Geology and Geochemistry of Intrusion around Mayo-Kole Area within Adamawa Massif, Northeastern Nigeria.

H. A. Ahmed[a,b]

[a]*Department of Geology, Modibbo Adama University of Technology, Yola Adamawa State, PMB, 2076, Yola-Nigeria.*

[b]*State Key Laboratory of Geological Processes and Mineral Resources, Center for Global Tectonics and School of Earth Sciences, China University of Geosciences, Wuhan 430074, China.*

**Corresponding author: hifzullahahmed@yahoo.com +8613164690700*

Abstract

The Intrusion in Mayo-Kole and environs belongs to the crystalline basement rocks of the northern part of Adamawa Massif, Northeastern Nigeria. Most of the work done within the study area was on regional scale, no detailed work has been done on the geochemistry of the area. Previous studies have focused on engineering geology and geotechnical assessment of gully sites in the area. The area under study consists of granite, granodiorite, diorite and gabbro. This intrusion is characterized by high-K calc-alkaline and classified as metaluminous and peraluminous. Field investigations along with petrographic and geochemical studies indicate that the series of intrusion in the study area are derived from a common magma source as a result of fractional crystallization. The geodynamic setting of this intrusion is classified as pre-plate collision setting derived from mantle fractionates, which was formed during the Pan African thermotectonic events in the Nigerian Basement Complex. The tectonic structures in the study area trend mostly NE – SW and subordinately NW-SE and N-S, conforming with the regional deformational structures which occurred during the Pan African thermotectonic events in the Nigerian basement.

Keywords: Adamawa Massif, Pre-plate collision, Geochemistry, Mayo-Kole, Northeastern Nigeria

1.0 Introduction

Mayo-Kole area is located in the Nigerian Topographical Map sheet JADA N.W, Sheet 217 and located within latitudes 8°45' 00''N and 8°50' 00''N of the equator and longitudes 12°07' 00''E and 12°12' 00''E of the Greenwich Meridian, with an areal extent of about 90Km^2. The study area Mayo-Kole and environs belong to the crystalline basement rocks of the northern part of Adamawa State, Northeastern Nigeria. (Fig. 1). The crystalline basements are ancient Precambrian rocks formed from series of orogenic circles within the mobile belt of central Africa. The rocks in the area are granite, migmatite gneisses, and the Older granites series (granitoids of variable mineralogical compositions) which evolved during the Pan African orogeny. Outcropping in some parts of the study area, overlapping the basement rocks are alluvium. The various regional dating revealed Liberian - (2500±200 Ma), Eburnean - (1800±200 Ma), and Kibarian - (1200±200 Ma) orogenic events including the study area Ogezi, (1977). Most of the work done within the study area was on regional scale, no detailed work has been done on the geochemistry of Mayo-Kole, but Obiefuna and Simon, (2010) worked the geology and geotechnical assessment of gully sites in the area.

The aim of this research project is to determine the geology and geochemistry of basement rocks in Mayo-Kole area and environs, in an attempt to shade more light on the petrogenesis and tectonic setting.

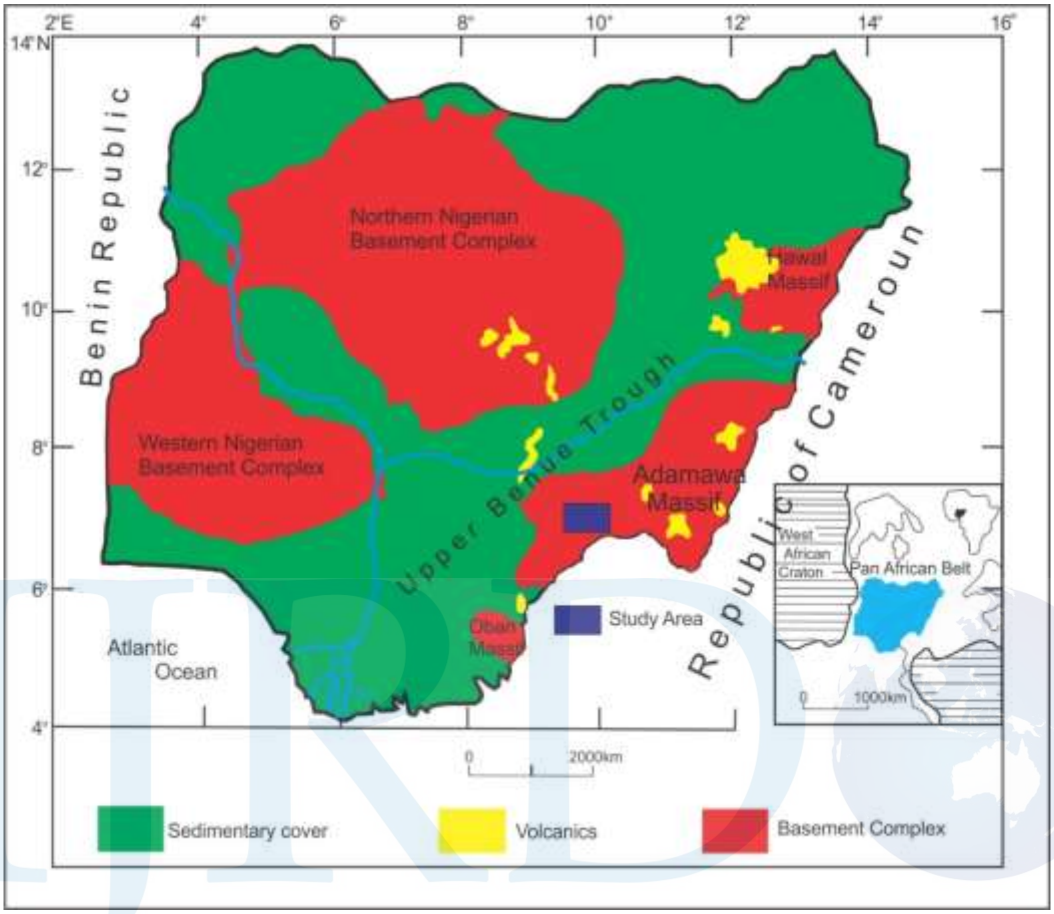

Fig.1 Regional Geology of the Study Area (Modified after C.A Kogbe, 1989)

1.2 Regional Geology

Studies have been carried out on the basement complexes of western, north-western, north-central and south-eastern parts of the country which were reported in the past (McCurry and Wright, 1971), but no detailed geological work has been carried out on the local geology of Mayo Belwa and environs. Most of the previous works on the study area were regional in extent. These include the works of (Islam and Baba, 1989), who divided the north-eastern Nigeria basement complex into four, the Mandara Mountain, Alantika Mountain, Shebshi Mountain and

Adamawa Massif. The study area forms part of the Adamawa Massif (Fig. 1). Ekwueme, (2003) considered the Adamawa Massif to be an extension of the Bamenda Massif that forms Part of the Cameroun volcanic line which extends into North-eastern Nigeria and located between the Cameroun highlands and Benue trough which is characterized by mostly igneous and metamorphic rocks. Adamawa Massif has undergone both Pre- Pan African and Pan African Orogeny. This has resulted into the consequent metamorphism, migmatisation and granitization of the pre- existing rocks (Rahman et al, 1988).

(Ekwueme, 2003) observed that the basement complexes of Nigeria are extensive Precambrian rocks which lie in the Pan African mobile belt between African and Congo Cratons, the closure of the Atlantic Oceans at the Cratons margin and the intracontinental basins and ocean led to the deformation and metamorphism of metasediments, partial melting of the mantle and lower crust and emplacement of the Older Granite which are very conspicuous in the area.

1.3 LOCAL GEOLOGY

Obiefuna and Simon, (2010) worked on the geology and geotechnical assessment of gully sites in the study area. From their observations, the study area lies within the contact between the Basement Complex rocks and the Bima Sandstone Formation. The Bima Sandstone occurs to the north of the study area and consists of reddish brown colour, fine to medium grained texture and highly indurated. They are thus highly ferrugunized, moderately to well sorted and largely weathered. They are stratified, moderately jointed, moderately consolidated, poorly to well cemented and clayey. Thin section studies indicate the presence of quartz, orthoclase and iron oxide inclusions. Exposures of Bima Sandstone are found along the valleys of Rivers Mbona and Bayo with thicknesses varying from 1.50 m to 5.00 m.

The basement rocks underlie the Bima Sandstone and occur to the south of the study area. They consist essentially of granite, granite-gneiss, migmatite-gneiss and gneiss. Geological structures such as quartz veins, pegmatite dykes and fault zones were observed in the rocks of the Basement Complex and vary from 1cm to 2cm in thickness.

1.3.1 The Older Granite Complex

The granite of the study area covers about 45% of the total study area. Field observations indicate that they are massive and vary widely in texture. The minerals are randomly oriented and show well oriented tabular feldspars (typically perthitic microcline or orthoclase) with plagioclase (calcic albite or oligoclase) and/or flaky biotite grains. They are porphyritic with phenocrysts of quartz and feldspar in a groundmass of biotite and hornblende. They are medium to coarse grained with average grain size between 1mm-25mm (0.1cm-2.5cm).Microscopic examinations of the granites indicate the predominance of quartz and feldspar over biotites and hornblende.

1.3.2 The Migmatite-Gneiss Complex

The gneisses are coarse-grained, banded crystalline rocks with phanerictic mineral grains for the dark colored mineral the biotite occur in association. The banding arises from the segregation of various minerals that are present into dark-colored (melanocratic) and lightcolored (leucocratic) layers. The dark bands consist of dark minerals such as biotites and horneblende whereas light bands consist of light colored minerals such as quartz and feldspar. The thickness of the bands is between 2mm to 2cm.

The migmatite gneiss which occurs in the vicinity of the study area is highly foliated and banded with leucocratic (feldspar and quartz minerals) and melanocratic (biotite and hornblende minerals) layering. The rock is intensely affected by brittle deformation resulting in the formation of joints, shear zones and fractures.

The granite gneiss which is also found south of the study area is strongly foliated and closely associated with the migmatite-gneiss. The rock type is light to dark colored and medium to coarse grained in texture. They contain feldspar, quartz, biotite and muscovite with poorly developed leucocratic layers.

2. Field Geology and Petrography

Geological structures such as quartz veins, pegmatite dykes, folds, joints and fault zones were observed in the rocks of the study area (Fig. 2). Faults observed in the study area include the strike-slip fault exhibiting left-lateral movement, as such is termed as sinistral fault (Fig. 3C). Quartz veins occur in biotite granite at Jada, in the northern part of the project area and in the southern part of the area around Gangwaso. Most of the veins follow direction of the joint which trend NE-SW, N-S and SW-NE (Fig 4a, b). In the study area, the sill intruded into the granitic rocks in Mayo-Kole area trending N-S, measuring about 60cm thick and 1.3m long (Fig. 4c).

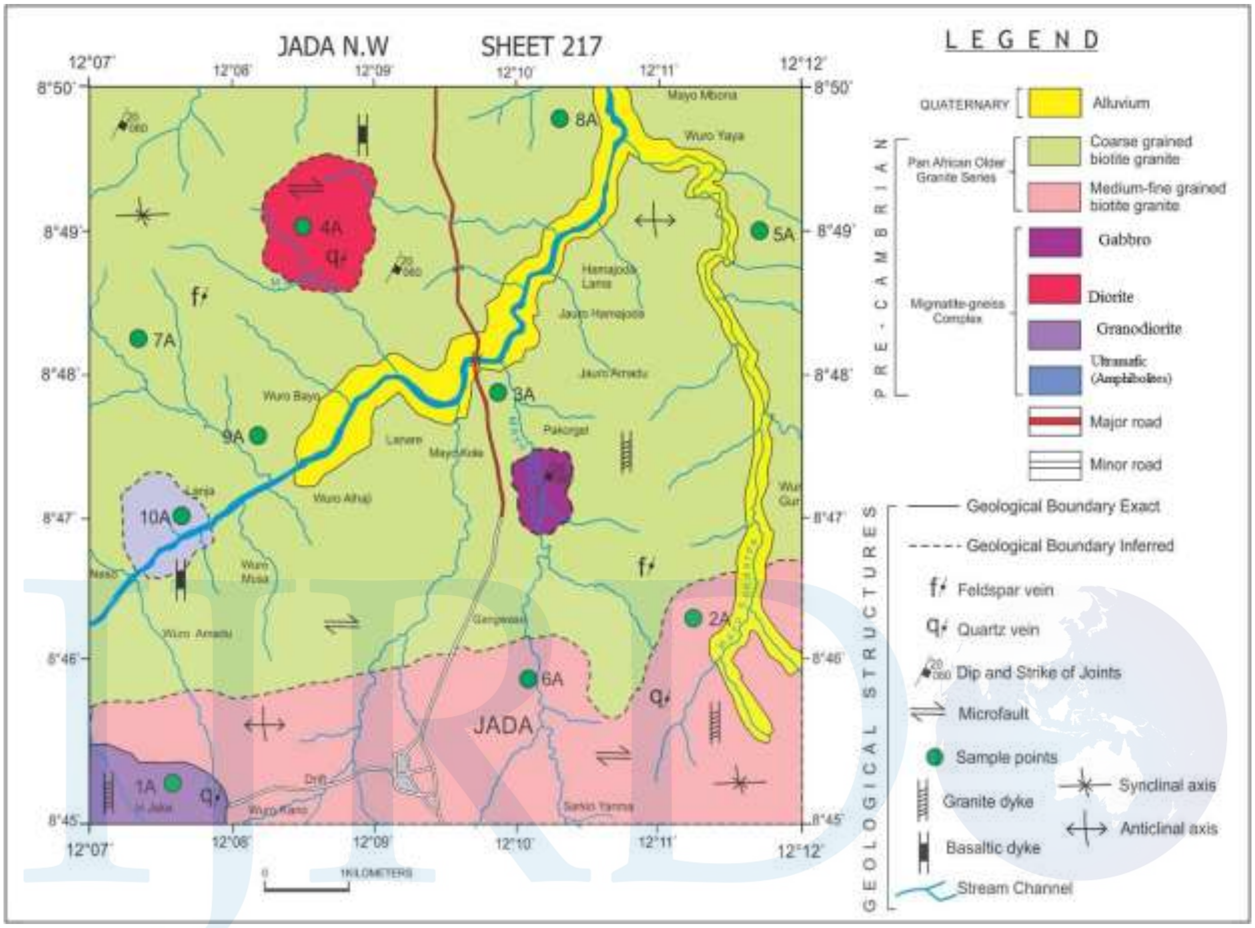

Fig. 2 Geological Map of the Study area and Environs

The petrographic studies reveal that mineralogy and textures are fairly uniform throughout the study area. Dominant feldspar phase is plagioclase. Biotite is the primary ferromagnesian minerals (Fig. 5). Others include quartz which occurs in high quantity in almost all the samples as indicated by the high percentages of silica in all the rocks. Quartz is generally anhedral (Fig. 5) in crystal form, has weak birefringence and shows grey to white first order interference. It has low relief, shows parallel as well as undulose extinction and is colourless under plane polarized light. Plagioclase feldspar (Fig. 4) appear as brownish to colourless under cross polars with single hatching while microcline has double hatching. Muscovite is pale yellow to colorless under plane polarized light, anhedral in crystal form and shows moderate relief and moderate birefringence. It is very weakly pleochroic, shows purple to red interference colors and cleaves in one direction.

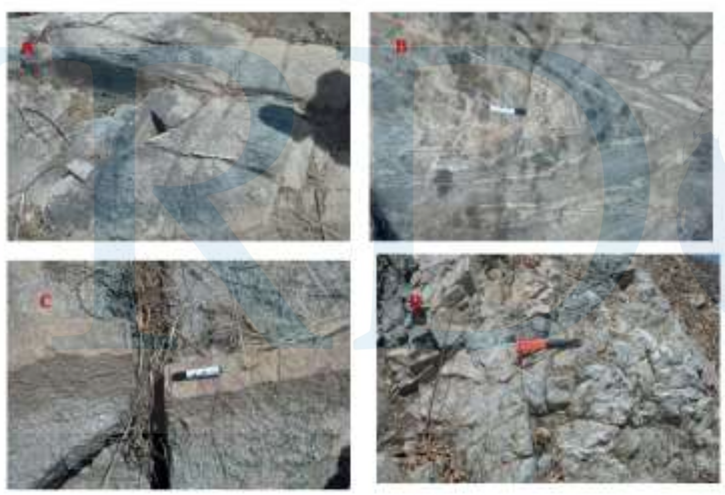

Fig. 3 Geological structures within the study area

Fig. 4 More geological structures within the study area

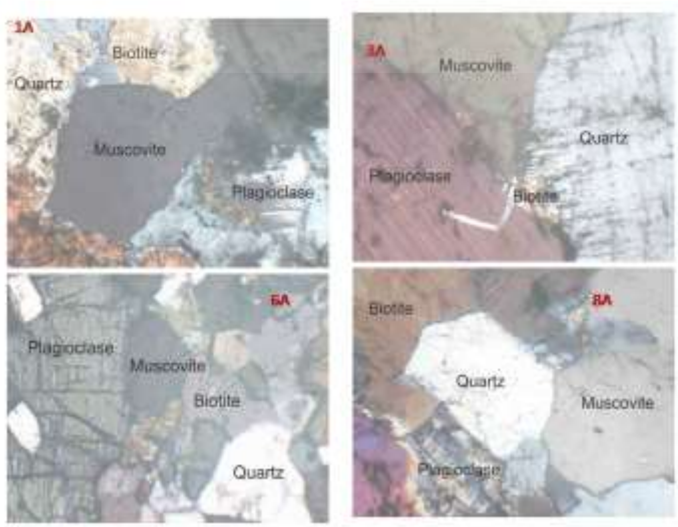

Fig. 5 Photomicrograph of minerals from thin sections of rock samples in the study area

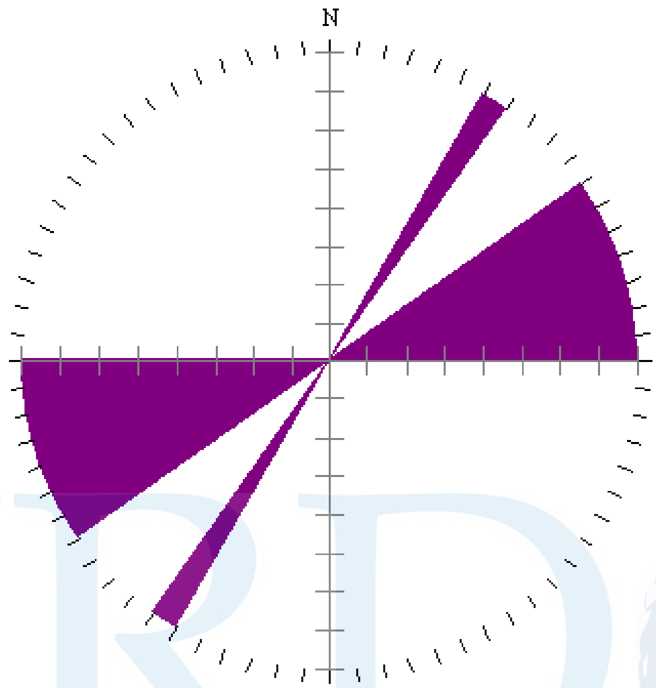

Fig. 6 Rose diagram showing NE-SW deformational trend of structures in the Study Area

3. Analytical Methods

The geochemical analysis on the rock samples was done at the petrological laboratory, Ashaka Cement Plc, Gombe State. At the laboratory, the analyses were undertaken using Energy Dispersive X-Ray Fluorescence Spectrometry (ED-XRF). The XRF equipment has an attached scanning electron microscopes fitted with a digital camera and computer central imaging with a printer. The micro scan equipment analyses at high magnification with exceptional depth of field to allow detailed micro structural examination of the samples. The ED-XRF is a non-destructive method of quantitative and qualitative elemental analyses of solid and liquid sample materials. In this process, the high energy content of an x-ray beam causes a sample to generate x-rays characteristics of the atoms in the sample (when inner K, L or M electrons are removed from target atoms and outer electrons fill the valencies). Elements present in the sample are identified from the energies of this characteristic radiation, and concentrations are evaluated from intensity measurements (Fitton, 1997).

4. Results

Results of the analyses for rock samples from the research area are presented in Tables and plots.

Table 1 Major elements composition of the study area

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
Granodiorite	65.87	0.201	12.676	2.03	0.055	0.391	9.039	3.089	2.947	0.006
Granodiorite	62.1	0.242	13.622	1.749	0.027	0.388	8.859	2.167	5.285	0.021
Ultrabasic	38.549	0.428	11.367	10.957	0.256	10.32	14.516	1.934	0.679	0.006
Granite	68.852	0.155	12.203	1.414	0.017	0.001	8.688	2.742	3.768	0.012
Granodiorite	61.876	0.243	13.552	1.747	0.026	0.393	8.876	2.164	5.246	0.021
Gabbro	50.473	1.151	11.373	9.151	0.192	3.201	11.5	1.823	2.23	0.194
Diorite	58.591	0.55	12.922	4.186	0.084	1.564	10.41	3.086	2.033	0.146
Granite	69.582	0.138	11.969	1.304	0.016	0.038	8.544	2.385	4.287	0.013

From Table 1, SiO_2 ranges from 34.417 to 69.528% for the rock samples while Al_2O_3 ranges from 8.565 to 13.662%. Ranges of other oxides are Fe_2O_3 (1.414 – 12.172%), CaO (8.544 – 15.132%), MgO (0.001 – 13.604%), SO_3 (0.292 – 0.303%), K_2O (0.679 – 5.285%), Na_2O (1.934 – 3.089%), P_2O_5 (0.006 – 0.682%), MnO_2 (0.016 – 0.256%) and TiO_2 (0.138 – 1.807%).

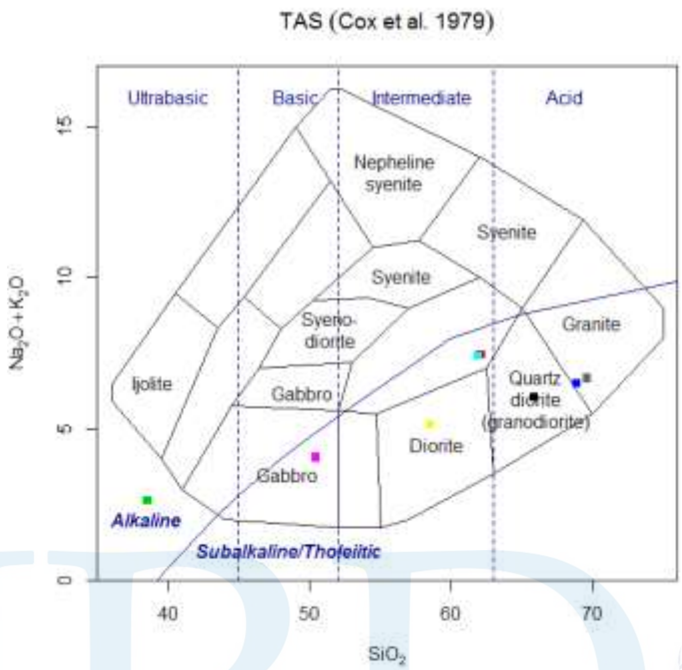

Fig 7 A SiO2 versus (Na2O + K2O) diagram of the samples from the study area (Cox *et al.*, 1979)

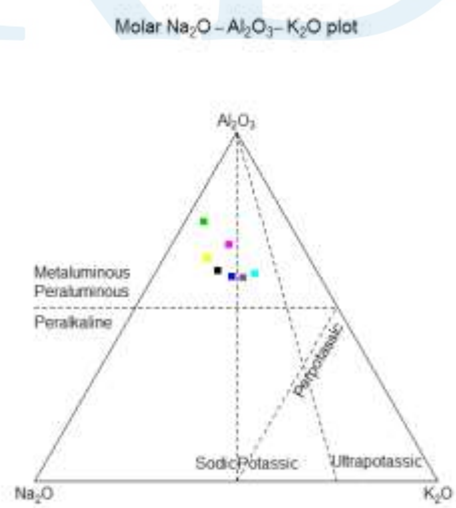

Fig 8 Molar Na_2O-Al_2O_3-K_2O plot

Fig 9. AFM diagram (Irvine and Baragar, 1971)

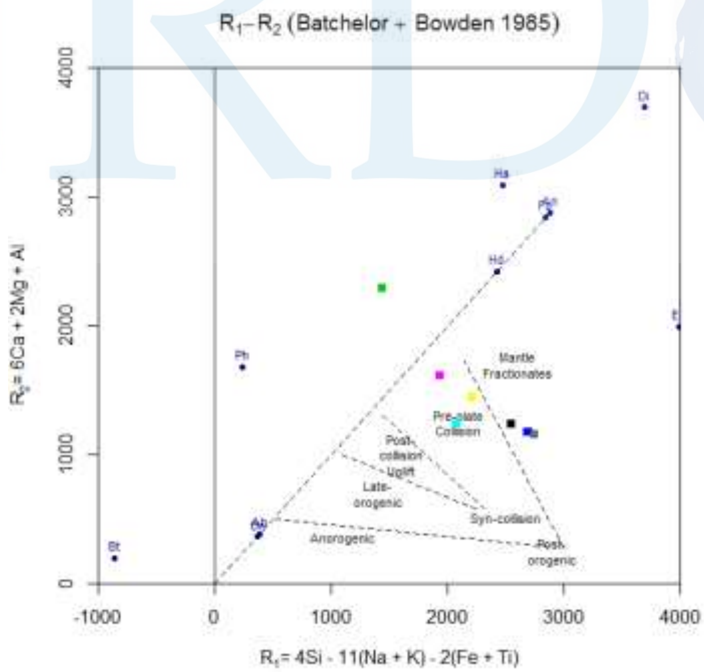

Fig. 10 Location of the Mayo-Kole intrusion samples on the two cationic parameters of R1 and R2 (Batchelor and Bowden, 1985)

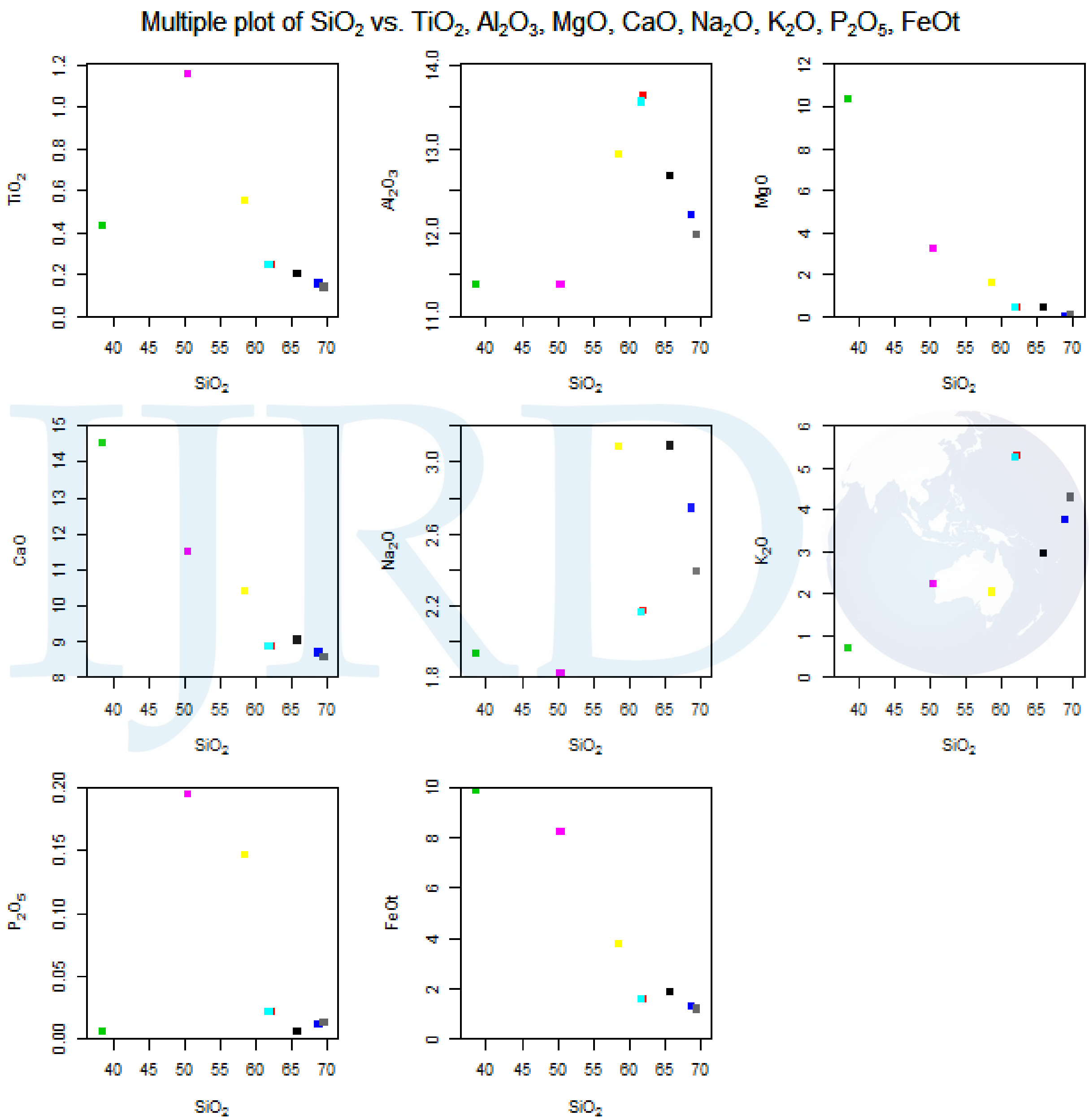

Fig. 11 Hacker diagram of samples from the study area

5. DISCUSSION

The samples from the study area indicate variation from felsic to ultrabasic rocks (Fig 7), including granite, granodiorite, diorite, gabbro and an ultrabasic rock. On the Na_2O-Al_2O_3-K_2O_5 diagram, all samples are classified as metaluminous and Peraluminous rocks (Figure **7**). Based on the AFM triangular diagram Irvine and Baragar, (1971), all rocks units of the Mayo-Kole intrusions are calc-alkaline in character (Figure 9). The correlation between SiO_2 and K_2O, indicates increasing K_2O with SiO_2 signifying that the rocks might be classified as high-K calc alkaline rocks.

On the variation diagrams (Fig.11), with increasing SiO_2, contents of Al_2O_3, P_2O_5, CaO, TiO_2, MgO, MnO and Fe_2O_3 are decreased and K_2O and Na_2O demonstrate increasing trend. These trends may reflect the crystal fractionation process in the evolution of the Mayo-Kole granitoids. Based on geochemical studies, Mayo-Kole granitoid can be classified as potassic granite ($K_2O > Na_2O$) (Table 1).

Based on Batchelor and Bowden, (1985) diagram that is offered by considering, two cationic parameters including R2 = 6Ca + 2Mg + Al and R1 = 4Si − 11(Na + K) – 2(Fe + Ti), samples of Mayo-Kole intrusion put into the pre-plate collision setting, and mantle fractionates (Figure 10). Moreover, the overall variation trend of samples in the study area indicates the evolution of magma by fractional crystallization. Mayo-Kole area is generally underlain by the Basement Complex rocks which have sequentially been invaded by the Pan African granites during the Pan African thermo tectonic period. The basement rocks consist essentially of medium to coarse biotite grained granites and pockets of mafic to ultramafic rocks.

Field studies indicate the rocks in the area were subjected to a wide range of tectonic activities involving fracturing, faulting, granitization and metamorphism. These are evidenced by the different structures discovered during the course of this project, typical of which are microfaults, joints infilled with veins, faulting, sill and foliation. The orientations of these structures are mainly NE – SW, and NW – SE and N – S in consonance with the Pan African orogeny (McCury, 1976; Dada, 1989; Rahaman, 2003).

The linear geochemical variations shown by Harker plots (Figs. 11) are indicative of the genetic relationships between the rocks which is an indication of possible fractional crystallization during formation from same sources. Not all the rock elements correlate with SiO_2. However, Al_2O_3, CaO and Na_2O have weak correlations (Fig. 11) as they show scatter plots due to possible accumulation of various components during fractional crystallization indicating plagioclase fractionation. All these indicate the importance of fractional crystallization in the evolution of this magmatic suite.

Their very low contents of P_2O_5, MnO_2 and TiO_2 values signify alkali affinity of these granites (Rogers and Greenberg, 1981).These magmatic rocks attained very high content of sodium and iron as well as strongly depleted in calcium and magnesium in their final stages of magmatic and subsolidus processes. SiO_2 also shows a good positive correlation with K_2O and with TiO_2 also supporting the role of fractional crystallization. The rock units in this study area thus might be regarded as a highly evolved magmatic suite.

The field and laboratory studies points out that the area forms part of the Nigerian Precambrian basement and the Adamawa Massif in conformity with previous works. The tectonic structures in the study area (Fig. 6) trend mostly NE – SW and subordinately NW-SE and N-S which conform the mostly widespread deformational structures which occurred during the Pan African thermotectonic events in the Nigerian basement, (McCurry and Wright 1971; Rahaman et al, 1988).

6. CONCLUSION

Field studies, petrographic and geochemical investigations indicate that the Mayo-Kole granitoid consists of granite, granodiorite, diorite and gabbro. Field relations and geochemical studies demonstrate that all of these rocks are related to a single parent magma which underwent fractional crystallization. The Mayo-Kole granitic intrusion has high-K calc-alkaline in nature. This magmatic suite is metaluminous to peraluminous. In terms of geodynamic setting, this intrusion is classified as pre-plate collision setting with contribution from mantle fractionates, which was formed during the Pan African thermotectonic events in the Nigerian Basement Complex.

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