

Research Article

Geochemical and Mineralogical Composition of Biu Basalt Deposit, Biu Area NE Nigeria

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Abstract: The aim of this study is to determine the geochemical and mineralogical composition of Biu Basalt Deposit of northeastern Nigeria. Detailed geological mapping of an area of 110 km² around Biu Dam site area have been mapped on a scale of 1:50, 000. Mapping revealed that the area is underlain by Basaltic rocks of Tertiary age. These are grouped into three types: Massive, slightly vesicular and vesicular basalt. Samples were collected at different locations representing the three types for petrographic and geochemical analysis. Petrographic study of ten rocks samples shows that the samples are essentially composed of Olivine, Augite, Plagioclase lath, Iron oxide and Calcite. Samples were analyzed geochemically using XRF method to determine some major oxides which include SiO₂, Al₂O₃, K₂O, Fe₂O₃ and CaO. The silica content in the rock samples has average values of 37.94% which is slightly lower than the standard value of 50%. Aluminium content has an average value of 11.16 which is less than the average value of 15%. CaO have an average value of 13.98% which is slightly above the standard value of 8.5%. Fe₂O₃ content has an average value of 12.59% is greater than the standard value 6%. K₂O has an average value of 1.14 which is greater than the standard value of 0.55%. These suggest that the basaltic rocks belong to the tholeiitic basalt.

Keywords: Basaltic rock, Biu dam site, geologic mapping, NE Nigeria, petrographic, XRF

INTRODUCTION

Basaltic rocks are generally believed to have originated from Upper mantle through partial melting and they occur in three different tectonic settings namely, Rift settings, Subduction zone and Intraplate settings (Blatt and Robert, 1996; Beeson, 1976; Ekwueme, 1993). Oceanic Rift is characterized by tholeiitic and marginally Alkaline Basalt in contrast. The Continental Rift is characterised by tholeiitic and Per-alkaline Basalts (Ozerov, 2010). Subduction zones host Cal- alkaline tholeiitic and Alkaline Basalt (Toramaru, 1990). Basaltic rocks can be of different types reflecting its different mineral associations and assemblages. The type of Basaltic rocks found in Biu area has not been clearly established in terms of its mineral assemblages and geochemistry (Ekwueme, 1993; McBirney, 1993).

The Biu Plateau is the largest area of volcanic rocks in Nigeria (Falconer, 1911). It belongs to the Tertiary-Recent Volcanic Province of Nigeria and Cameroon which is characterized by numerous widely scattered occurrences of alkali olivine Basalt together with less important trachyte and phonolite (Keer, 1977). Part of the volcanic activity in the Province is located along the "Cameroon Line", which extends North-Eastwards from the Gulf of Guinea Islands, through Cameroon Mountain and the Bermuda Volcanic District

of Western Cameroon towards Lake Chad (McCurry, 1976). However, the Biu Plateau like the Adamawa Plateau of Cameroon Line and many other smaller volcanic occurrences is situated away from the Cameroon Line without an obvious structural control over its location (Fig. 1a and b).

The Biu Plateau has not been extensively studied, but some geologists have made an appreciable attempt at describing the rock type in the area (Umaru, 1982). For example Du Preeze (1949) gave a brief general account of the geology and thus recognizing a distinction between older eroded Basalt and Younger Cones and flows. He also stated that the Biu Plateau Basalt and the Newer Basalt of the Jos Plateau are equivalent and traceable to youthful volcanic cones which are characterized by steep side and breach central Craters.

Biu Basalt is generally Olivine rich. Carter *et al.* (1963) working in part of Adamawa, Bauchi and Borno Provinces gave an account of the Basalts of Western and Eastern Biu Plateau (Islam *et al.*, 1989). They gave the petrographic descriptions and chemical analysis of some exposed rock sections in the area. Grant *et al.* (1972) obtain the ages of the fine-grained Basalt of Biu Plateau indicating an Older Pliocene Group and the Quaternary Group. These ages were discussed briefly by Turner (1978). Turner (1978) pointed out that Biu Basalt erupted in Pliocene and Quaternary period. He

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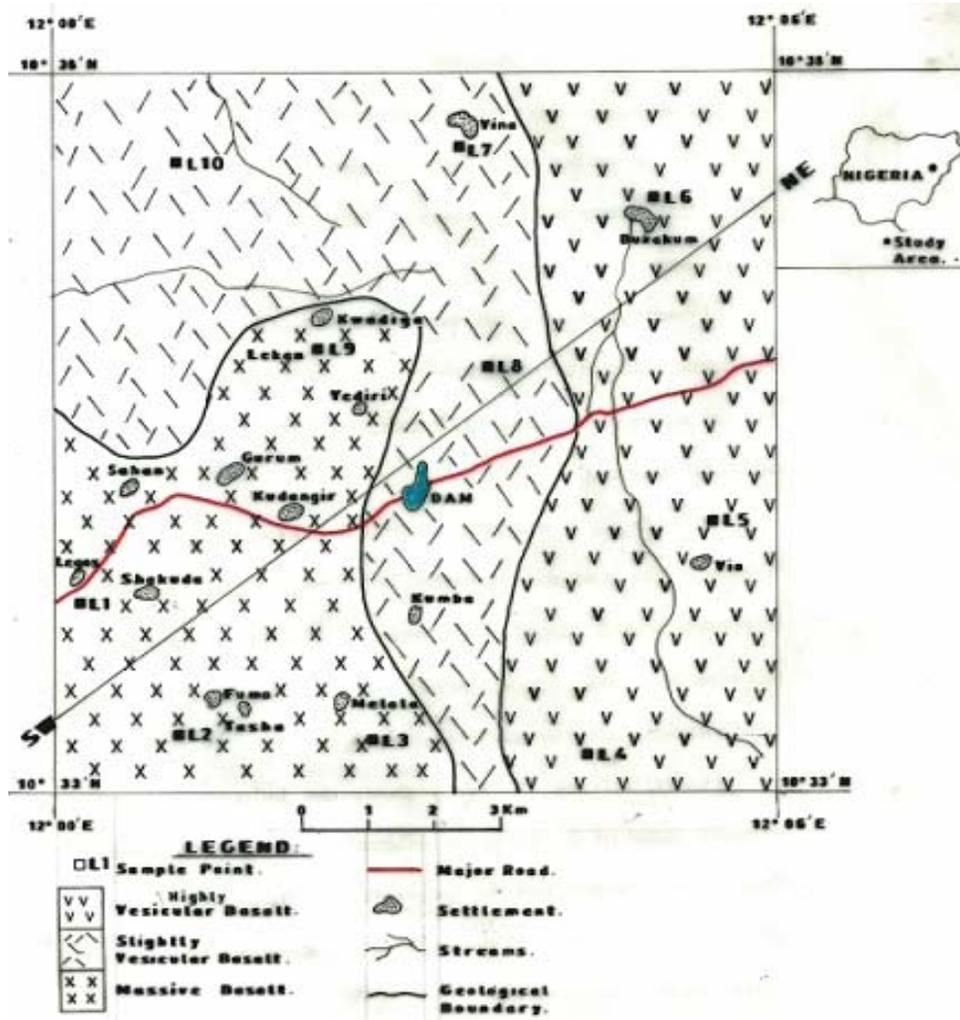


Fig. 1a: Geologic map of the study area

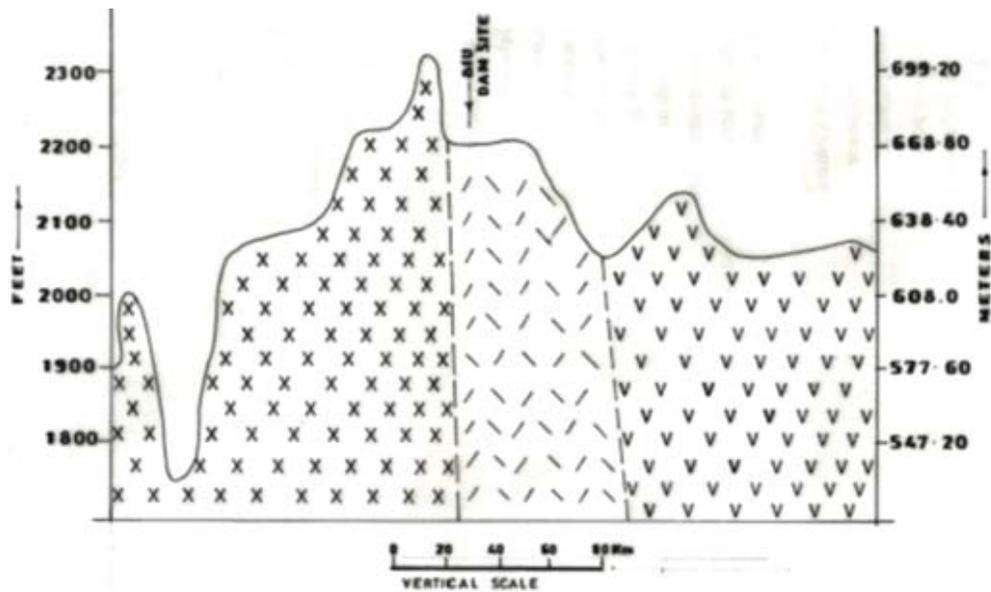


Fig. 1b: Geological section of the study area (Fig. 1a)

noted the Pliocene Basalt consists of an extensive Lower Group and thus giving more emphasis on the volcanic activities which were concentrated in the West where several volcanoes can be distinguished. He also described the Biu Type of Basalt as being dense, fine grained and dark coloured having vesicles filled with the mineral zeolite while the Miringa Type includes bombs, rhyolite, agglomerate and other tephra.

The Biu Plateau which extends over 500 km² is situated on the structural and topographic divides between the Benue and Chad Basins (Falconer, 1911). The structural divide is broad East-West ridge or well of Basement whose surface expression terminates at around the western edge of the Plateau (Turner, 1978). The two Basins are linked towards the western part of the country although; a surface rise (i.e., the Zambuk ridge) persists and is reflected in a thinning of the Cretaceous succession (Carter *et al.*, 1963).

The Biu Plateau Basalt mainly overlies the Basement Complex Rocks and is predominantly Granites and Granite gneiss (Hyndman, 1985). The general level of the sub-Basalt surface is at an altitude of about 460 m, but rises 600 m in the Southwest. The buried land surface consisted of gently undulating plains on both Basement and Cretaceous rocks which must have been particularly featureless in the Northeast (Turner, 1978).

Grant *et al.* (1972) gave K-Ar ages for five Basalts from the Biu Plateau area which indicates an Older Pliocene group (5.0 to 2.9 my) and a Younger group of Quaternary age (less than 1.4 my).

Turner (1978) briefly discussed these age with reference to laterite that occurs above and below the Pliocene Basalt. The Ultra-mafic nodules from the Miringa area were described by Du Preeze, (1949) who recorded the occurrence of nodules containing garnet as well as the more usual olivine and pyroxene. However based on the work of Turner (1978) two types of Basalts are identified in the Biu Plateau these are the Biu type and the Miringa type of Basalts.

The Biu type of basalt consists of intensive flows of Basalts which are dense, fine grained and dark in colour. Some of them contain vesicles which are partially or completely filled with secondary minerals probably calcite or zeolite. The most peculiar thing about the Biu Type of Basalt is the degree to which the olivine has been altered. Some Olivine crystals are completely altered while some are partially altered along their margins and cracks. The rate of alteration of the Biu Basalt suggests that they are older than the Miringa Type which is Pliocene in age (Turner, 1978).

The Miringa type of basalt occurs mainly as the volcanoes around Miringa zone or region and consists of volcanic bombs, rhyolite, agglomerates and slightly vesicular Basalt lava-flow etc. This however, suggests a more explosive eruption compared to the Biu Type. The Miringa Type is peculiar in the freshness of olivine phenocryst and grains which have undergone little or no alteration. The Miringa Type of Basalt represents the

Quaternary flows (Turner, 1978). Recent related works include Akinmosin and Osinowo (2008) and Obiefuna and Orazulike (2011) who carried out geochemical and mineralogical assessment of Ishara and Bima Sandstone deposits respectively.

The stratigraphy of the rocks of the study area is made up of three types of Basaltic rocks represented chronologically as Massive Basalts which appear to be the oldest followed by slightly vesicular Basalts and the vesicular Basalts which are the youngest.

The age variations between these Basalts are due to time of their eruption, nature of their eruption and also the manner in which they solidified. When magma erupts from fissure or vent, they tend to solidify and then the fissure would form the massive Basalts. While if magma erupts forcefully and is highly viscous, the solidification of its surface tends to entrap the gases in form of vesicles and after which they solidified to form vesicular Basalt commonly known as scoria or pumice.

The concentration and manner of alignment of the volcanoes relates to its structural control. The occurrence of the line of volcanoes from Yamarkumi Hill, Sabon gari Hill, Implasar Hill, Jogul Hill and Tabura Hill suggests the existence of a major linear fracture in the Basement.

Keer (1977) suggested that the fracture probably developed during powerful up-thrust of the Basaltic magma. Turner (1978) however, argued that, more fundamental tectonic control cannot be suggested in the earth movement forming the Chad Basin during Pleistocene but added that the Plateau was constructed in three stages; the earliest eruption probably of fissure type or Hawaiian to Strombolian with fluid lava spreading thickly over wide extended areas. The second stage is where the phreato-magmatic processes intercepted the emission of lava so that their relatively large tephraing volcanoes formed with their lava pile or build up on the southern part of Biu Plateau area. This stage was followed by a distinct break in activities at the end of Pliocene where substantial weathering with laterization as well as erosion took place. The third phase resumed activities in the Pleistocene from the upper most flow continued to the NNE trend around Miringa zone of the Biu Plateau.

The present investigation was carried out in Biu area of northeastern Nigeria which is underlain entirely by the Tertiary Biu Basalt Deposit. This study intends to classify the basalt deposit as exposed in this area on the basis of its chemical and mineralogical composition. The geochemical studies include analysis of the oxide element while petrographic study includes field observation of the collected sample as well as its mineralogical composition under cross and plane polarized light. From these the Biu Basalt will be classified in relation to its mode of origin and occurrence.

Table 1: Joint measurement in the study area

| Joint strike | DIP (°) |
|--------------|---------|
| 083 | 45 NW |
| 118 | 32 NW |
| 074 | 12 SW |
| 138 | 22 SE |
| 243 | 88 SE |
| 148 | 78 NE |
| 203 | 14 NE |
| 074 | 17 SE |
| 050 | 74 SW |
| 090 | 054 SE |
| 189 | 09 SW |
| 194 | 29 NW |
| 144 | 39 SE |
| 157 | 82 SW |
| 026 | 53 NW |
| 017 | 68 NW |
| 275 | 78 SW |
| 243 | 34 SE |

STUDY AREA

The study area is situated on the Biu Plateau and it is located around the Biu Dam Area. The study area lies within latitude 10° 33'N and 10° 38'N and longitudes 12° 00'E and 12° 06'E. It has an area extent of about 110 km². Biu shares a common boundary with Gombe State and is traversed by numerous foot paths linking the villages to the towns.

The study area has a high relief which is generally regarded as a single unit. The study area is drained by network of streams such as streams from Biu-Damaturu which subsequently flows North-east to the Upper Hawul River and flow west into River Gongola. In the study area, the drainage pattern is dendritic which is characterized by irregular branching of tributary streams.

The study area has two distinct types of climatic seasons namely the dry and wet seasons. The dry season commence from November and end in April. This period records no significant of rainfall or none at all. The wet or raining season starts from April and end in October with June-September period recording greater amount of rainfall. At least 10 to 25 mm of rainfall is experienced in March whereas May and June record 100 to 150 mm of rainfall.

The land is generally covered by scattered shrubs and some few trees. The vegetation of this area is of savannah type and generally devoid of thick forest. The shrubs are few on the volcanoes and increases away from the cones.

MATERIALS AND METHODS

The first stage involves the use of topographic map in the identification and demarcation of the study area.

The second stage involves a reconnaissance survey and subsequently a detailed geological mapping was carried out using geological tools such as: topographic map, Compass-Clinometer, Global Positioning System (GPS), Sample bag, Camera.

The third stage is the data acquisition which involves the laboratory analysis of the collected

samples from the field. The samples were subjected to a number of laboratory tests such as Petrographic analysis (thin section) and geochemical analysis (XRF).

Field work which involved examination of the basalts in the field and collection of rock samples from different Basaltic outcrops in the study area was carried. During the field work, fresh samples were obtained from the rock outcrops using geologic hammer. The samples are properly labeled indicating different stations. Structures of different outcrops were noted and measured when necessary such as strike and dip of fractures. Photographs were taken from different sides of the existing outcrops to note the structures encountered. Observations and measurements were recorded in the field notebook.

The data obtained from the field were plotted on a Rose diagram to determine the dominant direction of the rock fractures (Table 1). Ten samples were collected randomly from the field, their mineral content, colour, texture and other physical properties were determined under both cross-polarized light and plane polarized light.

Thin section or slides of rocks for this petrographic study of the rock sample are obtained by cutting of a thin slide from a specimen using diamond saw. One side of the sample was polished to a perfectly smooth flat surface using super glue as an adhesive and heated on an electric oven or heating plate to harden it. It was then mounted on the rock cutting machine where the specimens were further reduced in thickness by a rotary grinding blade. Then the specimen is made very thin and almost transparent and removed from the machine and finished to the correct thickness (0.03 mm) using carbonundum powder. The surface of the specimen was then be coarse with a thin glass using Canada balsam and heated to become hard.

Microscopic examination was carried out to determine the different minerals contained in the Basaltic rocks in the study area. It was carried out in the Department of Geology of the Modibbo Adama University of Technology (MAUTECH) Yola Nigeria. The instrument used is the polarizing microscope with magnification of ×10.

X-Ray Fluorescence (XRF) analysis was carried out on ten selected samples for their major oxide composition in the chemical laboratory of the Ashaka Cement PLC Ashaka Gombe State Nigeria.

The material and equipment used include; base map: For compiling geologic information observed in the field. Mapping board: To support the map while working. Compass Clinometer: For measuring Dip and Strike direction. Geologic hammer: For breaking of sample. Field notebook: For recording observations. Tape: For measuring length and width of structure. Camera: For snapping identified feature in the field. Sample bag: For sample collection. Hand lens: for magnification and Global Positioning System (GPS): For locating the study area on the map.

RESULTS AND DISCUSSION

Three types of Basalts are found namely; Massive basalt, Slightly Vesicular basalt and Vesicular basalt. The massive basalts are dark coloured, fine grained in texture with whitish feldspartic minerals. It also contains Phenocrysts of olivine and secondary minerals such as calcite. The slightly vesicular basalt has smaller number of vesicles and their cavities are smaller in size and scattered. They are light to dark gray in colour.

The vesicular basalt has cavities which vary considerably in shapes and sizes. They are spherical, ellipsoidal, cylindrical and irregular in shape. The basalts are lateritized mainly reddish brown in colour except in some cases where they have been weathered to clay. The clays are light to dark gray in colour and are believed to have been formed as a result of the weathering of the Basalt.

The massive basalts are Phaneritic and very fine-medium grained in texture. They are called Phaneritic because their textures are visible to the naked eye or with hand lens. This texture is as a result of rapid cooling suggesting there is not enough time for the minerals to grow into large crystals. They are very hard to break with the hammer during sample collection.

About, 23% of the study area is covered by massive basalt. They are mostly found emplaced and occasionally occur as fragments around the volcanic Cones with olivine appearing as Cones. They appear commonly as large Phenocryst which are completely or partially altered to brownish yellow colour. The Calcite occurs as secondary mineral in some of the massive basalt.

The slightly vesicular basalts are mostly fine grained in texture and dark gray to light gray in colour. Although some portions of the samples appear to be reddish brown in colour which indicates that the rocks have under- gone weathering with irregular spherical, reticular or ellipsoidal shape of acutities that are smaller in size than those of the vesicular basalt. The acutities as observed in the samples collected were confirmed to be Calcite. They covered about 30% of the study area.

They are mostly dark gray in colour with larger vesicles than the slightly vesicular basalts. The cavities are sometimes interconnected and occur as fragments in almost all parts of the study area. In some cases they display reddish brown colour which are believed to be affected by weathering. The vesicular basalt constitutes about 47% of the study area. The vesicular basalts display an amygdaloidal structure as a result of filling in of their cavities by secondary minerals such as calcite. Vesicular basalts exhibit small rounded voids called vesicules formed during the cooling of molten magma and freezing around pockets of gases and looks like a rock hard sponge.

The lateritic soil formed from the weathering of the basalt are brownish to reddish brown in colour except



Plate 1: Showing laterite

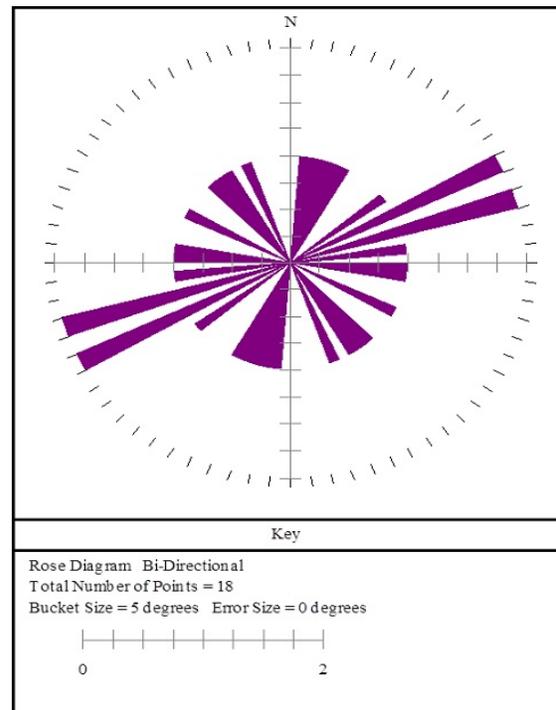


Fig. 2: Rose diagram showing orientation of fractures in the study area



Plate 2: Massive basalt (L1)

in some cases where they are found to occur as light gray to dark gray clay (Plate 1).

Joints are the fractures along which the internal adjustment within the rock bodies takes place (Fig. 2). They cracks or fractures present in the body of a rock along which there has been no relative movement (Garg, 2009). The joints may be formed due to variety of processes (in response to regional deformation connected with stresses of tectonic origin). Photographs of the structural form of these massive, slightly vesicular and vesicular basalts are indicated in Plate 2 to 8.



Plate 3: Massive basalt (L3)



Plate 4: Slightly vesicular basalt (L7)



Plate 5: Slightly vesicular basalt (L8)



Plate 6: Vesicular basalt (L4)

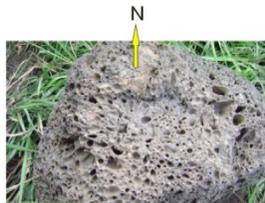


Plate 7: Vesicular basalt (L5)



Plate 8: Showing joint

Thin section of massive basalt, slightly vesicular basalt and vesicular basalt were observed under the microscope both under plane polarized light and under cross polarized light looking at some physical properties like colour, cleavage, form and relief (Plate 9a, b to 14a, b).

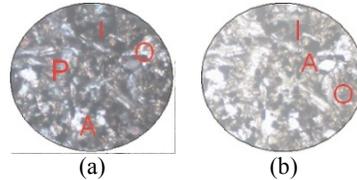


Plate 9: Massive basalt (L1)

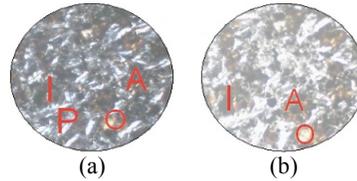


Plate 10: Massive basalt (L2); P = Plagioclase lath; I = Iron oxide; O = Olivine; Plate a = under cross polarized light; A = Augite; plate b = under plane polarized light

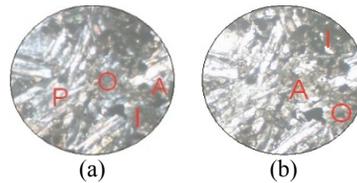


Plate 11: Slightly vesicular basalt (L7)

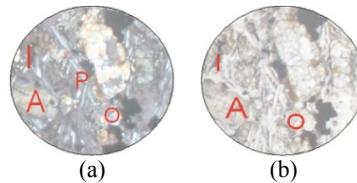


Plate 12: Slightly vesicular basalt (L8); P = Plagioclase lath; I = Iron oxide; O = Olivine; Plate a = under cross polarized light; A = Augite; plate b = under plane polarized light

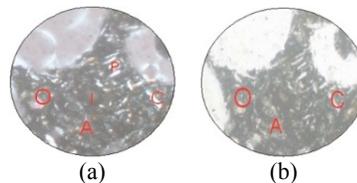


Plate 13: Vesicular basalt (L4)

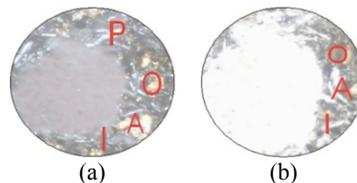


Plate 14: Vesicular basalt (L4); P = Plagioclase lath; I = Iron oxide; O = Olivine; Plate a = under cross polarized light; A = Augite; plate b = under plane polarized light; C = Calcite

The laboratory analysis shows that basalt collected in the study area shows little variations in mineral compositions. The study indicates that the samples display similarity in texture and mineralogy whereas mineral like olivine indicate partial to complete alteration.

Microscopic examination reveal that the samples collected at locations 1, 2, 3 and 10 are fine grained massive basalt with phenocrysts of olivine set in a ground mass consist of augite, olivine, plagioclase and iron oxide (Table 2).

Plagioclase is colourless under plane light and non pleochroism and cleavage in two directions with lath-like structure and very low relief with weak birefringence. Interference colour is gray to white of first order and extinction is oblique and exhibit albite twinning.

Augite is light under plane polarized light and non pleochroic with perfect cleavage in two directions. It shows prismatic structure with very high relief and

strong bireferengence. Interference colour is greenish to dark green under cross polarized light and display symmetrical extinction which polysynthetic twinning.

Olivine is colourless under plane polarized light non-Pleochroic with cleavage. It is anhedral to subhedral and has low to moderate relief; bireferengence is also moderate with upper order interference colour. It has parallel Extinction with no twinning.

Iron oxide is opaque, non Pleochroic with no cleavage. It is anhedral with high relief and no bireferengence. Interference colour is opaque with extinction and non twinning.

Petrographic analysis shows that the samples collected at locations 4, 5 and 6 are fine grained slightly vesicular basalt. The basalt attains Phenocrysts of olivine in a ground-mass of plagioclase lath (andesite), augite, olivine and iron oxide with Olivine altered to brownish red colour.

Table 2: A visual estimate of mineralogical composition of basaltic rocks in the study area

| S/No | Location | Sample No. | Minerals under plane polars | Minerals under cross polars | Mineral (%) |
|------|----------|------------|-----------------------------|-----------------------------|-------------|
| 1 | Legos | L1 | Olivine | Plagioclase | 23 |
| | | | Augite | Olivine | 29 |
| | | | Iron Oxide | Augite | 34 |
| 2 | Fuma | L2 | Olivine | Iron oxide | 14 |
| | | | Augite | Plagioclase | 25 |
| | | | Iron Oxide | Olivine | 28 |
| | | | | Augite | 32 |
| 3 | Melala | L3 | Olivine | Iron oxide | 15 |
| | | | Augite | Plagioclase | 24 |
| | | | Iron Oxide | Olivine | 26 |
| | | | | Augite | 35 |
| 4 | Gumya | L4 | Olivine | Iron oxide | 15 |
| | | | Augite | Plagioclase | 27 |
| | | | Iron Oxide | Olivine | 35 |
| | | | Calcite | Augite | 22 |
| | | | | Iron oxide | 15 |
| 5 | Vio | L5 | Olivine | Calcite | 01 |
| | | | Augite | Plagioclase | 28 |
| | | | Iron Oxide | Olivine | 32 |
| | | | Calcite | Augite | 20 |
| | | | | Iron oxide | 18 |
| 6 | Burakum | L6 | Olivine | Calcite | 02 |
| | | | Augite | Plagioclase | 29 |
| | | | Iron Oxide | Olivine | 30 |
| | | | Calcite | Augite | 22 |
| | | | | Iron oxide | 17 |
| 7 | Vina | L7 | Olivine | Calcite | 02 |
| | | | Augite | Plagioclase | 22 |
| | | | Iron Oxide | Olivine | 31 |
| | | | | Augite | 34 |
| 8 | Dam | L8 | Olivine | Iron oxide | 13 |
| | | | Augite | Plagioclase | 20 |
| | | | Iron Oxide | Olivine | 32 |
| | | | | Augite | 35 |
| 9 | Sama | L9 | Olivine | Iron oxide | 13 |
| | | | Augite | Plagioclase | 23 |
| | | | Iron Oxide | Olivine | 29 |
| | | | | Augite | 32 |
| 10 | Kwadiga | L10 | Olivine | Iron oxide | 16 |
| | | | Augite | Plagioclase | 23 |
| | | | Iron Oxide | Olivine | 29 |
| | | | | Augite | 34 |
| | | | | Iron oxide | 14 |

Table 3: Major chemical composition of basalt (%) in the study area

| S/No | Location | Sample | | | | | | | | | | | | |
|------|----------|--------|------------------|--------------------------------|--------------------------------|-------|-------|-----------------|------------------|-------------------|-------------------------------|--------------------------------|------------------|-------|
| | | No. | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | CaO | MgO | SO ₃ | K ₂ O | Na ₂ O | P ₂ O ₅ | Mn ₂ O ₅ | TiO ₂ | L.O.I |
| 1 | Legos | L1 | 36.30 | 10.98 | 13.31 | 14.50 | 8.45 | 0.44 | 1.08 | 0.78 | 0.65 | 0.24 | 2.50 | 20.68 |
| 2 | Fuma | L2 | 36.86 | 10.89 | 12.92 | 13.99 | 9.12 | 0.37 | 1.08 | 0.60 | 0.50 | 0.22 | 2.42 | 21.01 |
| 3 | Melala | L3 | 37.34 | 11.34 | 12.23 | 14.10 | 9.18 | 0.51 | 1.12 | 0.96 | 0.48 | 0.24 | 1.88 | 21.17 |
| 4 | Gumya | L4 | 37.74 | 10.67 | 12.28 | 13.66 | 11.76 | 0.28 | 0.87 | 0.74 | 0.47 | 0.22 | 1.86 | 23.65 |
| 5 | Vio | L5 | 39.58 | 11.67 | 12.18 | 13.38 | 8.10 | 0.30 | 1.06 | 0.73 | 0.42 | 0.21 | 2.25 | 19.42 |
| 6 | Burakum | L6 | 38.11 | 11.37 | 11.67 | 14.48 | 8.43 | 0.28 | 0.93 | 0.78 | 0.51 | 0.21 | 1.93 | 20.64 |
| 7 | Vina | L7 | 36.51 | 11.22 | 13.46 | 13.91 | 9.23 | 0.32 | 1.22 | 0.90 | 0.52 | 0.25 | 2.21 | 21.06 |
| 8 | Dam | L8 | 38.09 | 11.60 | 11.87 | 13.83 | 7.93 | 0.38 | 1.34 | 1.07 | 0.61 | 0.22 | 2.01 | 19.58 |
| 9 | Sama | L9 | 37.22 | 11.42 | 12.78 | 13.82 | 8.84 | 0.31 | 1.27 | 0.98 | 0.56 | 0.24 | 2.14 | 20.57 |
| 10 | Kwadiga | L10 | 37.08 | 11.51 | 13.04 | 13.61 | 8.52 | 0.41 | 1.28 | 1.02 | 0.65 | 0.24 | 2.31 | 20.05 |

Table 4: Some major chemical composition (%) of basaltic rocks in the study area

| Oxide | Sample No. | | | | | | | | | | Range | Average | As |
|--------------------------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------|---------|-------|
| | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | | | |
| SiO ₂ | 36.30 | 36.86 | 37.34 | 37.74 | 39.58 | 38.11 | 36.51 | 38.08 | 37.22 | 37.08 | 36.30-39.58 | 37.94 | 50% |
| Al ₂ O ₃ | 10.98 | 10.89 | 11.34 | 10.65 | 11.66 | 11.37 | 11.22 | 11.60 | 11.42 | 11.51 | 10.65-11.61 | 11.16 | 15% |
| Fe ₂ O ₃ | 13.31 | 12.92 | 12.23 | 12.28 | 12.18 | 11.67 | 13.46 | 11.87 | 12.78 | 13.04 | 11.67-13.46 | 12.57 | 6% |
| CaO | 14.50 | 13.99 | 14.10 | 13.66 | 13.38 | 14.48 | 13.91 | 13.38 | 13.82 | 13.61 | 13.38-14.50 | 13.98 | 8.5% |
| K ₂ O | 1.07 | 1.08 | 1.12 | 0.93 | 1.06 | 0.93 | 1.22 | 1.34 | 1.27 | 1.28 | 0.93-1.34 | 1.14 | 0.55% |

Plagioclase is colourless under plane polarized light, non pleochroic and cleaves in two directions. It exhibit lath- like structure with very low relief and weak birefringence. The interference colour is gray to white of first order with oblique extinction and exhibit Albite twinning.

Augite shows light green to pale green under plane polarized light and non pleochroic with perfect cleavage in two directions. It shows prismatic structure with very high relief and strong birefringence. The interference colour is greenish black under cross polar and shows symmetrical extinction and exhibit polysynthetic twinning.

Olivine is colourless under plane polarized light and non pleochroic with no cleavage. It is anhedral with low to moderate relief and moderate birefringence. It revealed upper second order interference colour with parallel extinction with no twinning. The olivine has been altered under plane polarized light.

Iron oxide is opaque and non pleochroic with no cleavage. It is anhedral to subhedral with high relief and non-birefringence. The interference colour is opaque with extinction and non twinning.

The petrographic analysis show that the samples collected at locations 7, 8 and 9 are fine-grained vesicular basalt with phenocrysts of olivine, iron oxide, plagioclase lath, augite and calcite.

Plagioclase is colourless under plane polarized light and non pleochroic and cleaves in two directions. It is lath-like structure with very low relief and weak birefringence. The interference colour is gray to white of first order with oblique extinction and exhibit albite twinning.

Olivine is colourless under plane polarized light and non pleochroic. It has no cleavage and appear in anhedral with low to moderate relief and moderate

birefringence. The interference colour is of upper order colour with parallel extinction and without twinning.

Augite is light green colour under plane polarized light and non pleochroic with perfect cleavage in two directions. It is prismatic with very high relief and strong birefringence. The interference colour is greenish black or dark green under cross polars. It shows symmetrical extinction and exhibit polysynthetic twinning.

Iron oxide is black (opaque) non pleochroic with no cleavage and anhedral form. It has high relief and birefringence is absent with opaque interference colour and no extinction and non twinning.

Calcite is colourless under plane polarized light non pleochroic with perfect cleavage in two directions. It is anhedral with low to moderate relief and weak birefringence. It indicate pearl green colour interference colour with symmetrical extinction and exhibit polysynthetic twinning.

Table 3 and 4 clearly show that the SiO₂ content ranges from 36.30 to 39.50% with an average of 37.94%. The average value is less than the standard value 50%. Al₂O₃ content of the Basaltic rock of the study area varies from 10.65 to 11.61% with an average of 11.16%. This average value is less than the standard value of 15%. Fe₂O₃ content range from 11.67 to 13.46% with an average value of 12.57% which is greater than the standard value of 6%. CaO content varies from 13.38.46 to 14.50% with an average value 13.98% which is above the standard value of 8.5%.

Finally, K₂O content range from 0.93 to 1.38% with an average of 1.14% which is slightly greater than the standard value of 0.55%.

The basaltic rocks of the study area are relatively rich in silica or saturated and generally poor in total alkali. They are thus tholeiitic basalts that may have commonly erupted only at ocean ridges.

Mineralization processes associated with basaltic rocks in the study area may be divided into the following:

- Primary mineralization
- Secondary mineralization
- Mineralization related to weathering process

Primary mineralization: Baba (2008) has reported the occurrence of gem minerals on the Biu Plateau. Preliminary investigation revealed that gem minerals are being exploited around Gunda where the minerals are mined from a contact zone between the basalt and granitoids of the Basement Complex Rocks. Gem minerals identified include corundum (Sapphire), aquamarine (beryl), amethyst, tourmaline, garnet and fluorite.

Secondary mineralization: This group consists of mineralization that formed after emplacement of the host rocks such as late large fluid interaction or contact metamorphic effect process, mineralization associated with diagenetic process; mineral deposits of this group include zeolites and clay minerals.

Mineralization related to weathering processes: These include those formed by lateritization which include bauxite and clay minerals such as bentonite and hormites formed by weathering of basalt and related pyroclastic rock.

The rocks in the study area have been found to be of great economic importance to the area. The basalt is being quarried for construction purposes. Transparent olivine of good colour is an attractive feature of geologic importance. The lateritic soil produced as a result of the weathering process in the area is being used in building of houses especially by the villagers and is also used as road fills. The clays are used for pottery. The pumice and scoria are used by women and children to clean their feet.

The result of chemical analysis of the basaltic rocks revealed all from the chemical analysis of the basalt, it is found to have relatively high content of element such as Al-Al₂O₃, Si-SiO₂, K-K₂O, Ca-CaO and Fe-Fe₂O₃ which are essential ingredients for plant growth. These has given rise to high productivity of crops such as rice, groundnuts, garden egg, pepper, maize as observed in the study area.

CONCLUSION

The basaltic rocks of the study area are tholeiitic basalt and they show little geochemical and petrographic variations which is related to their mode of occurrence and origin. They are fine- medium grained in texture and are composed of olivine, augite, plagioclase lath, iron oxide and calcite.

In conclusion, the petrographic study has shown that phenocrysts of olivine and plagioclase have been found to be embedded in a groundmass of olivine, augite, plagioclase lath, iron oxide and calcite. The olivine crystals have mostly been found to be undergoing alterations. These minerals however vary from one rock unit to another particularly in terms of abundance.

We recommend that trace elemental and isotopic study of the basaltic rocks of the study area should be carried to confirm the results of the present investigation.

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