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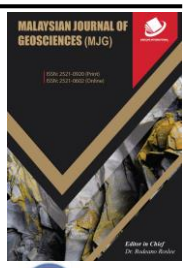

PETROLOGY AND GEOCHEMISTRY OF BASEMENT GNEISSIC ROCKS AROUND OKA-AKOKO, SOUTHWESTERN NIGERIA

Adegbuyi, O., *Ogunyele, A. C., Akinyemi, O. M.

Department of Earth Sciences, Adekunle Ajasin University, P.M.B. 001, Akungba-Akoko, Ondo State, Nigeria.
Corresponding Author's Email: abimbola.ogunyele@aaua.edu.ng

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ABSTRACT

The gneissic rocks of Oka-Akoko area forms part of the Migmatite-Gneiss-Quartzite Complex of the Southwestern Nigerian Basement Complex. The petrologic units in the study area include grey gneiss, granite gneiss, Older granite, charnockite and minor felsic and basic rocks. Twelve gneissic rock samples comprising six granite gneiss and six grey gneiss from the area were collected for petrographic and geochemical analyses. Petrographic analysis revealed that the granite gneiss is more enriched in quartz and alkali feldspar than the grey gneiss. The grey gneiss is richer in plagioclase, hornblende and opaques compared to the granite gneiss. Interpretation of petrographic and geochemical analyses results revealed that Oka-Akoko granite gneiss and grey gneiss were derived from igneous protoliths of granitic and granodioritic compositions respectively. The grey gneiss is ferroan, alkalic to alkali-calc and metaluminous suggesting that its igneous protolith(s) is a M-type granitoid derived from melting of rocks from upper mantle or lower crustal region under conditions of limited availability of H_2O and low oxygen fugacity while the granite gneiss is magnesian, alkali-calc and slightly peraluminous suggesting that its igneous protolith(s) is an I-type granitoid derived from the partial melting of crustal igneous rocks.

KEYWORDS

Basement Complex, gneissic rocks, igneous protoliths, Oka-Akoko, peraluminous.

1. INTRODUCTION

Oka-Akoko is located in Akoko Southwest Local Government Area of Ondo State, Southwestern Nigeria. The area lies within longitudes 05°46' – 05°50'E and latitudes 07°23' – 07°28'N. It is bounded in the north by Ikare-Akoko, in the west by Akungba-Akoko, in the east by Epinmi-Akoko, and in the south by Ikun- and Afo-Akoko. The area forms part of the Precambrian Basement Complex of Southwestern Nigeria (Figure 1).

The Basement Complex of Nigeria comprises mainly of the Migmatite-Gneiss-Quartzite Complex rocks of Archaean to Paleoproterozoic age (ca.>2.0 Ga), Upper Proterozoic Schist Belts and Older Granitoids of Pan-African age (500-750Ma) which intrude the former two units [1-7]. Oka-Akoko area comprises mainly of gneisses in association with porphyritic Older granite, charnockite, pegmatite, aplite, vein quartz and amphibolitic inclusions (Figure 2). The gneisses are of two types: granite gneiss and grey gneiss. [1,8] referred to grey gneiss in the area as early and quartzo-feldspathic gneiss respectively, and explained that it is granodioritic to tonalitic–quartz-dioritic in composition. The grey gneiss is the second most abundant rock type in the area forming enclaves within the granite gneiss (Figure 2). It is dark grey to dark green in colour and medium-coarse grained with well-developed thin mineralogical bands (Figure 3). The light-coloured bands are quartzo-feldspathic while the dark coloured bands are rich in ferromagnesian minerals. The grey gneiss contains intrusions of pegmatite and quartzo-feldspathic veins and is regarded as the oldest rock in the area [1].

The granite gneiss is light grey in colour, medium-coarse grained and characterised by weak foliation defined by the alignment of streaks of light and dark coloured minerals (Figure 4). The granite gneiss contains xenoliths of the grey gneiss and amphibolite. This suggests that the granite gneiss post-dates the grey gneiss in the study area.

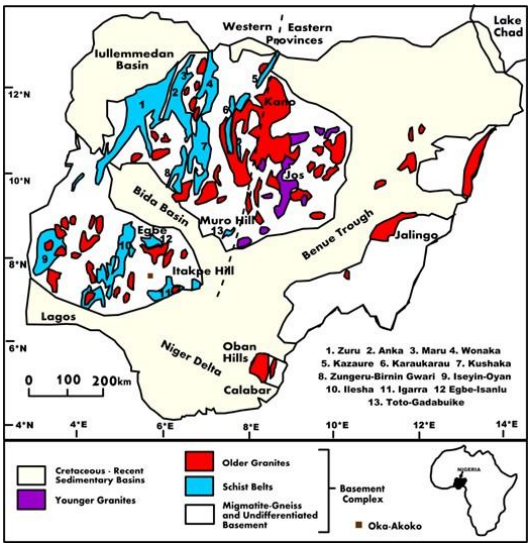

Figure 1: Outline geological map of Nigeria showing Oka-Akoko (study area) (modified after [4])

These gneisses (grey and granitic varieties) are widespread in the area constituting about 90% of the rock types found in the area and have been intruded by the Pan-African granitoids (granite, charnockite, pegmatite and aplite). They occur as massive rugged hills and rolling plains assuming batholithic dimensions and forming impressive outcrops which tower few hundred metres above the surrounding lowlands and showing different types of geological structures such as folds, faults, foliation, joints etc (Figures 3 and 4) [9]. These structures suggest that the area has been subjected to at least two phases of deformation.

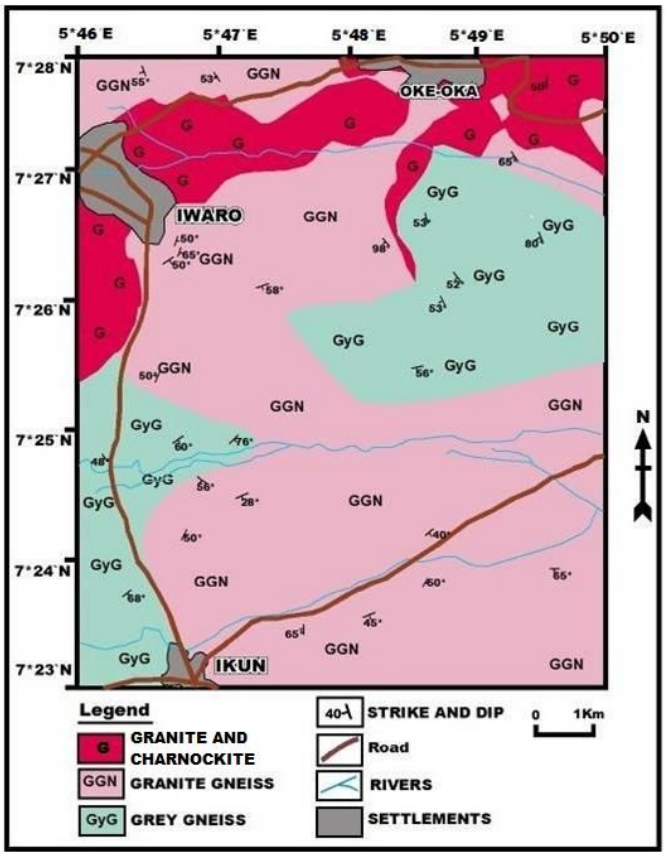

Figure 2: Geological map of Oka-Akoko

Figure 3: Folded grey gneiss intruded by pegmatites in Oka-Akoko

Figure 4: Folded and jointed granite gneiss containing inclusion of grey gneiss in Oka-Akoko

Metamorphism in the area is of amphibolite to granulite facies grade [8]. Geological studies of the area and adjacent areas such as Ikare, Arigidi and Idoani have been undertaken by several researchers [1,8,10-12].

This paper is aimed at determining the mineralogy, geochemical compositions and petrogenesis of the basement gneisses around Oka-Akoko. These characteristics of the gneisses are yet to be fully known.

2. METHODOLOGY

The study area was geologically mapped and twelve (12) fresh representative gneissic rock samples comprising six granite gneiss and six grey gneiss were collected for petrographic and geochemical studies. Thin sections of the samples were prepared and studied under a petrographic microscope. The minerals present in the thin sections were identified and counted by the microscope and photomicrographs were captured. X-Ray Fluorescence (XRF) spectrometer was used to determine the major elements present in the gneissic rocks.

Detailed processes of the methods of study are contained in [13]. The mineralogical and geochemical results were plotted on discrimination diagrams for the purpose of petrological classification, determination of chemical affinities and petrogenesis.

3. RESULTS AND DISCUSSION

Petrographic analysis results (Table 1) revealed that Oka-Akoko granite gneiss samples contain quartz (31.2–37.7 wt. %), plagioclase (17.4–23.9 wt. %), opaque minerals (2.5–6.1 wt. %), biotite (12.3–23.0 wt. %), microcline (16.6–25.2 wt. %), orthoclase (1.2–6.7 wt. %) and hornblende (2.1–7.3 wt. %). In the grey gneiss samples, the following result was obtained: quartz (27.0–28.8 wt. %), plagioclase (24.6–26.7 wt. %), opaque minerals (7.3–8.7 wt. %), biotite (11.5–16.1 wt. %), microcline (8.2–11.4 wt. %), orthoclase (4.4–6.9 wt. %) and hornblende (9.4–13.0 wt. %). QAP diagram revealed that the granite gneiss is granitic while the grey gneiss is granodioritic in composition (Figure 5) [14].

Table 1: Modal compositions of the granite gneiss and grey gneiss around Oka-Akoko (values in wt. %)

Minerals	Granite Gneiss							Grey Gneiss						
	GGN1	GGN2	GGN3	GGN4	GGN5	GGN6	Av. GGN	gGN1	gGN2	gGN3	gGN4	gGN5	gGN6	Av. gGN
Quartz	34.0	36.7	31.2	33.3	34.6	31.9	33.62	28.0	27.1	27.9	27.0	28.8	27.0	27.63
Plagioclase	17.4	23.1	21.2	22.9	19.9	18.7	20.53	24.0	26.1	24.6	26.6	26.7	26.1	25.68
Microcline	19.1	24.7	16.6	25.2	19.0	21.1	20.95	11.4	8.0	11.4	11.2	10.1	11.3	10.57
Orthoclase	2.0	1.2	5.2	1.4	2.1	6.7	3.10	5.1	4.9	6.1	4.4	6.9	5.5	5.48
Hornblende	2.1	2.1	7.1	3.8	7.3	2.4	4.13	13.0	12.1	9.4	9.8	10.1	9.5	10.65
Biotite	20.3	10.6	14.1	13.0	15.1	15.1	14.70	11.1	14.1	14.5	11.5	12.1	16.1	13.23
Opaques	5.4	3.7	4.9	2.5	3.1	6.1	4.28	8.7	7.1	8.7	7.3	7.1	7.1	7.67
Total	100.2	99.7	100.3	102.1	101.1	102.0	101.31	101.3	99.4	102.6	97.8	101.8	102.6	100.91

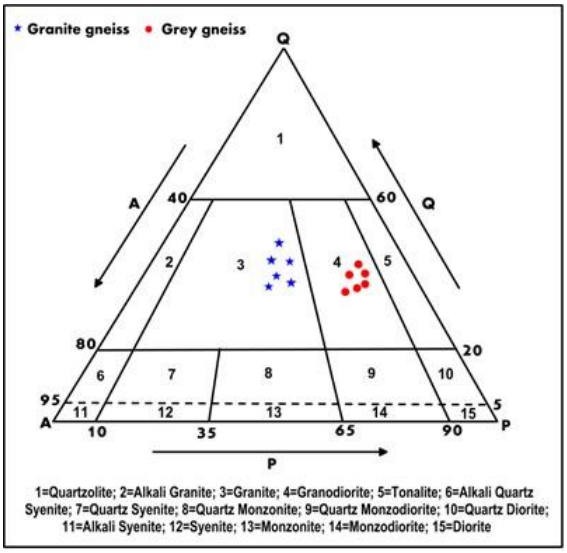

Figure 5: QAP diagram for Oka-Akoko granite gneiss and grey gneiss [14]

Geochemical analysis result (Table 2) shows that the granite gneiss of Oka-Akoko contain predominantly SiO_2 (65.34–69.78 wt. %), Al_2O_3 (15.68–17.46 wt. %), K_2O (4.33–4.67 wt. %), Na_2O (3.62–4.42 wt. %), FeO (1.33–2.03 wt. %) and Fe_2O_3 (1.01–1.74 wt. %) while the grey gneiss contains mainly SiO_2 (59.49–62.76 wt. %), Al_2O_3 (15.67–18.66 wt. %), Na_2O (4.31–5.31 wt. %), K_2O (3.12–5.65 wt. %), Fe_2O_3 (2.67–5.53 wt. %), FeO (2.11–3.67 wt. %) and CaO (2.63–4.53 wt. %).

The granite gneiss of Oka-Akoko is more silicic than the grey gneiss. Hence, based on silica content, the granite gneiss is silicic or acidic while the grey gneiss is intermediate in composition. This further supports the granitic nature of the granite gneiss and granodioritic composition of the grey gneiss as revealed by the QAP diagram (Figure 5). Also, the granite gneiss contains more K_2O than the grey gneiss and this is reflected in the higher amount of K-feldspars (microcline and orthoclase) present in the former than the latter. However, the grey gneiss contains more TiO_2, Al_2O_3, FeOtotal, MgO, CaO, and Na_2O than the granite gneiss and this account for the higher amount of opaques (iron minerals and others), hornblende, and plagioclase in the grey gneiss than the granite gneiss.

Table 2: Major element compositions of granite gneiss and grey gneiss around Oka-Akoko (values in wt. %)

Major Oxides	Granite Gneiss						Grey Gneiss					
	GGN1	GGN2	GGN3	GGN4	GGN5	GGN6	gGN1	gGN2	gGN3	gGN4	gGN5	gGN6
SiO_2	66.72	65.34	69.78	66.73	66.40	68.10	62.66	60.76	59.49	62.60	59.50	62.76
TiO_2	0.44	0.41	0.4	0.43	0.46	0.40	0.41	0.93	1.04	0.81	0.50	0.90
Al_2O_3	16.52	17.46	15.68	17.43	16.68	16.73	15.73	17.82	18.66	15.67	17.50	17.70
Fe_2O_3	1.63	1.74	1.01	1.64	1.33	1.80	2.67	2.53	2.87	4.10	5.53	3.32
FeO	2.03	1.98	1.33	1.33	2.07	1.52	3.67	4.33	3.97	2.34	3.23	2.11
MnO	0.05	0.07	0.25	0.31	0.10	0.09	0.11	0.11	0.12	0.11	0.13	0.12
MgO	1.00	1.22	0.68	0.81	1.21	0.98	0.66	1.67	1.29	1.70	1.31	1.10
CaO	2.62	2.74	1.58	2.22	2.35	1.38	2.63	4.12	4.43	2.84	4.53	2.63
Na_2O	4.40	3.78	4.42	4.40	4.42	3.62	5.31	4.31	4.33	4.40	4.31	5.31
K_2O	4.33	4.57	4.35	4.33	4.67	4.66	4.65	3.12	3.74	5.65	4.43	3.34
P_2O_5	0.17	0.18	0.16	0.15	0.16	0.14	0.12	0.12	0.11	0.12	0.11	0.11
LOI	0.11	0.33	0.23	0.19	0.13	0.43	0.71	0.91	0.10	0.12	0.20	0.48
TOTAL	100.02	99.82	99.88	99.79	99.98	99.85	99.33	99.81	99.99	100.34	101.28	99.98

Oka-Akoko granite gneiss has lower silica content than the Arigidi, Ilesha, Jebba and Idofin-Osi-Eruku granite gneisses but higher silica content than the NE Obudu granitic gneiss (Table 3) [11,15-18]. The Al_2O_3 and total alkali (Na_2O + K_2O) contents of Oka-Akoko granite gneiss is higher than that of Arigidi, Ilesha, Jebba, Idofin-Osi-Eruku and NE Obudu granitic gneisses indicating its higher peraluminous and alkaline nature.

The major element composition of Oka-Akoko granite gneiss is very similar to that of Idofin-Osi-Eruku and Arigidi-Akoko granite gneisses; however, the latter is less alkaline and aluminous and contains more cafemic oxides (CaO, FeO_{total}, and MgO). The Kabala grey gneiss and Idofin-Osi-Eruku early or grey gneiss are more siliceous and sodic than the Oka-Akoko grey gneiss but the latter has higher TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, K_2O and CaO than the Kabala and Idofin-Osi-Eruku grey gneisses [19].

Discrimination diagrams of Garrel & McKenzie and Tarney indicate that all Oka-Akoko granite gneiss and grey gneiss samples show preference for igneous field, hence, they are of igneous origin (Figures 6 and 7) [20,21]. K_2O versus Na_2O discrimination diagram of Middleton also confirms that the protoliths of both the granite gneiss and grey gneiss are magmatic rocks because they plot outside the eugeosynclinal field (Figure 8) which represents sedimentary protoliths field [22].

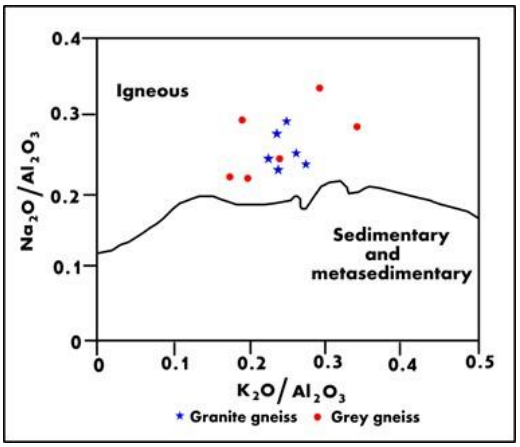

Figure 6: Na_2O/Al_2O_3 versus K_2O/Al_2O_3 discrimination diagram for Oka-Akoko granite gneiss and grey gneiss [20]

Table 3: Comparism of average major element composition of the granite gneiss and grey gneiss of Oka-Akoko with similar rocks from other parts of Nigeria

Major Oxides	1	2	3	4	5	6	7	8	9
SiO_2	67.18	70.92	75.79	76.11	60.82	68.86	61.30	66.34	70.41
TiO_2	0.42	0.45	0.03	0.29	0.67	0.40	0.88	0.59	0.33
Al_2O_3	16.75	13.09	11.80	11.83	15.08	15.10	17.26	15.91	14.82
Fe_2O_3	1.53	2.32	1.53	2.82	5.39	3.45	3.50	2.26	3.17
FeO	1.71	3.76	-	-	-	-	3.28	2.04	-
MnO	0.15	0.32	0.02	0.02	0.06	0.06	0.12	0.08	0.06
MgO	1.00	1.11	0.44	0.11	1.35	1.04	1.17	1.29	0.17
CaO	2.15	3.20	0.44	0.42	3.09	2.49	3.53	3.28	3.32
Na_2O	4.17	1.81	1.60	3.53	3.37	3.41	4.67	5.22	4.81
K_2O	4.49	1.45	6.58	4.43	4.55	4.27	4.16	1.61	1.62
P_2O_5	0.16	-	0.06	0.03	0.42	0.11	0.12	0.15	0.13
LOI	0.24	-	1.14	0.35	0.60	-	0.42	0.61	-
TOTAL	99.95	98.43	99.43	99.94	99.40	99.19	100.39	99.47	99.38

1 = Average major element composition of Oka-Akoko granite gneiss (present work).

2 = Average major element composition of Arigidi-Akoko granite gneiss, Southwestern Nigeria [11]

3 = Average chemical composition of granitic gneiss of Ilesha schist belt, Southwestern Nigeria [15].

4 = Average major element composition of granitic gneiss of Jebba area, Southwestern Nigeria [16].

5 = Average major element composition of granitic gneiss of NE Obudu, Southeastern Nigeria [18].

6 = Average major element composition of granite gneiss of Idofin-Osi-Eruku area, Southwestern Nigeria [17].

7 = Average major element composition of Oka-Akoko grey gneiss (present work).

8 = Average chemical composition of Kabala migmatitic grey gneisses, Northwestern Nigeria [19].

9 = Average chemical composition of early gneiss of Idofin-Osi-Eruku area, Southwestern Nigeria [17].

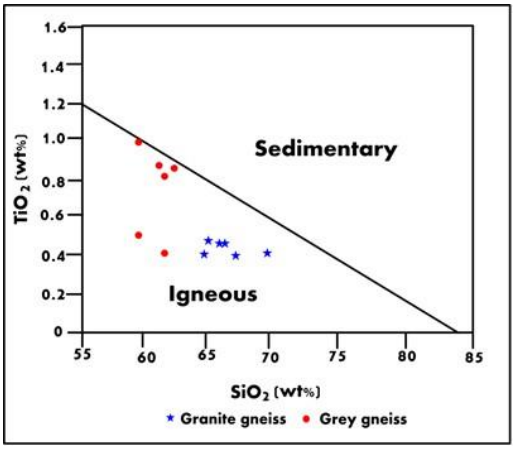

Figure 7: TiO_2 versus SiO_2 discrimination diagram for Oka-Akoko granite gneiss and grey gneiss [21]

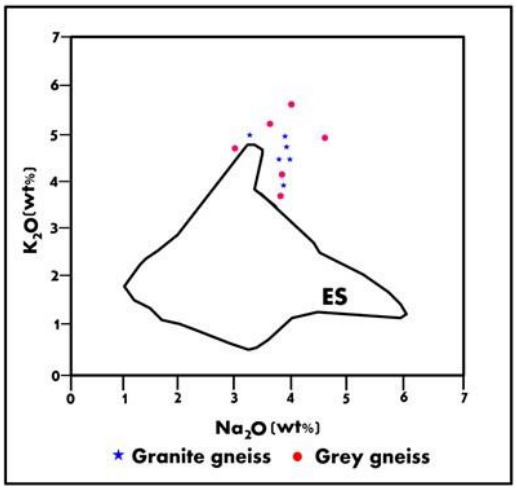

Figure 8: K_2O versus Na_2O discrimination diagram for Oka-Akoko granite gneiss and grey gneiss [22]

On the K_2O versus SiO_2 plot, both the granite gneiss and grey gneiss plot dominantly in the shoshonitic field due to their enrichment in K_2O (Figure 9) [23]. The discrimination plot of Irvine and Baragar shows that the granite gneiss is sub-alkaline while the grey gneiss is sub-alkaline to alkaline (Figure 10) [24]. The grey gneiss is ferroan (that is, FeO_{total} enriched) while the granite gneiss is magnesian (MgO enriched) as revealed by the $FeO_{total}/(FeO_{total} + MgO)$ versus SiO_2 diagram (Figure 11) [25]. Ferroan rocks are usually associated with conditions of limited availability of H_2O and low oxygen fugacity [25].

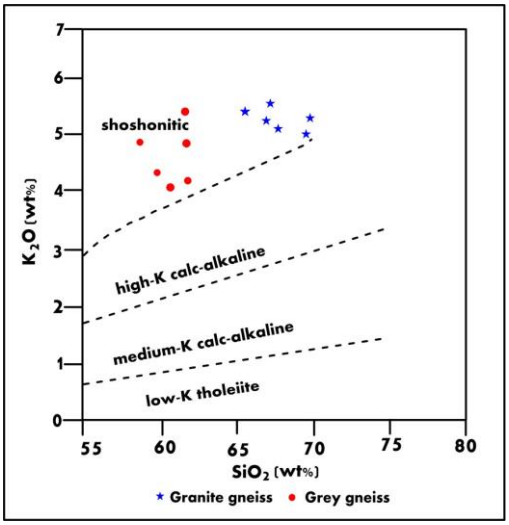

Figure 9: K_2O versus SiO_2 plot for Oka-Akoko granite gneiss and grey gneiss [23]

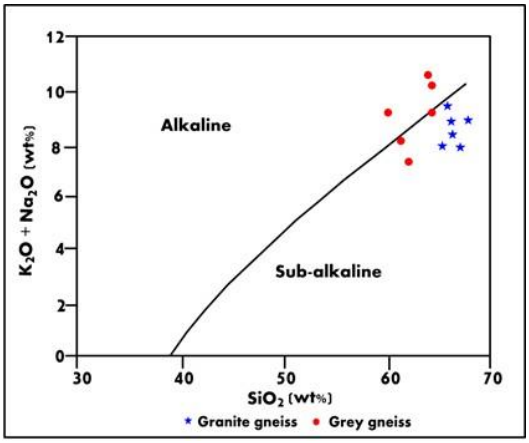

Figure 10: $K_2O + Na_2O$ against SiO_2 plot for Oka-Akoko granite gneiss and grey gneiss [24]

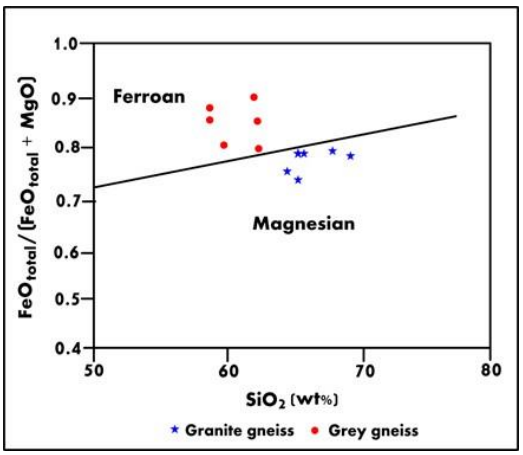

Figure 11: $FeO_{total}/(FeO_{total} + MgO)$ vs. SiO_2 diagram for Oka-Akoko [25]

Furthermore, Oka-Akoko granite gneiss is alkali-calcic while the grey gneiss is alkalic to alkali-calcic as revealed by the $Na_2O + K_2O$ - CaO against SiO2 diagram (Figure 12) [25]. The granite gneiss plots in the peraluminous field while the grey gneiss plots in the metaluminous field on the $Al_2O_3/(Na_2O + K_2O)$ against $Al_2O_3/(Na_2O + K_2O + CaO)$ molecular diagram of Maniar and Piccoli (Figure 13) [26]. The metaluminous nature of the grey gneiss coupled with its ferroan and alkalic to alkali- calc characteristics suggest that its igneous protolith(s) is a M-type granitoid derived from melting of rocks of upper mantle or deeper crustal region under conditions of limited availability of H_2O and low oxygen fugacity [25,27,28]. The protolith(s) of the granite gneiss is inferred to be I-type granitoid derived from the partial melting of crustal igneous rocks as revealed by its slight peraluminous nature (Figure 14).

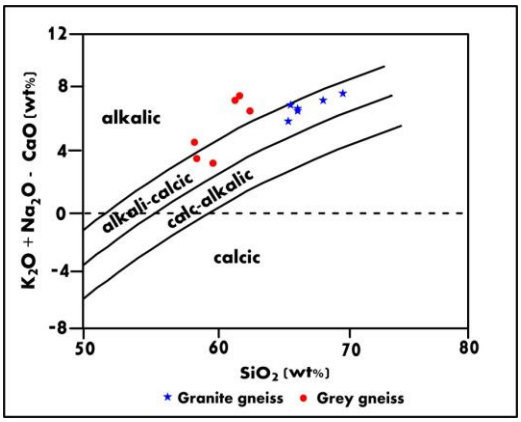

Figure 12: $K_2O + Na_2O$ - CaO versus SiO_2 plot for Oka-Akoko granite gneiss and grey gneiss [25]

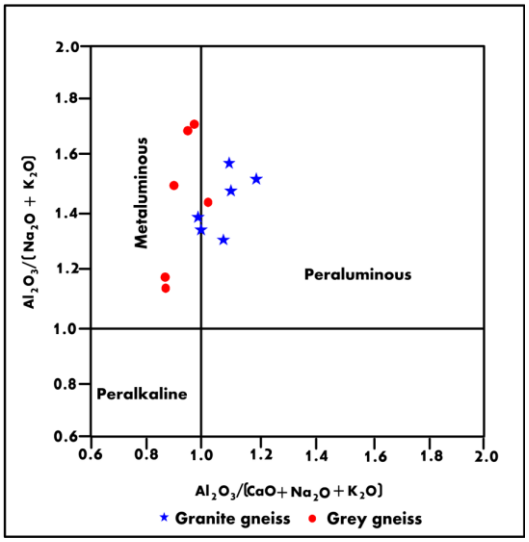

Figure 13: $Al_2O_3/(Na_2O + K_2O)$ versus $Al_2O_3/(CaO + Na_2O + K_2O)$ molecular plot for Oka-Akoko granite gneiss and grey gneiss [26]

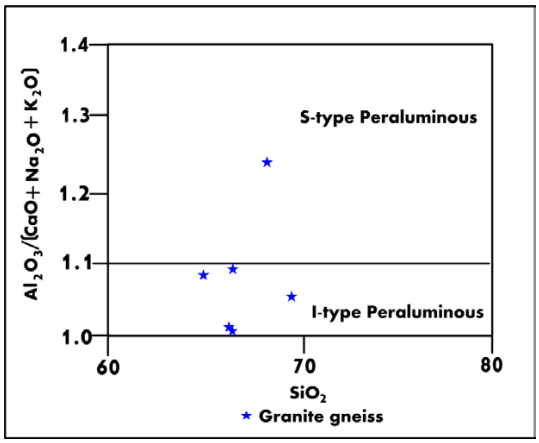

Figure 14: $Al_2O_3/(CaO + Na_2O + K_2O)$ versus SiO_2 plot for Oka-Akoko granite gneiss [29]

The results obtained from this study correlates with the works of [1,8] on the basement gneissic rocks of Ikare area, Southwestern Nigeria. The Oka-Akoko grey gneiss is similar in composition to the Kabala gneiss which is granodioritic [19]. The granite gneiss of Oka-Akoko is similar to Idofin-Osi-Eruku and Jebba granite gneisses which are also peraluminous, potassic, calcic to alkalic and silica-rich and inferred to be products of partial melting of crustal rocks [16,17].

4. CONCLUSION

This study shows that the granite gneiss and grey gneiss of Oka-Akoko are orthogneisses of granitic and granodioritic compositions respectively. The grey gneiss is ferroan, alkalic to alkali-calc and metaluminous suggesting that its igneous protolith(s) is a M-type granitoid derived from melting of rocks from upper mantle or lower crustal region under conditions of limited availability of H_2O and low oxygen fugacity while the granite gneiss is magnesian, alkali-calc and slightly peraluminous suggesting that its igneous protolith(s) is an I-type granitoid derived from partial melting of crustal igneous rocks.

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