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Compositional characteristics and petrogenetic features of metasediments of Ijero-Ekiti area, Southwestern Nigeria

Značilnosti sestave in petrogeneze metasedimentov z območja Ijero-Ekiti v jugozahodni Nigeriji

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Abstract

Metasediments and subordinate mafic-ultramafic units within ancient migmatite-gneiss complex intruded by granite and pegmatite characterize the basement terrain of Ijero-Ekiti. Compositional characteristics and petrogenetic features of the metasediments (quartzite, biotite schist and amphibole schist) were investigated and reported. Mineralogical determinations from optical studies show that Ijero-Ekiti quartzite is composed of quartz and microcline, while the schistose units contain varying proportions of quartz, muscovite, biotite, and hornblende with subordinate opaque minerals.

Analytical data on major elements composition using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) method revealed the siliceous (SiO_2 content ranging from 65.96–70.40 %) nature of the rocks. Trace element geochemistry using X-ray fluorescence (XRF) techniques show abundance of Ba, Zr, Sr, Rb and Ni in the quartzite, while the schistose rocks show enrichment in Ni and Rb. Ternary plots of MgO-CaO-Al_2O_3 and variation plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 suggests sedimentary protolith for the investigated rocks. SiO_2 versus CaO and Na_2O versus K_2O plots show all samples in the field of greywacke. K_2O versus SiO_2 plot and ternary plot of (Na_2O + K_2O)-Fe_2O_3-MgO indicate calc-alkaline affinity for all samples. Provenance indicators such as Ba, and the concentration of immobile trace elements like Th in the quartzite unit suggests derivation of this sedimentary protolith from weathering of granitic rocks. Chemical Index of Alteration (CIA) for the schistose units shows moderate weathering intensity while index of compositional variability (ICV) reveals average compositional maturity for the sediments.

Key words: metasediments, protolith, Ijero-Ekiti, provenance, calc-alkaline

Izvleček

Metasedimenti in podrejeno mafično-ultramafične kamnine v starem migmatitno-gnajsnem kompleksu, intrudiranem z granitom in pegmatitom, so značilni za kristalinično podlago v Ijero-Ekiti. Poročamo o raziskavah značilnosti sestave in petrogeneze metasedimentov (kvarcita, biotitovega skrilavca in amphibolovega skrilavca). Mikroskopsko določene mineraloške značilnosti pričajo o tem, da sestoji ijero-ekitski kvarcit iz kremena in mikroklina, medtem ko vsebujejo skrilave kamnine različne deleže kremena, muskovita, biotita in rogovače s podrejenim deležem neprozornih mineralov. Analizni podatki o sestavi glavnih kemičnih prvin, določenih z induktivno vezano plazemsko masno spektrometrijo (ICP-MS), nakazujejo silikatno oz. silicijsko naravo kamnin (vsebnost SiO_2 se giblje med 65,96 % in 70,40 %). Geokemična sestava slednih prvin, določena z rentgensko fluorescenco (XRF), razkriva vsebnosti Ba, Zr, Sr, Rb in Ni v kvarcitu in obogatitev z Ni in Rb v skrilavih kamninah. Ternarni diagrami MgO-CaO-Al_2O_3 in variacijski diagrami Na_2O/Al_2O_3 s K_2O/Al_2O_3 nakazujejo sedimentno poreklo protolita raziskovanih kamnin. Na diagramih SiO_2 s CaO in Na_2O s K_2O se uvrščajo vsi vzorci v polje muljastega peščenjaka. Diagram K_2O z SiO_2 in ternarni diagram (Na_2O+K_2O)--Fe_2O_3-MgO pričajo o kalk-alkalni afiniteti vseh preiskanih vzorcev. Kazalniki porekla, kot je Ba, in vsebnosti nemobilnih slednih prvin kot Th v kvarcitni enoti nakazujejo, da izvira ta sedimentni protolit iz preperevanja granitnih kamnin. Indeks kemijskega preperevanja (CIA) skrilavih kamnin priča o zmerni stopnji preperevanja, medtem ko nakazuje indeks spremenljivosti sestave (ICV) povprečno sestavno zrelost izvornih sedimentov.

Ključne besede: metasedimenti, protolit, območje Ijero-Ekiti, izvor, kalk-alkalne kamnine

Introduction

The basement complex of Nigeria comprises Neoproterozoic-Early Paleozoic rocks and rocks of Pan-African age. These basement rocks, are loosely classified into three main lithological units. These are the ancient migmatite-gneiss complex, the schist belts and the Pan African granites[1] (Figure 1). The migmatite-gneiss suites are mainly sedimentary series with associated minor igneous rocks which have been variably altered by metamorphic, migmatic and granitic processes[2–4]. Schist belts more prominently occur in the western part of the country as an integral part of the basement rocks. They form essentially N-S trending belts of low to medium grade supracrustal rocks with minor metavolcanic assemblages of mafic to ultramafic rocks (Figure 1). The schist belts are composed largely of metamorphosed pelitic and psammitic assemblages. These bodies were believed to occur along west of 8° Meridian[2, 5, 6]. However, some poorly developed schist belts exist beyond these limits[7–10]. Schist belts exhibit distinct petrological and structural features. Some of these belts in the southwest include the Iseyin-Oyan, Igarra, Egbe-Isanlu and Ife-Ilesha schist belts[11–14]. The others are Lokoja-Jakura, Toto-Gadabuike belts[13, 15, 16] while the Obudu schist belt is the recently highlighted belt in southeastern Nigeria[10]. This study, presents geochemical and petrogenetic features of the metasediments around Ijero-Ekiti. The results are bringing better understanding to the evolution of schistose assemblages.

Lithological Association and Petrography

The study area is located 42 km northwest of Ado-Ekiti, the Ekiti State capital. The area lies between latitudes 7°46′N to 7°53′N and longitudes 5°00′E to 5°07′E. The metasediments of Ijero-Ekiti area are quartzite, biotite schist and amphibole schist. The schistose rocks underlie the central region where they are associated with units of migmatite gneiss complex. The latter comprises migmatite gneiss, biotite gneiss and calc gneiss, with subordinate epidiorite, granite and pegmatite (Figure 2). Quartzite occurs in isolated lenses around Ijero-Ekiti town and as thick-bedded, steeply inclined and extensive ridge around Oke-Oro (Figure 3). Biotite schist in the study area shows a north-south foliation trend and are poorly exposed. They are geomorphologically characterized by extensive lowlands particularly when they

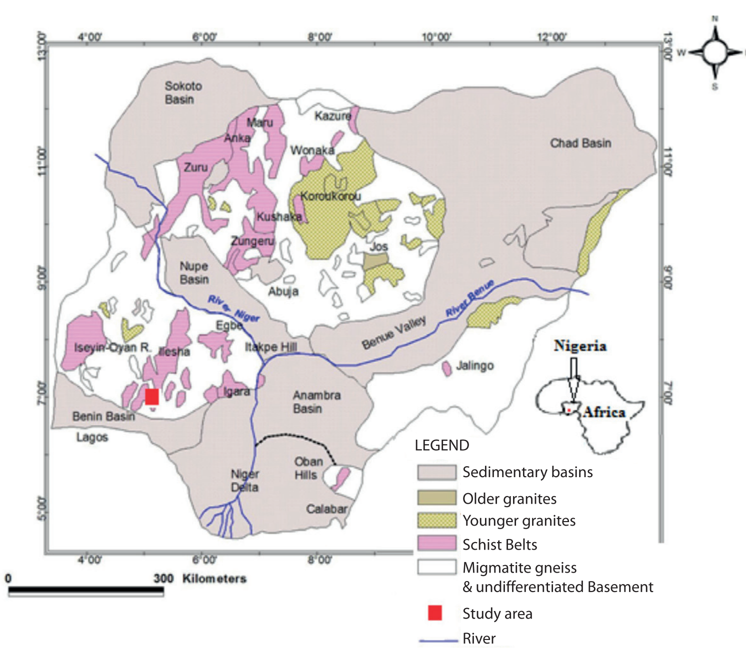

Figure 1: *Geological map of Nigeria showing location of the study area within the undifferentiated basement complex of the country.*

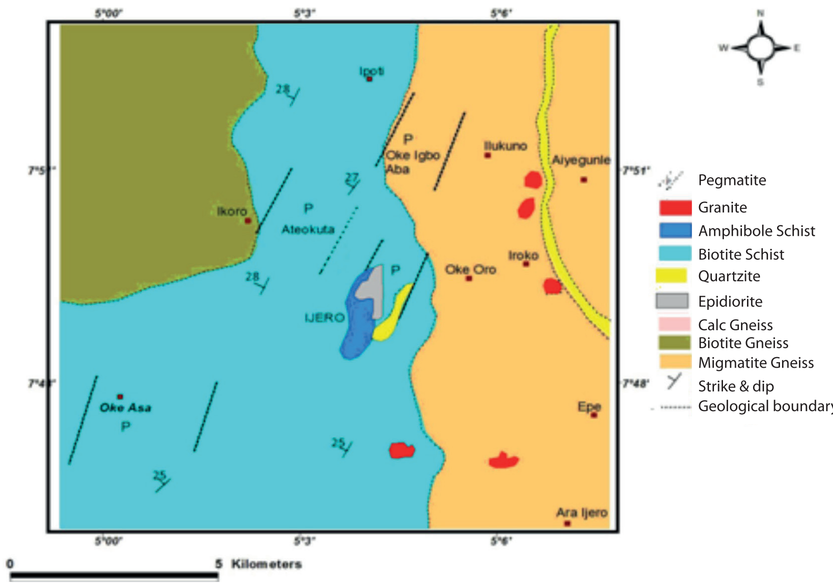

Figure 2: *Geological map of Ijero-Ekiti[17].*

Figure 3: *Exposure of the massive, thickly bedded, and steeply inclined Quartzite in the study area.*

occur in contact with quartz ridge or gneisses. This is a direct result of high susceptibility to weathering due to pronounced fissility. Therefore some outcrops occur as highly denuded masses along the major river channels. The occurrence of amphibole schist is restricted to the centre of the study area. Direct contacts between metasediments and associated rocks are poorly exposed. Pegmatite bodies form intrusions in older schistose rocks. Migmatite gneisses in the eastern part of the study area are found as denuded and highly foliated outcrops. They are invaded by scattered discontinuous but extensive north-south trending quartzite lenses. The northwestern part of the area is covered by fine-grained biotite gneisses. Calc-gneisses are restricted to the area around Ijero-Ekiti town. They are equigranular exhibiting weak foliation and are composed of quartz, muscovite and rare microcline crystals. Characteristic feature of calc-gneisses is their grayish to greenish colour and the lack of quartz vein intrusions.

Materials and methods

The study involves systematic geological mapping, samples were collected using standard geological techniques and thin sections study of each rock unit was undertaken. Forty-five samples (fifteen each for the three metasediments) were collected. Caution was taken to ensure that all the samples used are fresh, not weathered and uncontaminated. Subsequently, the samples were crushed, pulverized and sieved using sieve size 0.075 mm for geochemical investigations. 0.2 g sample aliquot was weighed into a graphite crucible and mixed with 1.5 g of $LiBO_2/LIBO_4O_7$. The sample charged was heated in a muffle furnace for 30 min at 980 °C. The cooled beads was dissolved in 100 m/L of 5 % HNO_3 (ACS grade Nitric acid) in de-mineralized water. An aliquot of the solution was poured into a propylene test tube. Calibration standard and verification standard were included in the sample sequence. Sample solution was aspirated into an ICP Mass Spectrometer (Perkin-Elmer Elan 9000) for the determination of major oxide at the Activation Laboratories in Ontario Canada.

Results and discussion

Petrography

For the biotite schist, biotite, muscovite and quartz are evidently visible minerals (Figure 4) but the amphibole schist shows preponderance of hornblende while quartz, biotite and accessory opaque minerals are the minor components (Figure 5). In thin section, quartz in biotite schist occurs as tiny and sub-angular grains with weak birefringence and low relief. In the amphibole Biotite occurs abundantly as the major schist, quartz grains occur as small, colourless and sometimes cloudy xenomorphic crystals. groundmass minerals and its characteristic green and brown colours, medium relief, weak birefringence colours and a low extinction angle ranging between 5° and 12° are its peculiarities. Modal analysis of the metasedimentary rocks are given in Table 1.

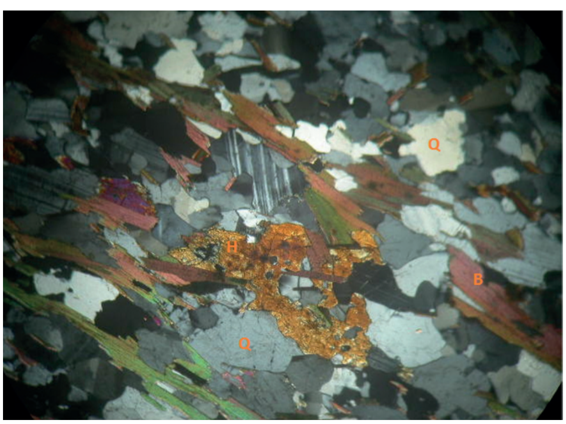

Figure 4: *Photomicrograph of Ijero-Ekiti biotite schist in transmitted light showing biotite (B), quartz (Q) and hornblende (H).*

Figure 5: *Photomicrograph of amphibole schist in transmitted light showing fine-grained sub-angular crystals of quartz (Q), stretched Hornblende(H) and aligned Biotite (B).*

Geochemical features

Analytical result (Table 2) indicates that average SiO_2 value in quartzite is 70.01 %. This value however, is slightly lower than the Okemesi quartz schist[18], quartz schist of Ibadan area[19]. Also, many other quartzite samples in the Nigerian metasedimentary belts[1, 20, 21]. These values make them chemically similar to quartz sandstones[22] and comparable to Jebba quartzite and micaseous quartzite of central Nigeria[23]. Conversely, the average SiO_2 value in the biotite schist (67.01 %) and amphibole schist (67.91 %) is within the limits for average schistose rocks of Nigeria[24, 25]. They are also similar to Jakura quartz mica schist[1]. Average Al_2O_3 content is lowest in quartzite (10.72 %) while amphibole schist (15.29 %) has higher average value than biotite schist (12.35 %) does. Conversely, Fe_2O_3 values in biotite schist ranges between 6.73 % and 7.79 % with an average of 7.26 % while in amphibole schist the

Table 1: *Modal composition of metasediments of Ijero-Ekiti*

Minerals	Quartzite			Mean	Biotite Schist			Mean	Amphibole Schist			Mean
Quartz	58	56	55	56	32	35	34	34	29	25	31	28
Hornblende	2	7	4	4	4	6	4	5	35	34	38	36
Biotite	8	5	6	10	43	37	46	42	9	11	8	9
Muscovite	26	23	26	25	12	15	13	13	9	4	4	6
Feldspar	4	3	4	4	3	3	3	3	10	18	10	13
Opaque	4	6	4	1	5	4	–	3	8	8	7	8
Total	100	100	100	100	100	100	100	100	100	100	100	100

values that range between 5.56 % and 6.03 % with an average of 5.88 %. Quartzite records iron oxide content ranging between 7.50 % and 9.12 % with a mean value of 8.14 %. Mean MnO content is generally lower than 1.5 % in all the metasediments. The values of SiO_2, Al_2O_3, Fe_2O_3 and MnO are however within the range for most metasediments[26]. MgO, CaO and Na_2O have average values that are generally less than 3.00 % with biotite schist (2.33 %) recording the highest mean MgO content. However, amphibole schist (2.04 %) has the highest mean CaO content and Na_2O (1.67 %) values as against 1.15 % and 1.56 % respectively for biotite schist and 1.49 % and 1.60 % for quartzite. Average Na_2O content of Ijero biotite schist is comparable to the phyllitic schist around Lokoja-Jakura area[1]. The average TiO_2 content is generally low in all the samples, however amphibole schist (0.05 %) records a slightly higher value as against quartzite (0.03 %) and biotite schist (0.03 %) from Okemesi area[18], but the values are lower than quartz schist and biotite muscovite schists of the same area. These values are comparable to the Ibadan quartz schist[19]. Mean K_2O content of biotite schist (4.03 %) is higher than quartzite (2.55 %) with amphibole schist (1.66 %) recording the least

Table 2: *Chemical composition of metasediments of Ijero-Ekiti*

Oxides (%)	Quartzite (*N* = 15 samples)		Biotite Schist (*N* = 15 samples)		Amphibole Schist (*N* = 15 samples)	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**
SiO_2	69.20–70.40	70.01	65.96–67.46	67.01	66.97–68.11	67.91
Al_2O_3	9.98–12.44	10.72	11.07–13.05	12.36	14.60–16.04	15.29
Fe_2O_3	7.50–9.12	8.54	6.73–7.79	7.26	5.56–6.03	5.88
MnO	1.14–1.56	1.35	0.10–0.27	0.18	0.11–0.24	0.17
MgO	0.82–1.20	1.08	1.74–3.61	2.33	1.09–1.43	1.25
CaO	1.38–1.63	1.49	1.13–1.20	1.15	1.94–2.16	2.04
Na_2O	1.62–1.93	1.60	1.53–1.80	1.56	1.34–2.00	1.67
K_2O	2.00–2.75	2.55	1.80–4.08	4.03	1.54–1.80	1.66
TiO_2	0.03	0.03	0.03–0.050	0.03	0.03–0.07	0.05
P_2O_5	0.31–0.51	0.39	0.84–1.02	0.92	0.01–0.033	0.01
LOI	1.30–2.90	2.23	2.80–3.90	3.10	3.51–4.70	4.01

Table 3: *Trace element composition of metasediments of Ijero-Ekiti*

Trace elements (µg/g)	Quartzite		Biotite Schist		Amphibole Schist	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Ba	15.0–76.0	52	85–211	123	94–162	121.2
Sr	19–55	34	43–94	59	59–281	183.7
Ni	4–32	18	115–192	134.7	164–223	196.3
Cu	5–21	11.5	15–53	29.5	42–70	53.7
Rb	17–31	24.5	35–157	101.2	75–128	99.8
Zr	169–242	199.2	50–143	88.3	39–102	70
U	15.4–28.2	19.5	15.8–29.3	21.4	7–23	11
Th	2.0–23	11.7	7.4–26	18.2	15–43	23
La	2–9	5	5–12	7	14–28	19
La/Th		0.43		0.39		0.83
Th/U		0.6		0.38		2.1
CIA (%)	**63–69**	**66**	**65–73**	**69**	**73–75**	**74**
ICV	**1.17–1.70**	**1.43**	**1.11–1.48**	**1.25**	**0.78-0.86**	**0.82**

mean value. The values are still within the limits for metasedimntary rocks[27] and comparable to that of Scottish metapelites[20], Igarra quartz mica schist[28], Okemesi quartz schist[18], the Burum marble[16]. These values are however higher than those for Ibadan quartz schist[19]. The metasediments (Table 3) shows a pronounced enrichment in Ba, Sr, Ni and Rb in biotite schist and amphibole schist than in the quartzite. Zr content of all the rocks is appreciably high but Cu values are comparatively low in all the rocks.

Provenance of the protolith and Tectonic Setting

Generally, when compared to similar rocks, the average SiO_2, Na_2O and K_2O values of Ijero metasediments are low. This may suggest addition of argillaceous materials, hence fluctuating energy levels in the environment. The indiscernible trend in the K_2O versus SiO_2 diagram (Figure 6) may imply that K-metasomatism or metamorphic differentiation within each rock group was minimal. The petrogenetic character of the rocks as established on the Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot (Figure 7)[29] shows the entire samples plotting in the sedimentary/metasedimentary field, implying that the rocks are largely of sedimentary origin, hence a common origin for the protolith of the rock units. In the MgO-CaO-Al_2O_3 diagram (Figure 8;[30], the samples plot outside the magmatic field also supporting the sedimentary antecedent of the rocks. These features makes the Ijero-Ekiti metasediments similar to those of Ilesha[13], Birnin-Gwari schist[31] and Jebba schists[23, 32]. The provenance of sedimentary rocks inferred from the framework constituents of the rocks[23, 33–35]. From a low Ba, Rb and Sr content of quartzite (Table 3) as against biotite and amphibole schist, and in particular, the high Zr content in all the samples may reflect the presence of detrital zircon in the rocks[13]. There is also a strong possibility of a sedimentary source of greywacke composition, although the contribution of a felsic source is certain[23, 32, 36]. This is further supported by the plot of the samples within the field of Franscisian greywacke on the SiO_2 versus CaO diagram of[27] (Figure 9).

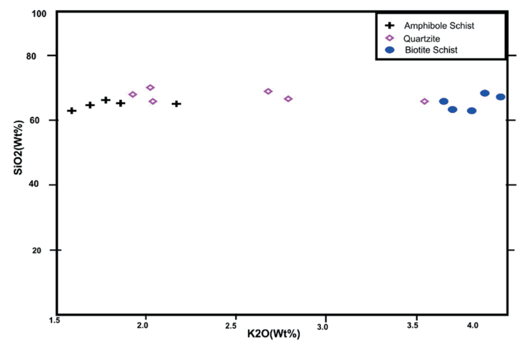

Figure 6: *SiO_2 versus K_2O plot of Ijero metasediments (After[37]).*

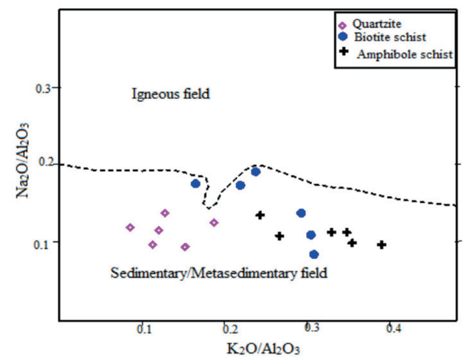

Figure 7: *Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot of Ijero metasediment (After[29]).*

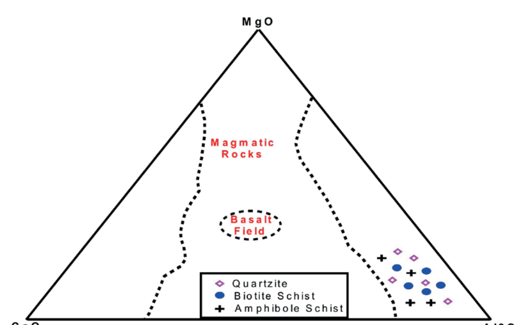

Figure 8: *MgO-CaO-Al_2O_3 plot of Ijero metasediments (After[27]).*

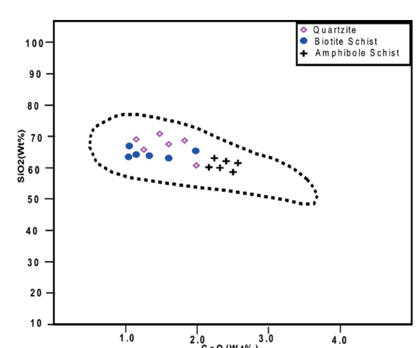

Figure 9: *SiO_2 versus CaO plot of Ijero metasediments (After[38]).*

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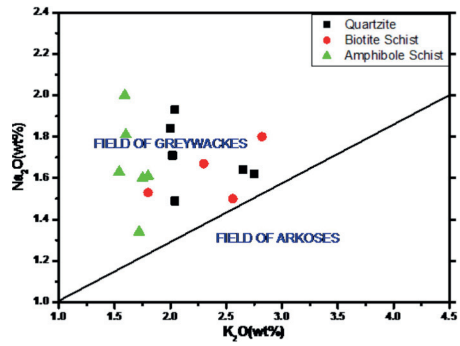

Figure 10: *Na_2O versus K_2O plot of Ijero metasediments (After[39]) metasediments.*

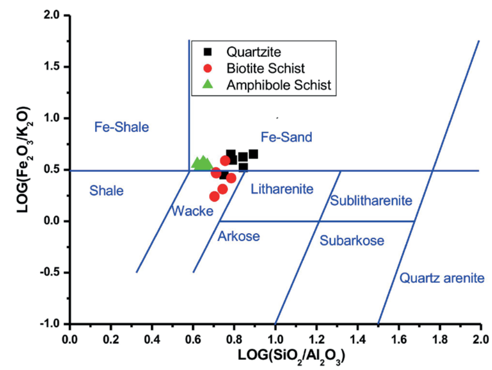

Figure 11: *Log (Fe_2O_3/K_2O) versus. Log (SiO_2/Al_2O_3) of Ijero.*

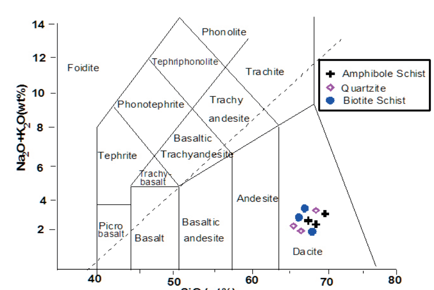

Figure 12: *Na_2O+K_2O versus SiO_2 (Total alkali versus Silica) plot of Ijero metasediments (After[38]).*

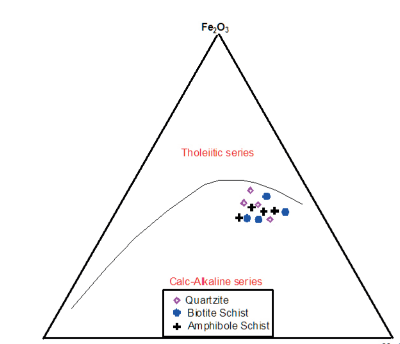

Figure 13: *(Na_2O+K_2O)-Fe_2O_3-MgO plot for metasediments of Ijero-Ekiti (After[41]).*

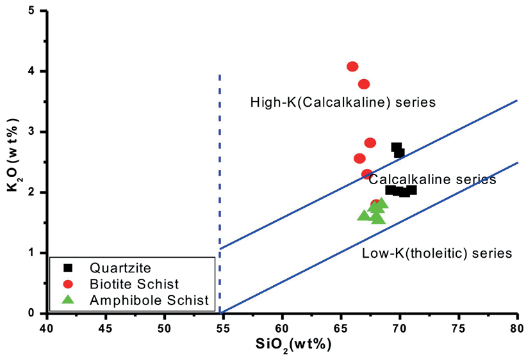

Figure 14. *K_2O vs SiO_2 Ternary plot for the metasediments of Ijero-Ekiti (After[38]).*

comparable to those of post Archean recycled upper crust sources[30, 42].

The results of the Chemical Index of Alteration (CIA)[43, 44] defined as

$CIA = [Al_2O_3 / (Al_2O_3 + CaO + Na_2O + K_2O)] \times 100$ (Table 3) reveal average values for the quartzite (66 %), biotite schist (69 %) and amphibole schist (74 %); these values indicate relatively intense chemical weathering of the source rocks. The Index of Compositional Variability (ICV)[45] defined as

$ICV = (Fe_2O_3 + K_2O + Na_2O + CaO + MgO + TiO_2) / Al_2O_3$ (w/%) which measures the abundance of alumina relative to other constituents of the rock except SiO_2 show that the quartzite, biotite schist and amphibole schist have average ICV value of 1.43, 1.25, and 0.82 respectively (Table 3). Compositionally immature pelitic rocks have high ICV, whereas mature pelitic rocks with little non-silicates possess low values (< 0.6)[1]. The calculated ICV value for the quartzite (1.43) shows the immature nature of the sedimentary protolith prior to meramorphism. Mature to moderately mature metasediments are characteristics of relatively stable cratonic environments[26]. This may mark sediment recycling or moderate to very intense chemical weathering of first cycle material[46].

Conclusions

Systematic geological mapping, petrographic study and geochemical evaluation of the schistose rocks around Ijero-Ekiti show that the metasediments are continental post-Archean supracrustal assemblages. The sedimentary protolith prior to metamorphism have had greywacke affinity, and are derived from granitic source rocks rich in felsic components the quartzite was derived from moderate to fairly intense weathering of these rocks. The schistose rocks were probably deposited in a miogiosynclinal basin that was characterized by subsidence with rapid rates of sedimentation.

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