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Research Article

PETROGRAPHY AND GEOCHEMICAL CHARACTERIZATION OF BASEMENT ROCKS WITHIN OKENE METROPOLIS, NORTH CENTRAL NIGERIA

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ABSTRACT

Petrographic studies and major elements geochemistry of rocks from Okene metropolis were carried out to determine their mineral composition and petrogenesis. Okene area is underlain primarily by the southwestern Basement Complex rocks of Nigeria. Migmatite, granite, charnockite, hornblende biotite gneiss, melanocratic banded gneiss, leucocratic biotite gneiss, quartzo-feldspathic gneiss and pegmatite dyke were identified. Thin section of four (4) representative samples of each rock unit were prepared and examined. The average modal composition of the rocks consists 47% Quartz, 14% biotite, 5% muscovite, 13% microcline, 7% plagioclase, 5% hornblende, 6% opaque and 2% accessories minerals. These averages compared favourably with the modal composition of similar rock types from other locations within the southwestern basement complex. Thirty-five (35) rock samples collected from eight (8) different rock types were analysed using EDXRF method. Major oxides composition of the rocks within Okene metropolis consists 71.89% SiO_2, 12.63% Al_2O_3, 6.35% Fe_2O_3, 0.58% MgO, 3.77% K_2O, 2.61% CaO, 0.37% P_2O_5, 0.08 % MnO and 0.13% TiO_2. The chemical data plots in the igneous field on the Na_2O/Al_2O_3 versus $K2O/Al_2O_3$, indicating that they are of igneous origin, while Na_2O + K_2O (wt. %) versus SiO_2 discriminated the rocks into high alumina, alkaline and theoleitic composition.

INTRODUCTION

Geologically, Nigeria is made up of three major geological components which includes the Pre-Cambrian Basement Complex, the Jurassic Granites and Sedimentary Basins which are of Cretaceous to recent in age. The Geology of Nigeria is dominated by crystalline and sedimentary rocks, both occurring approximately in equal proportions (Woakes *et al*., 1987). Okene metropolis is underlain primarily by the southwestern basement complex rocks of Nigeria, which consists of major rock types like migmatites, banded gneiss, Pan-African granite, charnockite and biotite gneiss (Rahaman, 1976). The area is also termed by some workers as migmatite-gneiss-quartzite complex, with ages ranging from Pan African to Eburnean (Rahaman, 1976 and Dada, 1989). Most of the research works carried out around the study area were on geophysical assessment of the groundwater potential and hydrogeochemistry (Owoade *et al*., 1989), origin and chemistry of Itakpe iron-ore deposit and its associated influence on the environmental media (Adegbuyi, 1990), regional geochemical evolution of Pan-African migmatite rock from the basement rocks from Igarra-Okene axis (Odigi, 1993), and thermo-tectonic evolution of the basement complex around Okene-area (Annor and Freeth, 1985). Furthermore, the basement rocks in the area had regionally been described in the past by previous workers: Jones and Hockey (1964), grant *et al*., (1972), Odigi *et al*., (1993), and Pearce and Gale (1977). This study therefore is to characterize the major basement rocks within Okene metropolis and environs based on mineralogy and geochemical composition of the rocks.

STUDY AREA

Okene metropolis covers three Local Government Areas, namely: Adavi, Okehi and Okene (Fig.1). the study area covers about 54 km^2 that is situated between Latitudes 7^0 30′ 15″ and 7^0 38′ 25″ N and Longitudes 6^0 7′ 25″ and 6^0 16′ 48″ E (Fig. 2). It falls within the tropical or woodland and tall grass Savannah climate zone, which is influenced by two climatic conditions of rain and dry seasons. It has a temperature range of 18.45 °C (65.21 °F) to 36.9 °C (98.4 °F) and an annual rainfall of about 1,500 mm (59.1 in) (Ogbonna *et al*., 2006). The rainy season usually starts in 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 (Aremu *et al*., 2014). The area is covered by grasses, shrubs and tall to medium-height trees (Ogbonna *et al*., 2006). Most of the rivers within the study area are perennial, and due to the nature of the topography and geological structures, they flow in different directions. Hence, the pattern of drainage system in the area could be described as radial. Popular hills are, Oborenyi, Okunchi, Anyioke, Atami and Odunmi. The ridges predominantly trends in the NW-SE direction.

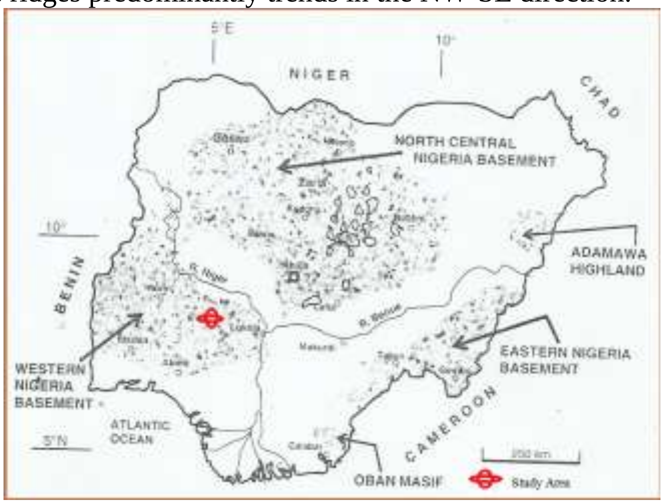


Figure 1: Basement Complex Geology of Nigeria (Modified after Obaje, 2009)

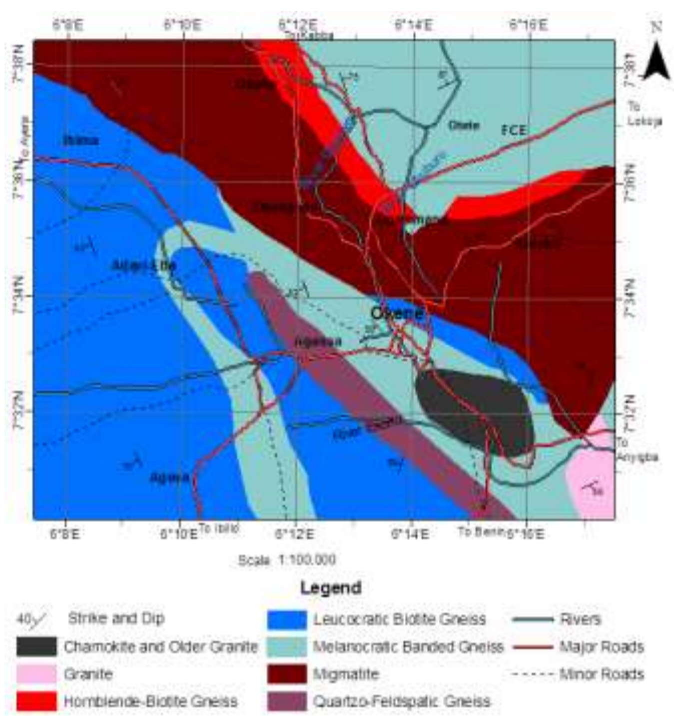
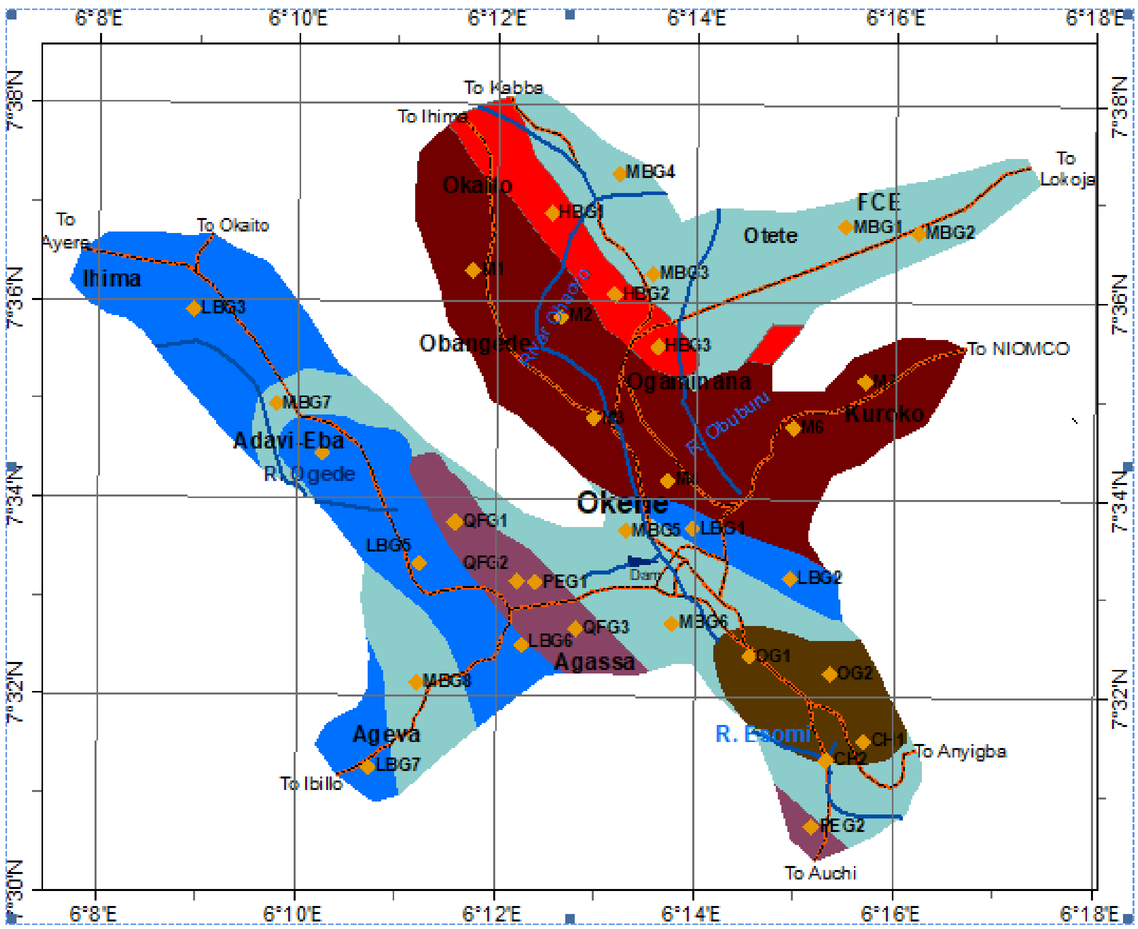


Figure 2: Geological map of Okene and environs (Modified after, Adegbuyi, 1981)

GEOLOGY OF THE STUDY AREA

Okene metropolis is underlain by Archaean-Early Proterozoic Basement Complex rocks of southwestern Nigeria according to Clark (1985), Alagbe & Raji (1990) and Oyinloye & Ademilua (2005) as shown in Figure 1. Oversby (1975) and Olarewaju (1981) reported that the area is dominantly underlain by Precambrian basement complex and composed of migmatite-gneiss complex with supracrustal rocks. Rahaman (1976) reported that the south western basement complex of Nigeria lies within the rest of the Precambrian rocks in Nigeria. He grouped the rocks in the entire region as migmatite –gneiss complex comprising largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes. Odeyemi (1999) suggested that, almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusive are tectonic in origin, because pre-existing primary structures have been obliterated by-subsequent deformation.



Scale 1:100,000

Legend

Charnockite and older granite	Melanocratic banded gneiss
Hornblende-biotite gneiss	Migmatite
Leucocratic biotite gneiss	Quartzo-feldspatic gneiss
Rivers_	Major-Roads
Rock sample locations	

Figure 3: Geological map of Okene metropolis showing rock sample locations

MATERIALS AND METHODS

Methods of investigation involved field study, laboratory analyses and geochemical data evaluation. Geological mapping involving traverse method and collection of representative rock samples from outcrops was employed. The various rock types within the study area were identified and systematically sampled at outcrops. At each sampling point, weathered surfaces were avoided, fresh representative rock samples were sampled, packaged in new polythene sample bag and labelled. Structural observations such as general trend/ strike and dip directions, folds, joints and structural measurements of strike, amount of dip, and extent of other intrusive bodies were taken on each outcrop where rock samples were collected. A total number of thirty-five (35) rock samples which include 8 melanocratic banded gneiss (MBG), 7 leucocratic biotite gneiss (LBG), 3 hornblende-biotite gneiss (HBG), 3 quartzo-feldspathic gneiss (QFG), 7 migmatite (M), 3 pegmatite (PEG), 2 charnockite (CH) and 2 granite (OG) were obtained within the study area (Fig. 3). The rock samples were described megascopically in the field and then prepared into thin sections by mounting each rock slice on glass slide with Canada balsam. The petrographic analysis was carried out in Petrology laboratory, Department of Earth Sciences, Kogi State University, Anyigba, Nigeria. In order to determine the chemical compositions of the rocks, samples were crushed, grinded and pulverized using agate wares. Each ground sample was homogenized; ground until no grains larger than 60 µm was left, and pressed into pellet with deionized water. The pelletized samples were then air-dried and introduced into the vacuum chamber of Energy Dispersion X-ray Fluorescence Spectrometer (EDXRF), Model EDS3600B, at Centre for Nanotechnology and Advanced Material, Akure, Ondo State, Nigeria.

RESULTS AND DISCUSSION

FIELD STUDIES

Field observations indicate that the basement rocks have been subjected to many episodes of deformation. Major rock types in the area are migmatites, banded gneiss and biotite gneiss (Fig. 3). Minor occurrences of pegmatite dyke, and quartzo-feldspathic veins were found in the area. Migmatite and biotite gneiss are the most wide spread rock type. They were exposed as high outcrop, and seen in river channels as highly weathered rocks. Gneisses and Migmatite rocks cover over 75 % of the study area (Fig. 3) into which the other successions of rocks have been emplaced. Typical outcrops of migmatites and gneisses within Okene metropolis are presented in Figures 4(a–f). The gneisses are segregated into the leucosome and melanosome bands. The rocks trends in NW-SE direction and generally dips to the west. The presence of varying magnitudes of folds, joints and faults as well as Quartzo-feldspatic veins of different dimensions and directions (mostly north-south) on the rocks are evidences of metamorphism and tectonic activities. The mega-veins are mostly in N-S direction. The leucocratic biotite gneiss contains high percentage of quartz, attributable to its light appearance, while the melanocratic banded gneiss is more of ferromagnesian minerals. The rocks are mostly equi-granular coarse-medium grained granitic texture. Biotite gneiss was observed to have fairly regular banding which could have resulted from mineral segregation in which predominantly dark bands vary in thickness from a few millimetres to several centimetres. Isolated charnockitic and older granite rocks were encountered in the SSE portion of the study area. The duo was well exposed in River Esomi channel along Okene-Auchi road. Pegmatite occurred as veins, cutting across the migmatite gneiss complex. They have an average strike of 45^0 NW-SE and are exposed along stream channels and road. No schistose rock was encountered.

PETROGRAPHY

Major constituents of rocks from Okene metropolis consists of quartz, biotite, microcline plagioclase, muscovite, hornblende, pyroxene and some accessories minerals at varying percentages based on microscopic studies. These minerals were observed to be made up of different proportions in the rock samples. Table 1 shows the modal composition of each of the rock unit. Quartz occurs as granoblastic and

anhedral crystals with well-defined outlines. It exhibits weak birefringence, low relief with wavy extinction. Few grains however appear cloudy. Microcline occurs as large euhedral crystals exhibiting cross hatched twining. Biotite content is relatively high, and they occur in oriented masses, with good mineral alignment. The polysynthetic twinning of plagioclase was conspicuous in the pegmatite and melanocratic banded gneiss (Fig. 5a & 5e). The quartz, plagioclase and microcline in the rock samples generally appeared colourless under plane polarized light. Biotite mineral exhibited Pleochroism,
going from light to dark grey as the stage is rotated. Other minor components include ferromagnesian minerals like hornblende (Fig. 4f). The quartz which is in relatively high proportion (33% - 67%) was

Figure 4: Showing rocks in the study area: (a) melanocratic banded gneiss (b) hornblende-biotite gneiss, (c) migmatite, (d) leucocratic banded gneiss, (e) quartzo-feldspathic gneiss and (f) pegmatite

observed to occur in two generations. The early quartz forms rounded inclusions in plagioclase or microcline crystals and tend to be interstitial in the quartz feldspar mosaic, (otherwise called mymerrkitised). The later generation forms large compound crystals that appear to have been super imposed on the general fabric. Alternation of biotite is common as the gneisses shows biotite bands with porphyroblastic quartz in a finer matrix. The green hornblende is associated with biotite in the melanocratic bands. Modal composition of granite and pegmatite ranged from 33-67% quartz, 13-14% biotite, 1-35% plagioclase, 4-11% microcline, 5-8% opaque and 3-6% accessories. It was observed that granite has the highest quartz content of 67%, while pegmatite has the least (42%) content of the mineral. The charnockite (CH) is composed of 46% quartz, 32% microcline, 10% pyroxene and 5% opaque minerals. The low quartz content of 42% in melanocratic banded gneiss coupled with its high biotite value of 30% and hornblende value of 12%, probably explains the mafic colour of the rock and its black bands. Pegmatite and charnockite occur as minor rock at the southern part of the study area. The pegmatite is rich in plagioclase feldspar (35%), while the charnockite shows 32% microcline feldspar, with no plagioclase mineral. The leucosome bands are made up of quartz, muscovite, and alkali feldspar; while the melanosome bands consist of plagioclase feldspar, biotite and hornblende. Quartz and feldspars (plagioclase and Microcline) alone constitute up to 65% volume fractions of the rock in thin section (Table 1). Feldspar is second to quartz in abundance, while minerals such as garnet and magnetite constitute the opaque minerals. However, the average modal composition of rocks within the study area consists of 47% Quartz, 14% biotite, 5% muscovite, 13% microcline and 7% plagioclase, 5% hornblende, 6% opaque and 2% accessories minerals (Table 1). This average compared favourably with the modal composition of similar rock types from other locations within the southwestern basement complex.

Table 1: Modal composition of major rocks from Okene compared with other similar rock types

Minerals	M	QFG	MBG	HBG	LBG	CH	G	PEG	Average	A	B	C	D	E
Quartz	51	48	42	43	42	46	67	33	47	40	35	30	39	30
Biotite	9	5	30	15	22	7	13	14	14	15	15	2	5	5
Microcline	22	27	-	-	10	32	11	4	13	20	10	28	43	39
Plagioclase	-	-	11	8	-	-	1	35	7	20	26	35	12	12
Muscovite	9	16	-	-	17	-	-	-	5	-	-	-	-	13
Hornblende	-	-	12	28	-	-	-	-	5	2	10	5	-	-
Opaque	5	4	5	6	9	5	5	8	6	3	4	-	-	-
Accessories	4	-	-	-	-	-	3	6	2	-	-	-	1	1
Pyroxene	-	-	-	-		10	-	-	1	-	-	-	-	-
	100	100	100	100	100	100	100	100	100	100	100	100	100	100

A is average modal composition for Gneisses from Ganaja area (Lokoja), Olatunji et al. (2013).
B is average modal composition of Migmatite Gneiss from Okene – Lokoja areas (Odigi, 2000).
C is average modal composition of Gneiss from North West Ekido, SE Lokoja (Imasuen et at., 2009)
D is average modal composition of Augen Gneiss from from Igbeti, SW Nigeria (Imeorkparia and Emofurata, 1991).
E is average modal composition of Migmatite from Ekiti State, SW Nigeria (Talabi, 2013).

GEOCHEMISTRY AND PETROGENESIS

Geochemical analysis of thirty-five (35) fresh samples of eight different rock units was carried out. The major elemental composition of the rocks presented in Table 2 shows that, the migmatite rock unit, SiO_2 concentration is 61.13 %, Al_2O_3 is 13.61 % and Fe_2O_3 is 12.93 %. This trend, in which $SiO_2 > Al_2O_3 > Fe_2O_3$ was observed in leucocratic biotite gneiss, hornblende biotite gneiss, quartzo-feldspatic gneiss, granite, pegmatite and charnockite, while values in melanocratic banded gneiss rock unit indicated richer Fe_2O_3 content compare to Al_2O_3 as shown in Figure 28a ($SiO_2 > Fe_2O_3 > Al_2O_3$). Granite has more SiO_2 content than all other rock units, while the Melanocratic banded gneiss rock unit has highest abundance of both alumina (Al_2O_3) and Iron oxide (Fe_2O_3). Migmatite, leucocratic biotite gneiss, quartzo-feldspartic gneiss and pegmatite rock units revealed a common concentration trend in which $K_2O > Na_2O > CaO > MgO$ (Table 2). Chemical composition of hornblende-biotite gneiss shows the order in which $CaO > Na_2O > K_2O > MgO$, which explain the abundance of plagioclase feldspar in the rock unit. However, the average major oxides composition of rocks from Okene metropolis consists 71.89% SiO_2, 12.63% Al_2O_3, 6.35% Fe_2O_3, 0.58% MgO, 3.77% K_2O, 2.61% CaO, 0.37% P_2O_5, 0.08 % MnO and 0.13% TiO_2 (Table 2).

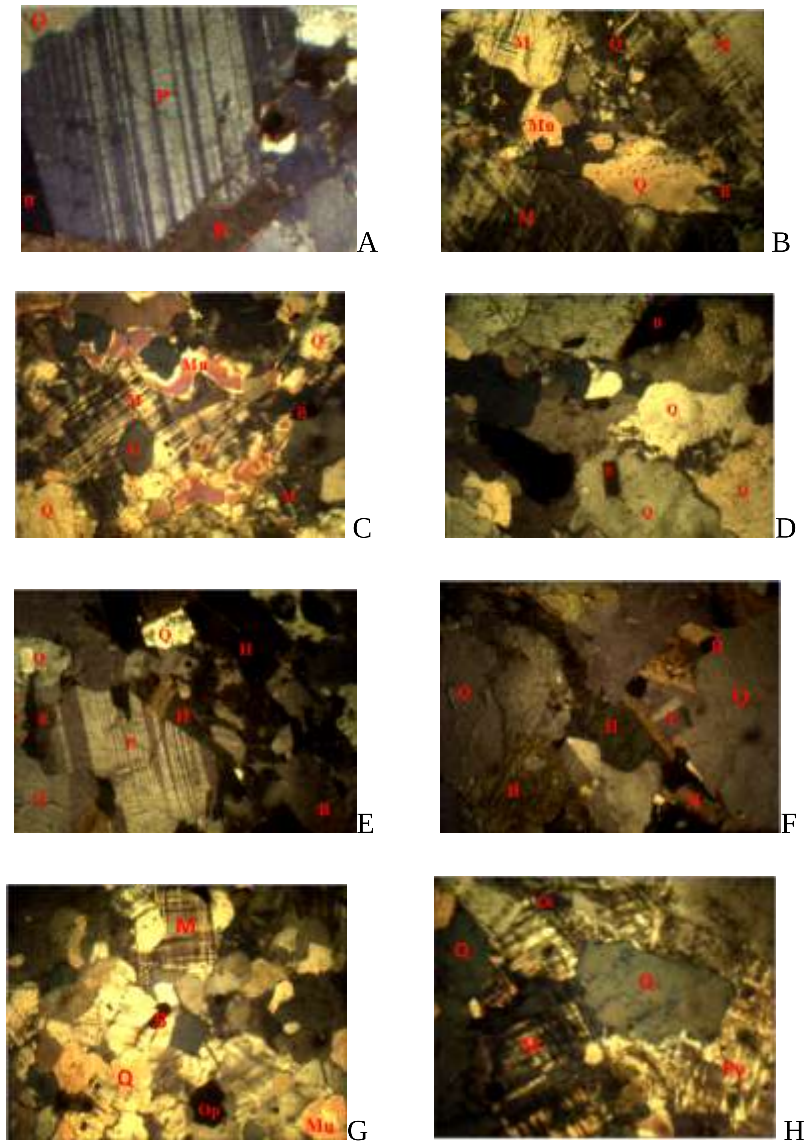


Figure 5: Photomicrograph of rocks (XPL; magnification = 20).

(A) Pegmatite, (B) Migmatite, (C) Quartzo-feldspartic gneiss, (D) Granite, (E) Melanocratic banded gneiss, (F) Hornblende biotite gneiss, (G) Leucocratic biotite gneiss and (H) Charnockite.

The geochemical data of the rocks were plotted on discriminatory diagrams to establish the geochemical evolution of the basement rocks underlying Okene metropolis. Figure 6 (a – f) show the plot of SiO_2 vs Al_2O_3 (a), SiO_2 vs Fe_2O_3 (b), SiO_2 vs MgO (c), SiO_2 vs CaO (d), SiO_2 vs Na_2O (e) and SiO_2 vs K_2O (f) for all the rock units in the study area. It revealed that all the major element composition apparently decreased with increasing SiO_2 content. According to Talabi (2013), the overall decreasing trend of major oxides versus SiO_2 in the various variation diagrams suggests high fractionation of mafic minerals like biotite. The plot of K_2O versus SiO_2 after Peccerio and Taylor (1976) in Figure 6f shows that most of the rocks plotted on the Calc-Alkaline and High-K Calc Alkaline series, suggesting that the rocks are alkaline

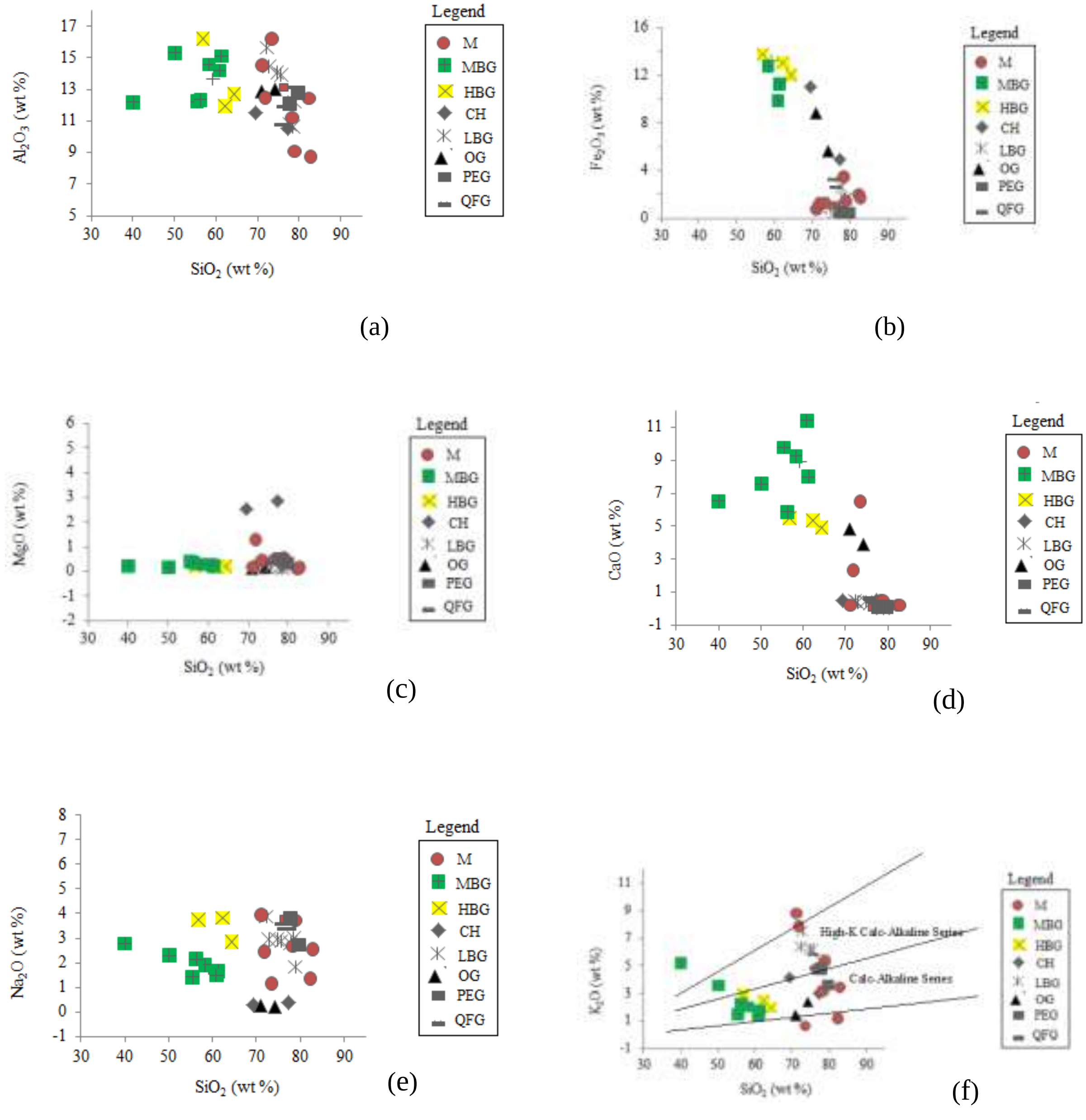


Figure 6: Harker diagram showing variations of major element oxides with silica for the rocks in Okene metropolis. The K_2O vs SiO_2 diagram is after Peccerio and Taylor(1976).

in nature. The origin of the basement rocks of southwestern, Nigeria is controversial. Rahaman and Occan (1978) suggested that the charnockitic rocks were original igneous rocks which retained their anhydrous affinity during the Pan-African orogeny. Elueze, (1982) worked on the petrochemistry of Precambrian gneisses and migmatites in the western part of Nigeria and opined that the varied petrochemical characteristics of the rocks were considered to be related to the progenic affinity of the rocks, implying that the rock units were derived from heterogeneous progenitors. Chemical data of rocks within Okene metropolis plot in the igneous field on the Na_2O/Al_2O_3 versus K_2O/Al_2O_3 after Garrels & Mackenzie (1971), indicating that they are of igneous origin (Fig. 7), while MacDonald and Katsura (1954) diagram of Na_2O + K_2O (wt.%) versus SiO_2 (Fig. 8) discriminated the rocks into high alumina, alkaline and theoleitic composition. Therefore, the migmatite and gneisses rocks represent metamorphosed products of fractionated igneous bodies.

Table 2: Average chemical composition of major elements in rocks from Okene metropolis

Oxides	Composition (Wt. %)										
	HBG n = 3	LBG n = 7	M n =7	MBG n = 8	QFG n = 3	G n=2	PEG n = 2	CH n = 2	Min.	Max.	Average
SiO_2	61.13	75.81	76.94	55.19	76.5	78.32	77.9	73.35	55.19	78.32	71.89
Al_2O_3	13.61	13.11	12.10	13.7	11.92	10.94	12.67	11.02	11.02	13.7	12.63
Fe_2O_3	12.93	1.35	1.70	16.91	2.03	7.53	0.66	7.98	0.66	16.91	6.35
MgO	0.19	0.16	0.44	0.27	0.34	0.24	0.43	2.70	0.14	2.7	0.58
K_2O	2.45	6.06	4.36	2.45	5.02	1.85	4.38	3.57	1.89	6.06	3.77
CaO	5.26	0.27	1.48	8.42	0.49	0.36	0.09	0.51	0.09	8.42	2.61
Na_2O	3.47	2.90	2.55	1.94	3.45	0.23	3.43	0.33	0.23	3.47	2.29
P_2O_5	0.48	0.30	0.38	0.46	0.16	0.31	0.43	0.38	0.16	0.48	0.37
MnO	0.14	0.03	0.03	0.13	0.06	0.09	0.02	0.16	0.02	0.16	0.08
TiO_2	0.34	0.01	-	0.52	0.03	0.12	-	0.01	-	0.52	0.13
	100	100	99.98	99.99	100	99.99	100.00	100.00			
Na_2O + K_2O	5.92	8.96	6.91	4.4	8.47	2.13	7.81	3.9			
K_2O/Al_2O_3	0.18	0.46	0.36	0.18	0.42	0.15	0.35	0.32			
Na_2O/Al2O3	0.25	0.22	0.21	0.14	0.29	0.02	0.27	0.03			

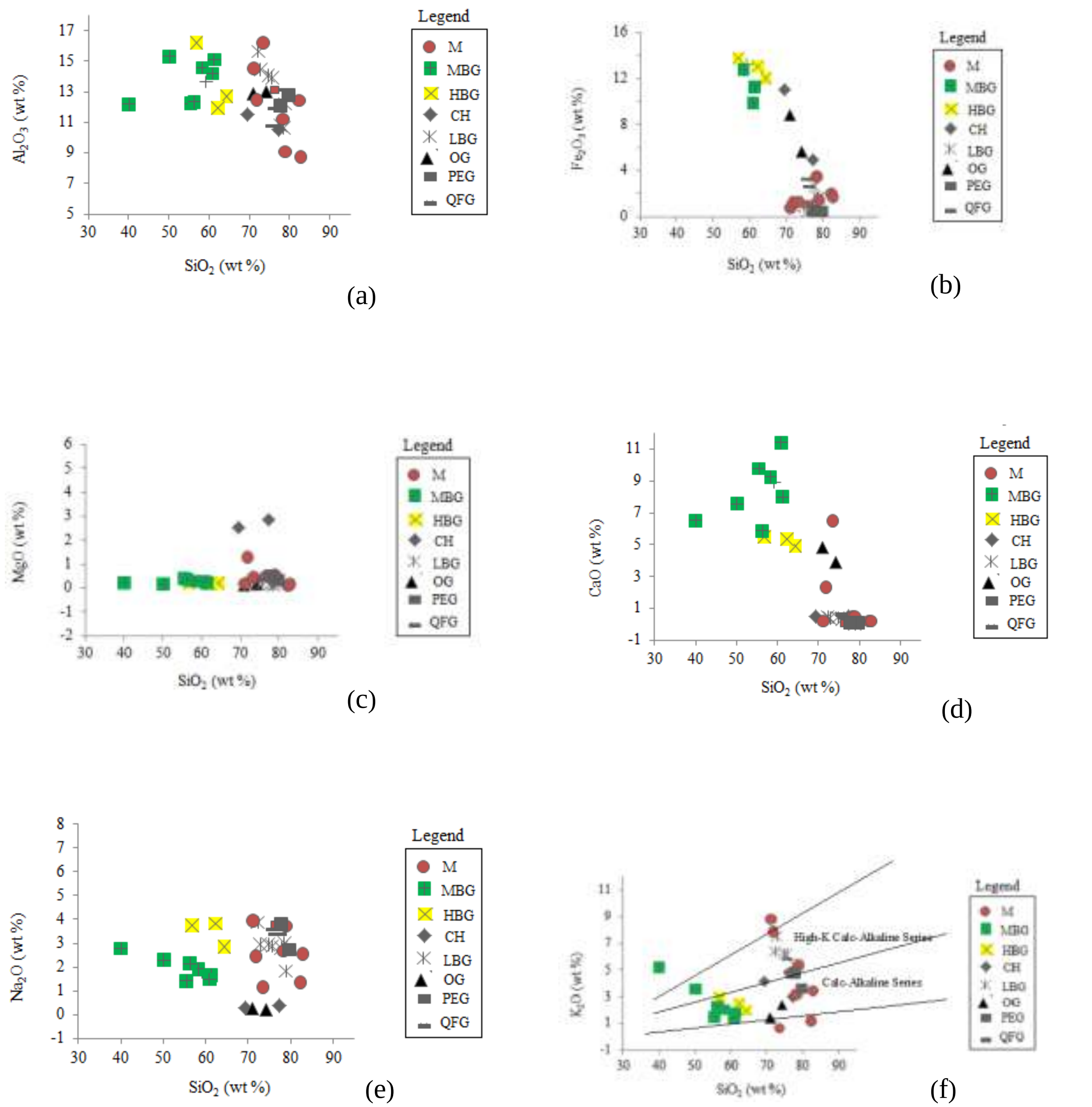


Figure 6: Harker diagram showing variations of major element oxides with silica for the rocks in Okene metropolis. The K_2O vs SiO_2 diagram is after Peccerio and Taylor(1976).

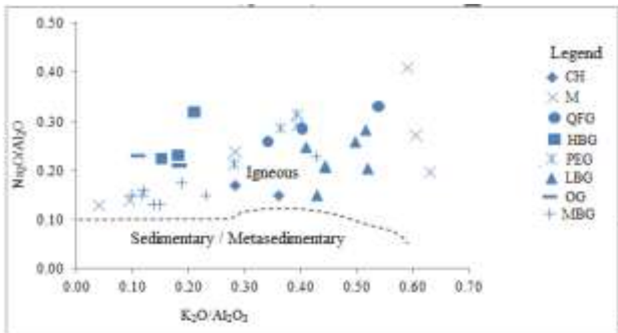


Figure 7: Plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 of rocks from Okene Metropolis (Modified after Garrels and Mackenzie, 1971).

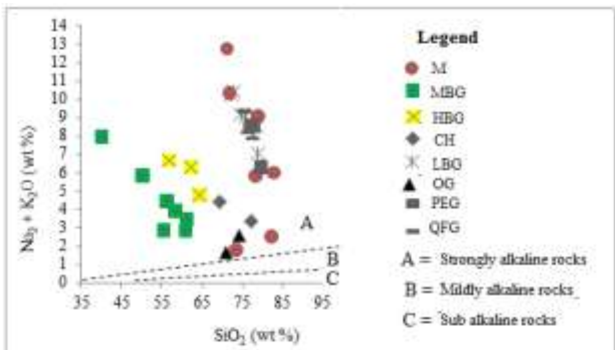


Figure 8: Plot of $Na_2O + K_2O$ versus SiO_2 of rocks from Okene Metropolis (Modified after MacDonald and Katsura, 1954).

CONCLUSION

Major rocks within Okene metropolis are migmatite, quartzo-Feldspartic gneiss, melanocratic biotite-gneiss, hornblende-biotite gneiss, leucocratic biotite gneiss, granite, charnockite and pegmatite. They consist of 47% Quartz, 14% biotite, 5% muscovite, 13% microcline and 7% plagioclase, 5% hornblende, 6% opaque and 2% accessories minerals. These minerals compared favourably with the modal composition of similar rock types from other locations within the southwestern basement complex. The chemical composition of the rocks implied that they are of igneous origin, which are Calc-Alkaline and High-K Calc Alkaline in nature, indicating that they were derived from ensialic calc-alkaline and k-calc alkaline magma. This position is however at variance with some workers who had earlier suggested sedimentary origin for granite and migmatite rock unit in the region.

REFERENCES

Adegbuyi, O and Olade, MA (1981). The Precambrian Itakpe Iron. Deposit in Central Nigeria, Theophrastus Publication, S.A. Anthens, Greece, 105- 118.

Alagbe, SA and Raji, BA (1990). Groundwater Resources of the basement complex in a semi-arid region: a case study of the Kan Gimi River Basin, Kaduna State. In: proceedings of First Biennial National Hydrology Symposium; National Water Resources Publication, Maiduguri, Nigeria, 559–571.

Annor, AE and Freeth, SJ (1985). Thermo-tectonic Evolution of the basement complex around Okene, Nigeria, with special reference to deformation mechanism. Precambrian Research, **28**(3-4) 269 – 281.

Aremu, MO, Majabi, GO, Oko, OK, Opaluwa, OK, Gav, BL and Osinfade, BG (2014). Physicochemical Analyses of Different Sources of Drinking Water in Okene local Government Area of Kogi State, Nigeria. *Journal of Civil and Environmental Research*. **6**(5) 143-150.

Clark, ID (1985). Groundwater abstraction from the basement complex areas of Africa. Journal of Engineering Geology **18** 25–34.

Dada SS, Lancelot, JR and Brigueu, AL (1989). Age and origin of the annular charnockitic complex at Toro, Northern Nigeria: u-Pb and Rb-Sr evidence. *Journal of African Earth Sciences* **9**(2) 227-234.

Elueze, AA (1982). Petrochemistry of Precambrian Gnisses and Migmatites in the Western part of Nigeria. Revista de Geociė̀ncias, **12(**1–3) 301–306.

Garrels, R M and Mackenzie, FT (1971). Evolution of Igneous and Sedimentary Rocks. W.W. Norton and Company, Inc. New York, N.Y. 394.

Grant, NK, Rex, D and Freeth, SJ (1972). Potassium Argon Ages and Strontium Isotope ratio measurement from Volcanic Rocks, North eastern Nigeria: *Continental Journal of Mineral Petroleum* **35** 277-292.

Imasuen, OI, Asuen, GO and Aibuki, OO (2009). Petrological and Geochemical Investigations of Metamorphosed Rocks Northwest Ekido, Bassa LGA, SE of Lokoja, Kogi State, Nigeria. *International Journal of Environmental Science* **5**(2) 70-75.

Imeokparia, EG, Emofurieta, WO (1991). Protoliths and Petrogenesis of Precambrian Gneiss from the Igbeti Area, SW. Nigeria, *Chemical Journal Erde*, **51** 39-54.

Jones, HA and Hockey, RD (1964). The Geology of part of south western Nigeria. Geological Survey Bull **31** 2

MacDonald, GA and Katsura, T (1954). Chemical Composition of Hawaiian Lavas. Journal of Petrology, **5** 82-133.

Obaje, NG (2009). Geology and Mineral Resources of Nigeria. Springer Dordrecht, Heidelberg. 59-62.

Odeyemi, IB (1999). Late-Proterozoic meta-conglomerates in the schist belt of Nigeria: Origin and Tectono-stratigraphic significance. *Journal of Technological Science* **3** 56-60

Odigi, MI, Ezepue, MC and Onyeagocha, AC (1993). Geochemical evolution of pan African Magmatic rocks of the Basement complex S.W Nigeria. *Journal of Africa Earth Sciences* **17** 541-552

Ogbonna, DO, Adejoh, A P, Ifatimehin, OO. and Idoko, O (2006). Climatic Benchmarking of the Propose Site for Salem University: in Reversed master plan for the proposed Salem University, Lokoja 24-36

Olarewaju, VO (1981). Geochemistry of the charnockitic and granitic rocks of the basement complex around Ado-Ekiti, southwestern Nigeria. *Ph.D Thesis, University of London*, U. K.

Olatunji, JA, Imasuen, OI and Onyeobi, TUS (2013). Geological Observation of Basement Rocks around Ganaja, Kogi State, Nigeria. *International Research Journal of Geology and Mining*, **3**(2) 57-66.

Oversby, VN (1975). Lead isotope study of Aplites the Precambrian basement rocks near Ibadan, Southwestern Nigeria. *Earth and Planetary Science Letters* **27** 177–180.

Owoade, A, Hutton, LG, Moffat, WS and Bako, MD (1989). Hydrogeology and water chemistry in the weathered crystalline rocks of southwestern Nigeria. Groundwater Management- Quantity and Quality *(Proceedings of the Benidorm Symposium).* IAHS Publ. no. 188.

Oyawoye, MO (1972). The basement complex of Nigeria in African Geology edited by T. F. J Dessau Vagie and Whiteman, A. J, *University of Ibadan* 66 - 102.

Oyinloye, A. O. and Ademilua, O. L., (2005). The nature of aquifer in the crystalline basement rocks of Ado-Ekiti, Igede-Ekiti and Ogbara odo areas, southwestern Nigeria *Pakistan Journal of Science and Industrial. Research* **48**(3) 154–161.

Pearce, JA and Gale, GH (1977). Identification of ore Deposition Environment from Trace Elements in Volcanic Processes in ore Genesis, *Institute of Mining and Metallurgy and Geological Society*, London.

Peccerio, A and Taylor, SR (1976). Geochemistry of Eocene Calc-alkaline Volcanic rocks from the Kastamonu area, northern Turkey. *Contributions to Mineralogy and Petrology*, **58** 63–81.

Rahaman, MA (1976). Review of the basement geology of south western Nigeria in Geology of Nigeria edited by C. A Kogbe. Elizabeathan pub. co, Lagos, pp. 41-58.

Rahaman, MA (1988). Recent Advances in study of the Basement Complex of Nigeria Precambrian geology of Nigeria. In OLUYIDE (eds) Precambrian Geology of Nigeria. *Geological Survey of Nigeria Publication*, Kaduna 11-43.

Talabi, AO (2013). Mineralogoical and Chemical Characterization of Major Basement Rocks in Ekiti state, SW- Nigeria. *Journal of Professional paper*, RM2- M&G, **60** 73-86.

Woakes, M, Ajibade, CA and Rahaman, MA (1987). Some metallogenic features of the Nigerian Basement, *Journal of Africa Science* **5** 655-664.