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Major Element Geochemistry of Crystalline Rocks of Mubi-Hong Area, Northeastern Nigeria

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Abstract

The Mubi-Hong area comprises of metamorphic (migmatitic gneisses, amphibolites, mylonites) and igneous (intrusive granitoids and volcanics) rocks. Granitoids of varied textures are dominant occurring crystalline rocks in the area. Forty (40) representative samples were used in the study. A combination of packages namely code 4B (lithium metaborate/tetraborate fusion ICP whole rock) and 4B INAA were analytic methods developed by Activation Laboratories, Ontario, Canada and used for the determination of major element compositions. Results show that the rocks in Mubi-Hong area have comparable chemical compositions, are calc-alkaline in nature and potassic rich. On a TAS ternary diagram most granitoids and metamorphic rocks plotted in the granite field suggestive that they are co-genetic and therefore sourced from similar protoliths while the volcanics plotted on the rhyolitic, phonolitic and basanite fields. Discriminant Function (DF) analysis shows that the rocks in Mubi-Hong area can be said to have dual Igneous (I-type) and sedimentary (S-type) parentage similar to other basement complex rocks in Nigeria.

Keywords: Element Geochemistry, Crystalline Rocks, Metamorphic and Igneous Rocks, Granotoids

Introduction

Mubi-Hong area is shown to be dominantly underlaid by Basement rocks amongst which are migmatite gneisses and granitoids of varied textures. The area is constituted of hill forming rocks amongst which are the Vimtim ranges, Hona hills and the Uba hills among others. Other crystalline rocks in the area include amphibolites, mylonites and volcanics (mainly basalts and rhyolites. The area of study forms part of the remobilized Pan-African terrain formed in the NeoProterozoic (ca.600 ± 150Ma) by continental collision between the converging West African Craton, the Congo Craton and the East Saharan block (Ferre et al.1996). . The area of study is located within Longitudes 12^o50^IE to 13^o25^IE and Latitudes 10^o00^IN to 10^o30^IN, covering parts of Garkida sheet 155 and Uba sheet 156. This work is aimed at providing the major element geochemical data of crystalline rocks in the area with the objective of broadening the knowledge of geochemistry of the rocks and to use such data to infer the petrogenetic evolution of the rocks.

The rocks are divided into 3 groups by several workers (Ajibade, 1976, 1982; McCurry. 1976; Holt, 1982; Woakes and Bafor, 1984 and Ajibade and Woakes, 1989). These groups include the following;

i).The poly-metamorphic migmatite-gneiss-quartzite complex with ages ranging from Achaean to Pan African. The Pan African ages reflect the overprinting of widespread and intensive Pan African Orogeny. Rocks of this group are largely migmatites and gneisses, basic schist, relict metasedimentary, calcareous, quartzitic and granulitic rocks.

ii). Low grade, sediment dominated schist belts trending north-south. These belts are considered to be Upper Proterozoic (Kibaran to Pan-African), infolded into the migmatite-gneiss-quartzite Complex. This group consists of schists, phyllites, pelites and banded iron formation.

Materials and Methods

The area of study which comprises Mubi-Maiha axis, Mubi-Gyella axis and Uba-Hong axis were mapped in detail and a geologic map of the area produced. Representative rock samples were collected where suitable rock exposures were encountered. Forty (40) representative rock samples were used for whole rock geochemical analysis and were selected based on the relative abundance of the rocks as follows Amphibolites (3), Migmatitic Gneiss (2), Mylonites (3), Diorite (2), Granodiorite (3), Porphyritic Granite (4), Coarse Grained Granite (8), Fine-Medium Grained Granite (4), Granite Porphyry (2), Aplite (2),Pegmatite (2), Basalts (2), and Rhyolites (3).

A combination of packages namely code 4B (lithium metaborate/tetraborate fusion ICP whole rock), and 4B INAA were analytic methods (developed by Activation Laboratories, Ontario, Canada) used for the determination of major element compositions. Average major element geochemical results are presented in Tables 1.

About 0.25g of the sample was digested with four acids beginning with hydrofluoric, followed by a mixture of nitric and perchloric acids, heated using precise programme controlled heating in several ramping and holding cycles which takes the samples to dryness. After dryness was attained, samples were brought back into solution using hydrochloric acid. With this digestion, certain phases may be only partially solubilized. The samples were then analyzed using Perkin Optima 3000 ICP.

The INAA analytic technique involves an approximately 30g of sample which was encapsulated and weighed in a polyethylene vial and irradiated with flux wires and an internal standard at a thermal neutron flux. After seven days decay, the samples were counted on a high purity Ge detector with a resolution of better than 1.7KeV. Using the flux wires, the decay corrected activities were then compared to a calibration developed from multiple certified international reference materials as a check on accuracy of the analysis. Seven (7) of the samples were rechecked by re-measurement. The sample was thereafter presented to the detector and in order to minimize noise, the detector is kept at cryogenic temperatures (liquid nitrogen, temperature = 77K). The initial signal appears very small and so the pre-amplifier (attached directly to the detector) amplifies this signal. The signal is shaped by the spectroscopy amplifier and then converted from an analog to a digital signal by the analog-to-digital converter and results stored in digital form (multi-channel analyzer). A computer was then used to visually show the resulting spectrum and to do the calculations on the spectrum. WinRock geochemical software was used to plot relevant bivariate and ternary diagrams which subsequently interpreted.

Table 1: Average Major Element Composition (as a percentage) in Rocks of Mubi-Hong Area

Major Element	MIG (n=2)	AMP (n=2)	MYL (n=3)	DIO (n=2)	GRD (n=3)	POG (n=4)	CGG (n=8)	FMG (n=4)	APL (n=2)	GPO (n=2)	PEG (n=2)	BAST (n=2)	RHY (n=3)
SiO_2	68.08	49.24	67.47	57.52	62.93	73.05	70.70	69.94	75.70	66.00	95.58	51.66	71.48
Al_2O_3	15.97	9.97	10.61	14.81	14.60	12.95	13.58	13.38	13.07	13.12	2.56	15.65	14.01
Fe_2O_3	5.10	10.43	10.29	7.74	6.43	3.41	3.17	3.75	1.17	5.62	0.93	7.06	3.24
MnO	0.084	0.192	0.208	0.106	0.068	0.041	0.047	0.051	0.009	0.076	0.010	0.198	0.132
MgO	2.16	10.24	0.75	4.41	1.64	0.40	0.48	0.78	0.065	1.25	0.125	5.33	0.21
CaO	4.83	17.81	1.45	5.75	3.61	1.46	1.68	1.82	0.51	2.90	0.24	6.25	0.21
Na_2O	4.28	0.47	1.99	2.84	3.00	2.76	2.95	2.92	3.11	2.77	0.19	5.68	3.31
K_2O	2.03	0.32	3.50	3.37	4.43	5.54	5.55	4.88	4.96	4.35	0.46	3.26	4.14
TiO_2	1.144	0.242	0.382	1.647	1.568	0.427	0.513	0.638	0.076	1.087	0.085	1.481	0.258
P_2O_3	0.23	0.19	0.13	0.61	0.45	0.13	0.16	0.21	0.02	0.37	0.04	0.52	0.05
LOI	0.84	1.69	2.52	1.44	0.96	0.69	0.69	0.75	0.78	1.00	0.75	1.85	6.63

NOTE: n=number of samples; MIG= Migmatite, AMP=Amphibolite, MYL=Mylonites, DIO= Diorite, GRD= Granodiorite, POG= Porphrytic Granite, CGG=Coarse Grained Granite, FMG=Fine-Medium Granite, APL=Aplite, GPO=Granite Porphyry, PEG= Pegmatite, BAST= Basalt, RHY= Rhyolite

Results and Discussion

Geology of Mubi-Hong Area

A total area of 7,200 Km^2 was mapped and the rocks identified are grouped into metamorphic (amphibolites, migmatitic gneisses and mylonites), plutonic (diorite, granodiorite, granites of varied textures, aplites and pegmatites) and volcanic rocks (basalts and rhyolites). These constitute the geology of the area as presented in Fig.1. The coarse grained granites constitutes over 60% of the entire study area while the porphyritic granite constitute about 15%, followed by migmatitic gneisses which make up about 10% of the area. Granodiorite, volcanics, aplitic and pegmatitic dykes make up the remaining 15% of the area. Diorite and granite porphyry do not constitute mappable units and therefore were discussed but not represented on the geologic map. The amphibolite outcrops as lenses and pockets within the migmatitic gneisses especially around Kwanan Mutuwa about 3 kilometers northeast of Hong town on the Mubi-Hong road. The rocks are characteristically dark-greenish in color, massive and structureless The migmatitic gneisses have been mapped in areas around Fadaman Reke, about 4km northeast of Hong town and also around the southwestern corner of the study area (Fig.1). Few outcrops have also been encountered on both sides of the Mubi-Maiha road especially around Pakka village some few kilometers from the Bridge and environs to the southeast of study area. Typically, the rocks have leucocratic (leucosome) and melanocratic (melanosome) bands and are generally low-lying.

The porphyritic granites constitute a major rock unit around Uba in the northeast, north of Maiha and WSW of Hong town in the mapped area (Fig.1). The rocks are porphyritic, marked by large euhedral crystals measuring about 5 to 7 mm of k-feldspars as phenocrysts.

The coarse grained granites constitute the most dominant rock type and occupy over 60% of the study area (Fig.1). They are prominent in almost the entire study area especially around Uba, Hong, Mubi, Maiha-Gyella areas in the North, central, and southern part respectively. They appear generally grayish, pinkish or dark-gray in color. Minor intrusives in the study area include diorites, granite porphyry, aplites and pegmatite.

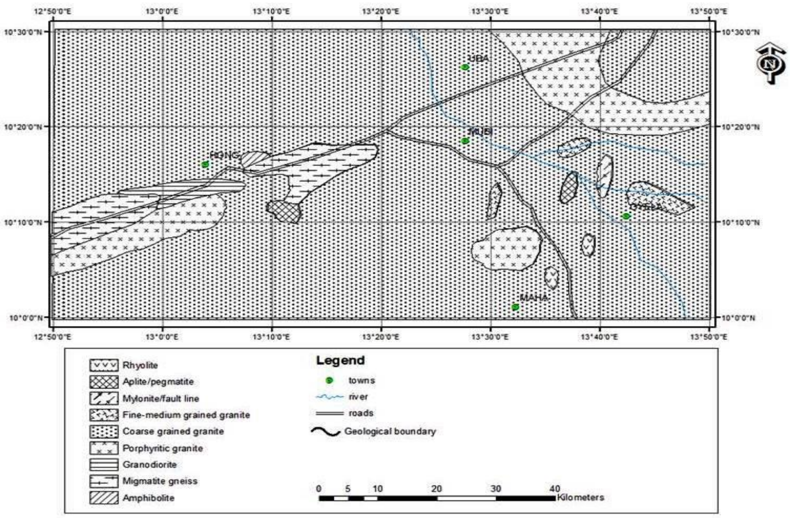

Figure1: Geologic Map of Mubi-Hong area

Major Element Geochemistry

Results of major element average compositions of the 40 representative samples are presented in Table 1. The result shows that the average value of silica in the metamorphics range from 68.08 wt% in the migmatite gneisses to 49.24 wt % in the amphibolites. Alumina value in the rocks ranges from 9.97 wt % in the mylonites to 15.97 wt % in migmatite gneiss The lowest average concentration of $Fe_2O_{3(T)}$ was obtained in the migmatite gneisses accounting for 5.10 wt % while the highest value was in amphibolites where average value of 10.43 wt % was obtained. MgO averages ranged from 0.75 wt% in the mylonites to 10.24 wt % in the amphibolites. MnO values in the metamorphic rocks averaged 0.084 wt% in the migmatite gneisses to 0.208 wt % in the mylonites. CaO are expectedly higher in the amphibolites averaging 17.81 wt %, thus attributable to presence of calcic-rich plagioclases such as andesine but lowest in the mylonites where average value of 1.45 was obtained. Na_2O averages ranged from 0.47 wt % in the amphibolites to 4.28 wt % in the migmatite gneisses. This is attributable to presence of soda-rich minerals such as albite in the leucosome component of the rock.

Silica average values in the granitoids and related plutonic rocks range from 57.52 wt % in the diorite to 95.58 wt % in the pegmatites. The high silica values in the pegmatite are due to silicification process which enriches the rock in such component as quartz. Alumina average values do not show much variation in the granitoids except in the pegmatites where very low average value of 2.56 wt % was obtained. Similarly, $Fe_2O_{3(T)}$ show significant variation with lowest average concentration of 0.93 wt % recorded in the pegmatites, while the highest was in the diorites where average value of 7.74 wt % was obtained. MgO average concentration ranged from 0.125 wt % in the pegmatite to 4.41 wt % in the diorite. In addition, Na_2O average values ranged from 0.19 wt % in the pegmatites to 3.11 wt % in the aplites, while K_2O average values ranges from 0.46 wt % in the pegmatites to the highest average value of 5.55 wt % in the coarse grained granites.

The volcanics have average silica values ranging from 51.66 wt % in the basalts to 71.48 wt % in the rhyolites, while alumina average values of 15.65 wt % and 14.01 wt % were obtained in the basalts and rhyolites respectively. MgO average value of 5.33 wt % was obtained in the basalts, thus attributable to presence of magnesia-rich minerals such as diopside and forsterite while average value of 0.21 wt % MgO in the rhyolite is in agreement with acidic rocks which are poor in magnesia. Similarly, CaO average values of 6.25 wt % and 0.21 wt % obtained in the basalts and rhyolite respectively may be attributable to the presence of calcic-rich plagioclases in the former than in the later.

On the AFM ternary diagram (Fig. 2a), most metamorphic rocks plot within the calc-alkaline field, while few of the samples plot within the tholeitic field. For the granitoids, it was observed that most of the samples plot within the calc-alkaline field with few plotting at the boundary between the tholeiite and the calc-alkaline field (Fig. 2b). On the other hand,only the pegmatites (sensu stricto) plotted within the tholeiitic field. Most volcanics in the area plotted within the calc-alkaline field with only a few plotting at the boundary (Fig. 2c), thus suggestive of a change in chemical composition as result of interaction with host rocks during ascent from depths.

On a CaO-Na_2O-K_20 (CNK) ternary diagram (Fig. 3a) most granitoids plotted near the potassic (K_2O) rich end, a trend that is suggestive of rocks that have evolved from a potassic protolith. The volcanics on the other hand do not show any peculiar trend and are deficient in CaO except for one sample of basalt which plotted near the CaO apex (Fig.3b), thus indicative of a rock that is enriched in calcic-rich plagioclases and possibly pyroxenes. On the AKF ternary diagram (Fig 3c), it was observed that most metamorphic rocks in the area are enriched in alumina where they plotted near the Al_2O_3 apex, and thus suggestive of the fact that their protoliths have been enriched in Al_2O_3 and therefore less affected by metamorphism and/or alteration process,. An exception to the above is one of the samples which appear to have been extraordinarily rich in Fe_2O_3, thus attributable to presence of mafic minerals typically amphiboles and diopside which may have contributed in the high iron content in the rock.

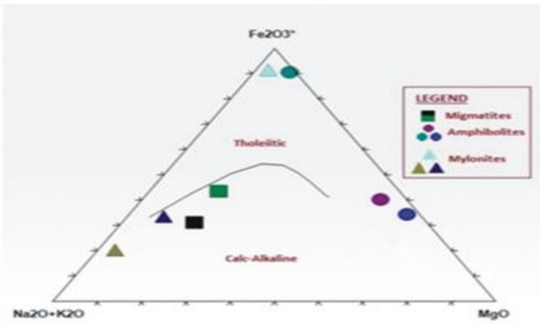

Fig. 2a AFM ternary diagram for metamorphic rocks of Mubi-Hong area

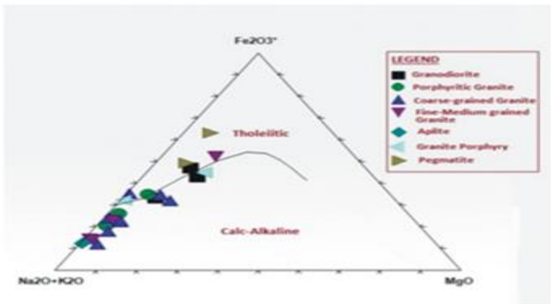

Fig. 2b: AFM ternary diagram for Granitoid and related plutonic rocks of Mubi-Hong area

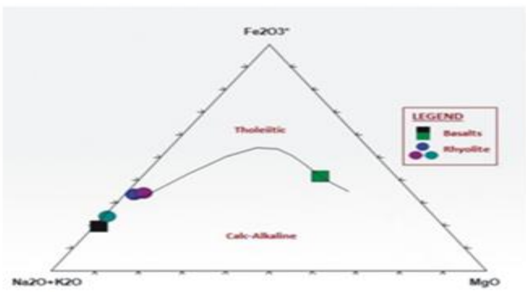

Fig. 2c : AFM ternary diagram for volcanics of Mubi-Hong area

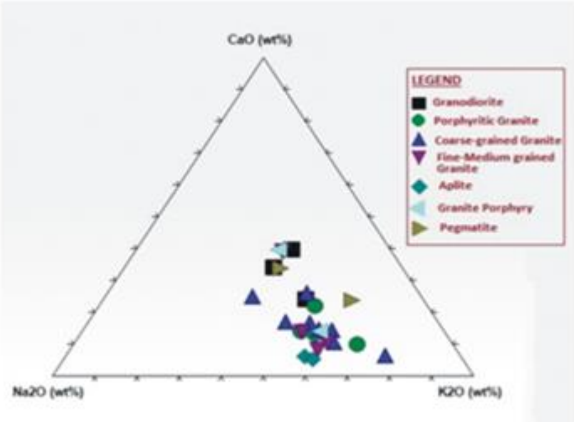

Fig. 3a : CaO-Na_2O-K_2O ternary diagram showing the position of granitoids and other plutonic rocks of Mubi-Hong area.

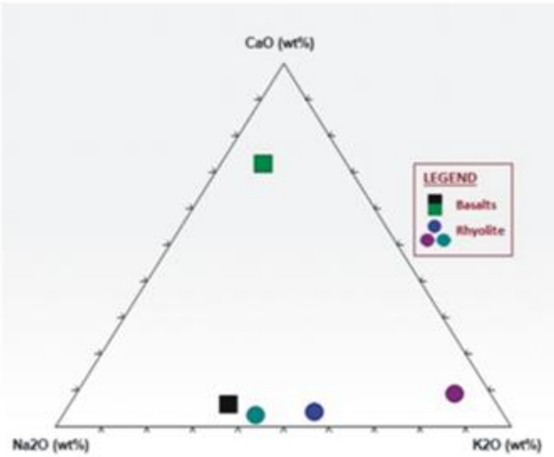

Fig. 3b : CaO-Na_2O-K_2O (CNK) ternary diagram showing the position of volcanics of Mubi-Hong area.

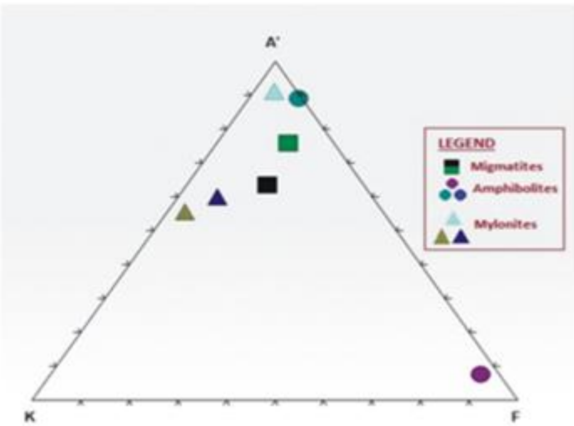

Fig. 3c : AK'F ternary diagram showing the position of metamorphic rocks of Mubi-Hong area.

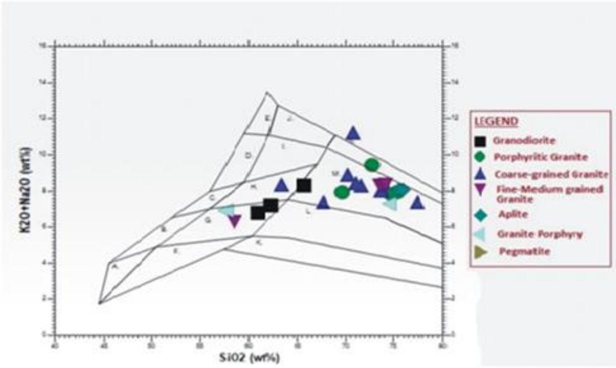

Fig. 4a : Total alkalis-Silica (TAS plutonic) diagram showing the position of granitoids an related plutonic rocks of Mubi-Hong area (Middlemost, 1997) (LEGEND=A. Diorite, Gabbro E Monzodiorite C. Monzonite D. Syenite E. Alkali Feldspar Syenite F. Quartz Diorite G Quartz Monzodiorite H. Quartz Monzonite I. Quartz Syenite J. Alkali Felds. Qtz. Syenit K. Tonalite L. Granodiorite M. Granite N. Alkali Feldspar Granite)

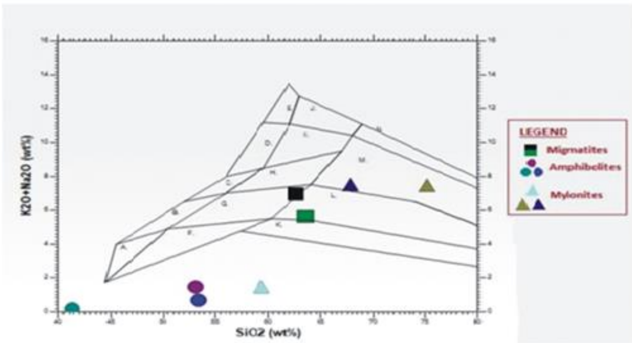

Fig. 4b : Total alkalis-Silica (TAS plutonic) diagram showing the position of metamorphi rocks of Mubi-Hong area (Middlemost, 1997) (LEGEND=A. Diorite, Gabbro B. Monzodiorit C. Monzonite D. Syenite E. Alkali Feldspar Syenite F. Quartz Diorite G. Quart Monzodiorite H. Quartz Monzonite I. Quartz Syenite J. Alkali Felds. Qtz. Syenite K Tonalite L. Granodiorite M. Granite N. Alkali Feldspar Granite)

The origin of the rocks in the area can be constrained using a discriminant function (DF) as defined by Shaw (1972) (provided SiO_2 is less than 90% and that MgO is less than 6%) as follows:

DF=10.44 - 0.21(SiO_2) - 0.32(Fe_2O_3) - 0.98(MgO) + 0.55(CaO) + 1.46(Na_20) + 0.54(K_2O)

Positive DF values were interpreted as igneous (I-type) origin while negative values as sedimentary (S-type) origin (Shaw, 1972). It was shown in this study that the gneisses and granitoids have average positive values of +3.45 and +1.19 respectively while amphibolites and mylonites have negative values of -2.62 and -2.27 respectively. It can thus be interpreted that the gneisses and granitoids are sourced from igneous protoliths similar to the Pulka granites of Baba *et al.* (2006) and the Malumfashi gneisses (Elatikpo *et al.* (2013). The presence of partially digested schistose xenoliths in the coarse grained granitoids of this study supports the magmatic origin for these rocks. On the other hand the amphibolites and mylonites have been sourced from sedimentary parents

(S-type) comparable to similar rocks from north-central Nigeria (Onyeagocha, 1986 and Ajibade, 1982).

The amphibolites have similar SiO_2 (49.24%) and Fe_2O_3 (10.43%) but much lower in Al_2O_3 (9.97%), MgO (10.24%) and K_2O (0.32%) when compared to amphibolites of Ilesha SW Nigeria (Olade and Eleuze, 1976) (Table 2). Major element averages such as SiO_2 (70.70%), Al_2O_3 (13.58%), Na_2O (2.95%) and K_2O (5.55%) obtained in this work for granitic rocks are comparable and similar to those of granitoids from Ilesha area, SW, Nigeria (Eleuze, 1987), Pulka granites, NE, Nigeria (Baba et al. 2006) and the Igbeti Porphyritic granites, SW, Nigeria (Rahaman *et al.* 1983). Similarly, the chemical composition of basalts obtained in this work are comparable to alkali basalts composition of Nockolds (1954) but differs in the fact that those of present study have much lower MgO (5.33%) and CaO (6.25%) but higher SiO_2 and Na_2O where average values of 51.60% and 5.68% respectively were obtained . Based on major element abundance, it is shown that SiO_2 average of 63% for migmatitic gneisses obtained in this work appears lower than those of Toteu, et al (1987), from northern Cameroun where average value of 68.38% was obtained. Similarly average values of Al_2O_3 (15.97%), Fe_2O_3 (5.0%), CaO (4.83%) and Na_2O (4.28%) obtained in this study are comparable and similar to rocks in Northern Cameroun (Table 2).

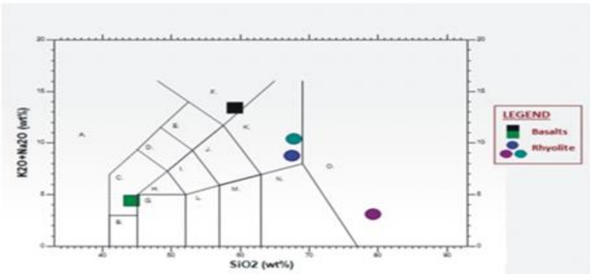

Fig. 5a TAS discrimination diagram (Le Bas, 1986) showing the position of volcanics in Mubı area (LEGEND=A. Foidite B. Picrobasalt C. Basanite (Olivine > 10%) D. Phonotephrit E. Tephriphonolite F. Phonolite G. Basalt H. Trachybasalt I. Basaltic Trachyandesite J. Trachyandesit K. Trachyte (Quartz < 20%) K. Trachydacite (Quartz > 20%) L. Basaltic Andesite M. Andesite N. Dacite O. Rhyolite).

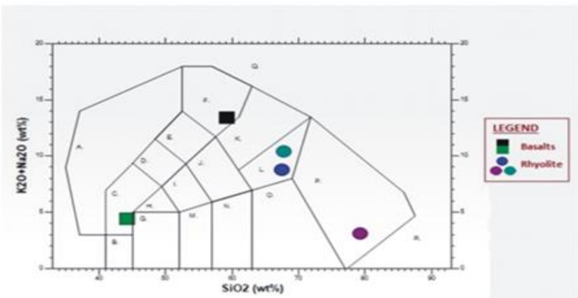

Fig. 5b. TAS discrimination plot (Middlemost, 1994) showing the position of volcanics in Mubi area (LEGEND=A. Foidite B. Picrobasalt C. Basanite (Olivine > 10%) C. Tephrite (Olivine < 10%) D. Phonotephrite E. Tephriphonolite F. Phonolite G. Basalt H. Trachybasalt I. Basaltic Trachyandesite J. Trachyandesite K. Trachyte (Quartz < 20%) L. Trachydacite M. Basaltic Andesite N. Andesite O. Daciten P. Rhyolite Q. Sodalitite, Nephelinolith, Leucitolith R. Silexite)

Conclusion

The Mubi-Hong area is constituted mainly of basement rocks with granitoids of varied textures as the dominantly occurring type. Major element geochemistry indicates that the rocks have comparable chemical compositions. Relevant geochemical plots shows that the rocks are essentially calc-alkaline in nature and are potassic rich. The plot of both granite and metamorphics in the granite field is an indication that they are co-genetic and sourced from similar sources. Though mineralization has not been established in this study further detail studies is required.

Table 2: Average Major Element Compositions (wt %) of Similar Rocks Compared to those of Mubi-Hong Area

Major Element	Sample 1	2	3	4	5	6	7	8	9	10	11
SiO_2	68.38	45.55	72.57	73.60	71.88	69.69	46.70	63.00	49.24	70.70	51.66
Al_2O_3	15.87	17.08	14.72	13.92	14.55	14.55	14.65	15.97	9.97	13.58	15.65
Fe_2O_3	4.5	11.90	1.39	0.17	1.85	1.34	9.94	5.10	10.43	3.17	7.06
MnO	0.11	0.19	0.03	0.01	0.03	0.05	0.15	0.084	0.192	0.047	0.198
MgO	2.31	14.57	0.34	0.17	0.45	0.38	6.82	2.16	10.24	0.48	5.33
CaO	4.07	14.40	0.84	0.52	1.52	1.71	12.42	4.83	17.81	1.68	6.25
Na_2O	4.03	1.09	3.58	2.79	3.35	2.56	2.59	4.28	0.47	2.95	5.68
K_2O	2.89	3.01	5.32	6.85	5.47	5.28	1.07	2.03	0.32	5.55	3.26
TiO_2	0.55	2.97	0.31	0.01	0.37	0.29	3.32	1.194	0.242	0.513	1.481
P_2O_5				0.06	0.09	0.31		0.23	0.19	0.16	0.52

1. Migmatite Gneiss, N. Cameroun (Toteu, et al.1987) 2.Amphibolite, Ilesha, SW, Nigeria (Olade and Eleuze,1976) 3. Granitic Rocks from NW Akwanga, Central Nigeria (Onyeagocha, 1986) 4. Granitic rocks from Ilesha area , SW, Nigeria (Eleuze,1987) 5.Pulka Granites, NE, Nigeria (Baba, et al, 2006) 6.Igbetti porphyritic granite, SW, Nigeria (Rahaman et al.,1983) 7. Alkali basalts (Nockolds, 1954) 8. Migmatite gneiss (this work) 9. Amphibolite (this work) 10.Coarse grained granite (this work) 11.Basalt (this work)

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