Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.7, 2013

Geochemistry and Petrogenesis of Gneisses Around Kafur-Yari Bori-Tsiga area within the Malumfashi Schist Belt, Northwestern Nigeria.

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Abstract

The gneisses around Kafur-Yari Bori-Tsiga area consist of varieties such as banded gneiss, augen gneiss and granite gneiss. This area is underlain by both igneous and metamorphic rocks; the schist and migmatite-gneiss are intruded by the Pan-African granitoids. Minerals such as microcline, plagioclase, quartz, hornblende, biotite, orthoclase forms the major components in the gneisses while garnet, zircon and sphene are the accessories minerals. Foliation in the gneisses is defined by parallel alignment of mafic and felsic minerals (bands) having a major strike range of NE-SW to N-S and lesser of E-W directions. The geochemical study revealed major oxides such as SiO_2 in the range of 63.85-73.84 wt%, Al_2O_3 has content between 12.77-16.05 wt%, Fe_2O_3 is between 1.18-6.70 wt%, Na_2O is between 1.93-4.78 wt% and K_2O between 1.49-6.96 wt %. The concentrations of high field strength elements (Hf, Th, U, Nb and Ta) is rather lower in the gneisses investigated and thus responsible for the small propotion of minerals like the zircon, sphene and apatite which all occurred as accessories minerals. The absence of minerals like sillimanite, kyanite, cordierite and staurolite which are typical of paragneiss confirmed an igneous protolith of the gneisses investigated.

Although, geochemical variations suggest igneous precursors for the gneisses of this area, it is obvious that they were not cogenetic but derived from differing sources and depths.

Keywords: "Basement Complex", cogenetic, Malumfashi, "Older Granite"

1. Introduction

The Palaeoproterozoic Malumfashi Schist belt (Adekoya, 1996; Mucke, 2005) is one among the 12 schist belts so far recognized in Nigeria. It is part of the broader Nigerian "Basement Complex" and comprises mainly of schist, gneisses, migmatite, quartzite and "Older Granites". Aplite and pegmatite form mostly the minor lithologies in this belt.

The gneisses of this area belong to the migmatite-gneiss-quartzite complex. They are the most widespread and occupy about 30% of the total surface area of Nigeria and probably the least studied of the major rock group (Rahaman, 1988). This rock group covered half of the "Basement Complex" of Nigeria (Kröner *et al*. 2001). It is a heterogeneous rock group and comprises largely of migmatite and gneisses; basic schists and gneisses; and relict metasedimentary calcareous, quartzitic and granitic rocks. The gneisses of this complex are reported to compose of relatively simple and monotonous mineralogy; quartz + plagioclase ± K feldspar + biotite ± hornblende. On age relation, earlier workers (Grant *et al.,* 1972; Ogezi, 1977 and Fiches *et al.,* 1985) attributed the migmatite-gneiss to Archean, Eburnean and Kibaran ages. However, works of Kröner *et al.* (2001); Dada (1989) and Bruguier *et al.* (1994) proves only Archean age with no evidence of Eburnian or Kibaran overprints, although, their studies was not a comprehensive study of all zircon types. Rahaman and Ocan (1978) and Burke *et al.,* (1976) have recognized at least a dozen of events in the migmatite-gneiss-quartzite complex with the emplacement of dolerite dykes being the youngest while igneous and /sedimentary activity being the oldest. Other events according to these same authors are shearing, chlorite and zeolite facies metamorphism, undeformed-slightly deformed pegmatite, quartz veins and dykes, emplacement of basic dykes, mangerite sheets, microgranodioritic dykes, mafic-ultramafic rocks, aplitic sheets and the formation of early gneiss.

Some scholars have attributed gneisses in the Nigeria "Basement Complex" to sedimentary origin while others are of the opinion that it is igneous in origin. According to Rahaman (1988), the geochemical data available were insufficient to equivocally distinguish between sedimentary and igneous gneisses. Grant (1970) on the basis of $^{87}Sr/^{86}Sr$ studies of the Ibadan granite gneiss supported an igneous origin while Burke *et al.* (1972) argued that the granite gneiss were derived from isochemical metamorphism of a shale-graywacke sequence (a sedimentary origin). Onyeagocha (1984) on the basis of field and geochemical evidence proposed an igneous origin by partial melting of crustal rocks for the granite gneisses of north-central Nigeria. Supportive of the igneous origin are also works of Ekwere and Ekwueme (1991); Imeokparia and Emofurieta (1991) while Freeth (1971) support a sedimentary origin. Elueze and Bolarinwa, (2004) studies of the granite gneiss of Abeokuta area which gave wide range of Ba and Zr concentration, concluded that the gneisses were of igneous parentage but with sedimentary input. This made it difficult to propose a single mode of origin for the granite gneisses in the

Nigerian basement due to their variable compositions from location to location (Elueze and Bolarinwa, 2004). Works done on the genetics of gneisses of the migmatite-gneiss-quartzite complex are restricted to the southwestern basement of Nigeria; Okonkwo and Ganev, 2012; Elueze *et al*.,2004; Oyinloye, 1998; 2002; 2004; 2011 and Olarewaju, 1988. However, gneisses of the Malumfashi schist belt where the study area is situated were earlier identified by McCurry (1976) on the basis of petrography and not geochemistry, and were on a regional scale. This paper therefore present results of geochemical investigation of gneisses around Kafur-Yari Bori-Tsiga area in the “Basement Complex” of northwestern Nigeria with a view to determine their characteristics and petrogenesis, in order to improve on the existing knowledge.

Plate 1: Granite gneiss along River Jare showing a ptygmatic folding.

Plate 2: Photograph showing the augen structure in augen gneiss around Unguwar Ari.

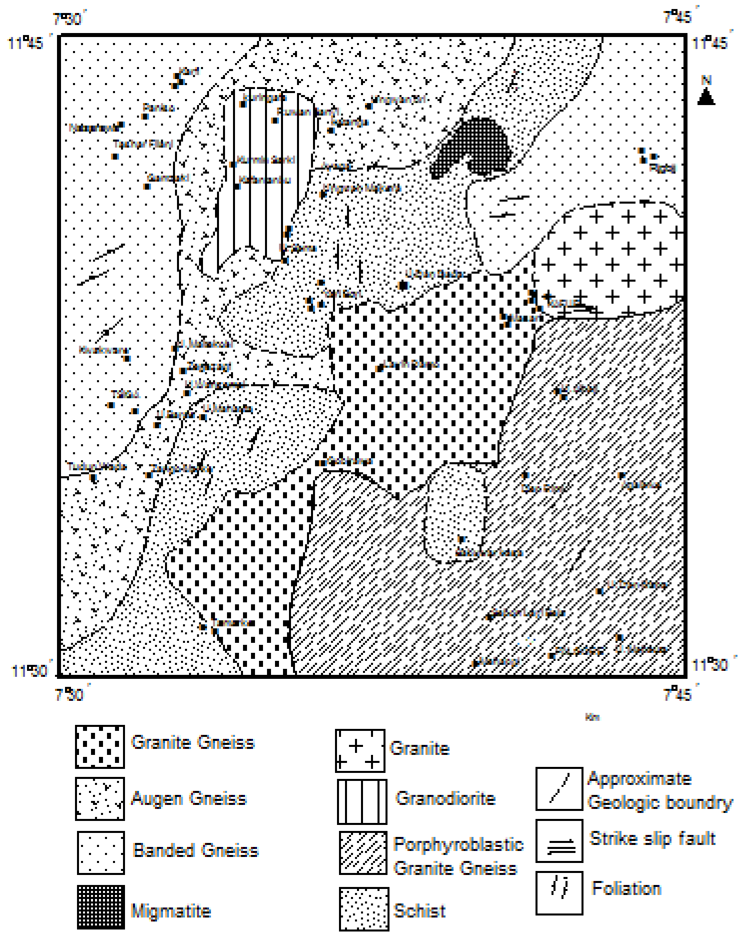

Figure 1: Geological map of Kafur-Yari Bori-Tsiga area.

2. Geochemistry

Eight representative samples of gneisses collected from Kafur-Yari Bori-Tsiga area were investigated in this study. The samples were crushed and packed at the geochemical laboratory of the Department of Geology, Ahmadu Bello University Zaria, Nigeria. Subsequent physical and chemical treatment as pulviration to 200 mesh (85%) and chemical analysis were carried out in ACME Analytical laboratories (Vancouver) limited Canada. Total abundances of the major oxides were measured using 0.2g of sample pulp, analysed by ICP-Emission Spectrometry following a Lithium metaborate/tetraborate ($LiBO_2/Li_2B4O_7$) fusion and dilute nitric digestion. Loss on ignition (LOI) was obtained by weight difference after igniting a sample split at 1000°C. The trace elements which are basically base and precious metals were measured using 0.5g of sample pulp digested in Aqua Regia and analysed by ICP-Mass Spectrometry. Data obtained were analysed using a geochemical data tool kits (GCDKits 3.0)

2.1 Major element geochemistry

The gneisses are characterized by higher SiO_2 in the range of 68.45-73.84 wt% and low contents of Fe_2O_3 and MgO, (1.18-6.70 wt %) and (0.16-0.98 wt%) respectively. In addition, soda remains consistently less than potash in all the gneisses except for samples 5 and 6 (Table 1).

Alumina (Al_2O_3) contents are generally within the same range (12.77-16.05 wt %) for the whole samples. On the alumina saturation index, the gneisses have index greater than one, suggesting that they have corundum in their norm (Fig.4)

Table 1: Major element compositions of gneisses in the study area

Analyte Wt%	P.Granite Gneiss 2	Augen Gneiss 3	Granite Gneiss 4	Granite Gneiss 5	Banded Gneiss 6	Augen Gneiss 7	Granite Gneiss 8	Banded Gneiss 9
SiO_2	63.85	71.94	73.11	67.22	70.75	68.45	73.84	73.75
Al_2O_3	14.68	14.41	14.09	16.05	15.45	15.08	12.77	13.99
Fe_2O_3	6.70	2.75	1.95	3.04	2.22	3.23	2.89	1.18
MgO	0.91	0.50	0.24	0.79	0.84	0.98	0.33	0.16
CaO	2.73	1.32	0.79	2.09	3.09	1.97	0.92	0.81
Na_2O	3.22	1.93	3.28	4.34	4.78	3.66	2.53	3.85
K_2O	5.52	6.96	5.54	4.25	1.49	4.90	5.37	5.05
TiO_2	1.00	0.31	0.16	0.57	0.21	0.50	0.26	0.07
P_2O_5	0.36	0.21	0.05	0.22	0.11	0.15	0.09	0.12
MnO	0.09	0.03	0.02	0.03	0.03	0.05	0.04	0.06
Cr_2O_3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
LOI	0.6	0.4	0.6	1.0	0.9	0.8	0.7	0.8
Total	**99.65**	**99.80**	**99.87**	**99.64**	**99.87**	**99.78**	**99.78**	**99.87**

Table 2: Discriminant function (DF) of the samples calculated

Analyte Wt%	P.Granite Gneiss 2	Augen Gneiss 3	Granite Gneiss 4	Granite Gneiss 5	Banded Gneiss 6	Augen Gneiss 7	Granite Gneiss 8	Banded Gneiss 9
SiO_2	63.85	71.94	73.11	67.22	70.75	68.45	73.84	73.75
Fe_2O_3	6.70	2.75	1.95	3.04	2.22	3.23	2.89	1.18
MgO	0.91	0.50	0.24	0.79	0.84	0.98	0.33	0.16
CaO	2.73	1.32	0.79	2.09	3.09	1.97	0.92	0.81
Na_2O	3.22	1.93	3.28	4.34	4.78	3.66	2.53	3.85
K_2O	5.52	6.96	5.54	4.25	1.49	4.90	5.37	5.05
DF	**3.17**	**1.26**	**2.44**	**4.35**	**3.53**	**3.14**	**0.78**	**3.21**

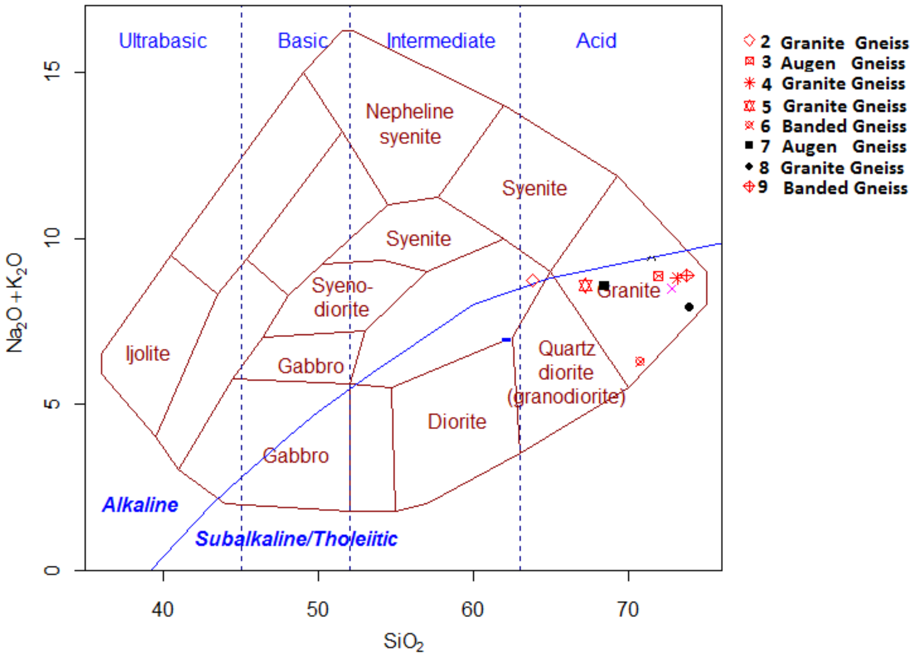

Fig. 2: A SiO_2 versus ($Na_2O + K_2O$) diagram showing the granitic protolith of gneisses in the study area (using the method of Cox *et al.*, 1979)

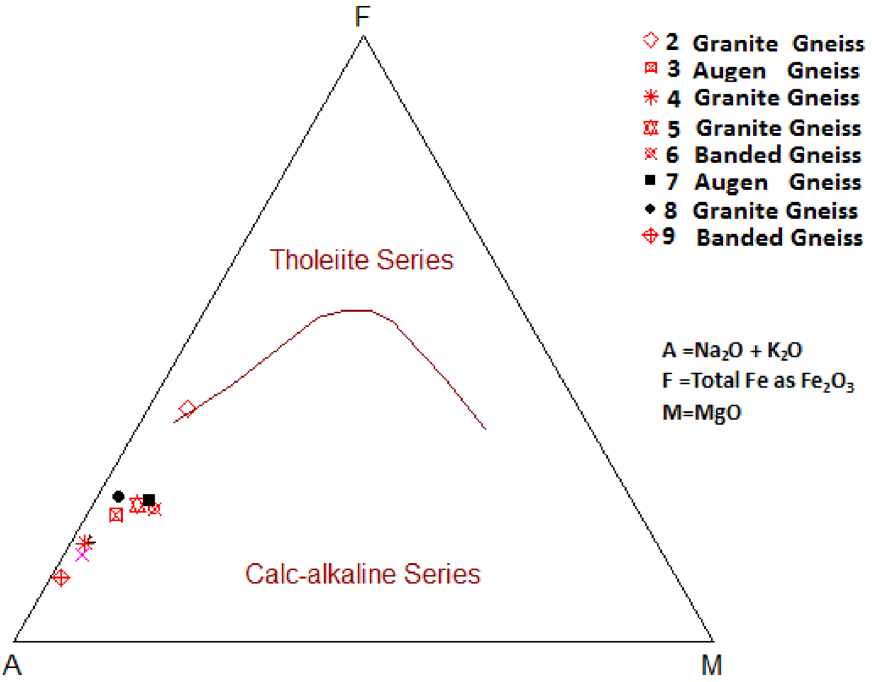

Fig. 3: AFM diagram showing plot of gneisses in the study area (using the method of Irvine and Baragar, 1971)

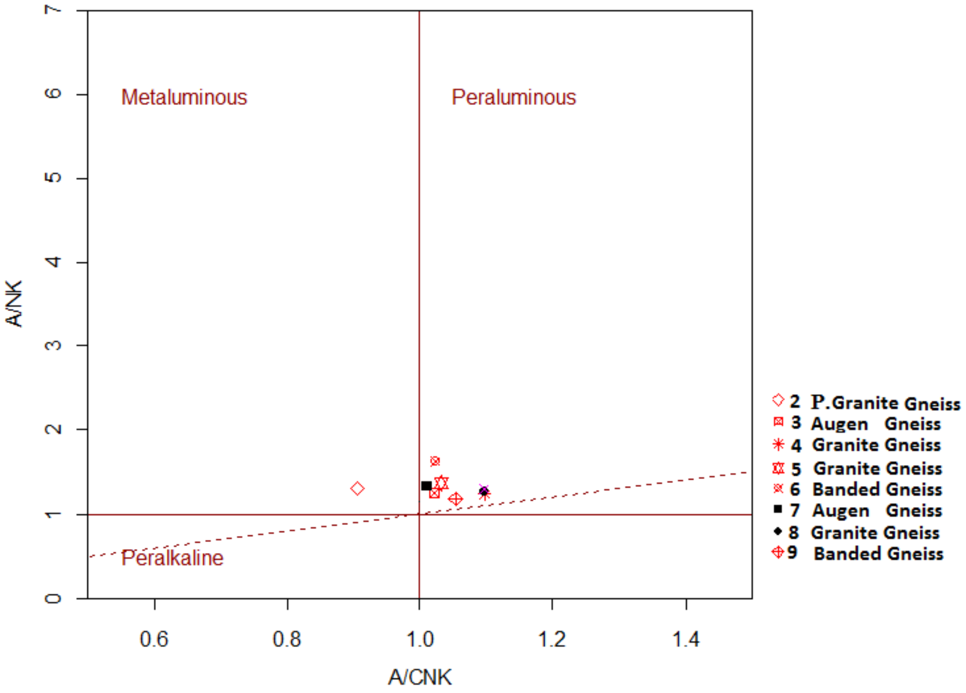

Fig.4: $Al_2O_3/(CaO + Na_2O + K_2O)$ versus $Al_2O_3/Na_2O + K_2O$ plot showing the dominantly Paraluminus nature of the gneisses of the study area (using the method of Shand, 1943)

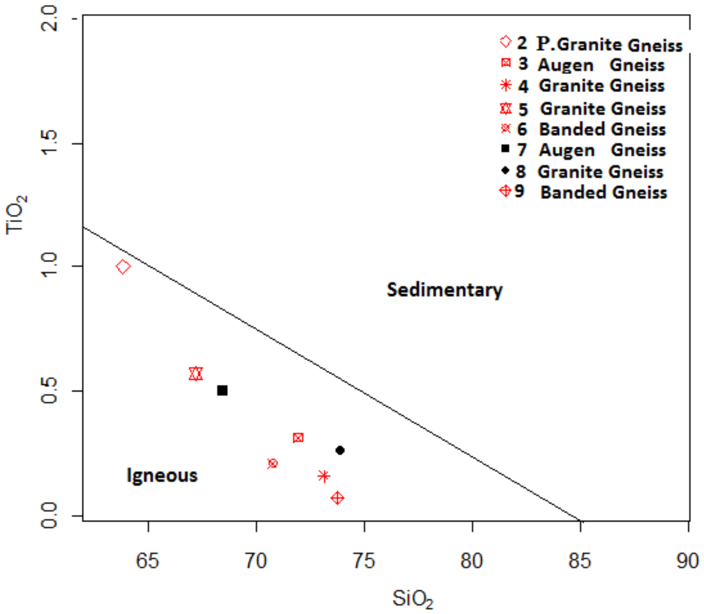

Fig.5: ATiO_2 – SiO_2 discrimination diagram showing plot of different gneisses in the study area (using the method of Tarney, 1977)

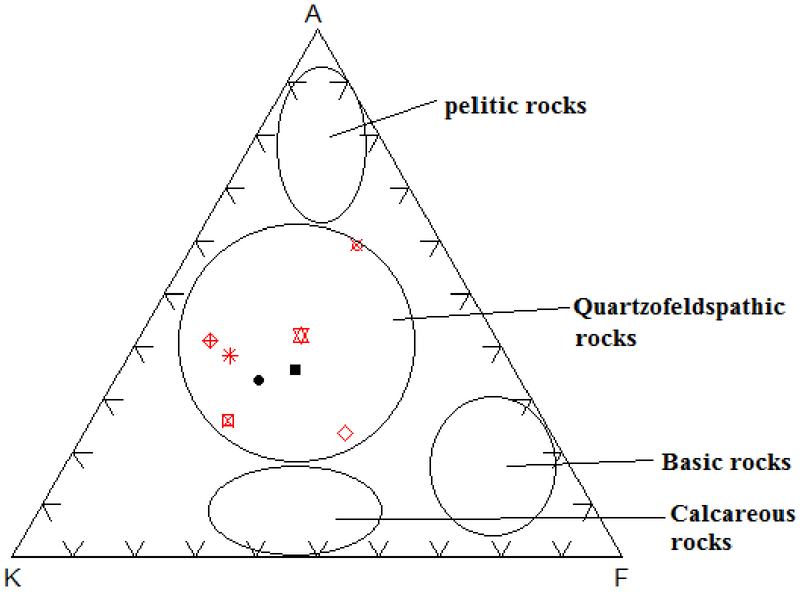

Fig. 6: The field of the gneisses in AKF triangular diagram (using the method of Eskola, 1915)

2.2 Trace Element geochemistry

Trace elements concentrations for the gneisses and their chondrite patterns normalized to average crust are presented in Table 3 and Figure 7 respectively.

Generally, there is marked enrichment of some large ion lithophile elements (LILE). Ba has a content between 702-1597 ppm in all the gneisses except for samples 4 and 6 when compare to the mean crustal value of 435 ppm, Rb has content in the range of 110.8-262.7 ppm as compare to the mean crustal value of 90 ppm except for the banded gneiss (sample 6) that is slightly lower than that; 70.1 ppm (Table 1).

Spider diagram of gneissic rocks normalized to average crust (Fig.7) indicates enrichment of Ba, Zr, Y, and Rb in banded gneisses, one of the granite gneiss (sample 5) relative to the rest granite gneisses and augen gneiss (sample 7).

There is marked depletion of transition elements like V, Cr while Ni and Co are relatively enriched. Sr concentrations in two of the granite gneisses (samples 4 and 8) are lower than the rest gneisses (Table 3). There is also depletion of high field strength elements (HFSE) like the Hf, Th, U, Nb and Ta (Table 3), but with enrichment of Zr in these rocks.

Table 3: Trace element compositions of gneisses in the study area

Analyte ppm	P.Granite Gneiss 2	Augen Gneiss 3	Granite Gneiss 4	Granite Gneiss 5	Banded Gneiss 6	Augen Gneiss 7	Granite Gneiss 8	Banded Gneiss 9
Ba	1153	980	253	1597	193	702	891	405
Be	5	1	<1	<1	4	1	<1	17
Co	45.3	32.5	40.1	34.2	59.2	42.1	45.3	45.7
Cs	4.4	13.3	4.4	3.7	4.5	11.0	8.7	22.7
Ga	22.5	12.8	20.0	24.2	17.3	21.7	18.4	18.1
Hf	11.9	4.3	5.1	5.7	2.0	5.7	7.7	2.1
Nb	43.2	8.1	31.7	8.2	7.7	14.0	20.8	17.7
Rb	191.9	245.5	262.7	110.8	70.1	209.5	250.1	260.0
Sn	3	2	6	2	3	5	7	7
Sr	245.5	198.1	58.0	740.7	319.4	249.0	50.6	104.4
Ta	2.9	0.7	2.6	0.7	1.3	1.5	2.0	4.8
Th	18.2	13.3	39.3	8.4	10.5	30.6	21.0	10.1
U	4.7	5.8	7.1	2.6	5.3	5.2	4.2	6.3
V	45	20	<8	45	27	38	9	<8
W	248.7	195.4	274.9	200.8	362.6	235.9	306.8	328.7
Zr	462.6	159.8	142.1	209.2	70.2	216.7	239.1	54.4
y	50.4	13.0	36.3	5.6	9.6	18.9	60.2	19.2
Mo	3.2	1.6	1.1	1.0	1.1	1.3	1.5	1.4
Cu	13.7	16.4	2.1	9.7	2.3	12.4	3.8	1.5
Pb	8.9	6.0	11.3	10.3	5.1	8.7	5.6	35.9
Zn	76	34	42	73	30	54	67	13
Ag	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ni	3.6	3.9	2.2	5.8	12.0	10.9	2.1	1.5
As	0.5	<0.5	<0.5	1.1	<0.5	2.0	<0.5	2.6
Au	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
Bi	<0.1	1.2	<0.1	<0.1	<0.1	0.4	0.3	0.2
Hg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ti	0.5	0.5	0.4	0.3	0.3	0.7	0.5	0.1
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 4: Interlithophile element ratios of K/Ba, K/Rb, Ba/Rb and Rb/Sr in different gneisses and granite in the study area.

Ppm	Granite 1	P.Granite Gneiss 2	Augen Gneiss 3	Granite Gneiss 4	Granite Gneiss 5	Banded Gneiss 6	Augen Gneiss 7	Granite Gneiss 8	Banded Gneiss 9
K/Ba	52.38	39.74	58.95	181.77	22.09	64.08	57.94	50.03	103.51
K/Rb	303.33	238.78	235.34	175.06	318.41	176.44	194.15	178.24	161.23
Ba/Rb	5.79	6.00	3.99	0.96	14.41	2.75	3.35	3.56	1.55
Rb/Sr	0.82	0.78	1.23	4.52	0.14	0.21	0.84	4.94	2.49

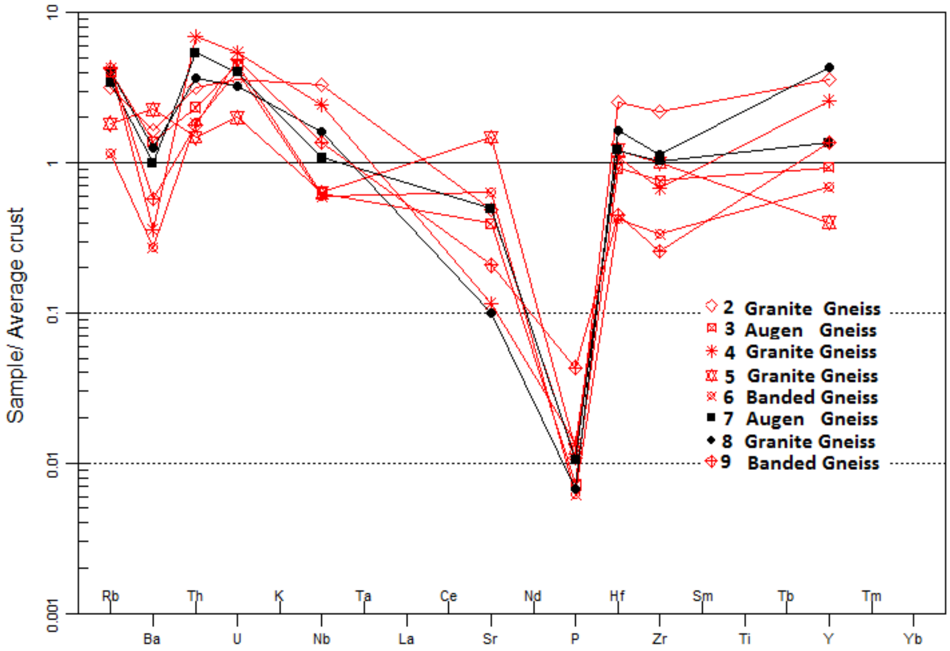

Fig.7: Spider diagram of trace elements normalized to average crust of gneisses in the study area (using the method of Weaver and Tarney, 1984)

3. Discussion

Major elements analysis of the gneisses shows characteritic high SiO_2 in the range of 68.45-73.84 wt% and low contents of Fe_2O_3 and MgO (1.18-6.70 wt%) and (0.16-0.98 wt%) respectively. These suggest that they were derived from a felsic (granitic) source. This was confirmed in the petrogenetic plots of Cox *et al.* (1979), Tarney (1977) and Eskola (1915), (Figures 2, 5 and 6). The consistent lesser content of soda to potash in most of these gneisses reflects the abundance of K-bearing rock forming silicates i.e microcline and biotite (Oyinloye, 2011). This trend is also characteristic of Archaean granitic rocks (Martin, 1986; Oyinloye, 2011). The non-variability of the alumina (Al_2O_3) contents for the whole samples analyzed which is within the range of 12.77-16.05 wt % suggest a calc-alkaline affinity. This was also confirmed on the petrogenetic plot (Fig.3) of Irvine and Baragar (1971). This could also be due to their low Fe-Mg bearing silicate mineral contents. The gneisses have corundum in their norm as can be seen by their alumina saturation index greater than one (Fig.4).

Except for the porphyroblastic granite gneiss (sample 2) that is metaluminus, all the rest gneisses are paraluminus (Fig.4). This could be due to their alkalis deficiency relative to alumina (Table 1). Also of importance is the fact that, only the metaluminus sample plot within the Quartz-monzonite in the petrogenetic plot of *Cox et al.* (Fig.2) and has lesser SiO_2 contents as compared to the rest gneisses but greater TiO_2 and MnO contents.

Protolith of gneisses can also be determined using a discriminat function (DF) as long as the MgO<6% and SiO_2<90% for all quartzofeldspathic rocks (Shaw, 1972).

DF= 10.44 - 0.21 SiO_2 - 0.32 Fe_2O_3(Total Fe) -0.98 MgO + 0.55 CaO + 1.46 Na_2O + 0.54 K_2O

Positive DF values suggest an igneous origin while negative DF values point to sedimentary. For all the gneissic samples calculated, the DF is always positive (Table 2)

Almost all the gneisses except for samples 4 and 6 are enriched in Ba, Rb and some lithophile elements when compared to the mean crustal value of these elements. Spider diagram of gneisses normalized to average crust (Fig.6) also indicates enrichment of Ba, Zr, Y, and Rb in banded gneisses, one of the granite gneiss (sample 5) relative to the rest granite gneisses and augen gneiss (sample 7). However, the depletion of transition elements like V and Cr is a result of their fractionation in spinel and imply moderate degree of partial melting at an intermediate depth (40-80 km). The two granite gneisses (samples 4 and 8) can be said to have formed at a relatively shallower depth (<40 km) by small degree of partial melting due to their lower Sr contents, the Sr must have been fractionated in plagioclase. The concentrations of high field strength elements (Hf, Th, U, Nb and Ta) is rather lower in the gneisses investigated and thus responsible for the small proportion of minerals like the zircon, sphene and apatite which all occurred as accessories minerals. The high proportion of large ion lithophile elements (Ba, Rb, and Sr) in the gneisses is due to their incompatibility nature with the mantle phases (olivine, orthpyroxenes and clinopyroxenes) thereby concentrating them in the melt that form the parent gneisses. The enrichment of Ni and Co which ought to have been fractionated in the olivine is as a result of the missing of the olivine in the parent rocks thereby giving room for their concentration and not depletion.

4. Conclusion

Field studies and geochemical investigations have revealed the metamorphic nature and evolution of the gneissic rocks in the Kafur-Yari Bori-Tsiga area, which form part of the basement complex of the area. These gneissic rocks are of igneous parentage and have cal-alkaline affinity. The absence of minerals like sillimanite, kyanite, cordierite and staurolite, which are typical of paragneiss, confirmed an igneous protolith of the gneisses investigated. Occurrence of zircon, sphene and apatite in most of these rocks is a result of the low contents of high field strength elements like Hf, Th, U, Nb and Ta in the gneisses of this area. Although, geochemical variations suggest igneous precursors for the gneisses of this area, it is obvious that they were not cogenetic but derived from differing sources and depths. Gneisses around Kafur area are derived from igneous rock formed at relatively shallower depth as evident by low concentration of Sr and low K/Rb ratios in samples 4 and 8 while the banded and augen gneisses from Tsiga and Karfi areas were formed from precursors derived by moderated degree of partial melting of the lower crustal material.

5. Acknowledgement

The assistance of Aminu Gidado during the field mapping is sincerely appreciated and acknowledged. The authors equally acknowledged the assistance of the District heads of Kafur and Karfi for providing accommodation and field securities that aid the smooth running of the mapping exercise. We are indebted to staffs of Acme analytical laboratory; Jean Dechavez, Helene Yates, Kamal Ahmed, Garry Bih and Susie Woo for their efforts in carrying out the geochemical analysis for the whole rock major and trace elements where carry out. The effort of Mr. A.K. Amuda of the Department of Geology Ahmadu Bello University Zaria towards the release of field equipment used during the field mapping is equally acknowledged and appreciated. We say kudus also to Mr. S.S. Magaji who acquainted the first author to the use of GCDKit, geochemical software used in the interpretation of the data analysed.

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