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PETROGRAPHIC STUDY OF IGNEOUS ROCKS AND SANDSTONE OUTCROPS AROUND THE LOKPAUKWU AXIS SOUTHEASTERN NIGERIA

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ABSTRACT
The study involved a field and laboratory based study of igneous rocks and sandstone around the Lokpaukwu axis, southeastern Nigeria. From the field relationships, the intrusives are found interbedded with shales in some places and outcropping as enlongate and domical bodies. Petrographic examination of the sandstones reveals the dominance of sub-angular to sub-rounded quartz with individual grains displaying point to floating point contact. Feldspar and rock fragments were present in smaller amount. The sandstones were classified as Sub-Arkose, Arkosic arenite and Quartz arenite. Thin section study on the igneous rocks shows subophitic texture where randomly oriented laths of plagioclase are partly enclosed in irregular bounded crystals of pyroxene. Mineralogically, they are composed dominantly of plagioclase (47.7%) and pyroxene (23.3%). Others include, Quartz (4.5%), olivine (4.25), biotite (11.7%), hornblend (3.2%) and opaque minerals commonly magnetite (5.25%). For the basalt, the specimen is generally fine-grained, inequigranular and melanocratic. It consists essentially of plagioclase feldspars which are elongate and subhedral to euhedral, and randomly oriented. The plagioclase feldspars are mainly in sub-ophitic to intersertal relationship with large crystals of clinopyroxene. The compositions of the intrusive in the study area suggest that the parent magma of these rocks was subalkaline and silica saturated. From the field relationships, the intrusives are found interbedded with shales in some places and outcropping as enlongate and domical bodies. The interbedding of the intrusives 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.

Keywords: Petrography, Igneous, Sandstone, Lokpaukwu, Southeastern, Nigeria

INTRODUCTION

The formation of the Southern Nigerian sedimentary basin may be traced back to the late Jurassic following the break-up of the South American and African continents in the Early Cretaceous, leaving the Benue Trough as a failed arm of RRR Triple junction (Murat, 1972; Burke, 1996). Various lines of geomorphologic, structural, stratigraphic and palaeontologic evidence have been presented to support a rift model (Burke *et al*., 1971, 1972; Fairhead & Green, 1989; Benkhelil, 1989).

Hoque and Nwajide (1985) summarized the tectonic evolution into four stages as described below in chronological order of their origin and development.

Rifting Stage:

A graben-like depression is formed by crustal extension followed by rifting, with broad lip adjourning the western margin of the trough (Anambra platform) and a smaller lip on the southern edge (the Afikpo platform)(Fig 1).

Trough Stage:

The first marine transgression took place in Albian (or Aptian) times; the trough was widened and deepened. There was a mild deformational episode during the Cenomanian which restricted deposition only in southern part of the trough. The Cenomanian deformation was perhaps very local and may have originated due to reactivation of the basin along basement faults.

Deformation Stage:

The accumulation of thick sediments in the trough led to the development of instability at the base of faulted crustal blocks which culminated in large-scale folding with fold axes parallel to the trend of the trough. The lips of the trough began to sag to form the Anambra Basin and the Afikpo Syncline. Large-scale alkaline basaltic volcanism took place (Hoque, 1984).

Platform Stage:

The deformed and uplifted (Benue-Abakaliki) trough became a positive element to shed detritus; the depressed platforms of Anambra and Afikpo became the major depocenters. In environments ranging from marine to parallic to fluvial, about 4000m of Post-Santonian sediments were deposited in the Anambra Basin. They are largely undeformed, but broadly upwarped with a few degree of dip towards the cratonic margin of the trough.

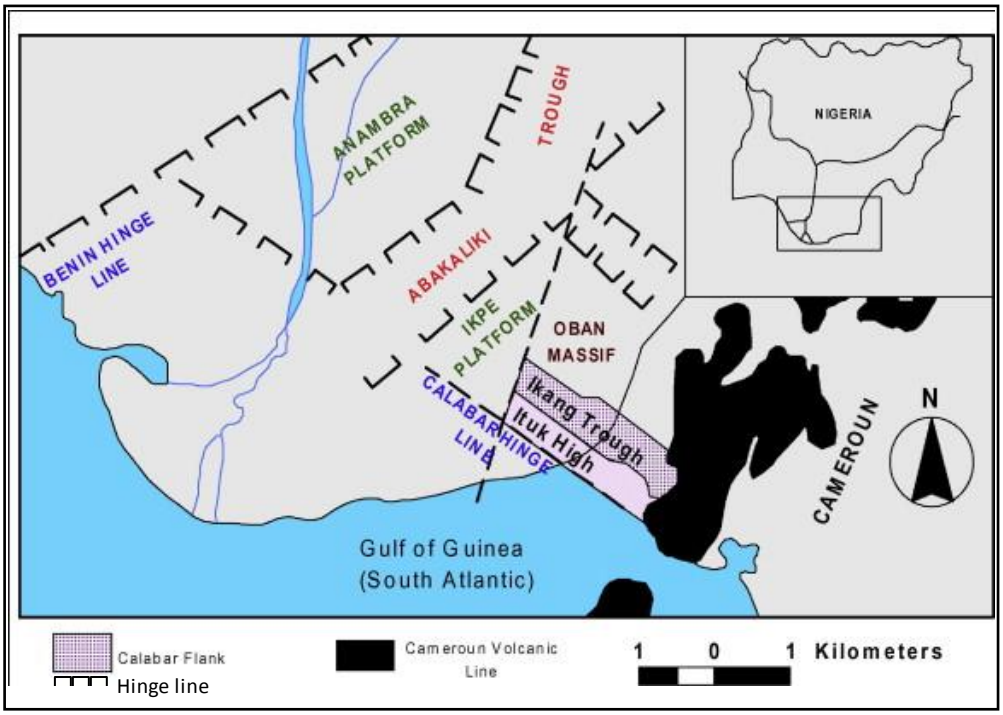


Fig 1: Tectonic map of southeastern Nigeria (adapted from Boboye and Okon, 2014).

The study area has several good outcrop locations exposed along the Enugu Port-Harcourt express road. Detail petrological study of Lokpaukwu and its environs is the focus of this work. This is achieved through field mapping and laboratory studies which is aimed at characterizing the textural and mineralogy of igneous rocks and sandstones sediments exposed around the Lokpaukwu axis as well as attempt a paleoenvironmental reconstruction of the study area.

LOCATION AND ACCESSIBILITY OF THE STUDY AREA

The study area falls within Lokpaukwu area and environs within the coordinates of Latitudes $N5^{0}47^{1}$ to $N6^{0}00^{1}$ and Longitudes $E7^{0}20^{1}$ to $E7^{0}30^{1}$ (Fig 2). The major localities here include; Lokpaukwu, Leru, Amuda-Isuochi, Lokpanta, Lekwesi covering an area of approximately $86km^{2}$. The study area is bounded to the East by Enugu Udi escarpment to the West by Owelli and North by Owerri-Ezukala.

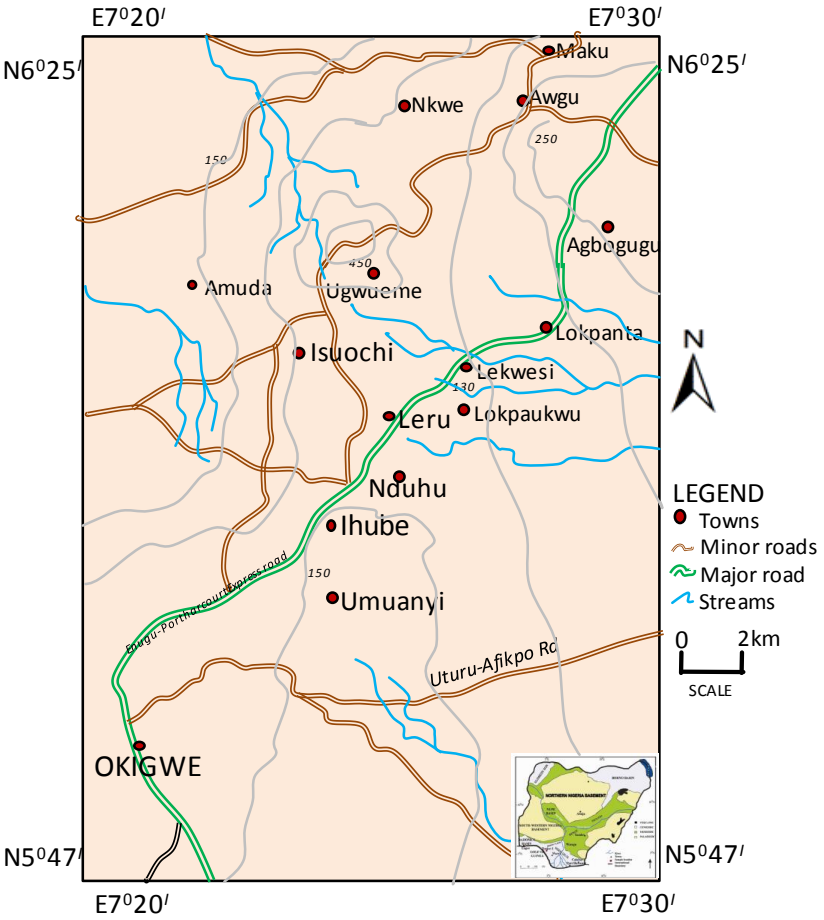


Fig 2: Location and accessibility map of the study area

METHODOLOGY

Fresh samples of the sandstones and igneous rocks in the studied area were selected for thin section petrography. A total of seven (7) already prepared thin- section slides (3 for igneous rock, 4 for sandstone) were studied and analyzed.

The samples were each mounted with polished side on a glass slide with araldite and Canada balsam. The mounted sample was ground on a lap wheel with a coarse abrasive and was later washed with water. This was followed by manual grinding with sludge of fine abrasive on a glass plate until the slide was fine or thins enough for individual mineral identification. The slide was then thoroughly washed with water and allowed to dry before covering with a cover slip. The slides were examined under the flat stage of a petrological microscope and studied for compositional analysis of the different mineral grains.

Point counting of 200 counts was made on each of the thin section by dividing the slide into grid line. Also percentage estimation of the mineral grains of (Folk, 1974) was deduced from the point count of each section, and result obtained for each sample was based on the results of the petrographic examination of each slide. The objective of point counting is to identify detrital minerals, authigenic minerals, cement and matrix; and their percentage proportion for each thin section.

RESULT

Description of Outcrops

Several outcrops were visited within the study area. Detailed description of each location with respect to sedimentological characteristics including texture, colour, sedimentary structure, nature of contacts, fossil cont etc were noted. Pictures were also taken and fresh samples collected for analysis. The various outcrops are described below

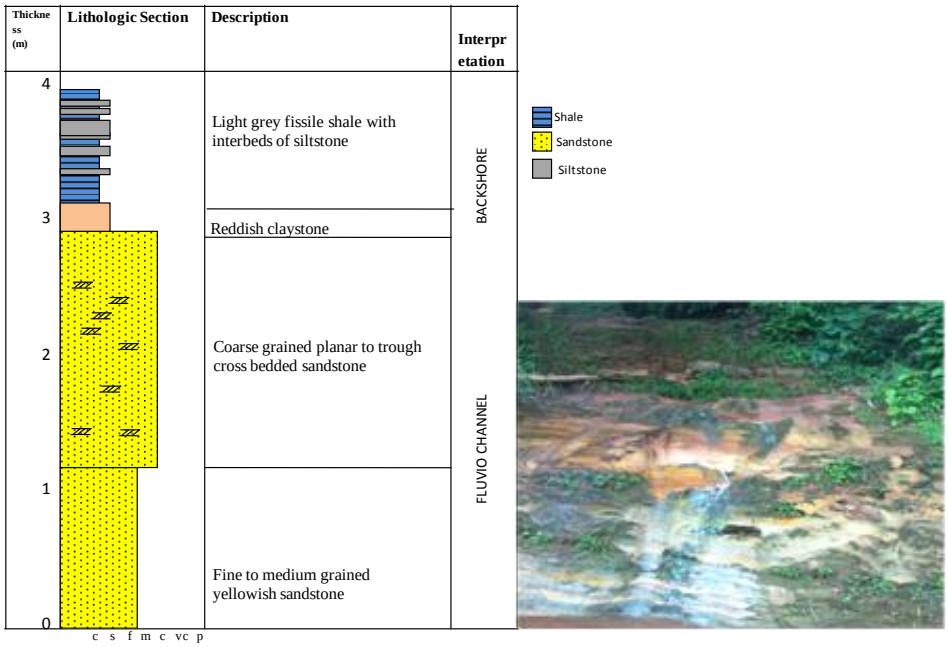


Fig 3: Litholog of section at km 74 Enugu Port Harcourt road

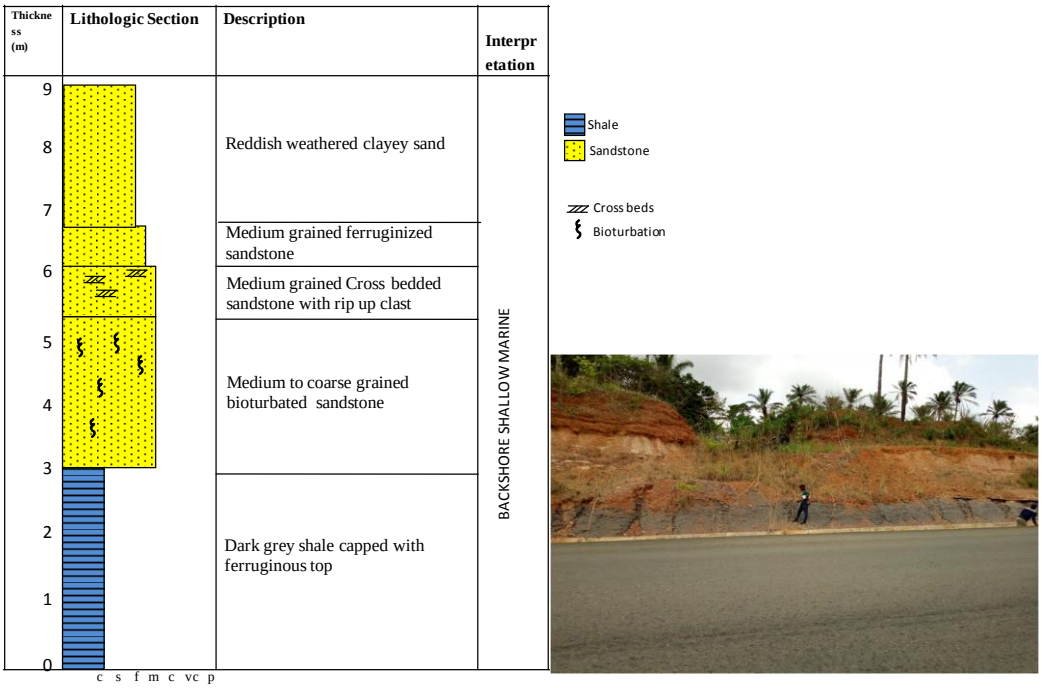


Fig 4. Litholog of section at Leru-Isuochi road

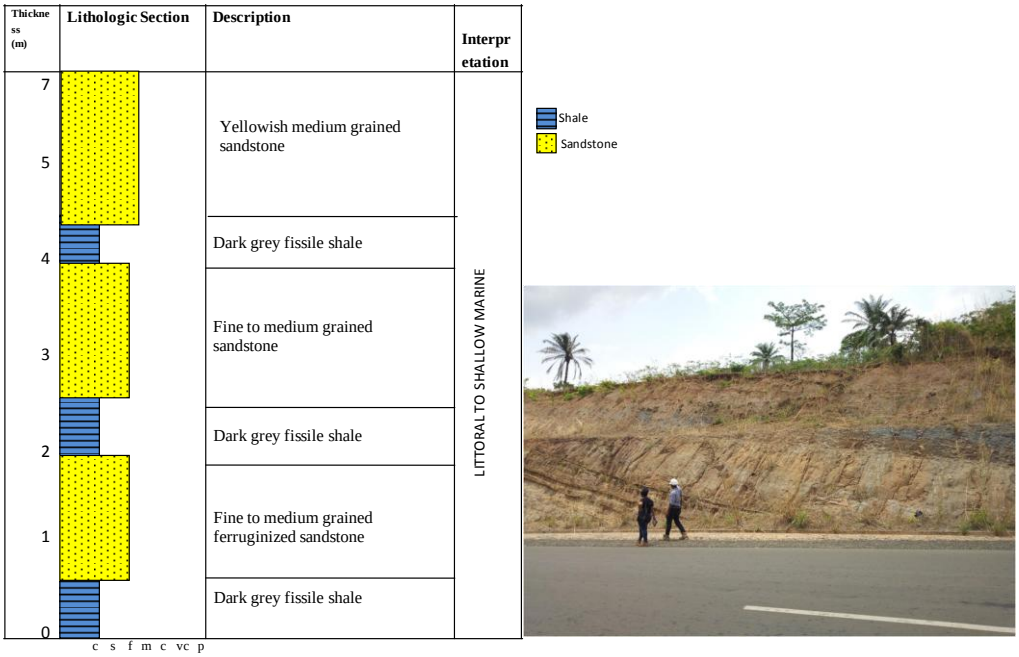
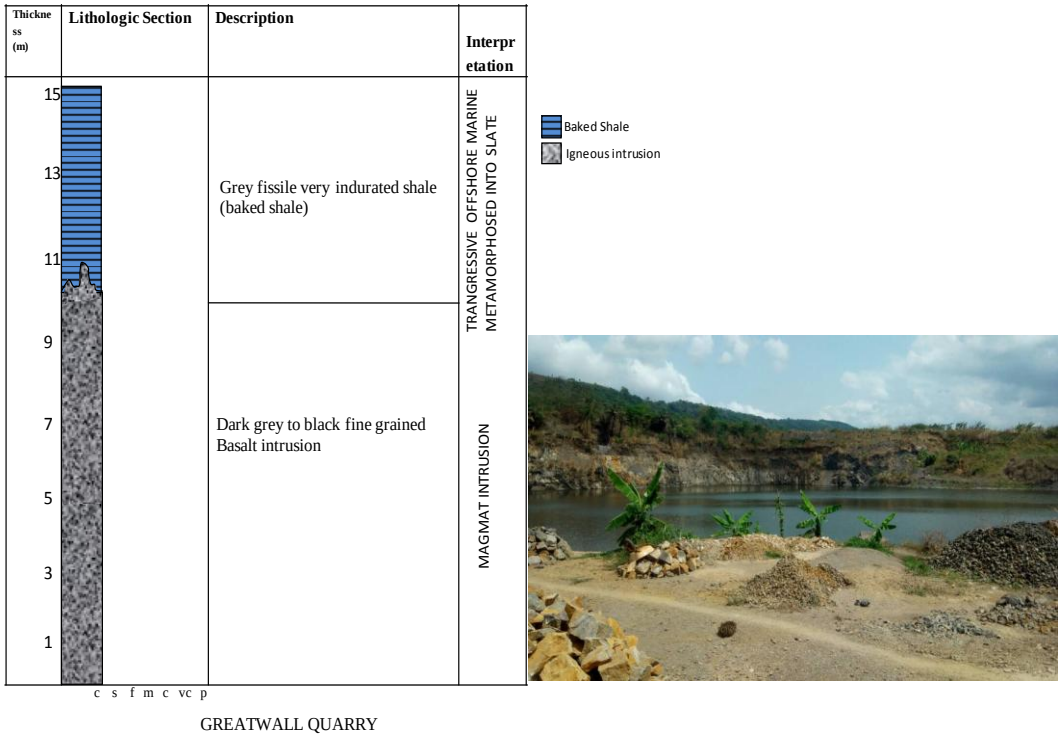


Fig 5: Litholog of section along Mmaku-Mgbidi road



GREATWALL QUARRY

Fig 6. Litholog of shale underlain by igneous intrusion at Lokpaukwu

Result of Thin Section Analysis

The result of thin section analysis of the rock samples is summarized in tables 1 and 2 for igneous rock and sandstone samples respectively. Thin section petrography of the representative igneous rock and sandstone samples is shown in Fig 7 and 8. Sandstone classification plot is also shown in fig 9.

Table 1: Mineralogical Composition of igneous rock samples in the study area

MINERALS	% COMPOSITION			AVERAGE
	DO1	DO2	BA1	
Quartz	4	5	5	4.5
Pyroxene	25	20	21	23.25
Olivine	4	3	5	4.25
Plagioclase	45	56	50	47.75
Hornblend	3	2	4	3.25
Biotite	11	11	10	11.75
Accessory Minerals	8	3	5	5.25
Total	**100**	**100**	**100**	**100**

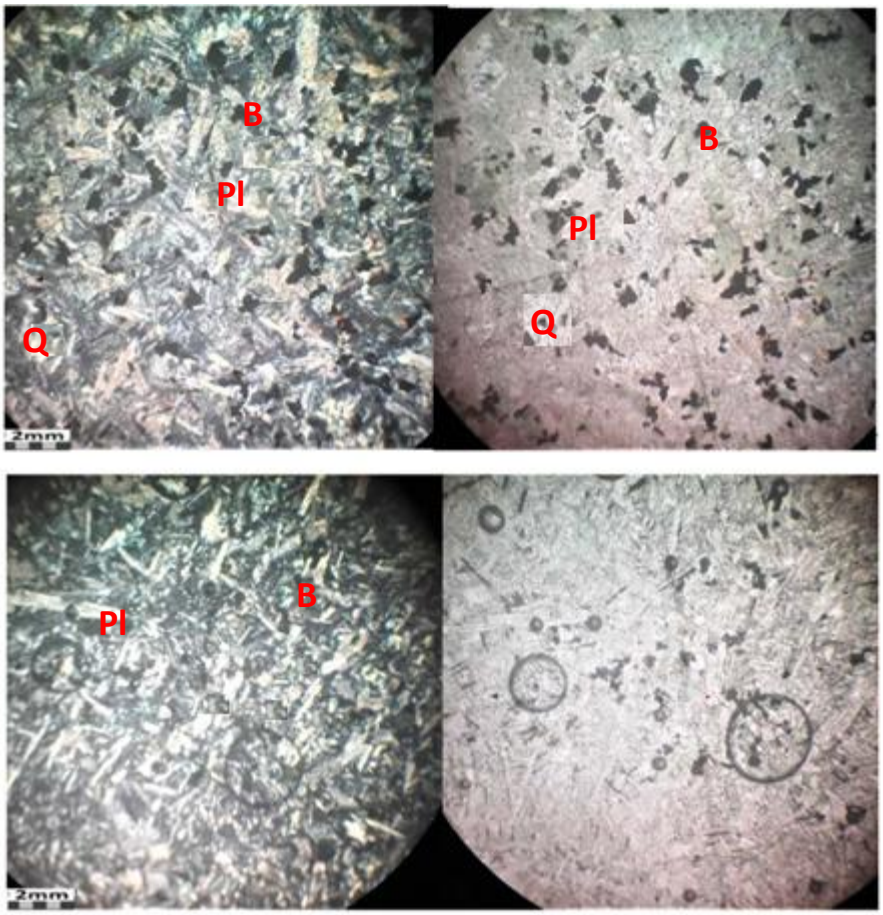


Fig 7a. Photomicrographs of Dolerite samples (DO1 and DO2)

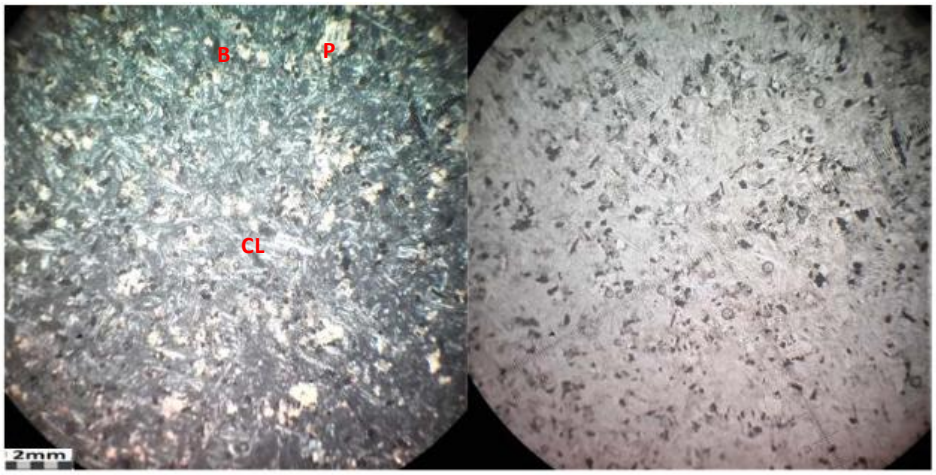


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Fig 7b. Photomicrographs of Basalt sample (BA1)
B = Biotite, Pl = Plagioclase, Q = Quartz, Cl = Chlorite

The Petrographic characteristics of Igneous rock samples

For the igneous rocks, the thin section analysis for the dolerite shows medium-grained, inequigranular and melanocratic. It consists essentially of plagioclase (47.7%) and pyroxene (23.3%). Plagioclase feldspars are elongate and subhedral to euhedral, and randomly oriented. The plagioclase feldspars are mainly in sub-ophitic to intersertal relationship with large crystals of clinopyroxene. Other minerals include, Quartz (4.5%), olivine (4.25), biotite (11.7%), hornblend (3.2%) and opaque minerals commonly magnetite (5.25%). Olivine occurs mainly as large equant phenocryst and irregular cleavage. The pyroxene here is augite. The opaque minerals occur as scattered grains of iron oxide and magnetite along the augite partings.

For the basalt, the specimen is generally fine-grained, inequigranular and melanocratic. It consists essentially of plagioclase feldspars which are elongate and subhedral to euhedral, and randomly oriented. The plagioclase feldspars are mainly in sub-ophitic to intersertal relationship with large crystals of clinopyroxene.

Table 2: Modal composition of representative Sandstone Samples in the Study Area.

Sample ID	**SA**	**AA**	**QA1**	**QA2**	**QA3**
QUARTZ (%)	77.0	69.0	95.6	96.1	98.8
FELDSPAR (%)	17.7	26.4	2.4	1.8	0
K-Feldspar	13.2	22.5	2.4	1.8	0
Plagioclase	3.7	3.9	0	0	0
Microcline	0	0	0	0	0
ROCK FRAGMENT(%)	5.3	3.6	2.0	2.1	1.2

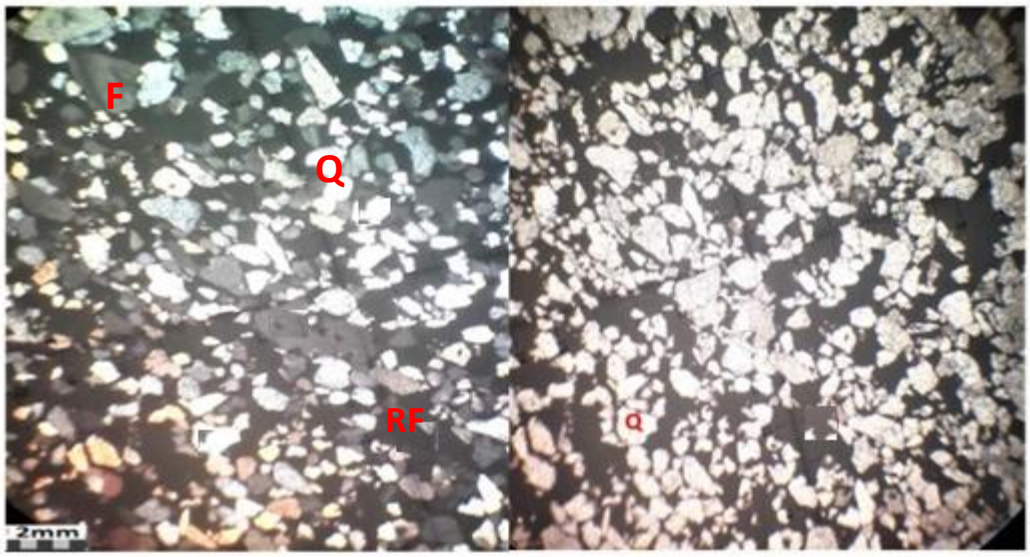

Fig 8a: Photomicrographs of representative sandstones (arkosic arenite)

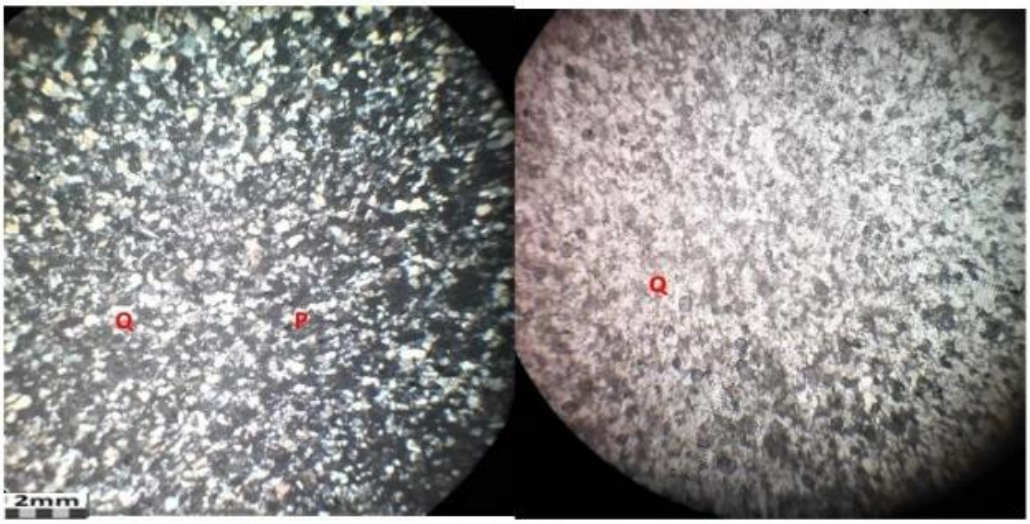

Fig 8.b. Photomicrographs of representative sandstones (Sub arkose)

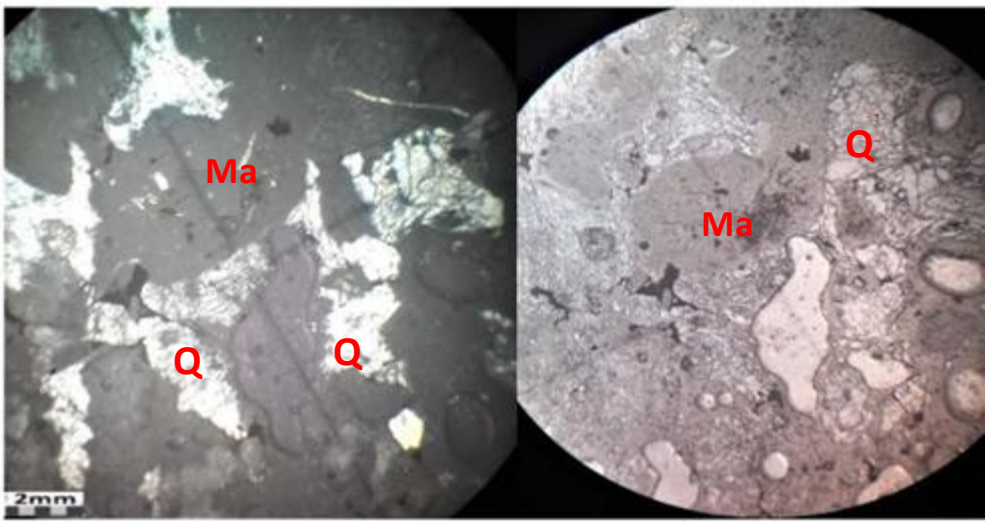

Fig 8c. Photomicrographs of representative sandstones (Quartz arenite I)

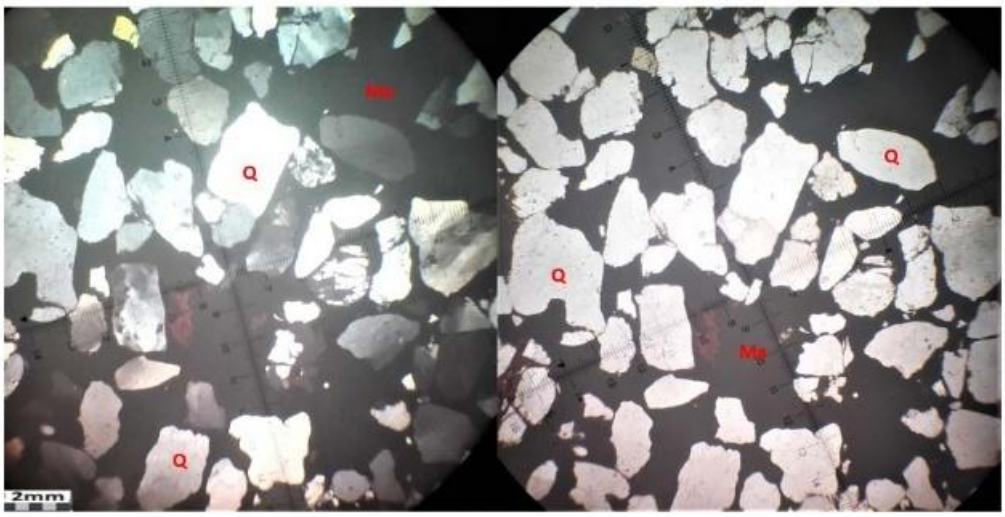

Fig 8d. Photomicrographs of representative sandstones (Quartz arenite II)
Q = Quartz, Ma = Matrix

Petrographic Characteristics of Sandstone samples

The modal analysis of the studied sandstone samples exhibits a comparatively simple mineralogy dominated by quartz, making up the bulk of these sandstones.

Feldspar and rock fragments were present in smaller amount. Petrographic examination of the sandstones reveals the dominance of sub-angular to sub-rounded quartz. They occur as colourless to faint coloured grains under cross polarized and plane polarized light (CPL and PPL) respectively. Matrix is made up of kaolinitic clay and silt. Cement is composed of calcite. The individual grains displayed a point to floating point contact.

The modal composition was recalculated for the purpose of rock classification into Quartz, Feldspar and Rock Fragment. The studied sandstones are designated as sub-litarenite (Fig 9), based on classification scheme of Folk and Ward, (1978). The tectonic setting of the depositional environment is assumed to influence.

Details of individual sandstone classes are described below:

Quartz Arenite

This sample consists of entirely coarse grained, moderately sorted, subangular to sub-rounded quartz grains, and minor rock fragments cemented by authigenic quartz, limonite, calcite and clay minerals. The grain sizes range within 0.5 to 2.0 mm. The polycrystalline quartz in this sample show some needle-shaped inclusion, suspected to be fluid inclusion which is present at the time of crystallization. Quartz grains contain abundant of vacuoles which is usually derived from a source of low temperature origin, such as a hydrothermal vein, and appear milky-white in hand specimen.

Subarkose

This sample consists mainly of, angular to rounded, moderately to well sorted, fine to medium grained quartz, plagioclase feldspars (multiple twinned) and minor amount of lithic fragments. The grain sizes range within 0.125 to 0.5 mm. There are some pinkish colour alterations on the rock fragments suggested to be hematite coating on some of the quartz and feldspar grains. The k-feldspar exhibits a simple carlsbad twin. The abundant cementing materials and matrix are possibly clay minerals and carbonates (calcite).

Arkosic Arenite

This sample consists of a fine to medium grained, moderately to well-sorted sandstone, dominated by carbonates and iron oxide cements filling the pore spaces, with minor inclusion of biotite mineral grains. The grain sizes range within 0.125 to 0.5 mm. The sandstone samples supported by small subangular to rounded quartz grains, plagioclase feldspars (multiple twinned) and rock fragments suggested to be mostly of sedimentary in origin. There is lots of mineral dissolution and the pore spaces are filled up with cementing materials.

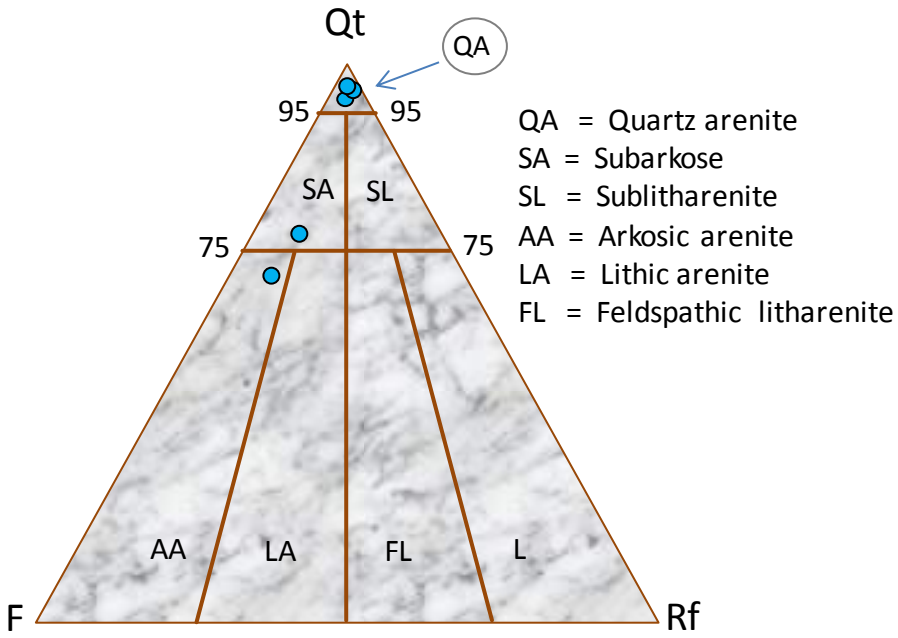

Fig 9. Triangular diagram for the classification of the sandstones (after Fol and Ward, 1978)

DISCUSSION AND CONCLUSION

The modal analysis of the studied sandstone samples exhibits a comparatively simple mineralogy dominated by quartz, making up the bulk of these sandstones.

Feldspar and rock fragments were present in smaller amount. Petrographic examination of the sandstones reveals the dominance of sub-angular to sub-rounded quartz. They occur as colourless to faint coloured grains under cross polarized and plane polarized light (CPL and PPL) respectively. Matrix is made up of kaolinitic clay and silt. Cement is composed of calcite. The individual grains displayed a point to floating point contact.

The sandstones were classified as Sub-Arkose, Arkosic arenite and Quartz arenite based on the classification scheme of Folks (1980).

From the field relationships, the intrusives are found interbedded with shales in some places and outcropping as enlongate and domical bodies. The interbedding of the intrusives 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.

Thin section study on the igneous rocks shows subophitic texture where randomly oriented laths of plagioclase are partly enclosed in irregular bounded crystals of pyroxene.

Mineralogically, they are composed dominantly of plagioclase (47.7%) and pyroxene (23.3%). Others include, Quartz (4.5%), olivine (4.25), biotite (11.7%), hornblend (3.2%) and opaque minerals commonly magnetite (5.25%). For the basalt, the specimen is generally fine-grained, inequigranular and melanocratic. It consists essentially of plagioclase feldspars which are elongate and subhedral to euhedral, and randomly oriented. The plagioclase feldspars are mainly in sub-ophitic to intersertal relationship with large crystals of clinopyroxene.

The compositions of the intrusive in the study area suggest that the parent magma of these rocks was subalkaline and silica saturated. From the field relationships, the intrusives are found interbedded with shales in some places and outcropping as enlongate and domical bodies. The interbedding of the intrusives 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.

Hand specimen analysis suggests the rock is dolerite (DO1 and DO2) and basalt (BA1) with respect to colour, texture, and specific gravity. This is because the rock has mafic minerals within 40 to 70% total volume and felsic rocks over 5%.

The petrology of intrusive rocks in the area and environs as presented in this study has implications 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 or a failed arm of an RRR triple junction involving the Gulf of Guinea, the South Atlantic and the Benue Trough (Burke et al 1972; Burke, 1996). 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, dolerite, basaltic and pyroclastic rocks.

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