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The Composition and Origin of the Amphibolite's in Kumunu, North Central Nigeria

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Abstract

The study area is bounded by latitudes 10o 00' 00" N to 10o 20' 00" N and longitudes 6o 15' 00" E to 6o 30' 00" E in Tegina Sheets 142 SE and part of 142 NE. Three samples of amphibolite's were analyzed for major element oxides using (ICM-MS). The mineral phases of the amphibolite's examined contains: diopside + hornblende, hornblende + garnet, hornblende, hornblende + biotite. The rocks are characteristic of amphibolite facies metamorphism. Al, Ti, Sc, Zr, Y, Ta, Hf, Nb and heavy REE were the elements less redistributed by the metamorphism or alteration in the studied area. The amphibolite's from Kumunu are similar to the low-k tholeiites affinity, typical of the early stages of development of recent island arc. The geochemical peculiarities of the amphibolites and associated rocks in the study area suggest an origin in a tectonic setting similar to modern volcanic arcs environment. Some of the geochemical features of the amphibolites can be explained through the involvement of a component of subducted sediment in the source region. This suggests that the amphibolites are derived from sedimentary rocks. It is suggested that the evolution of the rocks is related subduction that occurred during the Pan-African event.

Keywords: Kumunu, Metamorphism, Paragenesis, Tectonic, Pan-African.

Introduction

The Pan-African schist belt which trends North to South has trans versing the Tegina District between Kumunu-Kagara and Madaka, North-central Nigeria. The Nigeria migmatite-gneisses-complex contains rocks ranges from surface to deep amphibolite facies [1]. Most are quartzofeldspathic and migmatitic, associated with migmatitic granitoids. They include an elongated granulite belt, which comprises kinzigites, two-pyroxene granulites, and mafic amphibolite's with relict kyanite-eclogitic assemblages. The study area is delimited by latitudes 10o 00' 00" N to 10o 20' 00" N and longitudes 6o 15' 00" E to 6o 30' 00" E in Tegina Sheets 142 SE and part of 142 NE (Figure 1). The regional geology of the Tegina Districts was undertaken by [1]. Several studies have investigated the geochemistry of rocks identified by in Niger and Zaria provinces, these includes, though the majority are concerned with the tectonic evolution of the area mainly on granites, amphibolites, gold and talcose rocks [1-9]. The contact zones between the granitic rocks and amphibolite's of the Kushaka belt are marked by abundance of fine-grained amphibolites xenoliths in the tonalities. The actual contact between the larger xenoliths and the tonalites is usually sharp and is sometimes characterized by a shear foliation in the tonalite [10, 11]. A body of schist with intercalated amphibolites was mapped around Tegina-Kagara road [9]. These meta sediments and metavolcanics rocks are over 30km from the main outcrops of the Kushaka Formation and are surrounded by Pan-African granitic or migmatitic rocks [8]. A variety of amphibolites and talc-bearing schists partly formed from tholeiitic basalt, Banded iron formations of several thick units are matrixes within the Kushaka schist belt described smaller scale structures in the Kushaka schist belt which demonstrate its longer and more complex history [7, 6, 5]. The Kalangai transcurrent fault is a major feature in the Kushaka schist belt [12]. This fault is important in mineralization control of gold and rare metals in the area [13, 14]. The main aim of this paper is to provide detailed petrochemical analyses of the amphibolites and to discuss their petrogenesis and tectonic constraints in Kumunu, North Central Nigeria.

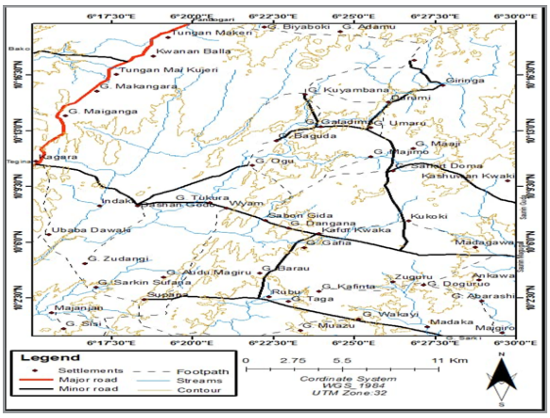

Figure 1: The location, accessibility, drainage and relief map of Kumunu area

Methodology

Three (3) Fresh samples of amphibolites were taken during the field work around Kumunu area with the aid of sledge hammer. Amphibolites were described based on their mode of occurrence, macroscopic characteristics, structural elements and field relation with adjacent rocks in the study area. Hand specimens were described based on the following macroscopic features. Samples taken from the field were prepared as thin section and photomicrographs of the thin sections of amphibolites were produced at the Petrographic Laboratory, Department of Geology, Ahmadu Bello University, Zaria, Nigeria. Three selected samples of amphibolites were analyzed for major element oxides at Activation Laboratories Limited (ACTLAB), analytical Laboratory Ancaster, Ontario, Canada. The major, trace and rare earth elements in amphibolite's from Kumunnu area were characterized using discriminant plots for genetic interpretation.

Results and Discussion

The amphibolites occur as narrow discrete bands in N-S towards the southwestern part of the study area Figure 2. They are well exposed along River Goro. Outcrops of the amphibolite's are lenticular, texturally

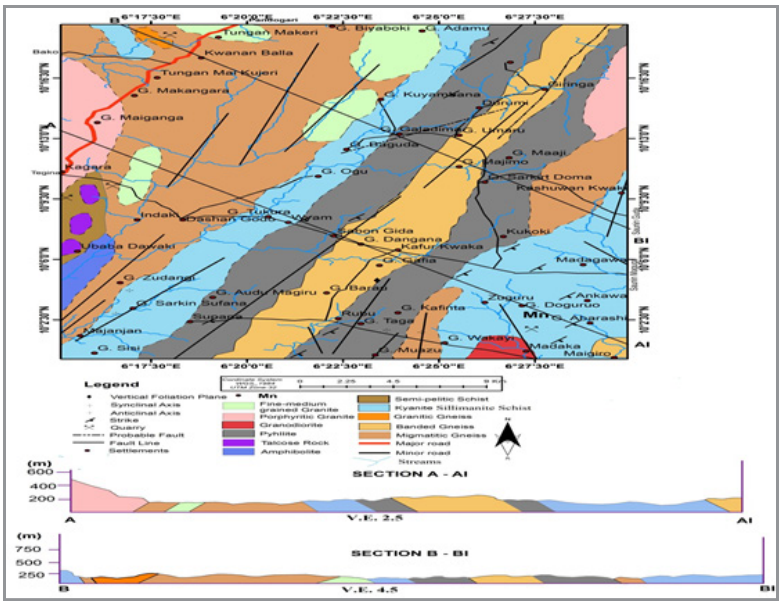

Figure 2: The geological map of Kumunu area.

distinctive and well oriented sub-parallel to the N-S foliated trend. In the extreme North-east of the Gidan Usman, running up to Gidan Ogu area, the phyllites dominates. It continues into the west of Gidian Sisi where the same rocks and their relationships can be observed several kilometers along the river channels. Two varieties of amphibolites were revealed in the field. They are the banded and massive varieties. The banded variety is medium grained, strongly foliated and dark green in color whereas the massive variety is fine to medium grained, weakly foliated and dark grey in color (Plate I). The remarks by have shown that the regional geology of Pan-Africa foliation cross-cuts the amphibolite-facies especially in sheared zones [6, 10]. The magmatic layering of the rocks responsible for the syn-kinematic recrystallization in deep conditions of these intrusive rocks as well as the Archean granite-gneisses of the same province of Africa terrain. Amphibolites form contacts with surrounding rocks (talcose rocks and granites) which are often marked by development of cataclastics and mylonites which represent a major fracture zone along Kumunu-Tegina road [9]. The color of the amphibolite's in the study areas varies. Outcrops along the River Durumi are generally grey while those in Indaki and Kumunu areas varies from green to dark green in color. This color variation is due to the presences of the clinochore minerals (Plate IIa-b).

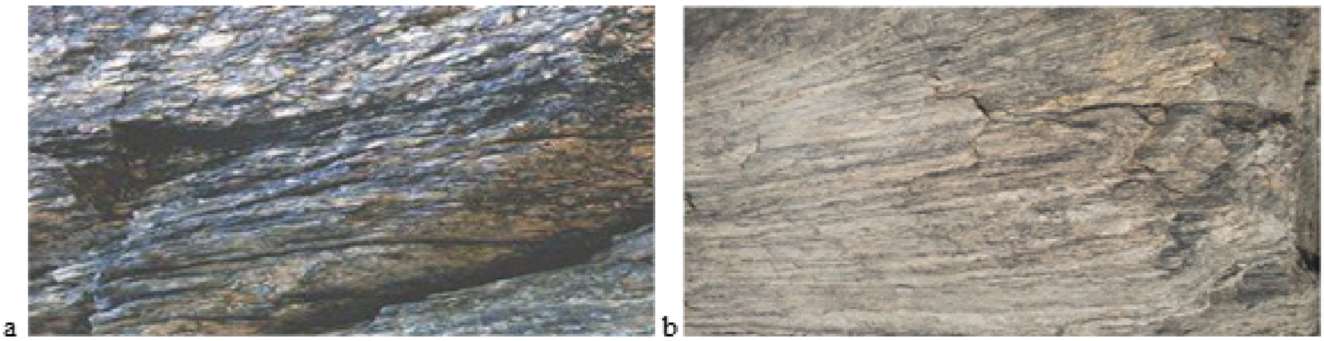

Plate I: (a) Mylonite with a reduced quartz and feldspar grain size around Gidan Ogu area (Latitude 10° 11' 46"N and Longitude 6° 15' 56" E)
(b) The banded amphibolite's along Kumun-Tegina road (Latitude 10° 11' 18"N and Longitude 6° 15' 40" E).

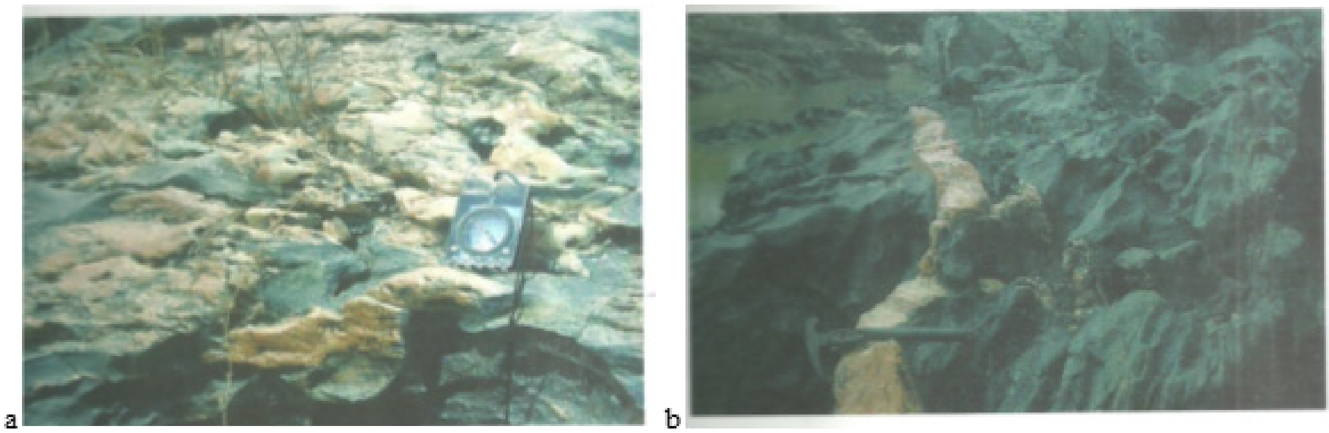

Plate II: (a) Photograph of amphibolite's and talcose rock around Kumunu North-west of Tegina (Latitude 10° 07' 32" N and Longitude 6° 17' 21" E)
(b) Amphibolite (dark colored) with N-S trending direction along River Goro cross cut by quartzite (light colored) (Latitude 10° 07' 23"N and Longitude 6° 16' 23"E)

In hand specimen, the banded amphibolites is green in color, fine to medium grained, highly foliated or lineated due to preferred orientation of dark and light-colored minerals (Plate IIIa) while the massive amphibolites shows weak foliation under microscopic observation. It consists of two main minerals, very dark green hornblende and colorless feldspar with high relief (Plate III b). The mineral assemblage in this rock contains quartz 23%, plagioclase 17%, hornblende 49%, chlorite 7%, epidote 1% and opaque minerals 3%.

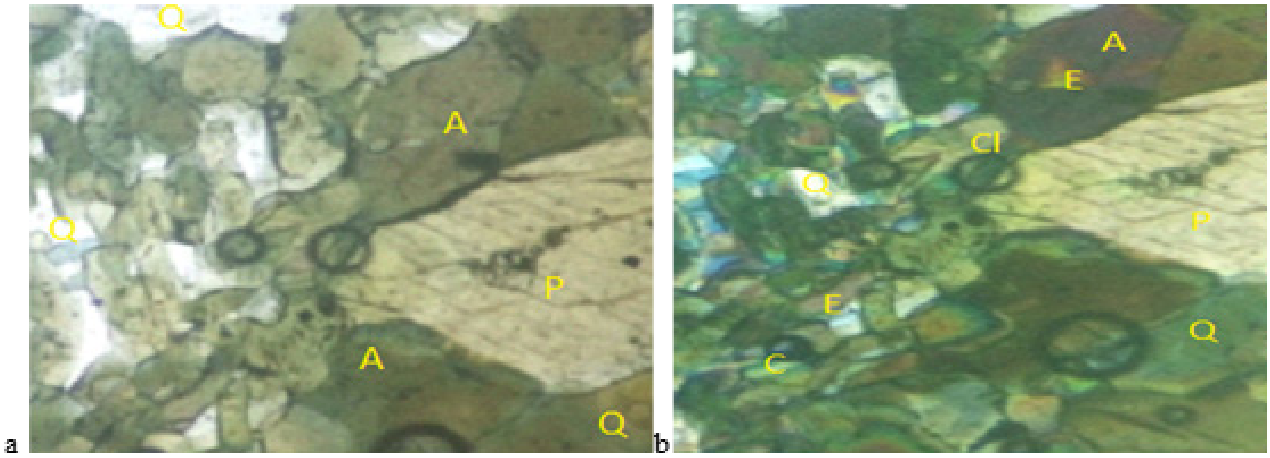

Plate III: Photomicrograph of under (a) plane polarized light (PPL) with brown colored biotite
(b) crossed polarized light (XPL) showing biotite and plagioclase feldspar with high relief. Qtz= Quartz, A= hornblende, C=chlorite, P= Plagioclase.

Amphibolite's

The major element compositions of the amphibolites and ratios of some oxides are presented in Table (1). The SiO_2 ranges from 49-53.98wt%; average 51.44, Al_2O_3 ranges from 13.32-14.01 wt%; average 13.78, Fe_2O_3(T) ranges from 8.05- 9.85wt%; average 8.93, MnO 0.15-0.32wt%; average 0.23, MgO 8.01-12.0 wt%; average 9.89, CaO ranges from 8.76-11.6 wt%; average 9.89, Na_2O ranges from 1.04-2.21wt%; average 1.72, K2O 0.22-0.41wt%; average 0.29, TiO_2 0.74-0.81wt%; average 0.78, P_2O 0.07-0.08wt%; average 0.08, and L.O.I ranges from 2.21-3.1 wt% average 3.17 in the amphibolites.

Table 1: Major elements composition of the amphibolites in the study area (values in wt %)

	Amphibolite	Amphibolite	Amphibolite		Range		
Oxide	S16	S17	S18	Sum	Min	Max	Average
SiO_2	49.0	51.35	53.98	150.3	49.0	53.98	51.44
Al_2O_3	14.0	13.32	14.01	41.33	13.32	14.01	13.78
$Fe_2O_{3(T)}$	8.90	9.85	8.05	26.8	8.05	9.85	8.93
MnO	0.15	0.32	0.21	0.68	0.15	0.32	0.23
MgO	12.0	8.99	8.01	29.0	8.01	12.0	9.67

CaO	11.6	8.76	9.32	29.68	8.76	11.6	9.89
Na_2O	1.04	1.92	2.21	5.17	1.04	2.21	1.72
K_2O	0.24	0.41	0.22	0.87	0.22	0.41	0.29
TiO_2	0.74	0.79	0.81	2.34	0.74	0.81	0.78
P_2O_5	0.07	0.08	0.08	0.23	0.07	0.08	0.08
LOI	2.21	4.21	3.10	9.52	2.21	3.10	3.17
Total	100.	100.0	100.0	296.1	99.9	100.	99.99
FeO	8.01	8.86	7.24	118.8	7.24	8.01	39.6
FeO/ MgO	0.67	0.99	0.9	4.09	0.67	0.99	1.36
FeO /MnO	53.4	27.69	34.48	174.7	27.7	53.4	58.2
Al_2O_3/ SiO_2	0.29	0.25	0.26	0.27	0.25	0.29	0.09
K_2O/ Na_2O	0.23	0.21	0.1	0.17	0.1	0.23	0.06
Al_2O_3 /TiO_2	18.9	16.86	17.3	17.63	17.3	18.9	5.88
Al_2O_3/ CaO+ Na_2O	1.11	1.25	1.22	1.19	1.11	1.25	0.40

The ternary diagram of CaO-Fe_2O_3+MgO-Al_2O_3 (after [15] (Figure 3). The ternary plots K20–CaO-Na_2O (after [16], Figure. 4.

The binary diagram of K_2O /Al_2O_3 versus Na_2O/ Al_2O_3, after [17] Figure 5.

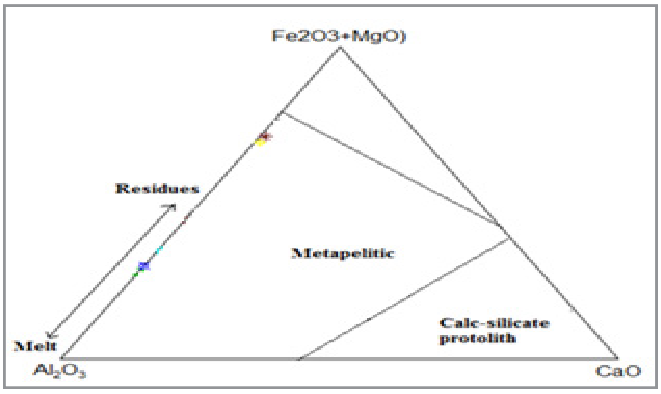

Figure 3: The ternary plot of CaO-Fe_2O_3+MgO-Al_2O_3 [15] shows the pelitic rock fields.

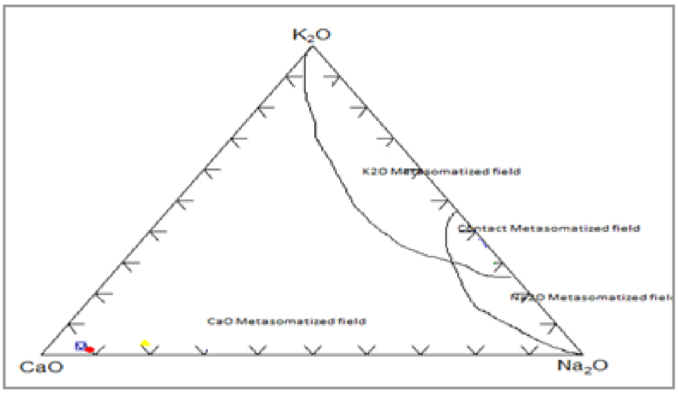

Figure 4: The ternary plots K20–CaO-Na2O (after [16].

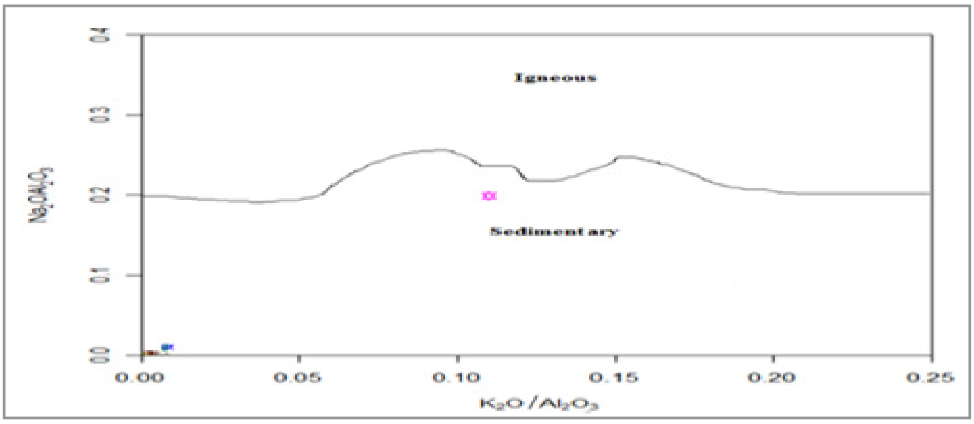

Figure 5: The binary plot of K_2O /Al_2O_3 versus Na_2O/Al_2O_3 after shows the rocks plotting in the sedimentary field [17].

The composition abundances of trace earth elements of the amphibolites is presented in Table (4). The Co ranges from 101–190ppm; average 137.33, Cr ranges from 48–1670 ppm; average 1061, Ni ranges from 90–1634.0ppm; average 978, Sc ranges from 63.0–68.5ppm; average 43.48, and V ranges from 76–359.0ppm; average 262.7. The content of Ba ranges from 2.0–161.0ppm; average 55.33 and show wider variations. The composition of (HFSE) shows that: Zr ranges from 31.0–54.0ppm, average 40 and Ta ranges from 0.1-0.5ppm; average 0.23, Th ranges from 0.1-.0.30 ppm, average 0.17 and U ranges 0.1-.0.30 ppm, average 0.17.

Table 2: Trace elements composition of amphibolites in the study area (values in ppm).

	Amphibolite	**Amphibolite**	**Amphibolite**		**Range**		
Code	S16	S17	S18	Tot	Min	Max	Ave
Sc	63.0	68.5	< 1	131.5	63.0	68.5	43.83
V	353.0	359.	76.0	788.	7 76.0	359.	262.7
Ba	2.0	3.0	161.	166	2.0	161.	55.33
Y	5.0	5.0	19.0	29	5	19	9.67
Zr	35.0	31.0	54.0	120	31	54	40
Cr	1670	1465	48.0	3183	48	1670	1061
Co	101	121	190	412	101	190	137.33
Ni	1210	1634	90.0	2934	90	1634	978
Cu	19.0	34.0	60.0	124	19.0	60	41.33
Zn	68	45	16	129	16.0	68	43
Ga	11	17	2	30	2.0	17	30
Sb	< 0.5	0.6	0.8	1.4	0.6	0.8	0.47
Ta	0.1	0.1	0.5	0.7	0.1	0.5	0.23
Th	0.1	0.1	0.3	0.5	0.1	0.3	0.17
U	0.1	0.1	0.3	0.5	0.1	0.3	0.17

On the Zr/Y versus Y plot (Figure 6) according to [18], the amphibolites fall in the Island arc basalt field (IAT)

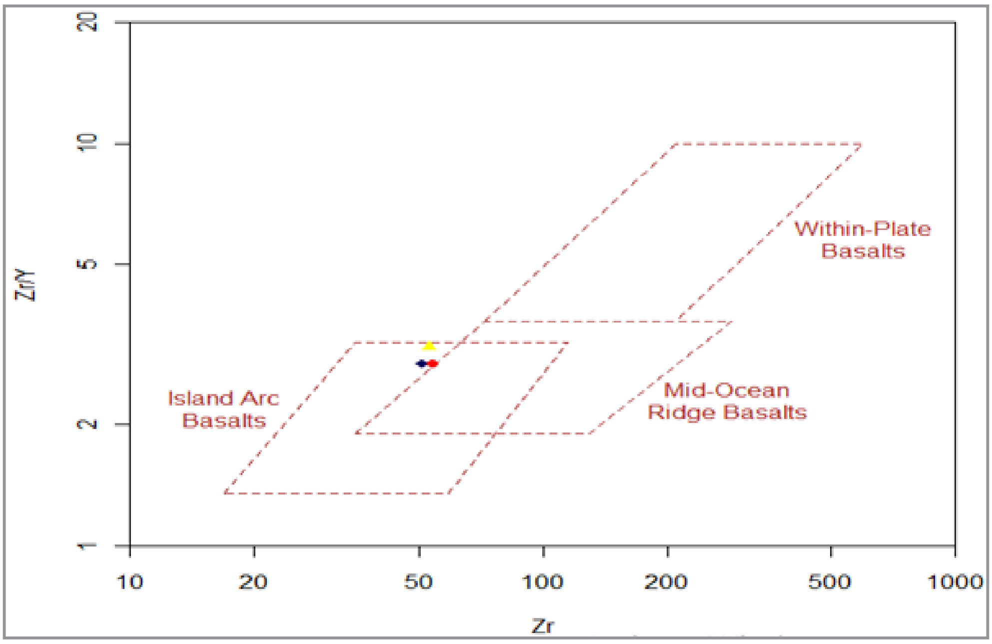

Figure 6: The discrimination diagram after showing the Island arc affinity of the amphibolites in the study area [18].

The concentration of ΣREE of the amphibolites ranges from 3.97-6.11ppm, average 4.64. The analytical data shows that the amphibolites of study area are enriched in light rare earth elements (LREE). The La ranges from 0.60-2.8 ppm; average 1.4, Ce ranges from 0.9-5.7ppm; average 2.57 Nd ranges from 0.40-2.5ppm; average 1.13 and in contrast of heavy rare earth elements (HREE) showing depleted values. Other composition of REE in the amphibolites include: Pr ranges from 0.06-1.67ppm; average 0.61, Gd ranges from 0.6-1.1ppm; average 0.74 and Tb ranges from 0.1-0.40ppm; average 0.23. The concentration of ΣLREE in the amphibolites ranges from 2.36- 13.87pm; average 6.24. while the concentration of ΣHREE ranges from 3.97ppm, average 4.64 and Eu anomalies ranges from 0.04-0.21. The rare earth elements composition of the amphibolites is presented in Table (3).

Table 3: Rare earth elements composition of amphibolites in the study area (values in ppm)

Code	Amphibolite	Amphibolite	Amphibolite		Range		
Elem Ents	S16	S17	S18	Total	Min	Max	Average
La	0.8	0.6	2.8	4.2	0.60	2.8	1.4
Ce	0.9	1.1	5.7	7.7	0.90	5.7	2.57
Pr	0.09	0.06	1.67	1.82	0.06	1.67	0.61
Nd	0.4	0.5	2.5	3.4	0.40	2.5	1.13
Sm	0.3	0.1	1.2	1.6	0.10	1.2	0.53
Eu	0.05	0.04	0.21	0.3	0.04	0.21	0.1
Gd	0.6	0.51	1.1	2.21	0.60	1.1	0.74
Tb	0.2	0.1	0.4	0.7	0.10	0.4	0.23
Dy	1.1	1.4	1.5	4.0	1.1	1.50	1.33
Ho	0.2	0.3	0.4	0.9	0.2	0.4	0.3
Er	0.7	0.3	0.67	1.67	0.30	0.67	0.56
Tm	0.11	0.15	0.11	0.37	0.11	0.15	0.12
Yb	0.7	0.5	1.4	2.6	0.50	1.4	0.87
Lu	0.31	0.54	0.32	1.17	0.31	0.54	0.39
ΣREE	6.46	6.2	19.98	32.64	6.2	19.98	10.88
ΣLREE	2.49	2.36	13.87	18.72	2.36	13.87	6.24
ΣHREE	3.97	3.84	6.11	13.92	3.97	6.11	4.64

Conclusion

The mineral paragenesis of the amphibolite's contains: diopside + hornblende, hornblende + garnet, hornblende, hornblende + biotite in its ferromagnesian phases. All amphibolites in the study area have hornblende and plagioclase as major constituents, whereas diopside occurs only in the amphibolites from the western part of study area. Biotite is very rare in the amphibolites and has been described only in the epidote-rich amphibolite's, while sphene is a common accessory phase in all amphibolites. Retrogression is evidenced by the chloritization of garnet, and epidotization of plagioclase and epidotization of hornblende, according to the plagioclases at low metamorphic grades up to the epidote [19-21]. The metamorphic event recorded in the Kumunu area is characterized by a high temperature metamorphism (M_1) [11]. The peak metamorphic conditions recovered from the metapelitic rocks around Tegina yield a P–T condition at 7–5 Kb pressure [11, 21, 22]. This is in line with that the foreland nappes derived from passive margin sedimentary beds of the West African Craton display of the high-pressure metamorphism had earlier reported that the amphibolites around Tegina area can be attributed to ensialic mode of evolution, implying that the mafic series must have been emplaced within a continental environment though tholeiitic in nature [22, 11]. The variation of metamorphism of amphibolite facies from high to low-temperature followed by anatexis and lower pressure conditions developed around Kumunu area suture zone, high-pressure conditions being recorded prior to anatexis in the frontal part of migmatite-gneiss complex of the Nigerian basement [22]. The geochemical features of the amphibolites from Kumunu are similar to the low-K tholeiites affinity, typical of the early stages of development of recent island arc. Al, Ti, Sc, Zr, Y, Ta, Hf, Nb and heavy REE were the elements less redistributed by the metamorphism and/or alteration in the studied area. The geochemical characteristics of the amphibolites and associated rocks in the study area suggest an origin in a tectonic setting similar to modern volcanic arcs in a oceanic subduction zone environment. On the other hand, two of the amphibolites from the studied area have geochemical characteristics more similar to those of mid-ocean ridge basalts, and therefore they may have originated in a back-arc spreading environment. It seems highly probable that the amphibolite is the remnants of a volcanic arc-back-arc basin pair. Some geochemical features of the amphibolites can be explained through the involvement of a component of subducted sediment in the source region.lt is suggested that the evolution of the amphibolites are related to subduction that occurred during the Pan-African event. The petrochemical peculiarities suggest that the amphibolite's from the Kumunu are derived from sedimentary rocks as evidenced from the rocks in the area.

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Conflict of Interests

No conflict of interests in this work

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