within Adavi Local Government Area of Kogi State, Nigeria. The extent of the study area is 30.77 km^2. Bakomba in the Kabba Junction area is a popular and linear settlement. Major access routes are Lokoja – Okene, and Lokoja – Obajana. The northwestern and southeastern parts of the study area are relatively flat. Across these two ends are lowlands and highlands, leading to undulating terrains with gullies and valleys (Fig. 1). There are perennial rivers across the lowlands and valleys, flowing in the northwest-southeast directions. The study area falls within the Tropical Savannah Climate or Woodland and Tall Grass Zone. This zone is influenced by two climatic conditions rainy and dry seasons. The rainy season starts towards the end of March and terminates at the end of October, while the dry season commences in November and continues till late February or early March of the following year.

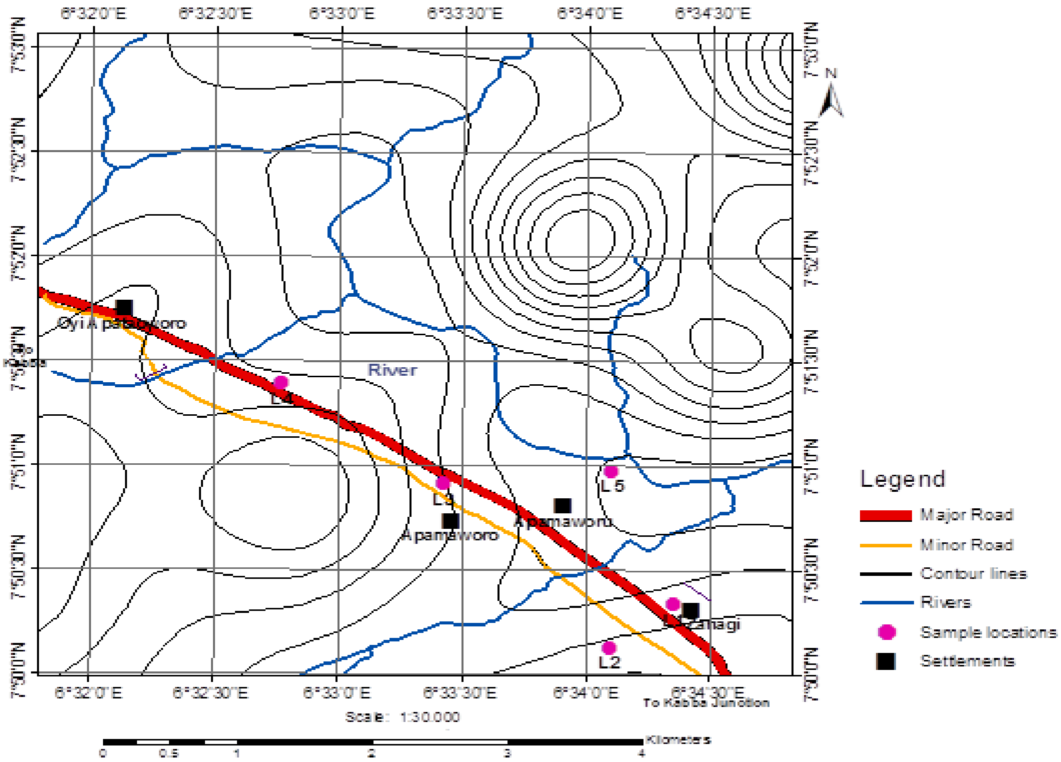

Fig. 1: Location and Accessibility map of the study area

2.2 Regional Geological Setting

The Precambrian Basement Complex of Nigeria lies within the Pan-African mobile belt, east of the West African Craton and Northwest of the Congo-Gabon Craton. Evidence obtained from the literature concerning the Eastern and Northern margins of the West African Craton indicates that the Pan-African belt evolved by plate tectonic processes which involved the collision of the passive continental margin of the West African Craton and the active margin of the Pharusian (Tuareg shield) in about 600 Ma according to Okonkwo and Folorunsho (2013), and Omosanye *et al*., (2012). The collision at the plate margins is believed to have led to the reactivation of the internal region of the Pan-African belt. The Nigerian Basement Complex lies within the reactivated part of the belt (Obiora, 2005). Radiometric ages indicate that the Nigerian Basement Complex is polycyclic and includes rocks of Liberian (2700 ± 200 Ma), Eburnean (2000 ± 200 Ma), Kibaran (1100 ±200Ma), and Pan African (600 ± 150 Ma) according to Obiora (2005). The Precambrian Basement Complex of Nigeria is exposed in five major locations, namely: north-eastern zone, south-western zone, south-eastern zone (extension of Bamenda Massif into Nigeria), north-eastern zone (the Hawal Massif) and the south-southeastern zone known as the Oban Massif (Fig. 2). Oyawoye (1972), Rahaman (1976), and McCurry (1976) sub-divided the rocks of the Basement Complex into different major groups. In all, attempts were made to distinguish the older groups from the Pan-African domain based on lithology, structure and degree of metamorphism. However, the different lithological types can be conveniently grouped into:

(i) Migmatite Gneiss Complex- These rocks are the oldest rocks of the Nigerian Basement Complex (Rahaman, 1988). They exhibit great variations in composition because of the differences in their protolith (Pelithic, psammitic or igneous) and the metamorphic (P-T) conditions under which they were formed. Most of the rocks display medium to upper amphibolite facies metamorphism.

Schist Belts- th**ey** constitute the most remarkable structural pattern in the Precambrian Basement Complex of Nigeria. They are essentially N-S trending belts which are more conspicuous in the western parts of the country. They were formerly referred to as the younger meta-sediments to distinguish them from the migmatitic gneisses which were designated as the meta-sediments; and

(ii) Pan African (Older) granites**-** They are syn- to- late-tectonic intrusions into the migmatite gneiss complex and the schist belts. They are otherwise known as the Older Granite to distinguish them from the Jurassic granites which are also found along their outcrops in Jos-Plateau and adjoining localities (Rahaman, 1988). They range in size from small sub-circular cross-cutting stocks to large elongate concordant batholiths. They are often weakly foliated and described as foliated granites and gneissic granites.

2.3. Sampling

A desk study was initially conducted to choose the form of geological fieldwork method. This was followed by a reconnaissance survey and then, the detailed geological mapping. Brunton compass clinometer, global positioning system (GPSMAP 78S), field notebook, measuring tape, Estwing geologic hammer, masking tape, permanent marker, and samples bags were used for the mapping exercise and sampling of rocks. Field mapping employed involved open-traversing through roads and pathways in the valleys and accessible highlands. At each outcrop, coordinates were taken; the texture, colour, orientation, dimensions, and mode of occurrence/emplacement of the outcrop relative to other nearby outcrops were established. Detailed observations and measurements of structural elements were also taken for inferences. A total of twelve (12) fresh and representative rock samples were collected from the study area using Estwing mini-sledgehammer. The samples were labelled according to the locations they were collected. Field names were also ascribed to each sample before they were transported to the laboratory.

2.4. Analysis of samples

The petrographic examination was carried out on five carefully selected rock samples using a Hillquist thin-section preparation machine in the Petrology Laboratory, Department of Earth Sciences (Geology), Kogi State University, Anyigba. Photomicrographs of the minerals were taken using a digital camera for a microscope (DCM 500). Parts of the same selected rock samples were prepared and geochemically analyzed for major, minor and rare earth elements. The rock samples for geochemical analysis were initially crushed, ground, sieved, homogenized, pelletized and analysed using an X-ray fluorescence machine in Nigeria Geological Survey Agency, Kaduna, Nigeria.

3.0 Results and Interpretation

3.1 Field Relation/Local Geology

The study area falls within the eastern flank of the South Western Basement Complex area of Nigeria. It is underlain with migmatite, banded gneiss, aplite, and charnockite. These rocks are mostly metamorphic. The terrain is undulating due to the alternation of high and lowlands. The outcrop of migmatite within Apamaworo settlement is felsic, fine to medium-grained texture and is relatively low-lying. The migmatite in the study area trends in the northeast-southwest direction and it is sandwiched by two differently trending banded gneiss (Fig. 2). The migmatite outcrops in many areas is characterized by various assemblages, and intruded by pegmatite. The entire northwest and southwest parts of Zariagi are underlain with migmatite, while the charnockitic rock outcrops are located at the outskirt of the Zariagi settlement (Plate. 1a). Next to the charnockite is low-lying banded gneiss, which was encountered in three different localities: (i) near Zariagi settlement, (ii) close to Oyi Apata-Oworo, and (iii) about 250m north-east of Apamaworu settlement (Fig. 2). The northwest and part of the southwest regions are underlain with banded gneiss. The banded gneiss close to Oyi-Apata-Oworo is exposed by a road cut. Megascopic studies revealed that it is segregated into leucosome and melanosome bands (Plate 1b). The leucosome band contains a high percentage of quartz and feldspar, giving it a light appearance, while the melanosome band consists of ferromagnesian minerals such as biotite. The rock is mostly equigranular and medium-grained. Visible minerals in the hand specimen are quartz, biotite and whitish feldspathic content, representing plagioclase variety. By estimation, migmatite and banded gneiss underlay more than 85 % of the study area, while the charnockite and aplite rocks share the remaining 15 %. Structural elements such as open joints, healed joints and cross-cutting joints on the outcrop were observed and studied.

Aplite occurs as major intrusions within the migmatite outcrop. Measurements on planar surfaces of the outcrop indicated that, the migmatite trend in the northeast-southwest directions, and dip towards the southeast. The intruded aplitic body trends in the north-south directions and shows pinkish feldspathic colouration (Plate 2a). Other intrusive rock bodies like quartz vein and pegmatite were encountered (Plate 2b). The pegmatite is coarse-grained, leucocratic, and observed to be discordant with the foliation of minerals in its host rocks in most cases (Plate 2b). Megascopic studies revealed it contains minerals like quartz, biotite, biotite, muscovite, feldspars and possibly hornblende.

Measurements of strike of veins and joints on rocks as presented in Table 1 were plotted to establish the dominant trends of the respective structures. The veins on migmatite gneiss trend in the NW-SE direction (Fig. 3a), while the veins on the outcrop of banded gneiss are in the NE-SW direction (Fig. 3b). The presence of varying magnitudes of minor folds and joints as well as quartz-feldspar veins of different dimensions and directions on the rocks are evidence of tectonic activities on the outcrops, indicating responses to deformational stresses acting on them.

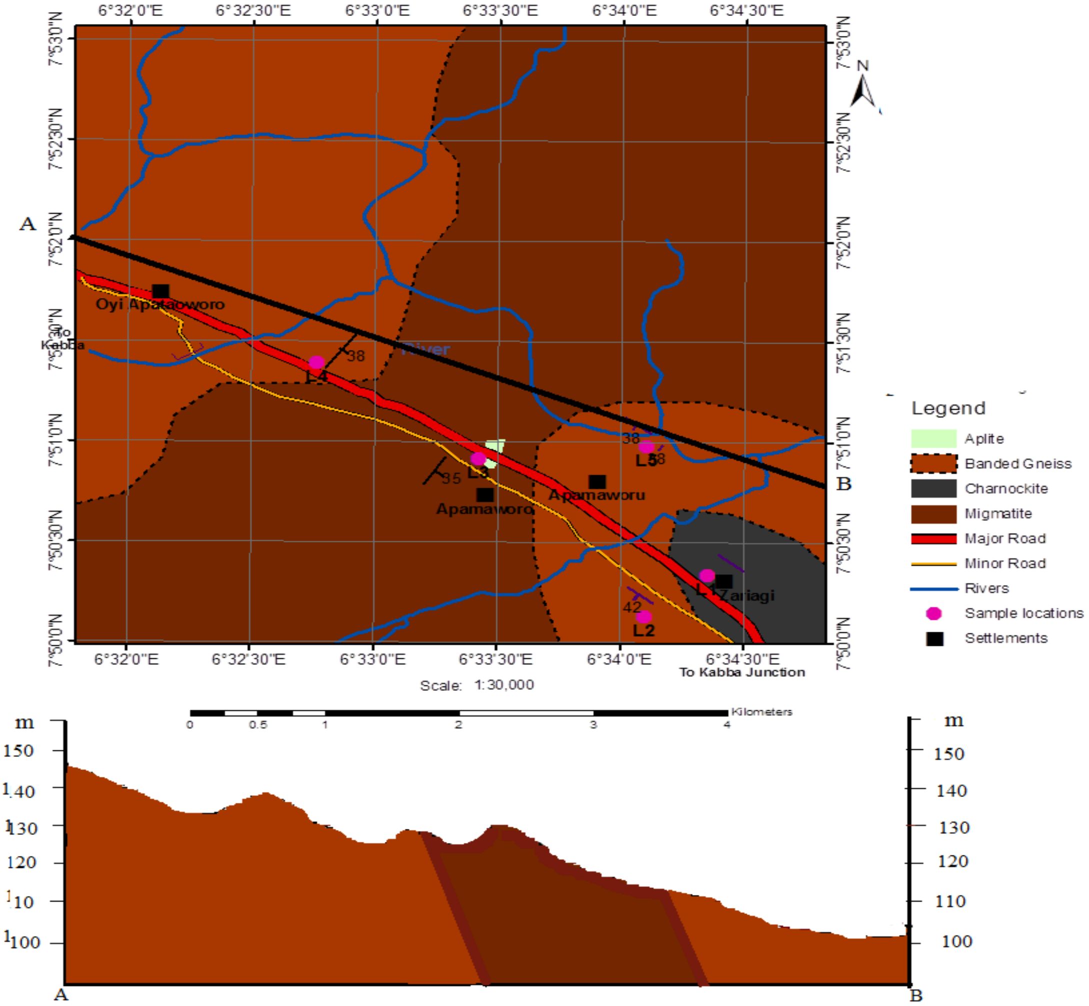

Fig. 2: Geological map and topographic cross-section of rocks in the study area

(a) (b)

Plate 1: Photographs of (a) charnockite, and (b) banded gneiss outcrops

Plate 2: **Photograph of pegmatite intrusion in (a) migmatite and (b) banded gneiss**

Table 1: Strike of structural elements on rocks in the Study Area

Veins on Migmatite (n = 41)	Veins on Banded Gneiss (n = 35)
98, 102, 115, 120, 119, 125, 135, 122, 100, 111, 120, 128, 130, 116, 118, 123, 113,100, 131, 124, 109, 110, 112, 114, 113, 100, 131, 124, 109,110, 112, 114, 123, 122, 117, 130 118, 124, 120, 116, 112	062, 068, 060, 062, 038, 050, 060, 065, 060, 062, 038, 054,048, 062, 044, 050, 038, 045, 048, 048, 039, 060, 058, 052, 060, 050, 052, 042,046, 040, 056, 050, 048, 056, 050

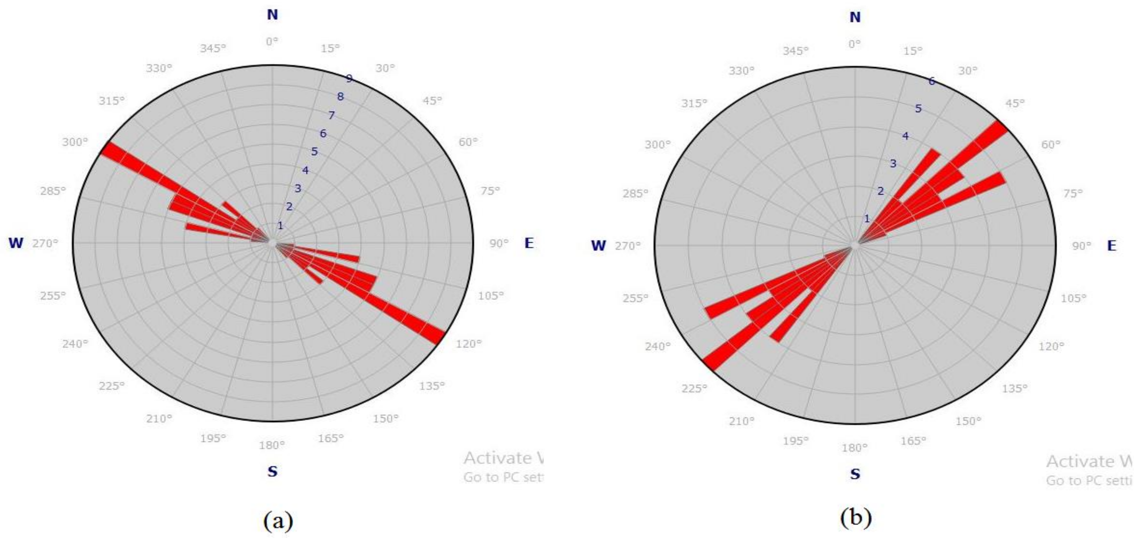

Fig. 3: Rosette diagram of veins in (a) migmatite, and (b) banded gneiss in the study area

3.2 Petrography
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Microscopic examinations of rock samples from the study area revealed the optical characteristics of respective minerals in each rock and their abundances as observed and identified. Except in aplite, quartz was the dominant mineral in rocks from the study area (Table 1), indicating that the rocks were the product of acidic magma crystallization. In Table 2 and Plate 3, the modal composition of minerals in migmatite is 62.12 % quartz, 24.50 % microcline (K-feldspar), 6.60 % biotite, 5.82 % muscovite and 0.96 % opaque minerals; the banded gneiss near Zariagi is composed of 51.83 %

quartz, 21.65 % microcline (K-Feldspar) 18.90 % biotite, 4.88 % muscovite and 2.74 % myrmekite; the banded gneiss close to Oyi-Apataoworo is composed of 58.63 % quartz, 21.58 % plagioclase, 6.47 % biotite, 7.19 % muscovite and 2.88 % opaque minerals; Charnockite indicated 50.00 % quartz, 25.26 % pyroxene, 12.89 % biotite, 8.76 % plagioclase and 3.09 % opaque minerals; and the aplite is composed of 23.14 % quartz, 57.40 % microcline (K-feldspar), 6.10 % biotite, 5.25 % perthite, 5.38 % muscovite, 1.12 % myrmekite and 1.61 accessories minerals.

Table 2: Summary of modal composition of minerals

Minerals	Migmatite		Banded gneiss (Zariagi)		Banded gneiss (Oyi)		Aplite		Charnockite	
	Total	Modal (%)	Total	Modal (%)	Total	Modal (%)	Total	Modal (%)	Total	Modal (%)
Quartz	569	62.12	170	51.83	326	58.63	172	23.14	97	50.00
Biotite	61	6.60	62	18.90	36	6.47	45	6.10	25	12.89
Plagioclase	-	-	-	-	120	21.58	-	-	17	8.76
Muscovite	55	5.82	16	4.88	40	7.19	40	5.38	-	-
Microcline	224	24.50	71	21.65	-	-	47	57.40	-	-
Perthite	-	-		0.00	-	-	39	5.25	-	-
Myrmekite	-	-	9	2.74	-	-	8	1.12	-	-
Pyroxene	-	-	-	-	-	-	-	-	49	25.26
Opaque	9	0.96	-	-	16	2.88	-	-	6	3.09
Hornblende	-	-	-	-	18	3.25	-	-	-	-
Accessories	-	-	-	-	-	-	13	1.61	-	-
Total	918	100.00	328	100.00	556	100.00	364	100.00	194	100.00

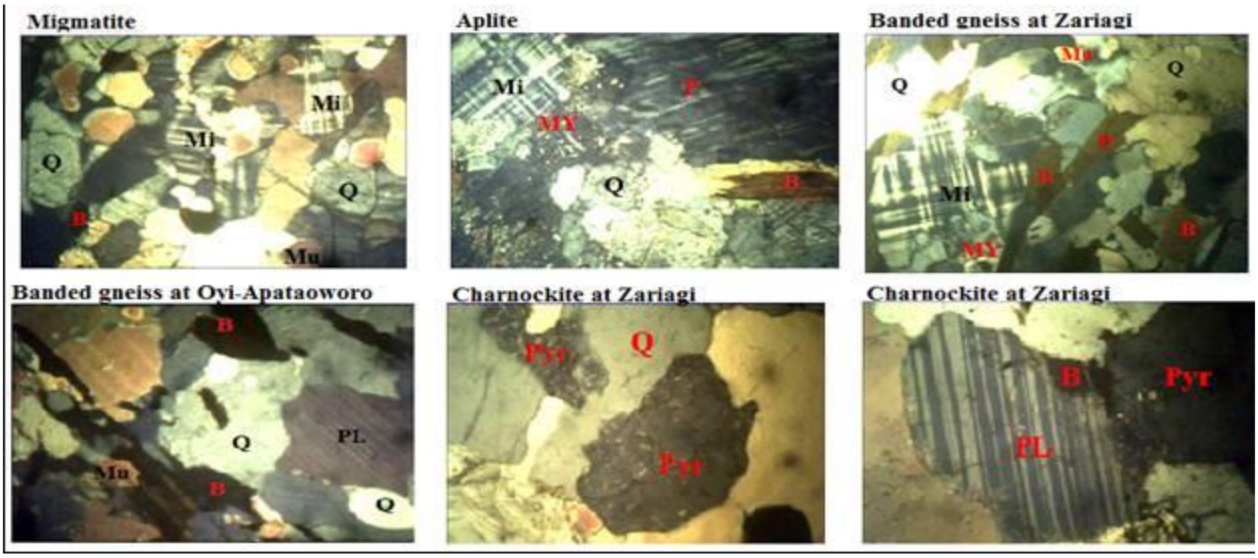

Plate 3: Photomicrograph of migmatite; XPL; X20. Where: Q = quartz, Mi = microcline, Mu = muscovite, B = Biotite, MY = Mymerkite, P = Perthite, PL = Plagioclase, and Pyr = Pyroxene

3.3 *Geochemistry*

The geochemical composition of basement rocks underlying the study area is presented in Table 3. The trend of SiO_2 content in banded gneiss near Zariagi (65.13 %), banded gneiss close to Oyi-Apataoworo (68.12 %), migmatite (69.13 %), aplite (63.16 %) rocks are similar. This variation corresponds with the abundance of quartz in the rocks, except with charnockite, which has 83.85 % SiO_2, indicating the most abundance (Tables 3 and Fig. 4). The Al_2O_3 contents are lowest (8.54 %) in charnockite, and closely ranged in banded gneiss near Zariagi settlement (14.21 %), banded gneiss close to Oyi-Apataoworo (12.36 %), migmatite (12.54 %), and aplite (15.90 %). This trend follows the abundance of muscovite content in the rocks (Table 2). The Fe_2O_3 content in banded gneiss near Zariagi is 7.03 %, while that of banded gneiss close to Oyi-Apataoworo is 8.08 %. These indicate that the abundance of Fe_2O_3 is similar and highest in banded gneiss unit. Also, the abundance of Fe_2O_3 in the different rocks (Table 3) corresponds to the amount of opaque minerals (Table 2) present in them. The MgO content in all the rocks are below the detection limit level in migmatite and banded gneiss close to Oyi-Apataoworo which indicated 2.34 % and 0.06 %, respectively. The abundance of K_2O is 10.65 % in migmatite, 8.02 % in banded gneiss near Zariagi, 9.50 % in aplite, 3.55 % in banded gneiss close to Oyi-Apataoworo, and 1.36 % in charnockite. This trend follows the abundance of potash-feldspar (microcline) content of the rocks (Table 2 and Plate 3). CaO is 1.07 % in migmatite, 2.95 % in banded gneiss near Zariagi, 4.47% in banded gneiss close to Oyi-Apataoworo, 2.95% in charnockite, and 4.03 % in aplite. Na_2O content ranged from 0.26 % in aplite to 1.61 % migmatite. Its content is generally low in all the rocks. The concentration of TiO_2, MnO and SO_3 content is low in all the rocks. However, the average composition of rocks in the Bakomba area is 69.90 % SiO_2, 12.71 % Al_2O_3, 4.50 % Fe_2O_3, 0.48 % MgO, 6.62 % K_2O, 3.09 % CaO, 1.32 % Na_2O, 0.96 % TiO_2, 0.07 % MnO and 0.34 % SO_3 (Table 3). These geochemical values compare favourably with an average chemical composition of the basement rocks from other localities within the Southwestern Basement Complex of Nigeria, such as those reported by Olatunji *et al*., (2013), Gideon, (2019) and Ngozi-Chika (2016). The concentrations of V, Cr, Co, Ni, Cu, Sr, Nb, Mo, Ag, Rb and Sn in all the rock samples are below their average crustal concentrations except, niobium (Nb) in aplitic rock and tin (Sn) in migmatite (Table 3). The aplitic rock is slightly enriched with Nb to 28 ppm as against its average crustal concentration of 20 ppm, while the migmatite is moderately enriched to 525 ppm as against its crustal average of 440 ppm (Table 3).

Table 3: Litho-geochemical composition

Major Oxides (Wt. %)	**Charnockite**	**Banded Gneiss (Zariagi)**	**Migmatite**	**Aplite**	**Banded Gneiss (Oyi)**	**Average**	**A**	**B**
SiO_2	83.85	65.13	69.26	63.16	68.12	69.90	71.89	58.50
Al_2O_3	8.54	14.21	12.54	15.90	12.36	12.71	12.63	15.80
Fe_2O_3	1.37	7.03	2.05	3.97	8.08	4.50	6.35	6.05
MgO	0.00	0.00	2.34	0.00	0.06	0.48	0.58	4.57
K_2O	1.36	8.02	10.65	9.50	3.55	6.62	3.77	2.22
CaO	2.95	2.95	1.07	4.03	4.47	3.09	2.29	6.50
Na_2O	1.54	1.34	1.61	0.26	1.84	1.32	2.29	3.06
TiO_2	0.17	1.07	0.26	2.10	1.25	0.96	0.13	1.35

MnO	0.03	0.14	0.04	0.06	0.09	0.07	0.08	4.57
SO_3	0.19	0.11	0.18	1.02	0.18	0.34		
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**			
$Na_2O + K_2O$	2.90	9.36	12.26	9.76	5.39	-	-	-
Na_2O/Al_2O_3	0.18	0.09	0.13	0.02	0.15	-	-	-
K_2O/Al_2O_3	0.16	0.56	0.85	0.60	0.29	-	-	-
Trace elements concentration in ppm								
V	6	22	24	6	16	-	-	80
Cr	56	21	27	15	50	-	-	330
Co	10	22	10	10	22	-	-	100
Ni	1	1	2	7	1	-	-	200
Cu	40	37	34	53	29	-	-	100
Sr	36	33	9	51	30	-	-	400
Nb	5	6	13	**28**	17	-	-	20
Mo	2	3	2	3	3	-	-	10
Ag	14	14	13	16	9	-	-	100
Rb	BDL	BDL	40	28	17	-	-	300
Sn	BDL	97	**513**	425	BDL	-	-	440

ND: Not Determined; BDL: Below Detection Limit, A: Average chemical composition of basements rocks within Okene metropolis, North Central, Nigeria (Gideon, 2019).
B: Average major oxides and trace element composition of the crust (Fairbridge, 1972).

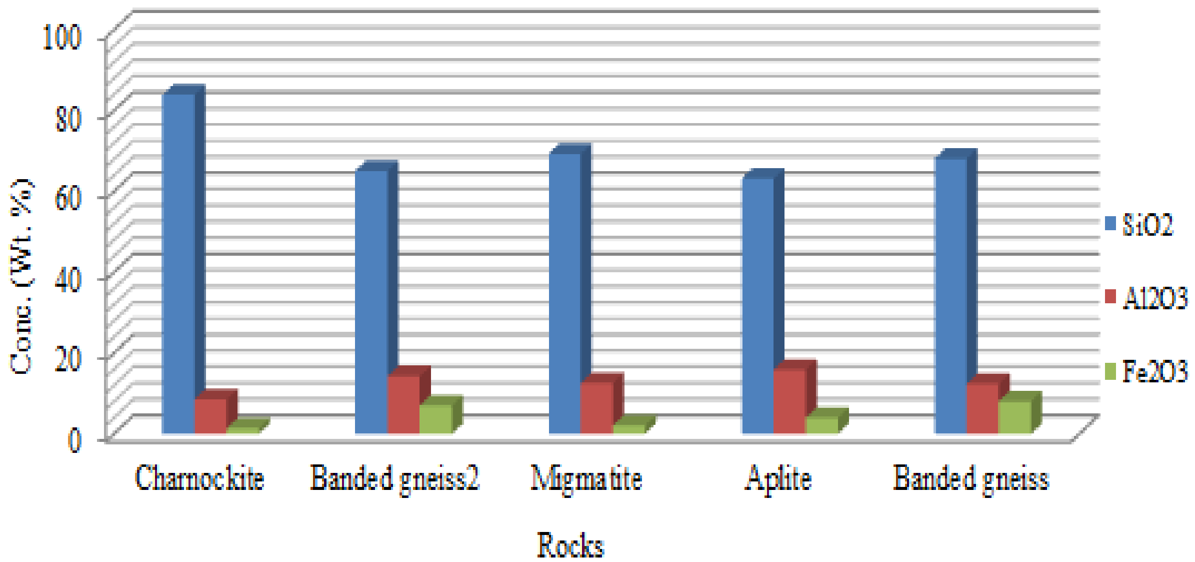

Fig. 4: Chart showing abundances of silica, alumina and iron oxide in rocks

To establish the nature and petrogenesis of the rocks, the geochemical data was plotted on various discriminatory diagrams. The plot of SiO_2 content against the concentrations of major oxides in all the rock types indicates that SiO_2 increased as other major oxides decreased, indicating high fractionation of mafic minerals (Fig. 6). The plot of K_2O/Al_2O_3 Vs Na_2O/Al_2O_3 after Garrels and McKenzie (1971) revealed that, all the rocks have an igneous origin as shown in (Fig. 7) The plot of SiO_2 Vs $Na_2O + K_2O$ after McDonald and Katsura (1954) shows that, the rocks plotted on the field of strongly alkali rocks (Fig. 8). This indicates that, the magma from which all the rocks evolved was strongly alkaline. However, based on the plot of SiO_2 Vs K_2O by Peccerio and Taylor (1976), the migmatite, aplite and banded gneiss near Zariagi settlement are of high-K alkaline series; the banded gneiss close to Oyi-Apataoworo is of medium-K alkaline series; and the charnockite is of low-K alkaline series (Fig. 9).

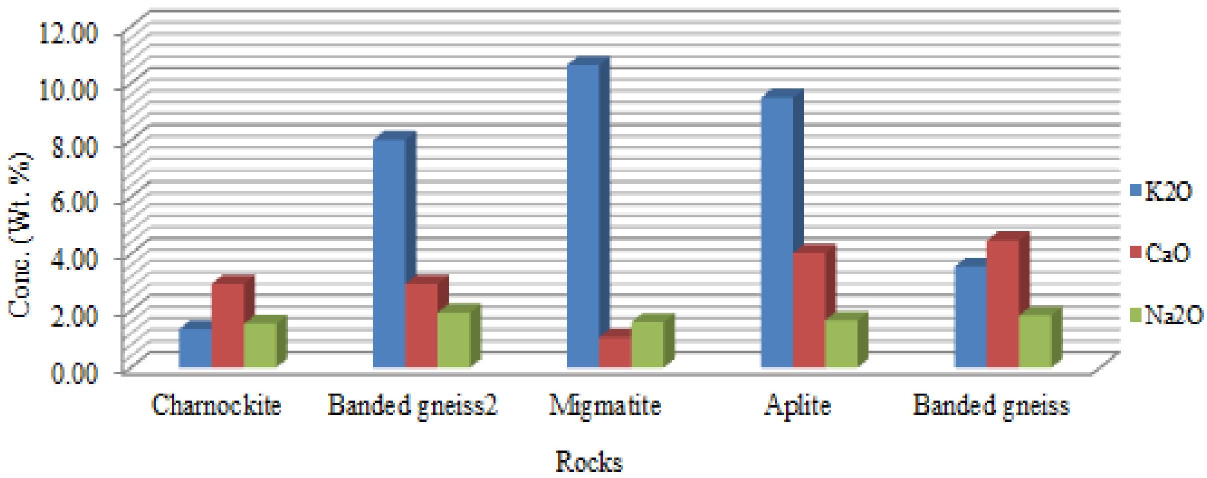

Fig. 5: Chart showing abundances of potassium, calcium and sodium oxides in rocks

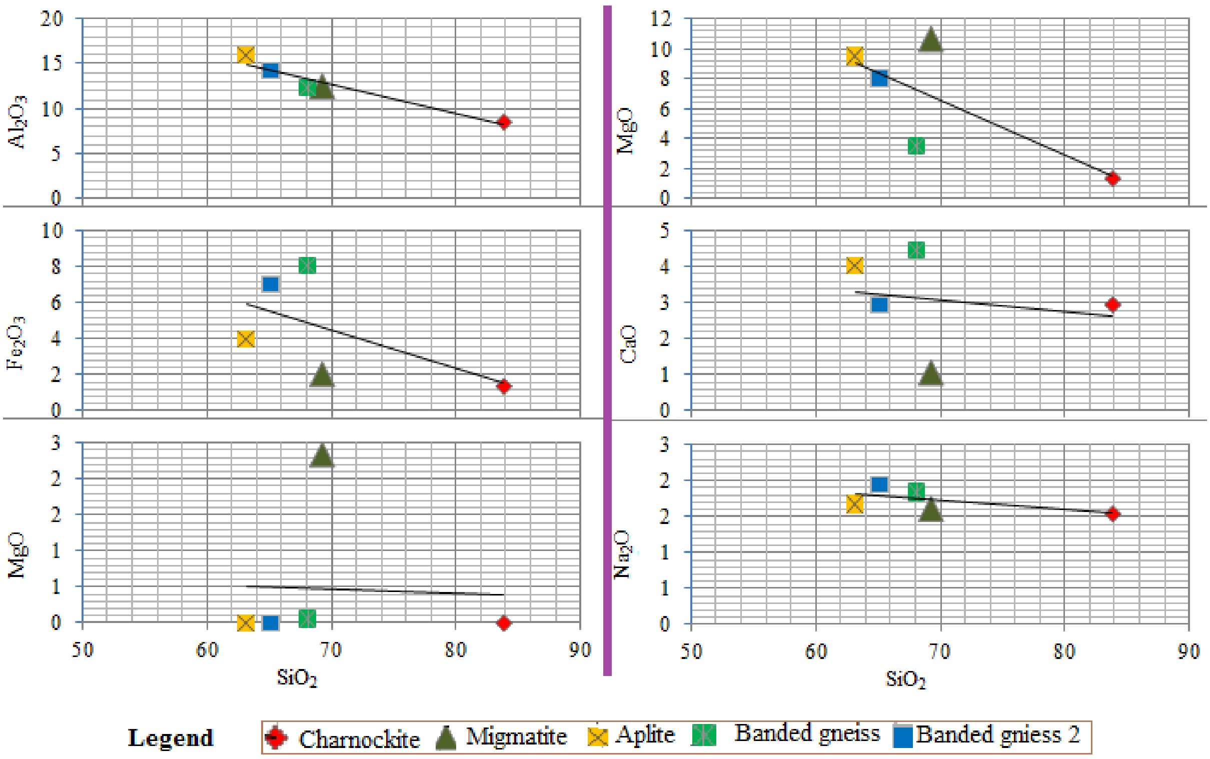

Fig. 6: Plots of SiO_2 (wt.%) against other major oxides (wt.%) in rocks

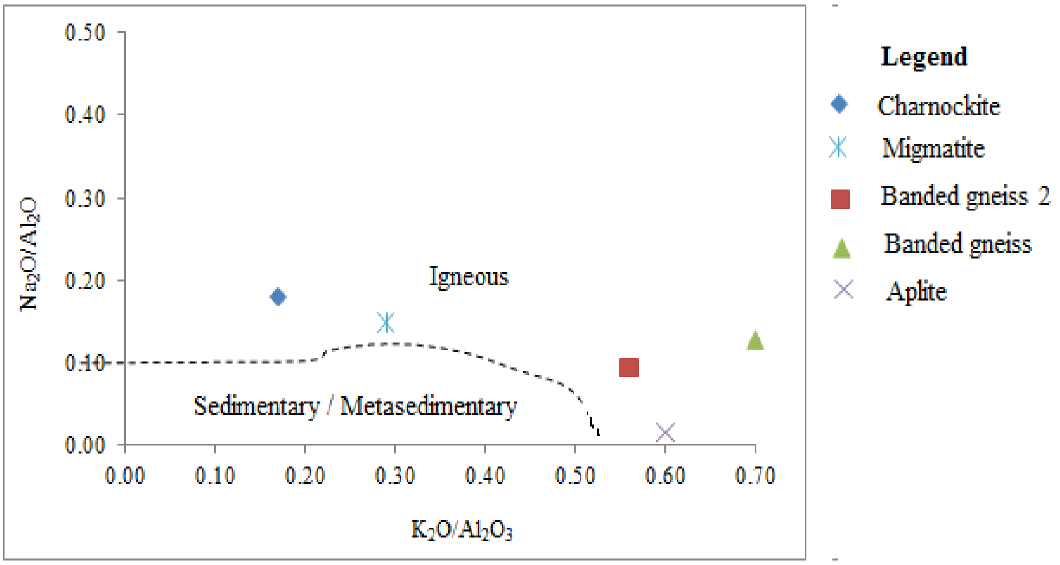

Fig. 7: Variation of concentration of K_2O/Al_2O_3 (wt.%) with Na_2O/Al_2O_3 (wt.%) (After Garrels and McKenzie, 1971).

The study area falls within the eastern flank of the South Western Basement Complex area of Nigeria and is underlain with migmatite, banded gneiss, aplite, and charnockite. Charnockitic rock was encountered on the outskirts of the Zariagi settlement in the southeastern part of the study area. The migmatite trends in the NE-SW directions, having various assemblages and sandwiched by banded gneiss. The banded gneiss is mostly equi-granular, medium-grained, and segregated into leucotome and melanosome bands. While the leucosome band contains a high percentage of quartz and feldspar, giving it a light appearance, the melanosome band consists of ferromagnesian minerals such as biotite. The texture of the pegmatite is coarse-grained and leucocratic in colour, while the aplite is fine-grained and pinkish in colour. Migmatite and banded gneiss rocks underlay more than 85 % of the study area, while the charnockite and aplite rocks share the remaining 15 % portions.

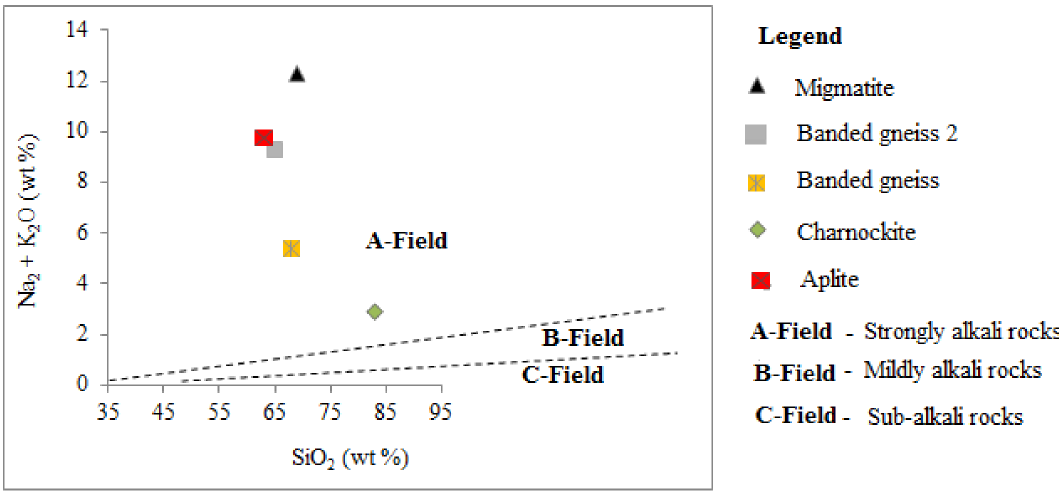

Fig. 8: Plot of SiO_2 Vs $Na_2O + K_2O$ (After McDonald and Katsura, 1954)

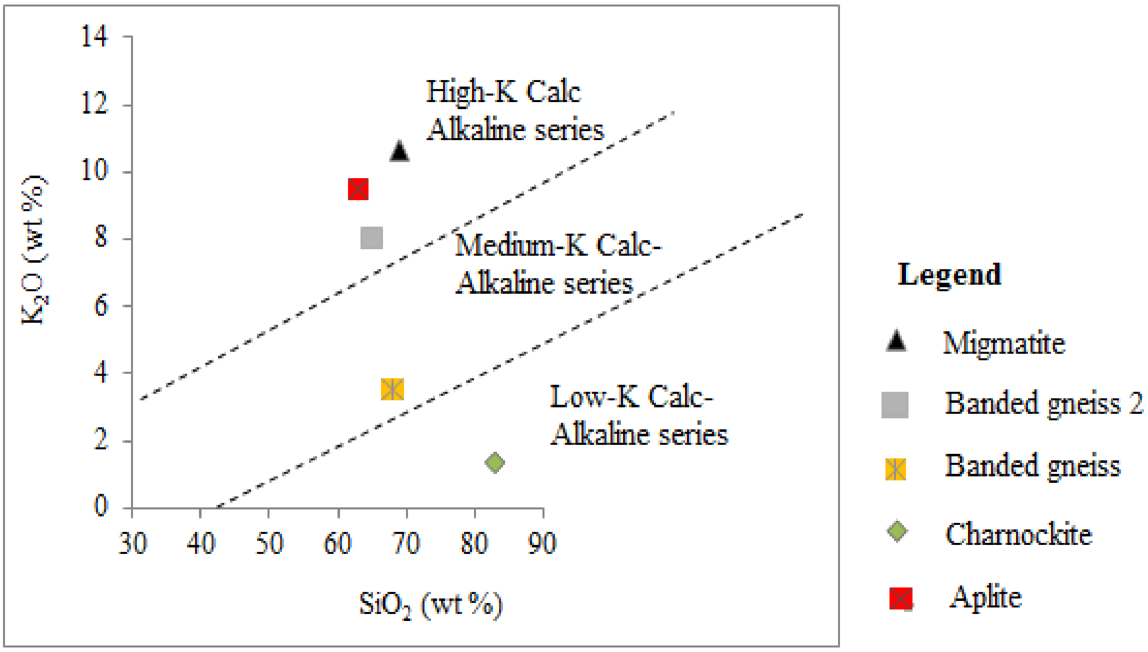

Fig. 9: Plot of SiO_2 Vs K_2O diagram (After Peccerio and Taylor, 1976)

Due to physical and environmental factors, exfoliation resulting from physical weathering was observed on the surfaces of all the encountered outcrops. Owing to deformational stresses acting on the rocks, structural elements such as open joints, healed joints, cross-cutting joints, fractures and minor folds were formed. Measured values of strike of veins and joints on outcrops of rocks were plotted using a Rosette diagram. The lineation of minerals on the outcrop of banded gneiss is dominantly in the NW-SE. The presence of varying magnitudes of fractures, veins, and joints of different dimensions and directions on the rocks is evidence of tectonic activities on the outcrops, indicating responses to deformational stresses acting on the rock bodies

Migmatite is composed of 62.12 % quartz, 24.50% potash-feldspar, 6.60 % biotite, 5.82 % muscovite and 0.96 % opaque (Table 2). The banded gneiss near Zariagi settlement is composed of 51.83% quartz, 21.65% potash-feldspar, 18.90 % biotite, 4.88% muscovite and 2.74% myrmekite minerals (Table 2). The aplite is dominated by 57.40 % potash-feldspar and 23.14% quartz. 6.10% biotite, 5.25% perthite, 5.38% muscovite. These rocks have similar feldspathic types and contents, except the aplite that is depleted in SiO_2 and enriched in potash feldspar. Whereas, the banded gneiss close to Oyi-Apataoworo is essentially composed of 58.63% quartz, 21.58% plagioclase, 6.47 % biotite, 7.19 % muscovite and 2.88% opaque minerals, and the charnockite is composed of 50.00 % quartz, 25.26% pyroxene, 12.89% biotite, 8.76% and 3.09% opaque minerals.

The average composition of the underlain rocks in the study area is 69.90 % SiO_2, 12.71 % Al_2O_3, 4.50 % Fe_2O_3, 0.48 % MgO, 6.62 % K_2O, 3.09 % CaO, 1.32 % Na_2O, 0.96 % TiO_2, 0.07 % MnO and 0.34 % SO_3 (Table 3). These values compare favourably with the average chemical composition of basement rocks within Okene metropolis, North Central, Nigeria as reported by Gideon, (2019). In Table 3, while the charnockitic rock has the most abundance (88.85 %) of SiO_2 and the least abundances of other oxides like A_2O_3 (8.84 %), Fe_2O_3 (1.37 %), MgO (0.00 %), K_2O (1.36 %), TiO_2 (0.17 %) and MnO (0.03 %), the aplitic rock unit has the least (63.16 %)

abundance of SiO_2 and high abundance of Al_2O_3 (15.94 %), Fe_2O_3 (3.97), K_2O (9.50 %), TiO_2 (2.10 %), and MnO (0.06 %). The trend of SiO_2 content against the concentrations of other major oxides in each of the rocks (Figure 3), revealed that the SiO_2 contents increased as other major oxides decreased, indicating high fractionation of mafic minerals. In Fig. 7, all the rocks underlying the study area have igneous origin using the plot of K_2O/Al_2O_3 Vs Na_2O/Al_2O_3 after Garrels and McKenzie (1971), while the plot of SiO_2 Vs Na_2O + K_2O developed by McDonald and Katsura (1954) revealed that, the magma from which all the rocks evolved was strongly alkaline (Fig. 8). However, based on the plot of SiO_2 Vs K_2O by Peccerio and Taylor (1976), the migmatite, banded gneiss near Zariagi settlement and aplite originated from high-K alkaline magma series, while the banded gneiss close to Oyi-Apataoworo originated from medium-K alkaline magma series; and the charnockite emanated from low-K alkaline magma series (Figure 9). This implied that the rock units in the Bakomba area were derived from heterogeneous alkaline magma series.

5.0 Conclusions

The geological mapping and geochemical investigation of the Bakomba-Kabba junction area revealed the following conclusions. The study

(i) The area is underlain by migmatite, banded gneiss, aplite, and charnockite rocks.
(ii) Migmatite and banded gneiss are the most abundant rocks in the area, while charnockite and aplite are less common.
(iii) Field observations indicate that the rocks were subjected to tectonic activities as evidenced by joints, veins, and folds.
(iv) Petrographic analysis revealed that quartz is the dominant mineral in all the rocks except aplite, indicating their origin from acidic magma.
(v) Geochemical analysis suggests that the rocks are igneous in origin and evolved from strongly alkaline magma.
(vi) Based on the geochemical classification diagrams, the migmatite, aplite, and banded gneiss near Zariagi crystallized from high-K alkaline magma series. The banded gneiss close to Oyi-Apataoworo originated from a medium-K alkaline magma series, while the charnockite evolved from a low-K alkaline series.
(vii) This implies that the rocks in the Bakomba-Kabba junction area were derived from heterogeneous alkaline magma series..
(viii) These rocks are composed of quartz, plagioclase, microcline, pyroxene, muscovite, biotite, hornblende and opaque minerals at varying proportions.
(ix) On average, their chemical composition indicates 69.90 % SiO_2, 12.71 % Al_2O_3, 4.50 % Fe_2O_3, 0.48 % MgO, 6.62 % K_2O, 3.09 % CaO, 1.32 % Na_2O, 0.96 % TiO_2, 0.07 % MnO and 0.34 % SO_3, suggesting high fractionation of mafic minerals of igneous origin that is strongly alkaline in nature.
(x) The variations and complexities of nature and the degree of alkalinity of magma that formed the sampled rocks implied that they were derived from heterogeneous alkaline magma series.

These findings provide valuable insights into the geological history and petrogenesis of the basement rocks in the southwestern Nigeria Basement Complex. Further studies, including radiometric dating, could be conducted to determine the age of the rocks and refine the understanding of their origin and evolution.

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Compliance with Ethical Standards Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public.

Competing interests

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Authors' Contributions

Both authors contributed equally to the design, field work and reportinh of the work