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Mineralogical and chemical characterization of major basement rocks in Ekiti State, SW-Nigeria

Mineraloške in kemične značilnosti glavnih kamnin podlage v državi Ekiti v JZ Nigeriji

Abel O. Talabi[1,*]
[1]Ekiti State University, Faculty of Science, Department of Geology, Ado-Ekiti, Nigeria
*Corresponding author. E-mail: soar_abel@yahoo.com

Abstract

Mineralogy and chemical composition of rocks constitute a reliable means of rocks' classification. Migmatite which occur in association with quartz schist/quartzite, Pan African Granites and charnockitic bodies around Ekiti State, southwestern Nigeria, were studied with a view to elucidate their mineralogical, compositional characteristics and their evolution.

Mineralogical determinations from optical studies revealed a high proportion of granular quartz and accessory muscovite in the quartz schist/quartzite. The migmatite on the other hand comprises mainly of quartz and feldspar (volume fractions ≤70 %) with minor muscovite, biotite and opaque minerals. Both Pan-African granite and charnockitic rocks have similar mineralogical composition with quartz and feldspar as dominant minerals. However, the charnockites have more mafic minerals compared to the granites.

Chemical analysis of the rocks involving major elements revealed the silicieous nature of all the rock units (migmatites, quartz-schist/quartzite, granites and the charnockites) in the study area. Three oxides (SiO_2, Al_2O_3 and Fe_2O_3) constitute about 70–75 % of the chemical composition in migmatites, granites and the charnockites while in quartz-schist/quartzite, it was over 80 %. The chemical compositions as well as different variation plots suggest sedimentary origin for the granite, migmatite and quartz-schist/quartzite rocks while the charnockite has a preference for igneous source. The (Na_2O+K_2O) - CaO versus SiO_2 plot indicated that majority of the rock units (migmatite, granite and charnockite) are in alkali-calcic and calcic-alkali categories while quartz-schist/quartzite is of calcic affinity.

Key words: mineralogy, Ekiti State, optical studies, major elements, Igneous source

Izvleček

Mineraloška in kemična sestava kamnin je zanesljiva osnova za njihovo klasifikacijo. Razvit je migmatit v združbi s kremenovim metamorfnim skrilavcem/kvarcitom. V študiji so preiskovali panafriške granite in charnokitska telesa z namenom pojasniti značilnosti njihove mineraloške in kemične sestave ter njihov razvoj. Z mineraloško optično preiskavo so ugotovili v kremenovem metamorfnem skrilavcu/kvarcitu velik volumenski delež zrnatega kremena in akcesorni muskovit. Po drugi plati vsebuje migmatit predvsem (≤70 %) kremen in glinenec s podrejenim muskovitom, biotitom in neprozornimi minerali. Panafriški graniti in charnokitske kamnine imajo podobno mineraloško sestavo s prevladujočima kremenom in glinencem, vendar vsebujejo charnokiti v primerjavi z graniti več mafičnih mineralov.

Kemične analize glavnih elementov so razkrile silicijsko naravo vseh kamninskih enot (migmatitov, kremenovega metamorfnega skrilavca/kvarcita, granitov in charnokitov) na raziskovanem območju. Trije oksidi (SiO_2, Al_2O_3 and Fe_2O_3) obsegajo kar 70–75 % kemične sestave migmatitov, granitov in charnokitov, medtem ko je ta delež pri kremenovem kristalastem skrilavcu/kvarcitu več kot 80 %. Kemična sestava in različni variacijski diagrami nakazujejo sedimentno poreklo granitnih, migmatitnih in kremenovo metamorfno skrilavih/kvarcitnih kamnin in prednostno magmatski vir charnokita. Diagram (Na_2O+K_2O) - CaO s SiO_2 prikazuje, da pripada večina kamnin (migmatit, granit in charnokit) alkalijsko-kalcijevim in kalcijsko-alkalijskim kategorijam, le kremenov kristalasti skrilavec/kvarcit kalcijski.

Ključne besede: mineralogija, država Ekiti, optične preiskave, glavne prvine, magmatsko poreklo

Introduction

Ekiti State in Southwestern Nigeria is underlain primarily by the basement complex rocks of Pre-Cambrian age comprising gneisses and migmatites, quartz-schist/quartzite, Pan-African granites and charnockite with migmatites covering over 50 % of the whole area (Talabi & Tijani, 2011).
Most rocks are made up of major and trace elements. These rocks components are subjected to intensive weathering processes especially in the tropical area (like Ekiti State) with subsequent release of regolith products into the groundwater of the area. The weathering processes are charachterized by intensive desilisification and ionic lost from the rock forming minerals. Crystalline rocks are formed by interlocking silicate minerals such as quartz, feldspars, micas, hornblende, pyroxenes, olivine and a host of minor accessories. Chemical weathering involves the dissolution of these minerals resulting in the formation of both soluble as well as solid phase products. History of the various transformations are documented in form of mineralogical and chemical dynaism of the rock.
A deligent search revealed scanty literature on the subject matter regarding the study area. Many of the research works in the study area were on geophysical assessment of the groundwater potential and hydrochemistry. Owoade et al. (1989) worked on hydrogeology and water chemistry in the weathered crystalline rocks of southwestern Nigeria and concluded that kaolinite was found to be the stable clay weathering product and that groundwater resides in the weathered regolith in the area. Bolarinwa & Elueze (2005) also reviewed the geochemical trends in the weathered profiles above granitic gneiss and schist of Abeokuta area, southwestern Nigeria. The research indicated that the Fe_2O_3 rich laterite is low in Na_2O, K_2O, CaO and MgO due to the removal of alkaline and earth elements, through leaching of the topsoil and laterite. Emofurieta & Salami (1993) while looking on the geochemical dispersion patterns associated with laterization process at Ile-Ife reported that the soils derived from the melanocratic bands are SiO_2 rich, compared to soils derived from the leucocratic bands. Based on their average $SiO_2/Al_2O_3 + Fe_2O_3$ ratios, the soils derived from the melanocratic bands are lateritic whilst the leucocratic derivatives are non laterite. This study therefore was to characterise the major basement rocks in Ekiti state using mineralogy and chemistry of the rocks.

Study area

Ekiti State is located between latitudes 7° 15′–8°5′ N and longitudes 4°44′–5°45′ E covering an approximate area of about 6 353 km^2 (Figure 1). The area lies entirely in the tropical climate with two distinct seasons; rainy and dry seasons. These two seasons have elastic boundaries in view of the recent global climatic variability. However, in general, on yearly basis, the rainy season commences in April and terminates in October while the dry season spans through November to March. The temperature is high throughout the year (mean annual temperature is 27 °C). The relative humidity is high (60–80 %) most months of the year while the mean annual rainfall is 1 500 mm. The study area is located in a hummocky terrain having a well pronounced undulating topography with prominent hills characterized by steep slope with elevation between 200 m and 500 m above mean sea level. Prominent hilly features include inselbergs, whalebacks and other categories of residual hills which are commonly associated with massive granite bodies. The inselbergs are striking feature of the Pan African granites occurring as picturesque prominent hills, rising sharply above their surrounding plains.

Geology of the study area

The study area is an Archaean-Early Proterozoic terrain underlain by the basement complex of southwestern Nigeria (Clark, 1985, Alagbe & Raji, 1990, Oyinloye & Ademilua, 2005). Furthermore, Oversby (1975) and Olarewaju (1981), indicated that the study area is composed of migmatite-gneiss-quarzite complex, with supracrustal rocks relics. In this study, geological appraisal through systematic mapping reveal the following distinguishable lithologies namely: Migmatite-gneiss, Quartzite/Quartz-Schist, the Pan-African granite, Charnockite, Aplite and Pegmatite (Figure 2). The rocks are not evenly distributed but migmatites predominate, covering a greater proportion of the study area (Figure2).

Material and method

The principal aim of the study was to establish the basic mineralogy and fabric properties of major rock types in the study area. Twenty (20) fresh representative samples comprising of 5 samples each of migmatite, quartz-schist/quartzite, granite and charnockite were subjected to thin section study. The nature of outcrop, colour, texture, mineralogy and structures were noted on the field. As for the geochemical investigations, collected samples were dried at temperature of 60 °C, crushed using a jaw crasher and pulverized with the ball milling machine and sieved to 80 mesh. Elemental compositions of the rocks were determined using Atomic Absorption Spectrophotometer (Unicam 969 model).

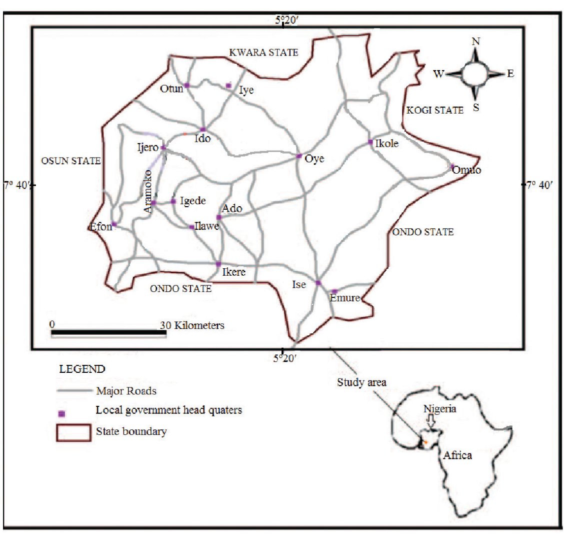

Figure 1: *Location map of Nigeria showing the study area (Talabi & Tijani, 2011).*

Ten (10) grams of each sample was weighed and put in a clean digestion bottle. Using a calibrated plastic syringe, 15 ml of 40 % hydrochloric acid was added with the help of an automatic pipette. Subsequently, ten (10 ml) of hydrofluoric acid was added. To avoid the escape of silicon fluoride (SiF_4) gas during mixing of the two acids the digestion bottle was tightly closed. The digestion bottle was later put on a water bath and warmed up to 70 °C for about two hours and allowed to cool down to 25–30 °C. A 100 ml saturated boric acid was added to the solution and the bottle was closed tightened. The bottle was put on a water bath up to 70 °C until the milky solution became clear. Distilled water was added to it after cooling to make a solution of 250 ml; part of distilled sample was put in a sample container which was then analyzed with a dilution factor of 25. Major elemental oxides such as SiO_2, Al_2O_3, K_2O, Na_2O, CaO, MgO, Fe_2O_3 and TiO_2 were obtained using Atomic Absorption Spectrophotometer (Unicam 969 model) with a precision of +0.5. The geochemical results were subjected to variation plots to infer the petrogenesis of the rocks.

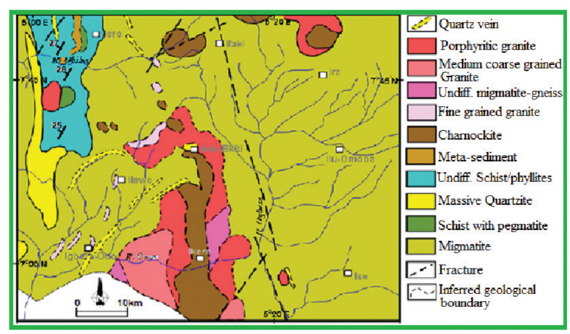

Figure 2: *Geologic Map of Study area (Talabi & Tijani, 2011).*

Results and discussion

Field petrographic features

Generally, geological appraisal through systematic mapping revealed outcrops of gneisses and migmatites representing highly denuded hills while quartz-schist/quartzite, Pan-African granites (porphyritic and fine-medium grained) and charnockite commonly form ridges, hills and whalebacks in the study area. The rocks are not evenly distributed but migmatites predominate, covering a greater proportion of the study area. The Pan-African granites comprise of felsic and mafic minerals. The felsic minerals contain quartz, orthoclase, plagioclase feldspar and muscovite. Quartz is colourless, white and occassionally grey in colour while orthoclase display white, pink or buff grey colour. Plagioclase feldspar is often white, pink, grey or dark grey coloured while muscovite is the flaky mineral of the mica groupdisplaying colourless colour. The mafic group comprise of the black coloured biotite andthe dark green to black hornblende. The biotite is differentiated from hornblende in terms of hardness. The former has a hardness range of 2–2.5 and can easily be scratched with a pen-knife while the later range of hardness is 5–6 on the Mohs scale of hardness.

Gneisses and migmatites

Gneisses and Migmatites cover over 65 % of the study area (Figure 2) into which the other successions of rocks have been emplaced. Typical outcrops of migmatites and gneisses in the study area are presented in Figures 3(a–d). Field observation revealed close structural relationship between quartzite and the intrusive granitic and charnockitic rocks. Migmatite rock exposures occur as highly denuded hills of essentially fine texture while the pegmatites are very coarse-grained with phenocrysts of feldspar over 2500 mm in length, usually of granitic composition and forming at a late stage of crystallization. In the study area, the migmatite-gneiss rocks composed of a mafic portion, made up of biotite, hornblende and opaque minerals while the felsic portion is quartzofeldspatic. Compositional variation in the rock outcrops are indicated by closely spaced alternating bands of leucocratic minerals (quartz and feldspars) and melanocratic minerals indicated by the preponderance of biotite minerals (Figure 3a). The banded gneisses with alternating parallel light and dark coloured bands are common in the study area especially at Ado, Iworoko, Ikere, Ise and Emure. Figure 3c shows drag folds of leucocratic veins and ptymatic structures while figure 3d represents a typical granite gneiss at Ado-Ekiti with alternating light and dark coloured bands.

Quartz-schist/quartzite

Quartz-schist/quartzite is a hard, non foliated metamorphic rock derived from sandstone during tectonic compression, a process where heat and pressure beneath the ground increases to form new rocks. Found on hills and mountains, quartzite endures little wear or decomposition based on its elevated locations. The quartz-schist/quartzite in the study area exhibits white to gray colour due to varied iron oxide content in the rock. A few good massive quartzite outcrops rising up to 100 mabove the surrounding terrain occur around Ado-Ekiti, while the ones at Ikogosi are highly schistose with muscovite flakes littering its environment. However, around the south western part of Ilawe-Ekiti, the quartzite rock exists as rubbles. Quartzite is very resistant to chemical weathering and often forms ridges and resistant hilltops. The nearly pure silica content of the rock provides little to soil formation and therefore the quartzite ridges are often bare or covered only with a very thin layer of soil and little vegetation.

The Pan-African granites

The Pan-African granites (ca. 600 Ma) occur as intrusions within the migmatite-gneiss-quartzite complex (Oyinloye, 2002, Oyinloye, 2011, Folorunso & Okonkwo, 2011, Omosanya et al., 2012 and Okonkwo & Folorunso, 2013). The granitic rocks outcropped as domes and small hills in the area. The granites are distinguishably unique because of their visible minerals, lack of foliation, fine-medium grained texture (Figure, 3e) and compact interlocking crystals that developed during the crystallisation of magma. However, granitic rocks of porphyritic texture (Figure 3f) occur around Ado-Ekiti, Ikere-Ekiti and close to Ikole-Ekiti. Some of the outcrops occur as well-rounded boulders devoid of any preferred orientation of component minerals. The contact relationship of the Pan-African granites with the surrounding country rock are abrupt in few cases while most are gradational over very short distances. Generally, the porphyritic granite is light coloured with signs of having been fairly weathered.

Charnockites

The charnockitic rocks outcropped as pavement and oval or semi-circular hills of between five and ten meters (10 m) high with a lot of boulders at some outcrops. They are generally massive, dark-greenish in colour with medium to coarse grained texture. The fresh outcrops with little or no sign of weathering have a lot of quartz, aplite and pegmatite intrusions occurring in it. The general trend of the intrusions

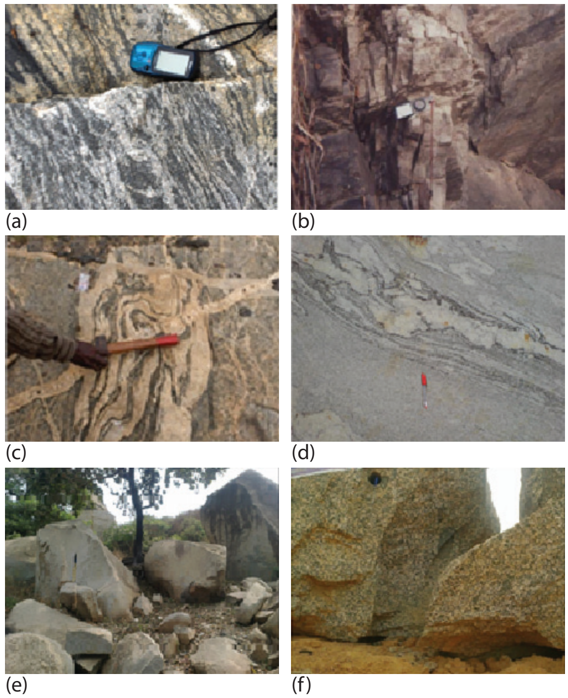

Figure 3: *Typical rock outcrops from the study area [(a) Migmatite, (b) Migmitite outcrop with pegmatite intrusion, (c) and (d) Granite gneiss, (e) Fine-medium grained granite, (f) Porphyritic granite.*

is N-S. The dominant trend of the joints that occur on the rock is N-S. The rock outcropped around Ado, Ikere, Otun, Ifaki, Itapa and Ikole areas. Two mode of charnockite occurrence have been revealed through field observation. The charnockites that occurr along the margins of Older Granites bodies especially the porphyritic granites as exemplified by the charnockitic outcrops in Ado, Ikere and Igbara-Odo areas. The other mode of occurrence comprise of charnockites that aligned in a NW-SE direction as shown by the charnockitic rocks at Oye, Itapa and Ijelu areas. The contact relationship of the charnockites to the surrounding rocks is variable. In some places on the one hand, gradational contact was observed between the charnockites and the surrounding Older Granites while on the other hand the contact is abrupt from migmatitic and granitic gneisses to the charnockitic rocks.

At Ifaki, the charnockites showed cross-cutting intrusive contacts with surrounding country rocks while at Ikere, the charnockites appear on slightly weathered surfaces said to have been broken up into xenolithic blocks by a foliated porphyritic granite. Furthermore, on the fresh surfaces, it is difficult to distinguish the contact between the granite and charnockite because the feldspars of the granite have the same greenish colour as the feldspars in the charnockite. However, the colouration fades away with increased weathering of the charnockite. Megascopic examination with the aid of hand lens revealed the presence of quartz, alkali feldspar, plagioclase and biotite as major minerals in the charnockitic rocks in the study area.

In summary, field observations highlight gneiss and migmatite, granite, quartz-schist/quartzite and Charnockite as major rock units in the study area with variable mineralogical composition. Granite contains more minerals that are suceptible to weathering i.e. high percentage of mafic minerals (biotite and hornblende) which got easily weathered because the iron (Fe) in their crystals structures can easily be oxidized. However, the quartz in such rocks will show mild resistance to weathering. The weathering of rocks and minerals are significant to mineral and chemical evolution of rocks.

Microscopic evaluation of rocks in the study area

Thin section petrography of the migmatite/gneiss shows abundance of feldspar (microcline), quartz, muscovite, biotite and opaque minerals. Microcline occurs as large euhedral crystals exhibiting cross hatched twining, biotite content is low, occur in disoriented masses and mineral alignment is poorly developed. Other minor components include ferromagnesian minerals like hornblende (Figures 4 & 5). Quartz and feldspar alone constitute up to volume fractions 70 % 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.

The quartzites/quartz-schist shows predominance of quartz, accessory muscovite and opaque minerals (Figures 6 & 7). Quartz occurs as granoblastic and euhedral crystals with well-defined outlines. It exhibits weak birefringence, low relief with wavy extinction. Few grains however appear cloudy. Muscovite that forms supporting minerals occupy intergranular spaces of interlocking quartz crystals and often is the platy brightly coloured minerals.

Quartz and muscovite constitute up to volume fractions 88 % of the rock in thin section (Table 2).

Table 1: *Modal composition of Migmatite (in volume fractions)*

Minerals	Sample 1	Sample 2	Sample 3	Average
Quartz	43	45	44	44
Feldspar	25	26	27	26
Hornblende	8	10	9	9
Pyroxene	-	-	-	-
Biotite	9	10	8	9
Muscovite	6	5	4	5
Opaque	9	4	8	7
Total	100	100	100	100

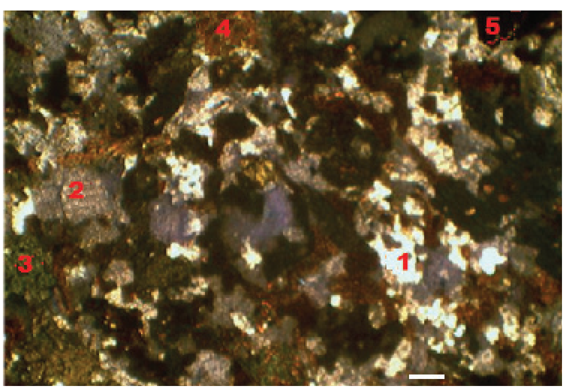

Figure 4: *Photomicrograph of migmatite gneiss in trasmitted light showing quartz (1), plagioclase (2), hornblende (3), biotite (4) and opaque mineral (5). Bar scale is 2* mm *crossed polars.*

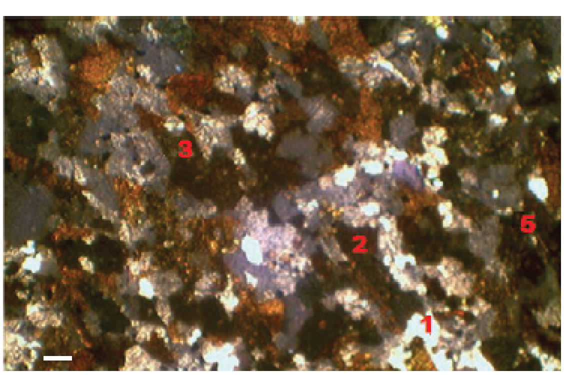

Figure 5: *Photomicrograph of migmatite gneiss in trasmitted light showing quartz (1), biotite (2), hornblende (3), microcline (4) and opaque mineral (5). Bar scale is 2* mm *crossed polars.*

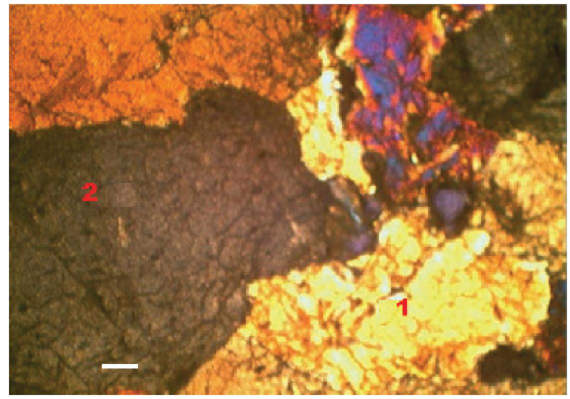

Figure 6: *Photomicrograph of quartzite in trasmitted light showing quartz (1) and muscovite (2). Bar scale is 2* mm *crossed polars.*

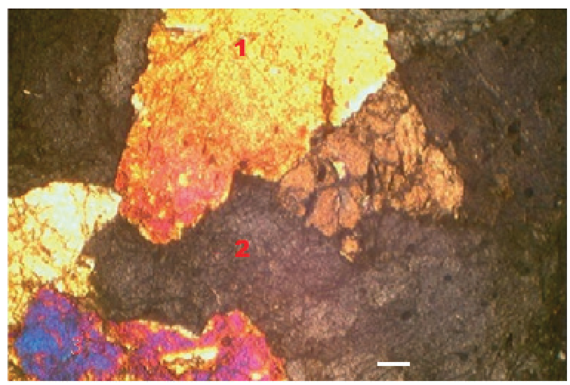

Figure 7: *Photomicrograph of quartz-schist showing quartz (1), muscovite (2) and muscovite. Bar scale is 2* mm *crossed polars.*

Table 2: *Modal composition of Quartzite (in volume fractions)*

Minerals	Sample 1	Sample 2	Sample 3	Average
Quartz	59	57	58	58
Feldspar	-	-	-	-
Hornblende	-	-	-	-
Pyroxene	-	-	-	-
Biotite	8	7	9	8
Muscovite	29	31	30	30
Opaque	4	5	3	4
Total	100	100	100	100

Quartz, feldspars, hornblende, biotite and some opaque minerals (probably iron oxide) were the major minerals identified in thin section of the Pan-African granite. The feldspars are large, well-formed crystals of albite with carlsbard twinning. The hornblende content in the granite is low. Quartz occurs as irregular masses of colourless and unaltered grains. Biotite is mainly the green and brown coloured minerals with medium relief. Figures 8 & 9 display the photomicrographs of porphyritic granite while Figures 10 & 11 represent that of fine-medium grained granite. In all the photomicrographs, quartz form the dominant mineral. All the quartz grains display low first order interference colour. Biotite displays the anomalous red colour interference. However, the polysynthetic twinning of plagioclase was not conspicuous.

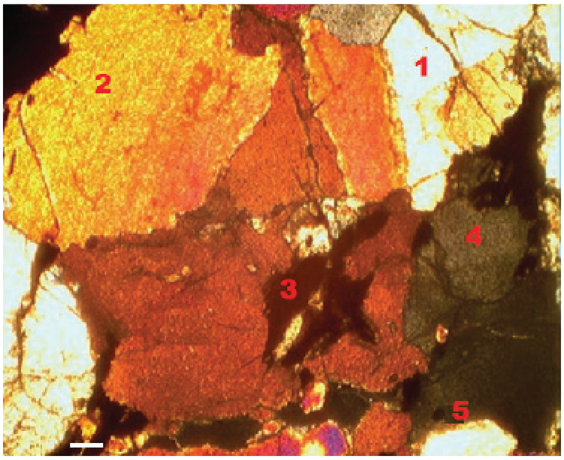

Figure 8: *Photomicrograph of porphyritic granite in transmitted light showing quartz (1), muscovite (2), biotite (3), hornblende (4) and opaque mineral (5). Bar scale is 2* mm *crossed polars.*

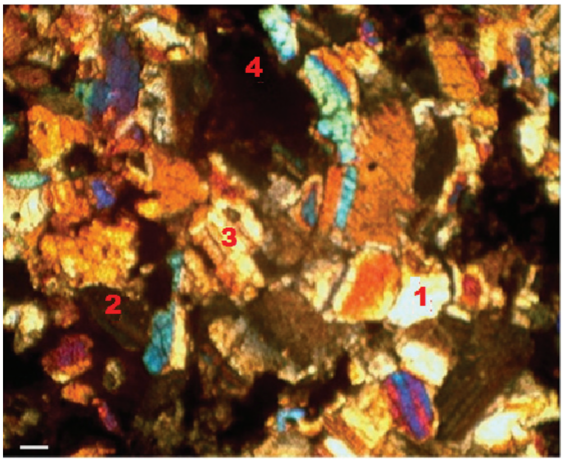

Figure 9: *Photomicrograph of porphyritic granite in transmitted light showing quartz (1), hornblende (2), plagioclase (3) and biotite (4). Bar scale is 2* mm *crossed polars.*

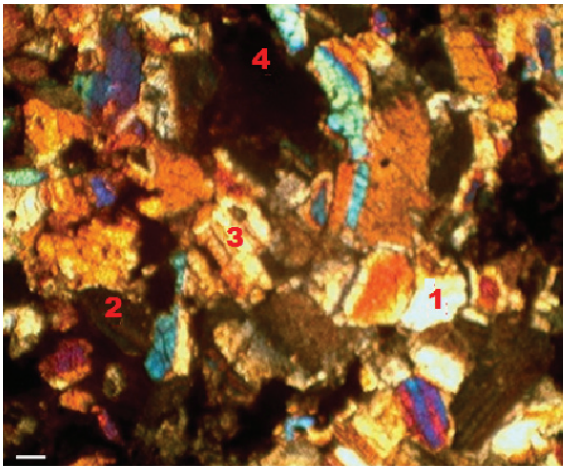

Figure 10: *Photomicrograph of fine-medium granite in transmitted light showing quartz (1), biotite (2) and hornblende (3). Bar scale is 2* mm *crossed polars.*

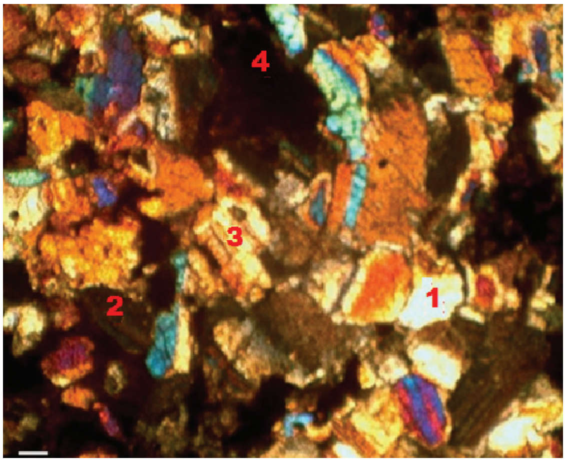

Figure 11: *Photomicrograph of fine-medium granite showing biotite (1), quartz (2) and hornblende (3). Bar scale is 2* mm *crossed polars.*

The modal analysis of the thin sections of the porphyritic granite (Table 3) gave an average of (45, 15, 10, 8, 15, and 7) % quartz, feldspar, hornblende, biotite, muscovite and opaque mineral, respectively. Also, that of the fine-medium grained granite (Table 4) gave (48, 32, 5, 7 and 4) % quartz, feldspar, hornblende, pyroxene, biotite and opaque minerals, respectively.

Table 3: *Modal composition of porphyritic granite (in volume fractions)*

Minerals	Sample 1	Sample 2	Sample 3	Average
Quartz	45	44	46	45
Feldspar	13	18	14	15
Hornblende	8	9	13	10
Pyroxene	-	-	-	-
Biotite	8	9	7	8
Muscovite	16	14	15	15
Opaque	7	8	6	7
Total	100	100	100	100

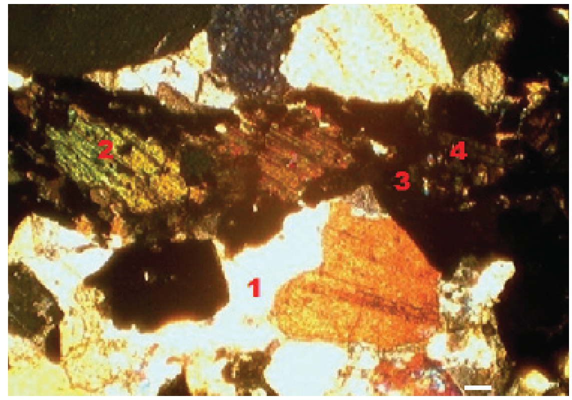

Figure12: *Photomicrograph of charnockite in transmitted light showing quartz (1), plagioclase (2), biotite (3) and hornblende (4) Bar scale is 2 mm crossed polars.*

Table 4: *Modal composition of fine-medium grained granite(in volume fractions)*

Minerals	Sample 1	Sample 2	Sample 3	Average
Quartz	47	48	49	48
Feldspar	32	31	33	32
Hornblende	6	5	4	5
Pyroxene	7	9	5	7
Biotite	5	4	3	4
Muscovite	-	-	-	-
Opaque	3	3	6	4
Total	100	100	100	100

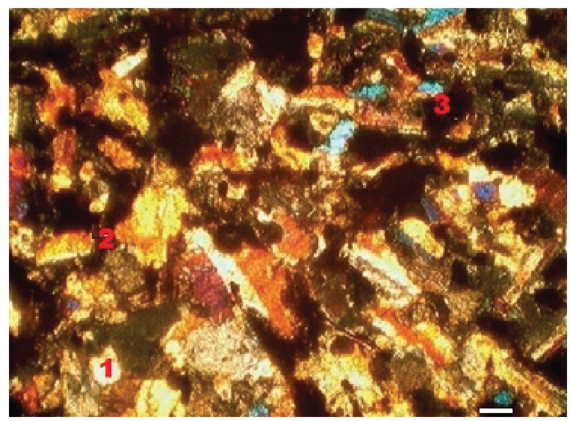

Figure13: *Photomicrograph of charnockite in transmitted light showing quartz (1), hornblende (2), and biotite (3). Bar scale is 2 mm crossed polars.*

In thin section generally, the minerals constituting the charnockitic rock include quartz, plagioclase, hornblende, biotite, pyroxene, muscovite and opaque minerals (Figures 12 & 13). The modal analysis of the thin sections of the rock (Table 5) gave an average of (45, 35, 8, 5, 2, 3 and 2) % quartz, plagioclase, hornblende, pyroxene, biotite, muscovite and opaque minerals, respectively.

Table 5: *Modal composition of charnockite (in volume fractions)*

Minerals	Location 1	Location 2	Location 3	Average
Quartz	47	44	45	45
Feldspar	33	37	35	35
Hornblende	7	9	8	8
Pyroxene	6	4	6	5
Biotite	2	3	1	2
Muscovite	2	1	3	3
Opaque	3	2	2	2
Total	100	100	100	100

Geochemistry

Geochemical analysis of five fresh samples of each rock unit was carried out and few variation diagrams were plotted to establish petrologic and petrogenetic processes of the basement rocks in the study area. The major elemental composition of the rocks in the study area is presented in Table 6.

In the migmatite rock unit, SiO_2 concentration in mass fractions ranged from 66.50–69.80 %, Al_2O_3 ranged from 14.65–15.46 %, Fe_2O_3 ranged from 2.13–3.46 % (Table 6). This trend though with variations, was observed in other rock units as SiO_2 in granite ranged from 71.89–75.02 % while SiO_2 in charnockite ranged from 65.21–67.77 %. The Al_2O_3 concentrations in granite and charnockite ranged from 14.98–15.68 % and 10.22–13.03 % respectively. The Fe_2O_3 content in granites ranged from 2.19–2.44 % while it ranged from 2.81–4.16 % in the charnockitic rocks. These three oxides (SiO_2, Al_2O_3 and Fe_2O_3) constitute about 70–75 % of the chemical composition of the rock units in the study area. The geochemical data were plotted on discriminatory diagrams to establish the geochemical evolution of the rock. The major element composition revealed different evolutionary trend for the various rock units as evidenced in Figure 14, showing a negative correlation with Si_2O. All the major element composition apparently decreased with increasing Si_2O content and showed medium to high-K affinity i.e fell mainly into the calc-alkaline and high-K calc-alkaline series as revealed in the plot of K_2O versus SiO_2 (Figure 14) after Peccerillo & Taylor (1976). Furthermore, a plot of Na_2O + K_2O-CaO versus SiO_2 diagram after Frost et al. (2001) (Figure 15) categorised most rock units into the alkali-calcic and calcic-alkali series. However, the quartz-schist/quartzite fell in the calcic group signifying abundance of quartz and muscovite in the rock unit. The overall decreasing trend of the various variation diagrams suggested high fractionation of mafic minerals like biotite.

The origin of the basement rocks of southwestern, Nigeria is controversial. Rahaman & 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, concluded that the varied petrochemical features of the rocks were considered to be related to the progenetic affinity of the rocks, implying that the units were derived from heterogeneous progenitors. Okunlola et al., (2009) suggested arenaceous sedimentary ancestry for the quartz schist and an igneous ancestry most probably mafic extrusive volcanics for the amphibole schist in Ibadan area, southwestern Nigeria. In addition, provenance indicators, such as Ba, in the quartz schists suggested derivation of this sedimentary protolith from the weathering of largely granitic rocks. However, Ademeso & Adeyeye, (2011), suggested a preference for igneous fields by the granite gneiss of Arigidi area, S/W, Nigeria. Oyinloye, (2011) in his research work on ‘‘Geology and Geotectonic Setting of the Basement Complex Rocks in South Western Nigeria: Implications on Provenance and Evolution’’ discovered that a mineral monazite was present in the basement rocks (amphibolite and granite gneisses) at Ilesha area, southwestern, Nigeria. The implication of presence of maonazite in the amphibolite which is supposed to be purely igneous is that the initial magma from which the precursor rocks were formed had input from a crustal or sedimentary source. Data from the present study when subjected to the plot of K_2O versus Na_2O (Pettijohn, 1975) indicates that migmatite, granite and quartz-schist/quartzite samples plotted in the field of arkoses while charnockite samples plotted in the greywackes (Figure.16). In addition, Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot (Garrells & Mackenzie, 1971) shows that granite plotted in the sedimentary field, quartz-schist/quartzite plotted in both fields while migmatite and charnockite plotted in the igneous field. However, further classification using the plot of alumina saturation versus alkalinity (after Maniar & Piccoli, 1989) i.e. [Al_2O_3/ ($Na_2O + K_2O$) vs. $Al_2O_3/Na_2O + K_2O$ + CaO)] classified three of the rock units (migmatite, granite and charnockite) as peraluminous plotting mostly in the S – type field of Maniar & Picooli (1989) granite classification diagram (Figure 18). Deductions from the various discriminatory diagrams suggest sedimentary origin for the granite, migmatite and quartz-schist/quartzite rocks while the charnockite has a preference for igneous source.

In summary, the major chemical composition of the analysed rock samples revealed SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, TiO_2, P_2O_5, MnO as major oxides. Granite has more SiO_2 content than the migmatite and charnockite. However, charnockite is richer in Fe_2O_3 content. In addition, variation diagram of (Na_2O + K_2O) – (CaO) vs SiO_2 diagram after (Frost, et al., 2001) indicates that most of the rocks in the study area are in the alkali-calcic and calcic-alkali series and in the S – type peraluminous field suggesting sedimentary protolith.

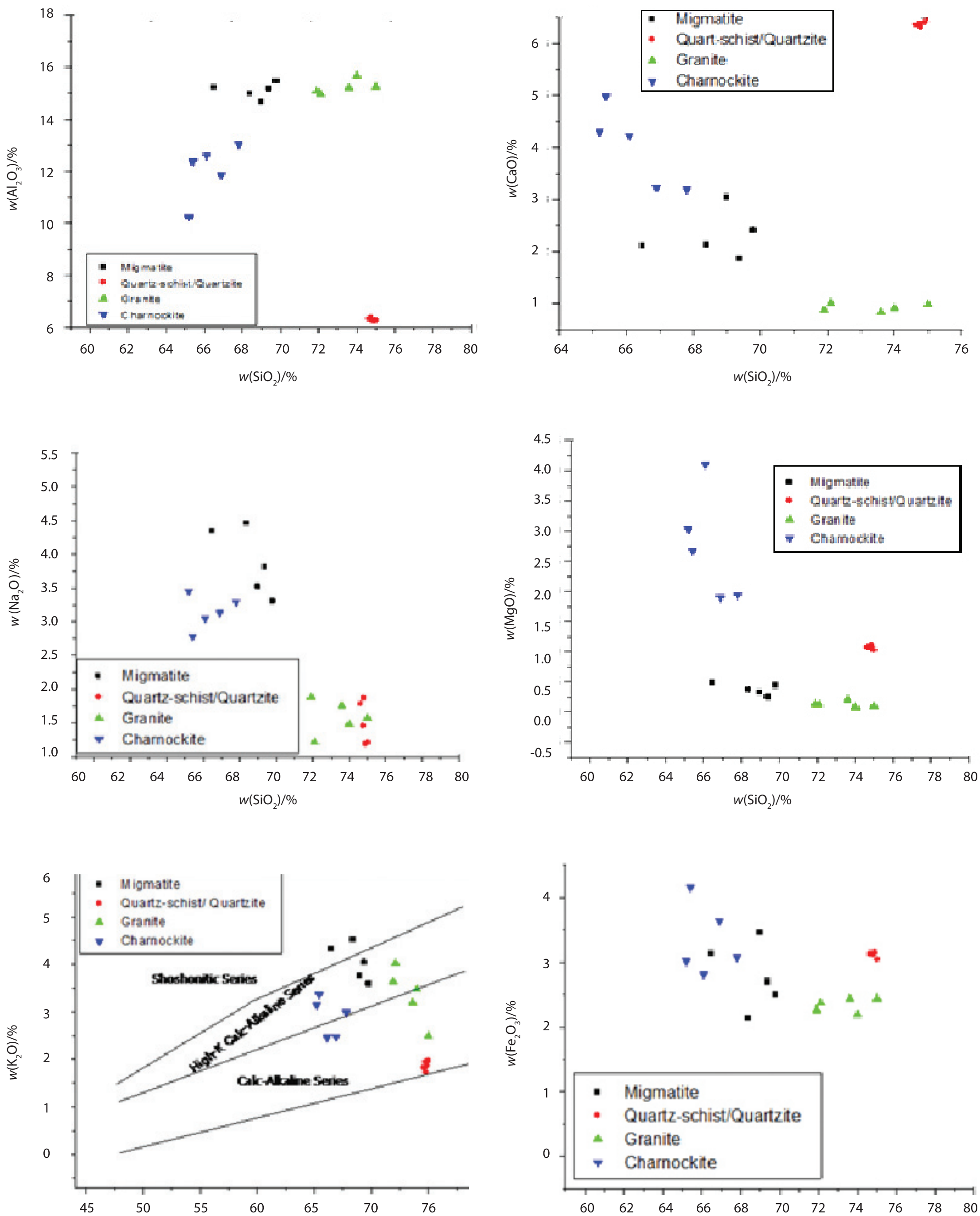

Figure 14: *Harker diagrams showing variations of major element oxides with silica for the rocks in the study area. The K_2O vs SiO_2 diagram after Peccerillo and Taylor (1976) indicates a high - K affinity of the rock units.*

Table 6: *Chemical composition (in mass fractions) of rocks in the study area*

Sample Code	Locality	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
Rock Type													
Migmatite													
Mf1	Oye	69.80	15.46	2.50	0.20	2.40	0.43	3.30	3.58	0.08	0.04	2.01	99.80
Mf2	Iworoko	69.40	15.18	2.70	0.34	1.86	0.24	3.80	4.04	0.09	0.06	2.21	99.92
Mf 3	Are	68.40	14.98	2.13	0.38	2.12	0.36	4.46	4.51	0.10	0.05	2.35	99.84
Mf 4	Igbemo	66.50	15.22	3.13	0.26	2.10	0.48	4.34	4.32	0.07	0.04	3.32	99.78
Mf 5	Ogbesse	69.00	14.65	3.46	0.40	3.03	0.31	3.52	3.76	0.06	0.05	2.02	100.30
	Min.	66.50	14.65	2.13	0.20	1.86	0.24	3.30	3.58	0.06	0.04	2.01	
	Max.	69.80	15.46	3.46	0.40	3.03	0.48	4.46	4.51	0.10	0.06	3.32	
	Mean	68.60	15.10	2.78	0.32	2.30	0.36	3.88	4.04	0.08	0.05	2.38	
	Std. Dev.	1.29	0.30	0.52	0.08	0.45	0.10	0.51	0.38	0.02	0.01	0.54	
Quartz – schist/quartzite													
Q6	Ado	75.02	6.25	3.04	2.17	6.48	1.02	1.20	1.97	0.04	0.01	2.62	99.82
Q7	Ado	74.92	6.22	3.14	2.16	6.40	1.10	1.18	1.86	0.03	0.02	2.72	99.75
Q8	Ilawe	74.78	6.34	3.13	2.18	6.38	1.08	1.45	1.94	0.04	0.02	2.68	100.02
Q9	Ijero	74.80	6.28	3.12	2.17	6.31	1.06	1.86	1.72	0.03	0.03	2.63	100.01
Q10	Ogbesse	74.65	6.30	3.13	2.15	6.36	1.07	1.78	1.82	0.04	0.02	2.66	99.98
	Min.	74.65	6.22	3.04	2.15	6.31	1.02	1.18	1.72	0.03	0.01	2.62	
	Max.	75.02	6.34	3.14	2.18	6.48	1.10	1.86	1.97	0.04	0.03	2.72	
	Mean	74.83	6.28	3.11	2.17	6.39	1.07	1.49	1.86	0.04	0.02	2.66	
	Std. Dev.	0.14	0.05	0.04	0.01	0.06	0.03	0.32	0.10	0.01	0.01	0.04	
Granite													
Gf11	Ado	75.00	15.24	2.44	0.09	0.98	0.09	1.57	2.49	0.03	0.23	2.15	100.3
Gf12	Ado	72.10	14.98	2.37	0.12	1.01	0.12	1.21	4.02	0.05	0.15	2.05	98.13
Gf13	Itapa	74.00	15.68	2.19	0.10	0.91	0.08	1.48	3.47	0.02	0.03	2.04	100.00
Gf14	Ikere	71.90	15.10	2.26	0.08	0.86	0.13	1.88	3.64	0.04	0.11	2.16	98.15
Gf15	Oshin	73.60	15.22	2.43	0.11	0.82	0.20	1.75	3.19	0.06	0.01	2.28	99.63
	Min.	71.90	14.98	2.19	0.08	0.82	0.08	1.21	2.49	0.02	0.01	2.04	
	Max.	75.00	15.68	2.44	0.12	1.01	0.20	1.88	4.02	0.06	0.23	2.28	
	Mean	73.30	15.24	2.34	0.10	0.92	0.12	1.58	3.36	0.04	0.11	2.14	
	Std. Dev.	1.33	0.27	0.11	0.02	0.08	0.05	0.26	0.57	0.02	0.09	0.10	
Charnockite													
Cf21	Ado	66.1	12.58	2.81	0.1	4.22	4.11	3.05	2.46	1.13	0.61	2.8	99.95
Cf22	Ikere	65.2	10.22	3.02	0.21	4.3	3.03	3.45	3.14	1.01	0.56	3.55	97.70
Cf23	Afao	65.4	12.36	4.16	0.17	4.98	2.67	2.78	3.36	1.1	0.67	2.55	100.20
Cf24	Ire	66.9	11.85	3.64	0.15	3.22	1.89	3.13	2.47	0.98	0.71	2.82	97.75
Cf25	Igbole	67.8	13.03	3.08	0.14	3.18	1.94	3.29	2.98	1.04	0.53	3.18	100.20
	Min.	65.2	10.22	2.81	0.1	3.18	1.89	2.78	2.46	0.98	0.53	2.55	
	Max.	67.8	13.03	4.16	0.21	4.98	4.11	3.45	3.36	1.13	0.71	3.55	
	Mean	66.3	12.01	3.34	0.15	3.98	2.73	3.14	2.88	1.05	0.62	2.98	
	Std. Dev.	1.07	1.09	0.55	0.04	0.77	0.91	0.25	0.4	0.06	0.07	0.39	

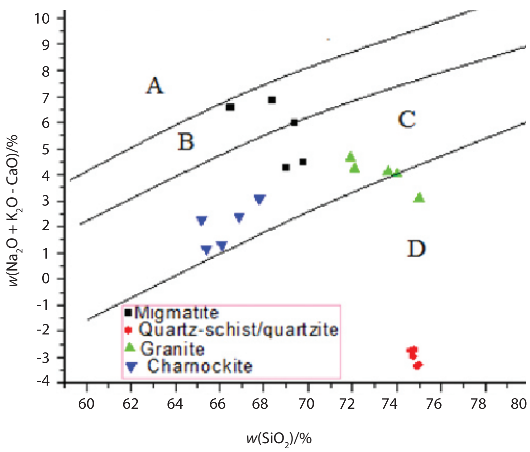

Figure 15: *$Na_2O + K_2O$-CaO versus SiO_2 diagram after Frost et al. (2001) showing the classification of the major rocks into A (alkalic), B (alkali-calcic), C (calcic-alkali) and D (calcic) groups.*

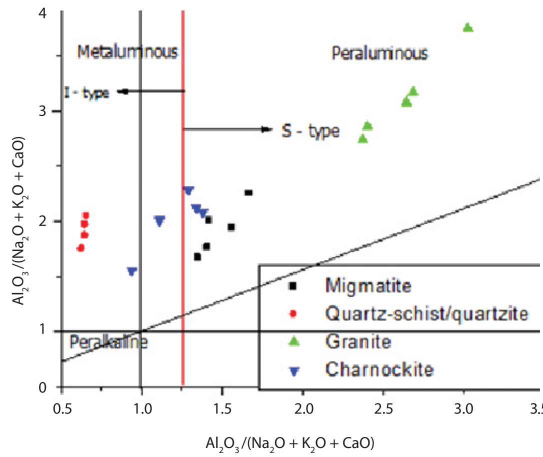

Figure 18: *Plot of alumina saturation vs alkalinity after Maniar & Picooli (1989) highlight the major rock units in the study area.*

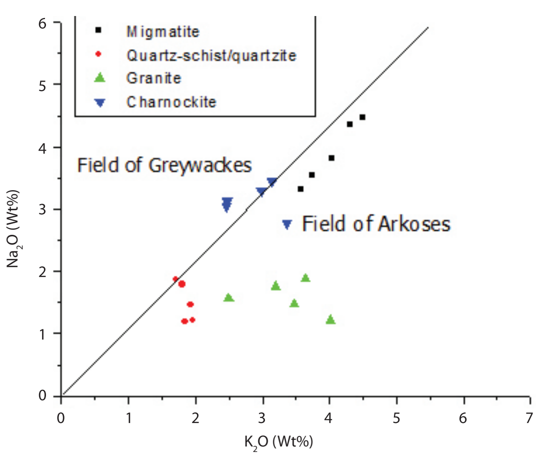

Figure 16: *Na_2O versus K_2O Discrimination Diagram (Pettijohn, 1975).*

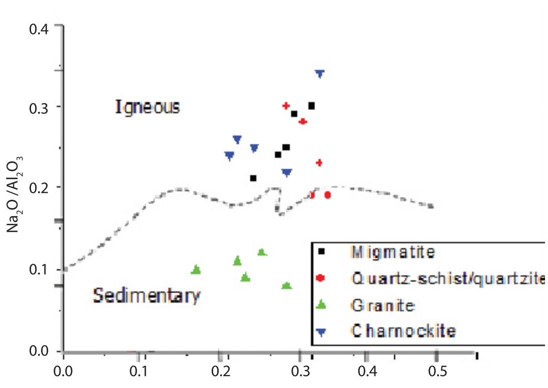

Figure 17: *Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot for some basement rocks in Ekiti State (Garrells & Mackenzie, 1971).*

Conclusion

This study revealed that gneiss/migmatite, quartz-schist/quartzite, the Pan-African granites and charnockites as major rock units in the study area. Mineralogically, quartz and feldspar are dominant in most of the rock units. Chemical assessment of the rocks indicated SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, TiO_2, P_2O_5, MnO as major oxides while variation diagrams of K_2O versus SiO_2 suggested that the rocks in the study area are calcic-alkali and alkali-calcic dominated. The various discriminatory diagrams suggest sedimentary origin for the granite, migmatite and quartz-schist/quartzite rocks while the charnockite has a preference for igneous source.

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