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*Keywords : abakaliki pyroclastics, benue trough, petrography, geochemistry.*

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PETROLOGICAL AND GEOCHEMICAL CHARACTERISTICS OF PYROCLASTICS OUTCROPPING IN ABAKALIKI AREA LOWER BENUE TROUGH, NIGERIA

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# Petrological and Geochemical Characteristics of Pyroclastics Outcropping in Abakaliki Area Lower Benue Trough, Nigeria

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*Abstract* - Bakaliki pyroclastics are part of the volcanoclastics of the Lower Benue Trough Nigeria. The petrological and geochemical study of the pyroclastics was carried out; to evaluate and re-appraise their petrology, stratigraphic position and origin which have remained subjects of controversy in the Benue Trough Geology. The pyroclastics outcrop as enlongate and domical bodies that are large and massive. Field relationships indicate that the volcanoclastics occur within the Abakaliki Shale of the Asu River Group and in some places they interbed with the shales. They occur mostly as agglomerates and welded tuffs cut by several quartz filled veins and segregations. The agglomerates are porphyritic with angular fragments of shales embedded in them. The tuffs are very fine grained and aphanitic in texture. Petrographic data obtained from this study show plagioclase and augite as the major mineral constituents with quartz, olivine, calcite and iron oxide as the accessories. Devitrified glass shards are common in the rocks. They are of basaltic composition. Geochemical analysis shows that the pyroclastics are subakaline, tholeiitic rocks of thin continental crust origin. They are classified as basalts, basaltic andesites, dacites and rhyolites.

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## I. Introduction

The study area is geographically located in the southeastern Nigeria (Fig. 1). Abakaliki Pyroclastics occur as volcanoclastics within the Albian Abakaliki Shale (Asu-River Group) Lower Benue Trough Nigeria (Fig. 2). This study intends to examine the petrology and geochemical characteristics of the pyroclastics and decipher the petrology, origin and stratigraphic position of the pyroclastics which have been subjects of controversy. The occurrence of early Cretaceous volcanic rocks in the Benue Trough was first mentioned by Wilson and Bain (1925). Farrington (1952), Okezie (1957, 1965) and Reyment 1965 described the volcanic rocks which they considered to be in close genetic relationship with lead-zinc mineralization. They however failed to distinguish between these rocks and the more widespread Cretaceous to Tertiary alkaline igneous rocks in the Benue Trough. Okezie (1965) considered them to be andesitic rocks. Two controversial aspects of Nigerian Geology are the petrology and stratigraphic position of the Abakaliki pyroclastics and the origin and evolution of the Benue Trough. The pyroclastics are considered by some workers as lower Benue's oldest volcanic rocks formed during the rifting of the Afro-Brazilian plate in early Cretaceous time that led to the origin of the Benue Trough (Uzuakpunwa, 1974 and Olade, 1975). The Abakaliki Pyroclastics have been variously reported to be Albian or Aptian in age (Uzuakpunwa, 1974). Olade (1979) considered the unit to be older than Asu River Shale and to be overlying the Pre-Cambrian Basement. McConnell (1949) and De Swardt (1950) reported it to be interstratified with Albian Shales. A post-Albian age was advocated by Tattam (1930), Farrington (1952) and Pergeter (1957). The rocks have been variously described as pyroclastic flows, intrusive breccias, submarine spilites, andesitic tuffs, basaltic agglomerates or degraded alkali basalts (McConell, 1949; Tattam, 1930; Okezie, 1957, Olade, 1979). The study has shown that the pyroclastics are subakaline, tholeiitic rocks of thin continental crust origin, classified as basalts, basaltic andesites, dacites and rhyolites.

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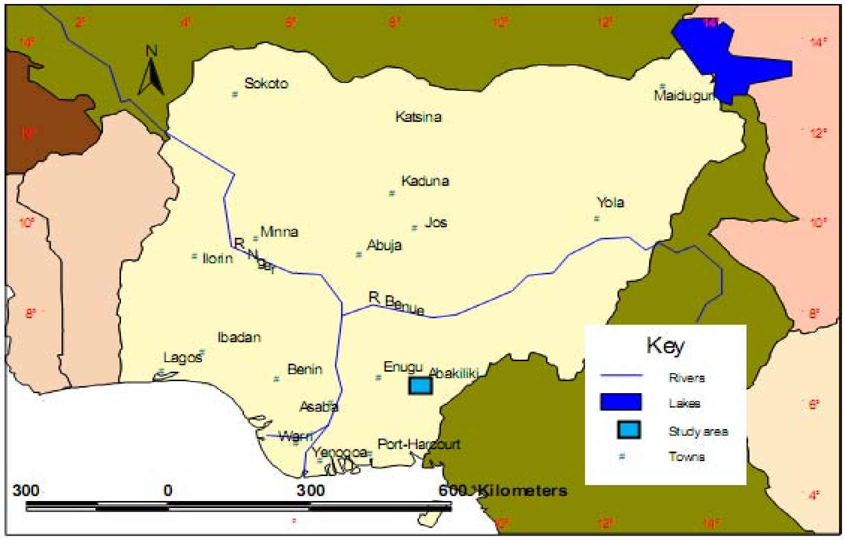


*Figure 1 :* Map of Nigeria showing the location of the study area and other major cities

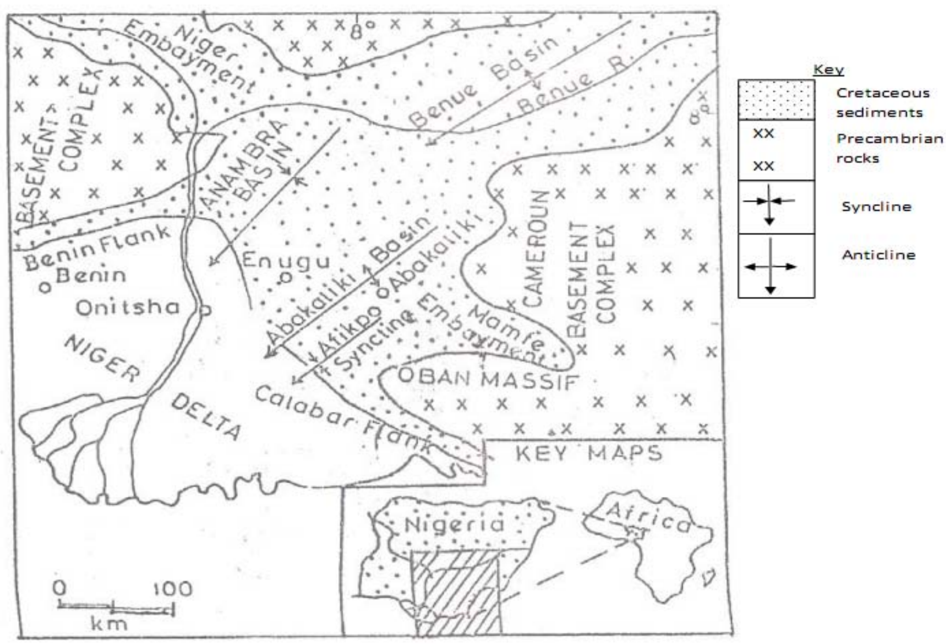


*Figure 2 :* Generalized map of sedimentary basins in southern Nigeria showing the position of Benue Trough. The Cretaceous basin is stipped (Modified from Hoque 1977)

## II. Geologic Setting

In southern Benue Trough, the Albian sediments are the oldest Cretaceous sediment (Table 1) deposited as first marine sediments due to Albian marine transgression in the Abakaliki area. This was followed by the Cenomanian Odukpani Formation in the Calabar Flank (Reyment, 1965). Further transgression and regression took place during Turonian period which deposited Eze-Aku Formation and Awgu Shale (Coniacian) (Murat, 1972). The tectonic event of the Santonian led to uplift, folding and widespread erosion in the sediment fill of the Benue Trough. Another transgression occurred in the Campanian-Maastrichtian resulting in marine sediment. Prior to the marine incursion in the early Campanian, the Abakaliki Basin in the southern sector of the Trough was folded into series of anticlines. Thus the Anambra Basin and Afikpo Synclines became the major depocentres for the Campanian-Maastrichtian sediments (Murat, 1972). The Nkporo/Enugu Shale and Afikpo Sandstone member were deposited in these basins. The Abakaliki Anticlinorium formed the axis of the Santonian uplift and represent stable structural feature, which controlled the development of the associated basins (Anambra Basin and Afikpo Sub-Basin).

*Table 1 :* Stratigraphic sequence showing the position of Eze-Aku Group relative to other formations in southeastern Niger Hoqueia (Modified from, 1977)

| AGE | | STRATIGRAPHIC SEQUENCE | | BASIN/ CYCLE |
|---|---|---|---|---|
| EOCENE | | AMEKI /NANKA FM | | ANAMBRA - AFIKPO BASIN (Second Sedimentary Cycle) |
| PALEOCENE | | IMO SHALE | | |
| UPPER CRETACEOUS | DANIAN | NSUKKA FM | | |
| | MAASTRICHTIAN | AJALI SS | | |
| | | MAMU FM | | |
| | CAMPANIAN | NKPORO GROUP/ ENUGU SHALE | | |
| | SANTONIAN | | | UPLIFT + FOLDING |
| | CONIACIAN | AWGU FM | | ABAKALIKI BASIN (First sedimentary Cycle) |
| | TURONIAN | EZE-AKU FM | Amasiri Ss / Eze-Aku Sh | |
| | CENOMANIAN | ODUKPANI FM | | |
| LOWER CRETA. | ALBIAN | ASU RIVER GROUP | | |
| PRE CAMBRIAN | | BASEMENT COMPLEX | | |

## III. Method of Study

The field aspect of the work involved description, measurements and sampling of the exposed sections of the Abakaliki Pyroclastics. The pyroclastics outcropping in Onu-ebonyi, Ogbaga, Juju Hill, Strabag quarry, Sharon mines and Azuinyiokwu Rivers were studied. Thin sections were prepared from the representative sandstone samples obtained in the field for thin section petrography which was studied under transmitted light petrographic microscope. Ten samples of the pyroclastic rocks were selected from the Onu-Ebonyi and Strabag quarries for geochemical analysis. The samples were crushed and ground to minus 200 mesh and analyzed using Atomic Absorption Spectrometer (AAS) for Fe, Mg, Ca, Na, K, Mn, P and Al. Mn and Al are analyzed using their respective lamps. Na and K are analyzed using Emission Spectrometry while P was analyzed using the Molybdenum-Blue method. All the elemental compositions were converted to their appropriate oxides and their percentages calculated.

## IV. Results

### a) *Local Stratigraphy and Field relationships*

Two most controversial aspects of Nigeria geology are the petrology and stratigraphic position of the Abakaliki Pyroclastics and origin and evolution of the Benue Trough (Hoque, 1984). The pyroclastics are considered by some workers as lower Benue's oldest volcanic rocks formed during the rifting of the Afro-Brazillian Plate in early Cretaceous times that led to the evolution of the Benue Trough. Based on field relationships, the pyroclastics exposed in Abakaliki area are grouped into two pyroclastic masses: the Onu-Ebonyi and Strabag quarry pyroclastic deposit.

The Onu-Ebonyi pyroclastics outcrops an enlongate feature and aligned on a NE-SW direction. The rock has been exposed as a large and massive outcrop due to quarrying. It is composed of agglomerates and tuffs (Fig. 3). The agglomerate is grey to dark in colour and porphritic in texture, comprising of angular to sub-angular fragments in a very fine grained groundmass. The tuffs are fine grained (aphanitic) with the colour ranging from grey to almost white. They show normal and graded bedding, as well as prominent cross-bedding or cross-laminations.

*Figure 3 :* Abakaliki Pyroclastic outcrop at Onu-Ebonyi showing tuffs (red arrow)

The Pyroclastic deposit in Strabag quarry is a dome-shaped body that is large and massive. Quarrying activities expose the rock for study (Fig. 4). The lower levels consist of pyroclastic flows and vesicular rocks interbedded with shales. The main pyroclastic body comprises mainly of tuff with a lot of quartz veins/segregations (Fig. 5) and nodules characterized by lieseagang rings but dominantly light grey on weathered surfaces where they appear brownish to reddish. They show normal and graded bedding and are generally fine grained with occasional phenocrysts of olivine. The texture is ophitic with thin plagioclase lathes interwoven with pyroxene crystals. Mudstone and shale xenoliths characterize the rocks.

*Figure 4 :* Outcrop of Abakaliki Pyroclastics exposed by quarrying at Onu-ebonyi

*Figure 5 :* Outcrop of Abakaliki Pyroclastics showing quartz vein exposed at Strabag Quarry

b) *Petrology*

The texture of the rocks generally ranges from porphyrtic through oophitic to aphanitic. The porphyritic rocks have angular to subangular minerals as phenocrysts in groundmass of very fine grained minerals. The oophitic manifests as random orientations of enlongate/prismatic plagioclase laths in a groundmass of dominantly (Fig. 6) very fine grained equigranular matrix of plagioclase and pyroxene.

The thin section study of the rocks shows that the dominant minerals are plagioclase, augite, quartz and accessory iron oxides, olivine and calcite minerals. Vitric fragments showing extensive alteration are common (Fig. 6). The plagioclase crystals are lath-like and wholly and occasionally partially enclose the augite crystals. Quartz is present as randomly arranged subhedral crystals. Olivine is present as phenocrysts. Iron Oxide is also present as matrix/groundmass minerals randomly oriented. Calcite is present as secondary vein and void fillers. The modal composition of the rocks is shown in Table 2.

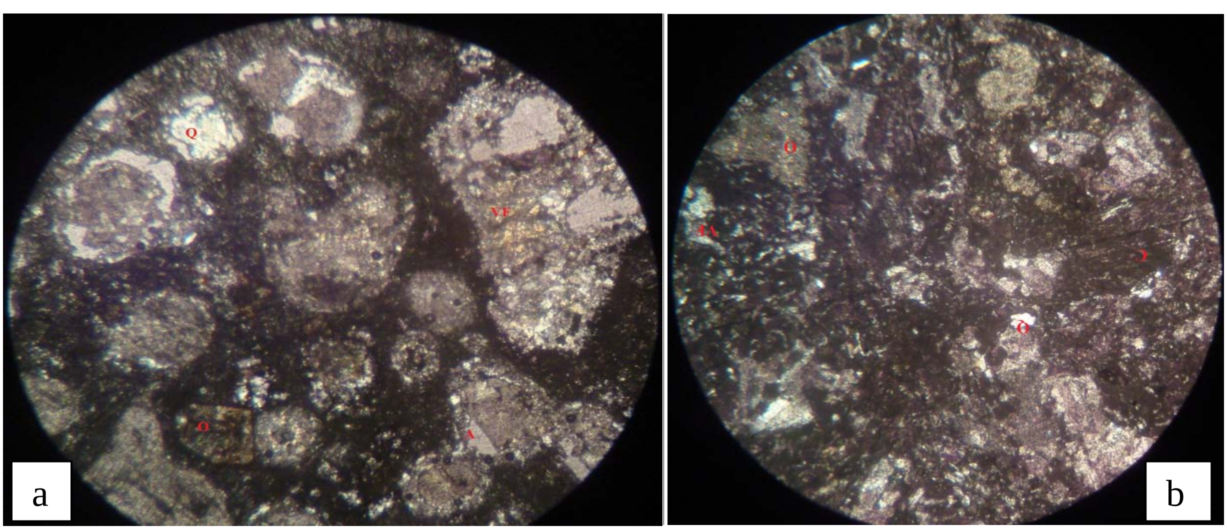


*Figure 6 a & b :* Photomicrograph of sample E4 and E7 showing Quartz (Q), Vitric fragments (VF), Olivine (O) and Albite

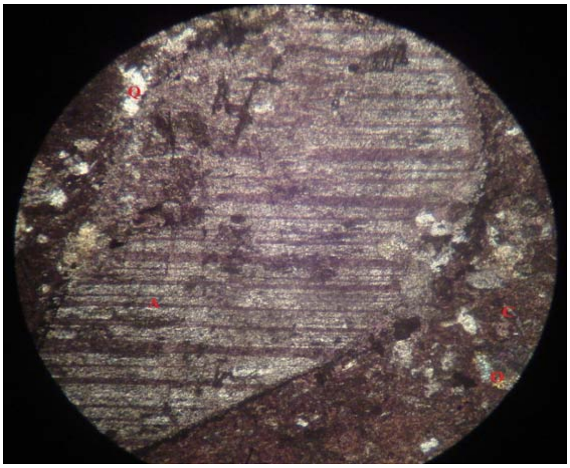

*Figure 7 :* Photomicrograph of sample E9 showing Albite (A), quartz (Q), Olivine (O) and Calcite (C)

*Table 2 :* Modal Composition of the Pyroclastic Rocks

| Mineral | E1 | E2 | E3 | E4 |
|---|---|---|---|---|
| Quartz | 40% | 25% | 20% | 20% |
| Plagioclase | 20% | 35% | 30% | 30% |
| Augite | 10% | 15% | 15% | 10% |
| Olivine | 10% | 5% | 5% | 10% |
| Iron Oxide | 10% | 10% | 15% | 20% |
| Calcite | 5% | 10% | 15% | 10% |

*c) Geochemistry*

The result of the geochemical analysis shows silica content of not less than 53.97% (Table 3). Samples E1, E2, E5, E7 and E8 show highest silica contents ranging from 70.04% to 81.01%. Samples E3, E4,E6, E9 and E10 have lower silica contents ranging from 53.97% to 66.44%. The $Fe_2O_3$ and MgO contents of the rocks are relatively high with Fe ranging between 7.57% and 20.11% and Mg between 6.14% and 14.24%. CaO content is high for samples E2,E 3, E5, E6 and E10. It varies from 7.09% to 12.5% and low for samples E1, E4, E7, E 8 and E9 varying from 0.73% to 4.71%. The total alkali ($Na_2+K_2O$) content is low for these rocks. The values range from 0.109% to 0.256%. MnO is low, values range from 0.014 to 0.755%. $P_2O_5$ and $Al_2O_3$ are also low though $P_2O_5$ is much lower. Generally the pyroclastic rocks appear to be higher in $SiO_2$, $Fe_2O_3$, MgO contents as compared to the other oxides (Table 3).

*Table 3 :* Chemical Analyses results for the Pyroclastic Rocks Converted to Percentages (%)

| Sample Nos | $SiO_2$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | MnO | $P_2O_5$ | $Al_2O_3$ | TOTAL | $Na_2O_+$ $K_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E1 | 81.01 | 7.69 | 6.80 | 2.44 | 0.14 | 0.035 | 0.165 | 0.00021 | 1.83 | 99.90 | 0.175 |
| E2 | 70.93 | 8.37 | 10.43 | 7.71 | 0.15 | 0.033 | 0.622 | 0.00054 | 1.75 | 99.99 | 0.183 |
| E3 | 58.49 | 17.6 | 13.97 | 7.09 | 0.204 | 0.044 | 0.473 | 0.00052 | 2.08 | 99.95 | 0.448 |
| E4 | 59.40 | 20.11 | 13.29 | 0.89 | 0.149 | 0.029 | 0.097 | 0.003 | 6.03 | 99.99 | 0.178 |
| E5 | 70.04 | 10.25 | 6.14 | 12.44 | 0.118 | 0.106 | 0.319 | 0.00019 | 0.59 | 100 | 0.224 |
| E6 | 66.44 | 13.81 | 6.29 | 11.69 | 0.153 | 0.103 | 0.199 | 0.00014 | 1.34 | 99.30 | 0.256 |
| E7 | 79.0 | 8.09 | 1.51 | 4.71 | 0.143 | 0.039 | 0.152 | 0.00014 | 1.34 | 99.98 | 0.182 |
| E8 | 72.7 | 12.25 | 8.71 | 2.18 | 0.122 | 0.036 | 0.124 | 0.00018 | 3.70 | 99.91 | 0.158 |
| E9 | 61.9 | 18.28 | 12.10 | 0.73 | 0.089 | 0.0305 | 0.014 | 0.00029 | 6.70 | 99.92 | 0.1195 |
| E10 | 53.97 | 12.69 | 14.24 | 12.5 | 0.083 | 0.026 | 0.755 | 0.00021 | 5.74 | 100 | 0.109 |

The plot of the total alkali against the total silica content of the rocks (Fig.8) shows that all the pyroclastic rock samples from the study area plot within the subalkaline rocks suite. Subalkaline rocks are grouped into the tholeiitic and calc-alkaline suites. The tholeiitic rocks show stronger environment in Fe relative to Mg than calc-alkaline rocks and generally have less variation in silica and alkalines (Best and Christiansen, 2001). The plot of $K_2O$ against $Si_2O$ is represented in Fig. 9; generally, the $K_2O$ content of the rock is very low varying from 0.029% to 0.106% (Table 3). Their Fe content is high relative to the Mg composition of the rocks (Table 3). These however suggest that the rocks are tholeitic. There is variation in composition of the pyroclastics from basaltic andesites through andesites to dacites and rhyolites. They are classified as intermediate and acid rocks. Samples E10, E 3, E 4 and E9 are andesitic rocks with silica percentage of 53.97%, 58.49%, 59.49% and 61.9% respectively (Table 3). Dacites and rhyolites are acidic rocks (silica content > 66%). Rhyolites are less common tholeitic rocks than dacites. Samples E6, E5 and E8 represent dacites and samples E7 and E1 are rhyolitic in composition. The plots of MgO against CaO Fig. 10 demonstrate that the rocks are extruded from a region of thin continental crust. Tholeitic rocks occur where the crust is oceanic and relatively mafic or at the thin continental crust (Best and Christiansen, 2001).

The representations in Fig. 11 distinguishes the tholeitic differentiation trend of Fe enrichment with limited felsic derivatives and the calc-alkaline differentiation trend of limited Fe enrichment and abundant felsic derivatives.

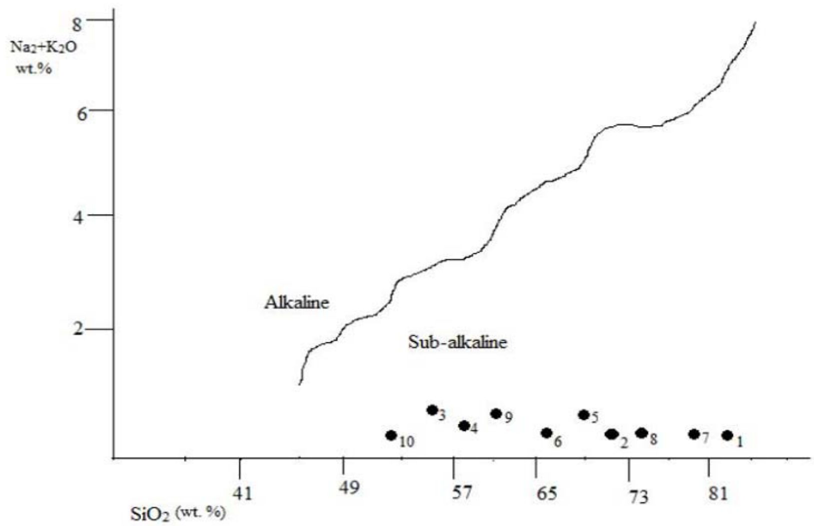


*Figure 8 :* Plot of total alkali ($Na_2O + K_2O$) against total silica ($SiO_2$) content of the rocks (method of Le Bas et al 1992)

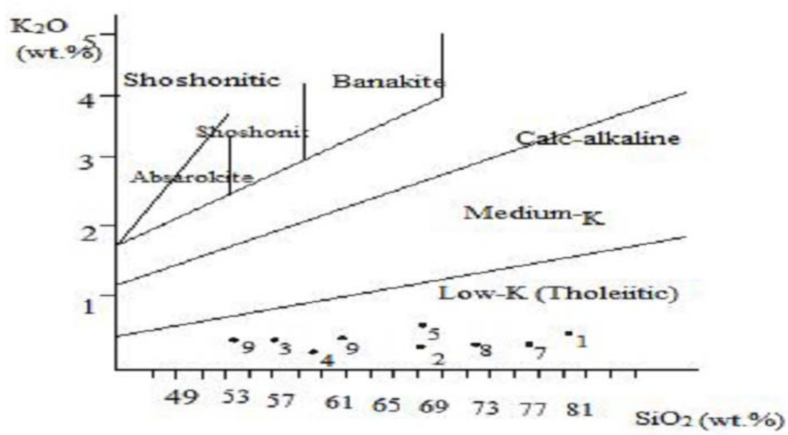


*Figure 9 :* Plot of $K_2O$ against $Si_2O$ (Method of Ewart, 1982)

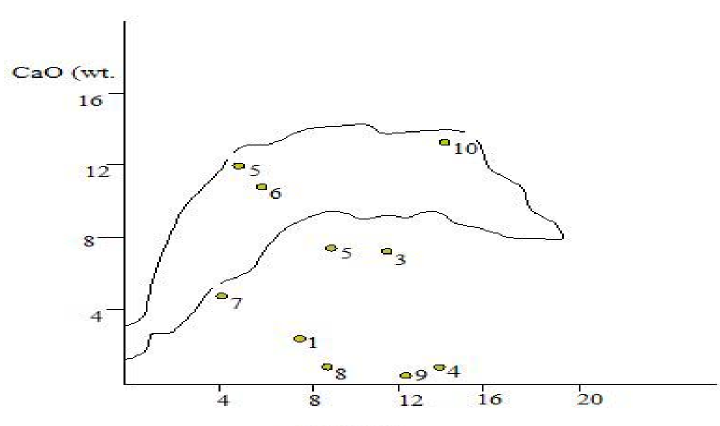


*Figure 10 :* Plot of CaO against MgO (after Davidson, 1996)

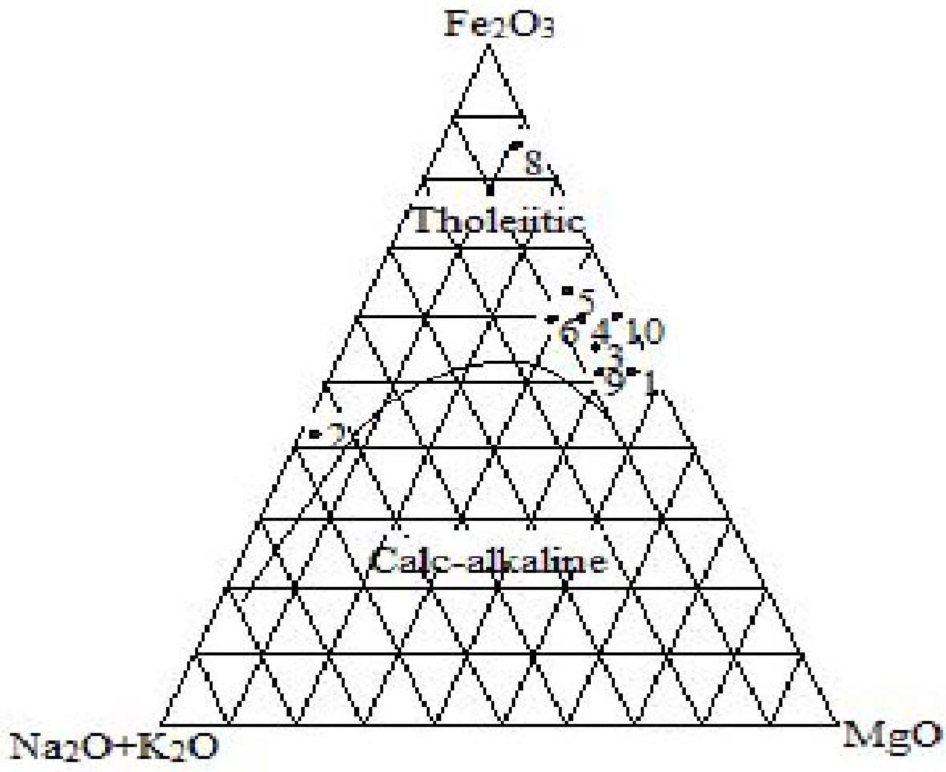


*Figure 11 :* Variation diagram showing the relationship of $Fe_2O_3$ with $Na_2O_3$ + $K_2O$ and MgO (Method of Best and Christiansen, 2001)

## V. Discussion

The petrology and geochemistry of the Abakaliki Pyroclastics as presented in this study have implications on earlier thoughts on the origin and evolution of Benue Trough. Most workers associate the origin of the trough to the splitting of the Afro-Brazilian plate in early Cretaceous time (Hoque, 1984). The trough is portrayed as a rifted depression (Kings, 1950; McConnell, 1969) or a failed arm of an RRR triple junction involving the Gulf of Guinea, the South Atlantic and the Benue Trough (Burke et al 1971, 1972; Burke and Dewey, 1973). Within the concept of plate tectonics, Burke et al (1972) postulated an active oceanic spreading along the Benue Trough and formation of about 150-200km wide of oceanic crust beneath the lower trough followed subduction motion along a Benioff zone which gave rise to more than 1300m of andesitic, basaltic and pyroclastic rocks. Olade (1975, 1979) cited Abakaliki Pyroclastics and associated intrusive as an evidence of initial volcanic activity related to a plume generated rifting of the Afro-Brazillian plate and regarded these volcanic forming a substratum of the rifted basin.

Olade (1979) proposed that the pyroclastics are not andesitic lavas and tuffs as opined by Burke et al, 1971) but rather are altered alkali basalts, pyroclastic flows and tuffs. He interpreted the pyroclastics as product of hotspot activity associated with initial continental rifting during Aptian-Albian times. Hoque (1984) said that the generating magma of the pyroclastics was dominantly alkaline and silica under-saturated and had no affinity with magma characteristic of andesitic volcanism at a convergent plate boundary or with a tholeitic and silica-oversaturated magama typical of a zone of oceanic spreading (Bailey, 1974, 1977).

The compositions of the pyroclastics as shown in the variation diagrams suggest that the parent magma of these rocks was subalkaline and silica saturated. The rocks include basalts, basaltic andesite, dacite and rhyolites of thin continental crust. From the field relationships, the pyroclastics are found interbedded with shales in some places and outcropping as enlongate and domical bodies. The interbedded nature invalidates Uzuankpunwa (1974) and Olade's (1979) ideas that the pyroclastics form the initial substratum for the Trough. The interbedding of the pyroclastics with the country rocks indicates both long age range and multiplicity of extrusive volcanic episodes interspersed with marine sedimentation for these sedimentary rocks of igneous origin.

## VI. Conclusions

The Abakaliki pyroclastics are rocks of intermediate to acid composition. They are mainly basalts, basaltic andesites and dacites. Basaltic andesites and dacites are the dominant rock types suggesting silica-rich parent magma. This fact is collaborated by the presence of quartz enclaves and segregations in the field. This agrees with Okezie (1965) and Burke et al (1972) who suggested that the pyroclastic rocks are andesitic lavas and tuffs and had affinity with a magma characteristic of andesitic volcanism and silica over saturated magma (Bailey, 1974, 1977).

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