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# Field relation and Petrographic study of Tertiary to Quaternary Volcanics in the Northern Benue Trough, Nigeria

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## ABSTRACT

The Northern Benue Trough experienced intrusions by Volcanic rocks in the Tertiary to Quaternary Period. Field investigations and analysis of petrographic characteristics were conducted to gain insights into the features of these volcanic plugs and the conditions of their emplacement, eight (8) representative samples of Basalts were thin sectioned and the mineral constituents of the rocks were studied under a Polarized microscope. The Geology of the study area was characterized by Fika Shales of the Pindiga Formation and basaltic plugs. Based on the Petrographic studies, it was observed that the Basaltic rock samples consist of the following average mineralogical compositions; Olivine (30%), Augite (20%), Plagioclase (21%), Iron oxides (19%) and Opaque minerals (10%). Olivine and Augite minerals appeared as phenocryst and surrounded with Opaque minerals which could be Fe or Ti oxides while the plagioclase minerals forming the groundmass of the porphyritic texture. The presence of Augite and Olivine as phenocrysts, while Iron oxides and Plagioclase minerals forming the groundmass in the basalts suggests the presence of magma mixing and possible wall rock interaction during the emplacements of basalts in the study area.

**Keywords:** Basaltic rocks, Benue Trough, phenocrysts, Pindiga Formation

## INTRODUCTION

This research assesses the nature and characteristic of environmental formation of the Basaltic plugs around Powoshi and environs, Billiri, north-eastern Nigeria and their effects on the environment (Fig. 1). Basaltic rocks mostly occur in the active plate settings such as rift, subduction and intraplate settings that originate from the upper mantle due to partial melting (Blatt and Robert, 1996; Ekwueme, 1993). The composition of the Basaltic rocks depends on the mineral association and assemblages. Most of the volcanic plugs that intruded the Cretaceous sedimentary successions affected their sedimentary properties and the organic matters presence within the sediments (Zhu et al., 2007). Basaltic rocks related to volcanic activities of the Tertiary and Quaternary Periods have been identified at several locations in the Yola and Gongola sub-basin of the Northern Benue Trough (Sarki Yandoka, 2015; Carter et al. 1963). The petrography and major elements geochemistry of these rocks in Yola arm sub-basin of the Northern Benue Trough have been discussed in details by Ntekim and Adekeye (2003); however, similar studies in Gongola sub-basin of the Northern Benue Trough are limited to provide information on the economic potential of these rocks. Therefore, this study attempts to understand the characteristics of the Volcanic plugs, environment of their Formation using field relationships and petrographic characteristics to highlight their economic potentials.

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## Location of the Study Area

The study area is located in Billiri Local Government area of Gombe State and forms a part of sheet 173 Kaltungo NE, it lies between latitude 10 ° 12 ˙ 20 ¨ N to 09° 11 ˙ 15 ¨ N and longitude 9 ° 52 ˙ E to 41 ¨ 20 ¨ E and covers an area of about 25 square km. The area is accessible through the major road linking Kashere to Billiri, and the outcrops are accessible through minor roads and footpaths that give access to the remote areas within the study area (Figure 1).

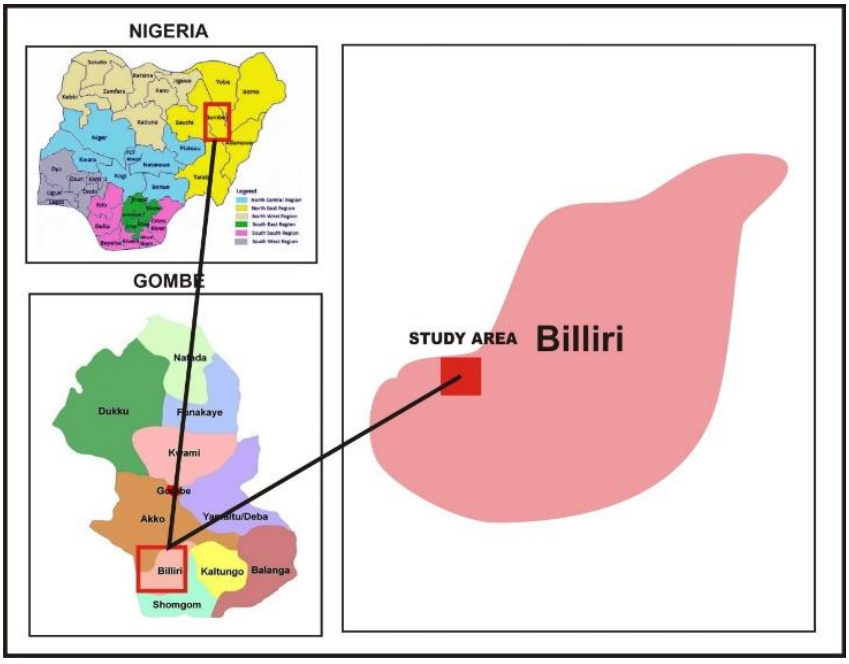


**Figure 1:** Location map of the study area

## Geological Settings

The Benue Trough is an intra-continental rift basin in the central West Africa that is trending in the direction of NNE-SSW for about 1000 km in length and 250 km in width (Abubakar et al, 2021). The Chad Basin and Niger Delta mark the northern and southern limits of the Benue Trough, as indicated by Nwajide (2013). The evolution of the Benue Trough is attributed to the Early Cretaceous tension that emerged during the Gondwana land breakup. Various authors, including Nwajide (2013) and Zaborski et al. (1997), have proposed diverse tectonic models to explain its origin and development. King (1950) categorized the Benue Trough as a rift basin resulting from tensional movement, while Stoneley (1966) suggested a Graben-like structure. Grant (1971) and Olade (1975) introduced the RRF triple-junction model and Aulacogen model, respectively. Benkhelil (1989) and Guiraud and Maurin (1992) argued that wrench faulting was the predominant tectonic activity during the Benue Trough's evolution. The Benue Trough is stratified into Southern, Central, and Northern parts, as delineated by Nwajide (2013). The Northern segment further divided into the N–S-trending Gongola Sub-basin and the E–W-trending Yola Sub-basin (Figure 2).

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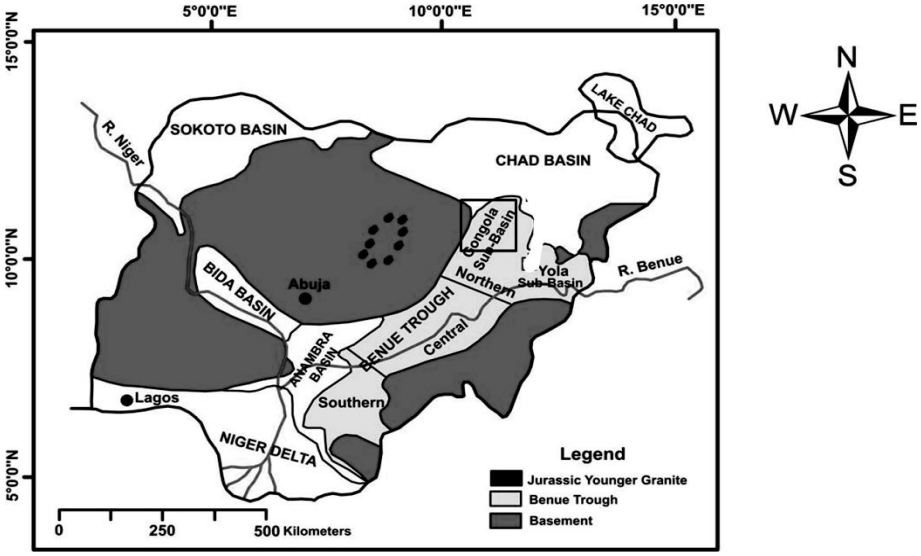


**Figure 2:** Map of Nigeria showing the location of the Gongola Sub-basin of the Northern Benue Trough (Modified after Abubakar, 2006).

Numerous authors have extensively documented reviews concerning the evolution, stratigraphy, and field geology of the Benue Trough, with a particular emphasis on the Northern Benue Trough. These scholarly contributions include works by Auwalu et al. (2020), Abubakar et al. (2006), Abubakar (2014), Obaje et al. (2004, 2006), Dike (2002), Benkhelil (1982, 1989), and Carter et al. (1963). The stratigraphic succession of the Gongola sub-basin of the Northern Benue Trough is shown in Figure 3.

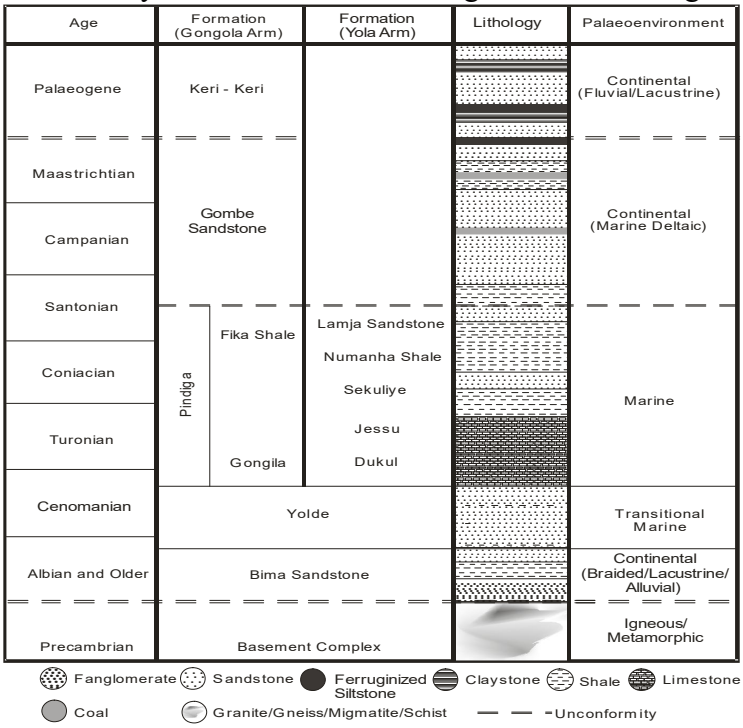


**Figure 3:** Stratigraphic succession of the Benue Trough (Abubakar, 2006).

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## MATERIAL AND METHOD

A traversing method of mapping was adopted using Compass clinometer and Global positioning system (GPS) for detailed mapping exercise. Fresh rock samples from various outcrops were sampled, using a Geological hammer. The samples were labelled appropriately before putting them into the sample bag and photographs of important structures were taken. Eight (8) representative samples of the basalts were selected and thin sectioned at University of Jos, Plateau State following the conventional procedures. These slides were studied under a Polarized microscope for the identification of the mineral constituents of the rocks.

## RESULTS

### Field Relation and Description of the Rocks in the Study Area

The Geology of the study area comprised of Cretaceous sedimentary rocks of Fika Shales of Pindiga formation and Tertiary-Quaternary volcanic basalts (Figure 4). The area is mostly flat surface occupied by Fika Shale of Pindiga Formation that is gray to black in colour with a lots of mud cracks and so many Ant hills outcrops revealing the underlying geology. Lithologically, the Fika Shales of Pindiga Formation in the study area are characterized by dark/black Shales intercalating with Claystone (Figure 5). The black shale can be interpreted as shales that are rich in organic matter and could be matured due to the effects of the intruded volcanic plugs in the study area.

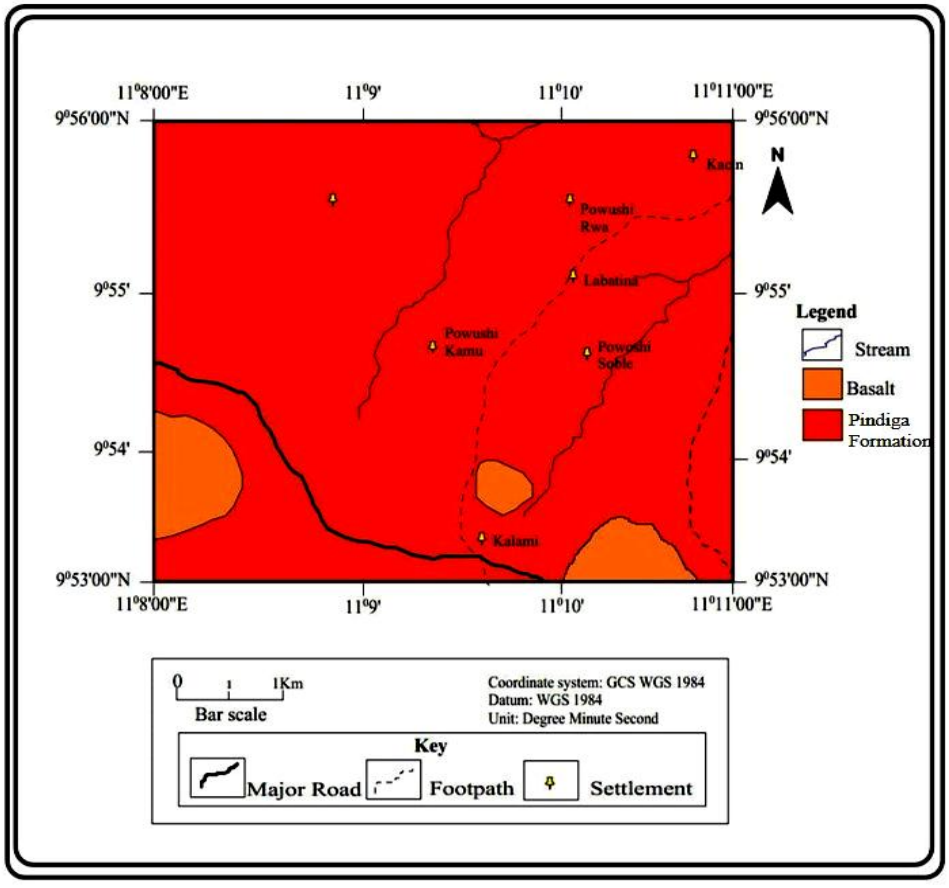


**Figure 4:** Geological Map of the study area

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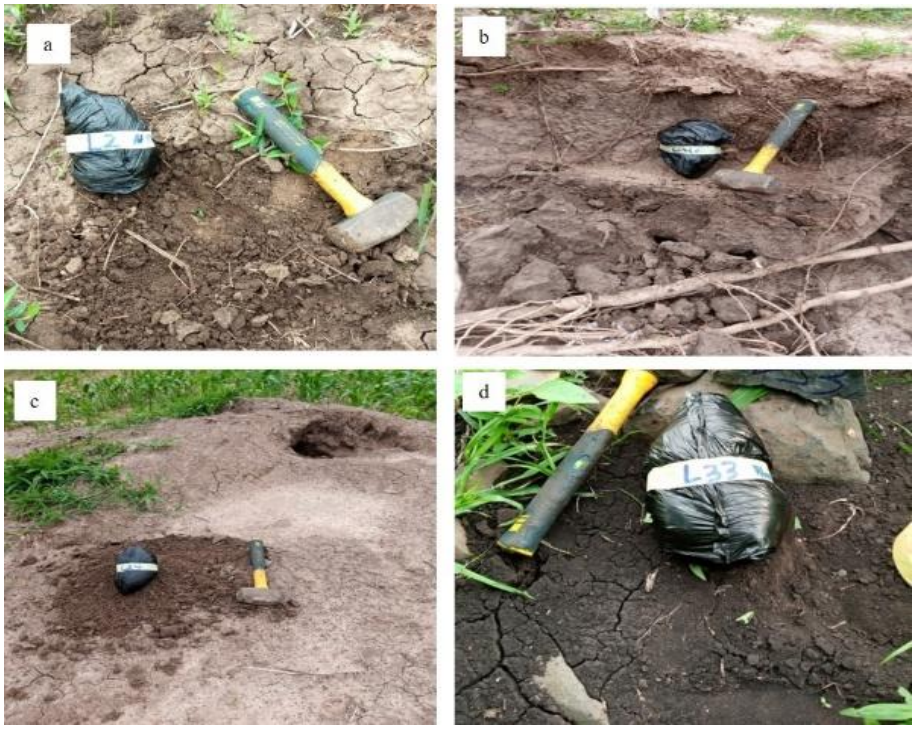


**Figure 5**a-d: (a) Shows Mudcracks on Pindiga Formation (b) clays along a river channel (c) Ant hill (d) Dark/black shale

Basaltic intrusions were also encountered in the Southern part of the study area, the Basalts are dark in colour which are covered by so many vegetation that forms Columnar Joint structures at the top of the Hills pointing towards NE directions. The Columnar Joint structures of the Basaltic intrusions were encountered at the peaks of Gamu Hill, and Toro Hill (Figure 6). These volcanic plugs occurred as Cones and Lava flow rising a few meters above their surroundings. Megascopic studies revealed that the basaltic rocks characterized by presence of reddish-brown, Olivine, and Plagioclase with medium to fine-grained porphyritic textures.


**Figure 6**: Hexagonal columnar joints at Gamu and Toro hills in the study area

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## Petrography

Microscopic examination reveals that the samples collected at location 26 consist of fine-grained basalt with a groundmass comprising Augite, Olivine, Plagioclase, and Iron oxide (Figure 7). Plagioclase, observed under plane-polarized light, appears colorless with no Pleochroism. It exhibits cleavage in two directions, displaying a lath-like structure and low relief, along with weak birefringence. The interference color is gray to white of the first order, and the extinction is oblique, showcasing albite twinning. Augite, when viewed under plane-polarized light, is light and non-pleochroic, featuring perfect cleavage in two directions. It presents a prismatic structure with very high relief and strong birefringence. Under cross-polarized light, it displays an interference color ranging from greenish to dark green and brown, demonstrating symmetrical extinction and polysynthetic twinning. Olivine, observed under plane-polarized light, is colorless and non-pleochroic with cleavage. It appears anhedral to subhedral, possessing high relief, and moderate birefringence with upper-order interference color. The extinction is oblique, and there is no twinning.

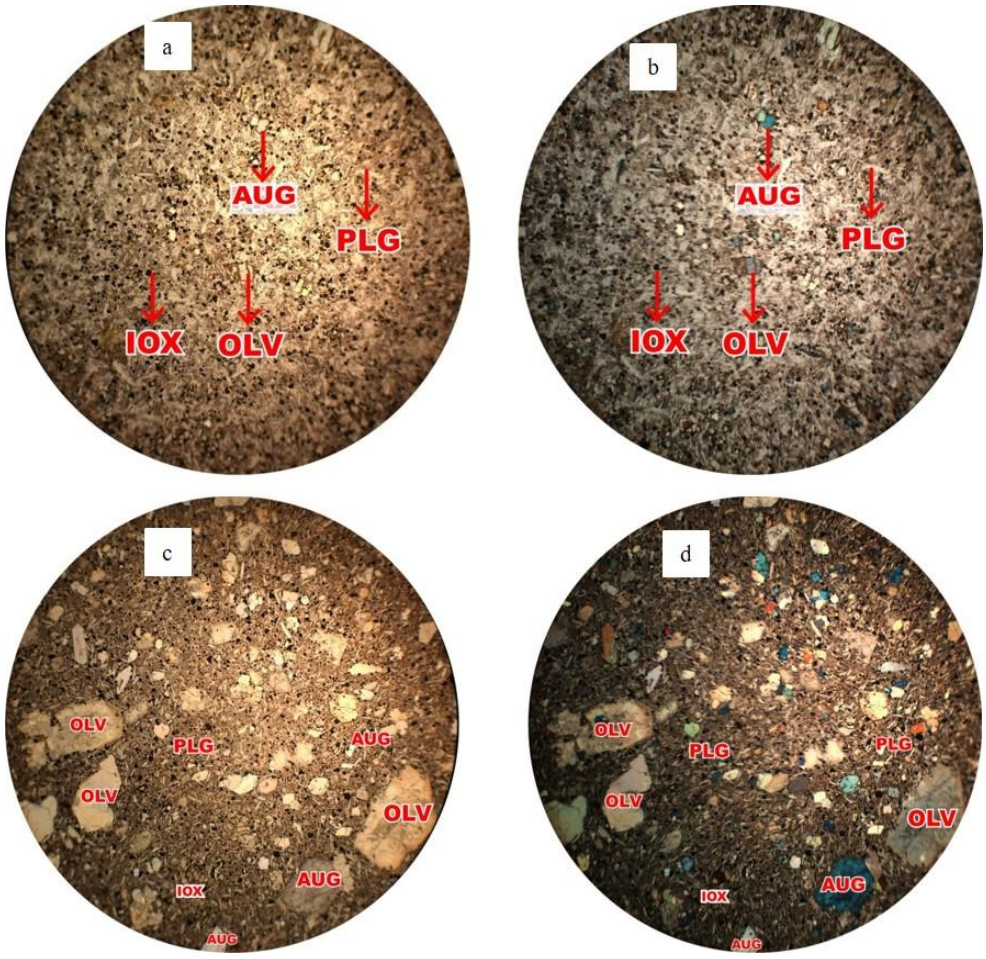


**Figure 7**a-d: Representative photomicrographs of the volcanic basalts under PPL and XPL.

*AUG=augite, PLG=plagioclase, IOX=iron oxide, OLV=olivine*

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## DISCUSSION

The Geology of the study area is identified by Fika Shales of the Pindiga Formation that are Turonian-Santonian in Age and Tertiary to Quaternary basaltic plugs (Carter et al. 1963). The map of the study area was produced on a scale of 1:25000. Petrographically, under cross and plane polarised lenses, it was observed that the samples consist of the following average mineralogical compositions; Olivine (30%), Augite (20%), Plagioclase (21%), Iron- oxides (19%) and Opaque minerals (10%). Olivine and Augite appeared as phenocryst and surrounded with Opaque minerals which could be Fe or Ti oxides (Fig. 7d). This suggestion is in line with the findings of Tsalha et. al., (2014) that reported Fe-Ti oxides are Magnetite and Ilmenites in basaltic rocks forming rim cores around Olivine as a result of alteration probably due to hydrothermal processes. In some basaltic samples, the Olivine and Plagioclase formed the groundmass with granular texture (Fig. 7a) that can in general be related to the inferred rate of cooling of the liquid during crystallization and wall rock interaction during the emplacements of the basalts.

## CONCLUSION

From the discussion above, the following conclusions can be drawn:

i. The Geology of the study area is identified by Fika Shales of the Pindiga Formation and Basaltic plugs.

ii. Field observation and petrographic studies revealed that the Basalts in the study area are Porphyritic in texture.

iii. The presence of Augite and Olivine as phenocrysts and Iron oxides and Plagioclase forming the groundmass in the Basalts suggested the presence of magma mixing and possible wall rock interaction during emplacements of the basalts.

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