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Lithological Delineation of Rocks Around Bali Sheet 255 NE and Environs Taraba State, Northeastern Nigeria

Yakubu Ishaku Mainta[1], Araga O. Adamu[2] & Hanly Bingary[3]

[1-2] Department of Civil Engineering, Federal Polytechnic Bali, Taraba State Nigeria
[3] Center for Applied Geosciences, University of Portsmouth, UK
Corresponding author: isaacmainta@gmail.com

Abstract

A study was carried out to evaluate the lithology and delineate rock units in Bali and Environs. Hand specimen and petrographic studies of sampled rocks allowed for the identification of the rock types and describing their geologic history. Four lithological units comprising of gneiss, granites, metasediments and pegmatite were identified and delineated. Petrophysical analysis reveals quartz, feldspars, biotite, and hornblende as the main rock-forming minerals in the granites and ortho-gneisses. Modal composition of the ortho-gneisses shows a range between 30-35% plagioclase feldspar, 18-25% quartz, 5-15% hornblende and 5-25% biotite mica with similar composition for the granites and therefore referred to as biotite-hornblende granites. The lithologies show variable degrees of metamorphism and alterations ranging from foliations, lineation and ferricretization. From the results of this study it was deduced that these rocks belong to the Older Granite Suites of the North-Eastern Basement Complex of Nigeria, having strong imprint of the Pan African Orogeny.

Keywords: Lithology, Basement Complex, Petrography, modal composition, North-Eastern basement Complex Bali, Taraba State

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1. Introduction

Nigeria is covered by crystalline and sedimentary rocks in nearly equal proportions. The Nigerian Basement Complex (NBC) forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Ajibad et al 1988 and Amuda, A. K. 2014). Generally the geology of northeastern region consist of ancient (Precambrian) crystalline Basement complex rocks represented mainly by granitic and migmatitic rocks, on which rest nonconformably sedimentary and volcanic rocks ranging in age from cretaceous to quaternary (carter et al. 1963). The area lies within the Undifferentiated Basement Complex (UBC) of North-eastern Nigeria.

The structural and tectonic framework of the Nigerian Basement Complex has been documented by several researchers (Annor& Freeth, 1985) to consist of northeast – southwesterly and northwest – south easterly lineaments that are superimposed over a prevailing north-southerly pattern (Adelana, S. M. A., Olasehinde, P. I., Bale, R. B., Vrbka, P., Edet, A. E., &Goni, 2008)and northwest southeasterly and northeast – southwesterly pair superimposed on a north - south set of joints (Annor et al., 1990). The structural characterization of most rocks of the UBC is dominated by foliation (NE-SW, N-S), fractures and faults NE-SW), Lineation (NW-SE), joints folds and minor faults (N-W, NNE-SSW) that showed cataclasis (B.W. Tukura., B.S..Jatau., L.T. Oloniniyi., B. Hanly., A.B. Oleka, 2016). These rocks include igneous rocks known as the Older Granites, metamorphic rocks including migmatites, gneiss and quartzites, and associated pegmatite occurrences.

2. Study area

The study area is geo-politically located in Bali Local Government Area (LGA) and part of Gashaka LGA of Taraba State. It lies between Latitudes 7° 45‘ to 8° 00‘N and Longitudes 10° 45‘to 11° 00‘E with a total of 86 km^2(Figure 1). It encompasses Bali town, GidanIshaku in the south, Osuah in the west, SarkinDutse in the North and Gidan Fulani in the northeast. The area geologically falls within the North-eastern basement Complex and part of the Mambilla Highland.(Figure 1). The study area is generally flat with gently undulating landscapes in most of the study area except the north-western part occupied by high hills of the Mambilla and the southeastern part of the map, just south of Bali town where high mountains also occur.

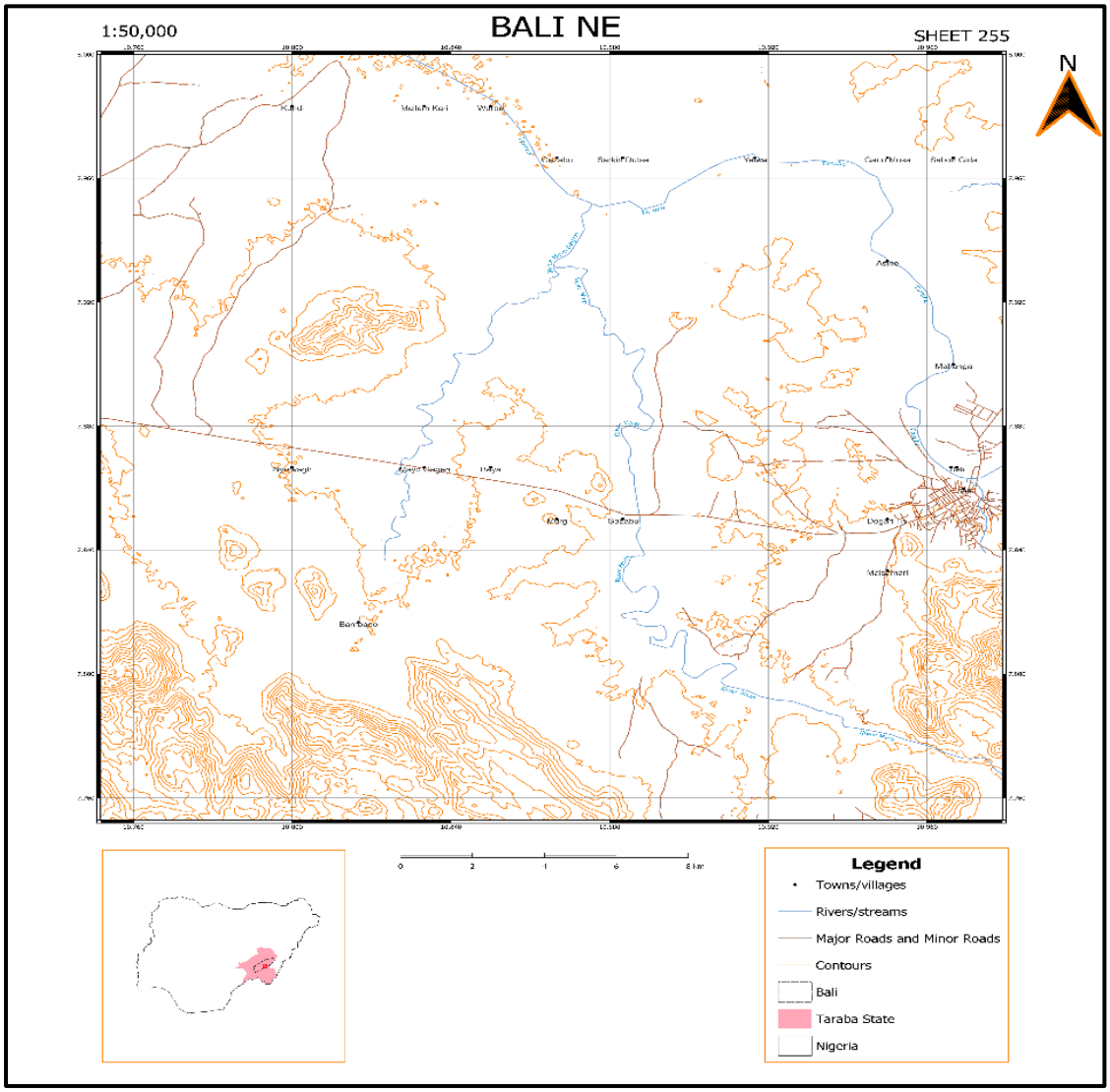

Figure 1. Location map of the study area showing Bali and environs

3. Material and Methods

Detailed field mapping using Compass; Global Positioning System (GPS) traversing method was carried out. Other field equipment used include Field Goggles, Geologic Hammer, clinometers, Hand lens, and Digital camera. The Compass clinometer was used to measure trend and angle of dip of lithological and structural features on outcrops. The geologic hammer was used to obtain rock samples from outcrops and often used as a scale when snapping geological features.

This research was conducted using a range of methods to determine the geological characteristics of rocks in the study area. It includes Remote Sensing, lithological mapping, and laboratory analyses of rocks.

3.1. Remote Sensing

This involved the acquisition of remotely-sensed data from the United States Geological Survey (USGS) platform. LandSat 8 images consisting of 9 spectral bands were downloaded and clipped to represent only the area of interest. The 7-6-2 band combination was used to identify spectral changes due to geology. Generally, this gave only a generic idea on the

properties of rock types, and more work had to be done on ground to determine the true geological properties within the area.

3.2 Lithological mapping

Mapping of rocks in the area was conducted between April and May 2023 before the onset of the rainy season. The traversing technique was adopted using GPS to show the location of outcrops and the different localities. Field observations were made including the identification of the colour of the rock, the strike direction of outcrops, primary and secondary structures associated with the rock unit and observable minerals, which were neatly recorded in a field notebook. Fresh rock samples were also taken using the geologic hammer and labelled with masking tapes. Eighteen (18) rock samples were taken across the study area which were representative of the various rock types. All samples were stored separately in rucksacks and transported to the laboratory for analyses.

3.3 Petrographic analysis

Petrographic analysis of rock samples was conducted at the Thin-section laboratory of the Geology Department, Ahmadu Bello University Zaria. The method involves cutting a thin slice of the rock and mounting it on a transparent glass slide using an epoxy. This is then polished to approximately 30 microns (0.03 mm) thickness and covered with a cover slide.

The prepared slides were then analysed using a petrographic microscope under Plane Polarised Light (PPL) and Cross Polarised Light (XPL). This allowed for the identification of the rock forming minerals which describes the actual rock type based on their modal compositions. Optical characteristics including colour, grain morphology, relative refractive index, cleavage, birefringence, pleochroism and extinction angles were used to identify and differentiate the minerals in each sample.

4. Results and Discussion

4.1 Geology of the study area

The initial geological characterization of the area was done based on hand specimen analysis. Four (4) rock types were identified. They include gneiss, granite, metasandstone and pegmatite. Further petrographic analysis was conducted to determine their mineralogical composition and relative geologic history. Geological map shown in Figure 11.

4.1.1 Gneiss

The gneisses in the area comprise of both ortho-gneiss (igneous origin) and para-gneiss (sedimentary origin). The ortho-gneisses occur as the major lithology distributed almost around the entire study area. Fresh exposures appear as light-coloured (leucocratic) medium-grained to fine-grained texture with thin to medium bands of dark coloured minerals in places. Foliations are observed to occur in the NE/SW directions and some NW/SE trends. In hand specimens, the leucocratic bands comprise of felsic minerals including quartz while the melanocratic bands comprise of biotite and some muscovite flakes (Figure 2). Petrographically, quartz, plagioclase feldspar, hornblende and biotite were observed under thin sections, with some opaque minerals. Modal composition of the ortho-gneisses shows a range between 30-35% plagioclase feldspar, 18-25% quartz, 5-15% hornblende and 5-25% biotite mica. The gneisses also exhibit variable mineral grain which are closely packed which preferred grain orientation. This indicates foliation direction which represents the direction of least stress as observed to be dominantly NE/SW in the field.

The para-gneisses appear mainly as low-lying, highly weathered outcrops. Evidence of schistosity akin to stratification can be observed, indicating its sedimentary origin (Figure 3). While the intense weathering might suggest that this unit is older than the ortho-gneisses, there was no observable evidence in the field to prove this. Consequently, obtaining a fresh sample for petrographic analysis was difficult but quartz and muscovite minerals were clearly identified on hand specimens.

Since literature on the geology of the area is generally lacking, it was difficult to compare these results with previous studies, but the findings are generally consistent in terms of structural orientation and mineralogy of most of the gneisses occurring in the North-Central and North-western basement rocks as document by (Tukura et al., 2016).

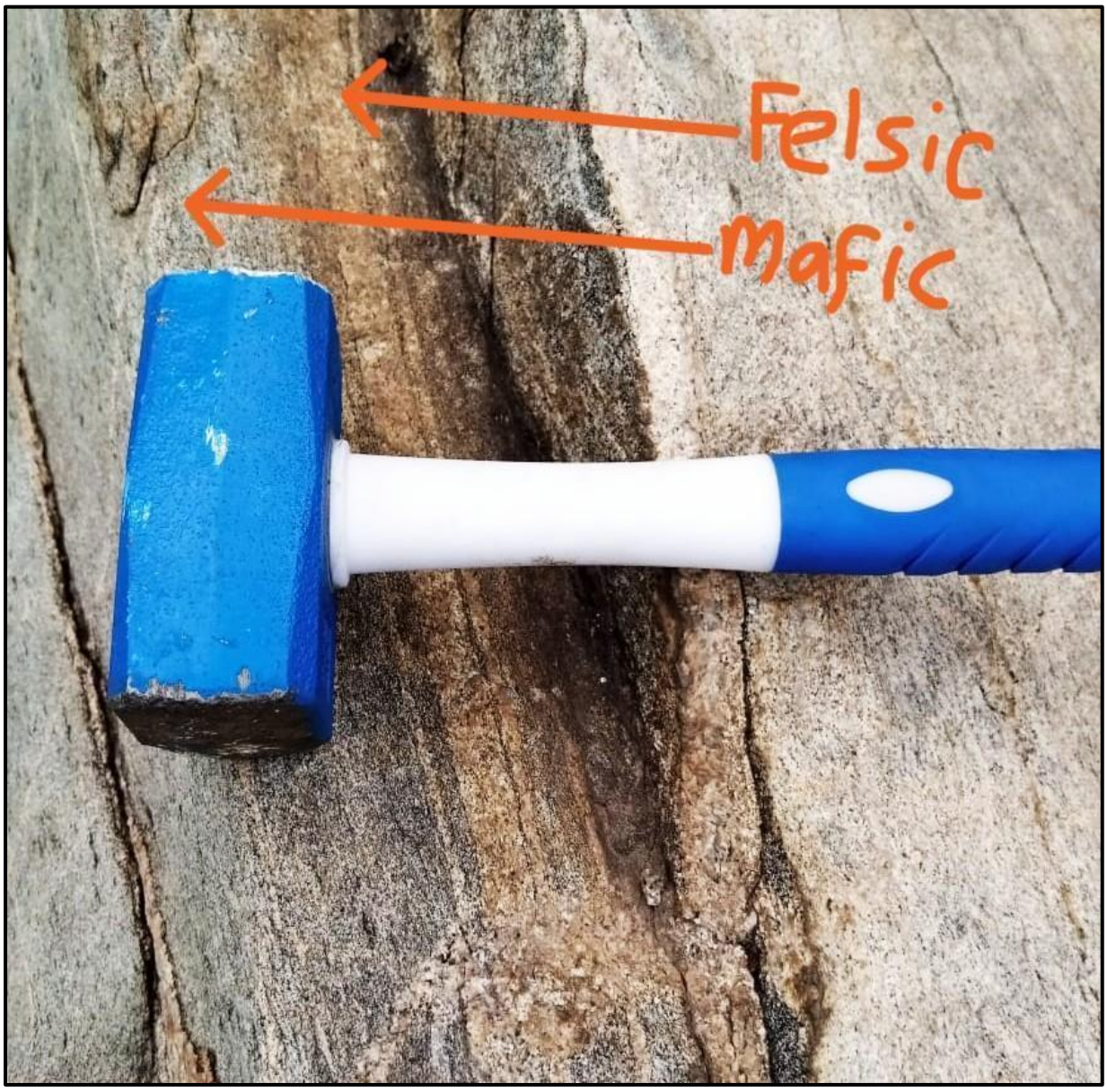

Figure 2. An outcrop of gneiss showing banding of mafic and felsic minerals

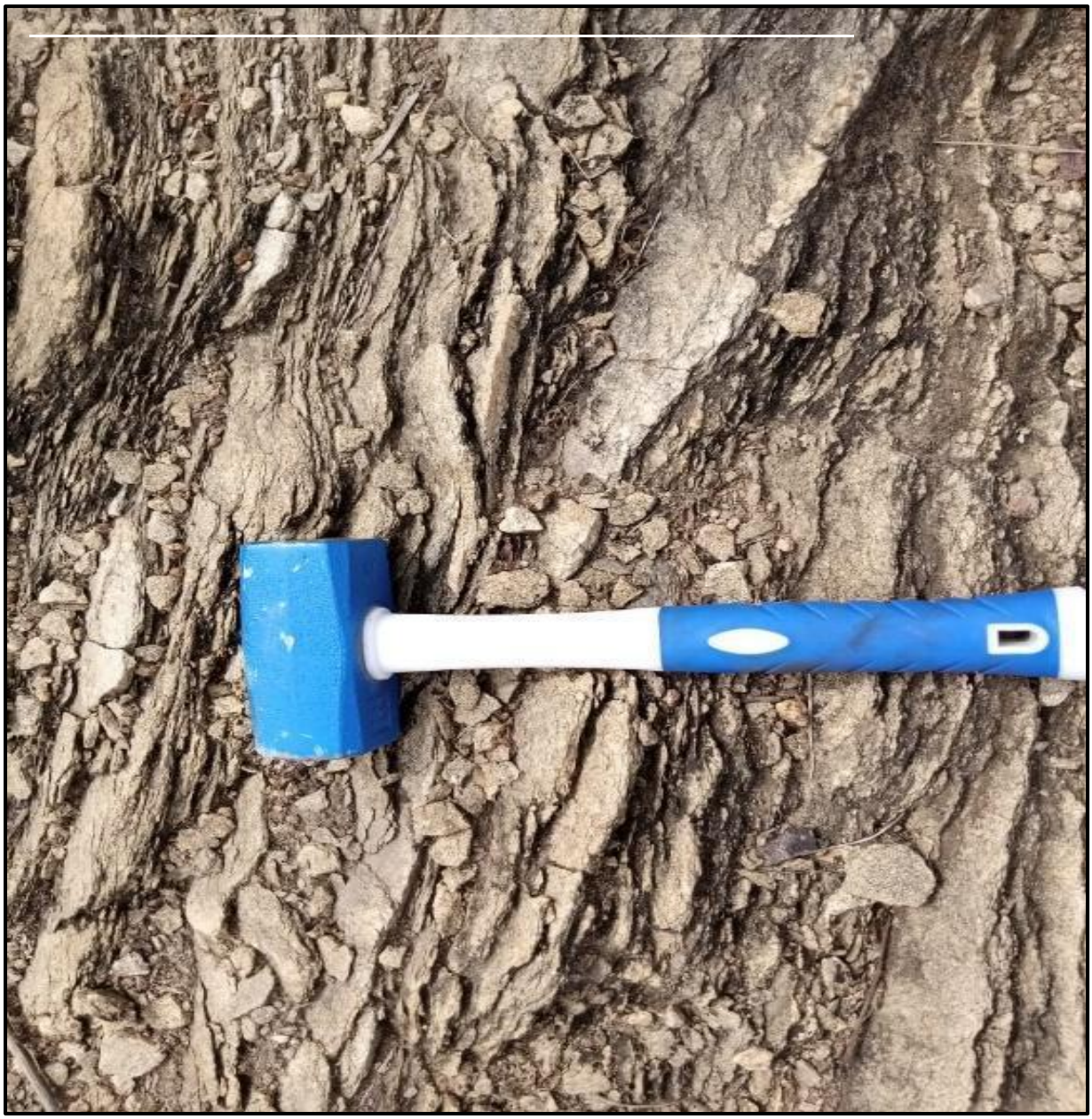

Figure 3. An outcrop of para-gneiss showing layering of precursor rock. Vertical orientation is due to metamorphism

Petrographic analysis of the granitic gneiss reveals the following minerals; quartz, biotite, hornblende, orthoclase, and plagioclase feldspar (Figure 4). Below is the description of the mineral constituents.

Biotite

Biotite exhibit large phenocryst in subhedral crystal form; it displays a strong pleochroism (brown-dark brown) as the stage is rotated. It displays moderate relief with a good cleavage in PPL. It displays foliation and a near parallel extinction an exhibit high birefringence in XPL.

Orthoclase

Orthoclase is colourless to cloudy in PPL and XPL; low relief and anhedral crystal, it has oblique extinction, low birefringence in XPL.The crystals of the mineral are zoned due to deformation. It shows a sign of incipient alteration giving it a sort of roughly scratchy appearance in cross polarized light.

Hornblende

Hornblende is black, dark green, dark brown, dark gray in colour in PPL and XPL and it occurs as prismatic crystals. Hornblende displays two sets of perfect prismatic cleavages at angles of 56° and 124° when view in higher magnification. Hornblende crystal also shows strongly pleochroic yellowish green to dark brown with moderate relief.

Quartz

Quartzmineral crystal is colourless in PPL and XPL; not pleochroic, subhedral in shape. It has no cleavage but minor cracks occur and display undulatory extinction, it has low relief with low birefringence and the crystal surface shows alteration with Fe content.

Plagioclase

Plagioclase is colourless in PPL and dark grey in XPL; displays anhedral crystal form, low birefringence (first order), and parallel extinction in cross polarized light.Plagioclase exhibit good cleavage and moderate relief in plane polarized light (PPL).

The modal composition of the rock-forming minerals is presented in Table 1.

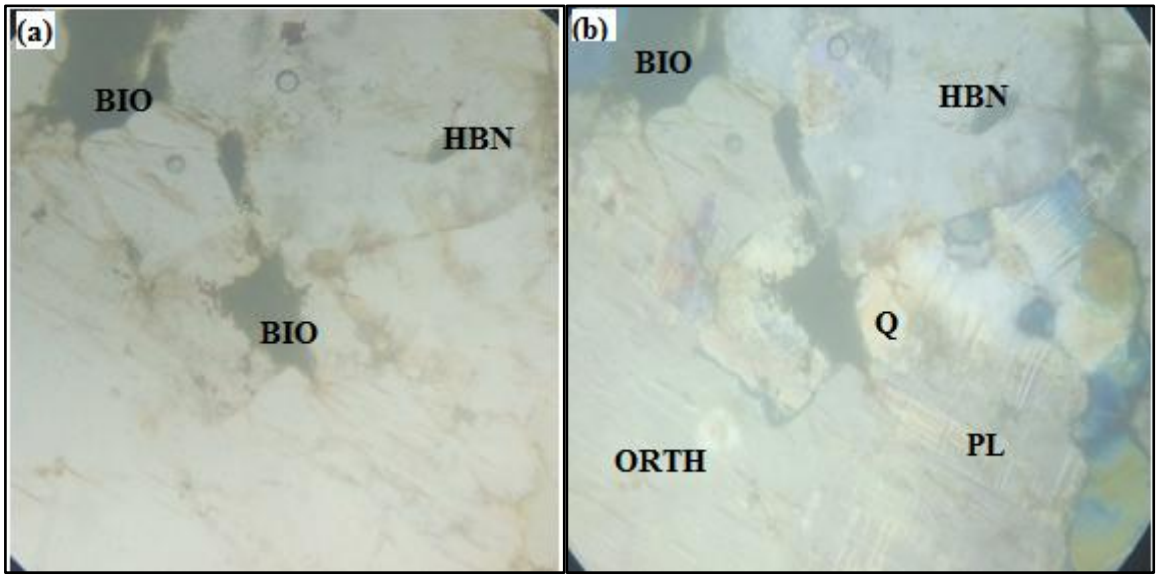

Figure 4. Photomicrograph of granitic gneiss (a) PPL, (b) XPL showing quartz (Q), orthoclase (ORTH), plagioclase (PL), biotite (BIO) and hornblende (HBN) as the main rock forming minerals Mg. x40.

Table 1: Modal composition of minerals in granitic gneiss

Minerals	Composition (%)
Quartz	26
Orthoclase	36
Plagioclase	28
Biotite	15
Hornblende	5
Total	100

4.1.2 Granites

The granites occur as relatively low lying to high hill features in the southern part of the study area and are more prominent around TivMambilla (Figure 5). They are generally leucocratic, medium to coarse-grained with cross-cutting in-filled veins, open veins, aplite and dykes (Figure 6). In some locations around the south-eastern part of the study area, large pegmatite dykes (up to 50 cm) were observed on the granites. Hand specimen observation reveals no preferred mineral alignment in the granites compared to the gneisses in the study area.



Figure 5. An outcrop of granite exposed around TivMambilla showing coarse-grained felsic minerals and some mafic minerals



Figure 6. An outcrop of granite exposed at Gazabu showing few micro fissures and aplite dykes

Petrographically quartz, K-feldspar (microcline), plagioclase, muscovite, biotite and apatite (Figure 7) were identified. The occurrence of these minerals depicts typical granitic mineralogy. Their optical properties are described below;

Quartz
It is colourless in PPL and XPL; forms large phenocryst crystals with undulose extinction. Quartzdisplays large mineral grains averagely about 1.5 cm, anhedral crystal form, and low relief. Quartz crystals display no pleochroism or cleavage, and exhibit a characteristics phenomenon known as undulose extinction in cross polarized light (XPL).

Orthoclase
It appears ash grey colour under XPL and dark ash grey under PPL. It's has anhedral crystal form with some inclusions of biotite grains. Orthoclasedisplays small to medium mineral grains, anhedral crystal form, and low relief. Orthoclase crystals display good cleavage with irregular extinction

Biotite
It is black PPL and dark-brown XPL. It has straight boundaries. Biotite exhibits a high birefringence in cross polarized light, it is light to light brown in colour (weak birefringence), and exhibit a characteristics phenomenon known parallel extinction in plane and cross polarized light. Biotite mineral crystals are aligning in preferential orientation which can also be called foliation with band of felsic and mafic minerals.

Plagioclase

The plagioclase is undergoing alteration into clay (sericite) which is the type of clay responsible for the presence of brown colour observed, it occurs as anhedral crystals, low relief, poorly developed cleavage in plane polarized light (PPL). In cross polarized light (xpl) it is gray, displays albite twinning and low birefringence.

Apatite

Apatite is the only accessory mineral identified. Apatite mineral is needle-like shape in PPL and XPL and apatite is the only accessory mineral observed.

The percentage of K-feldspar ranges from 25-45% compared to plagioclase (10-15%). Modal composition of quartz in different samples range from 15-27% while the mica (biotite and mica) are within the 10-15% ranges. This is summarized in Table 2.

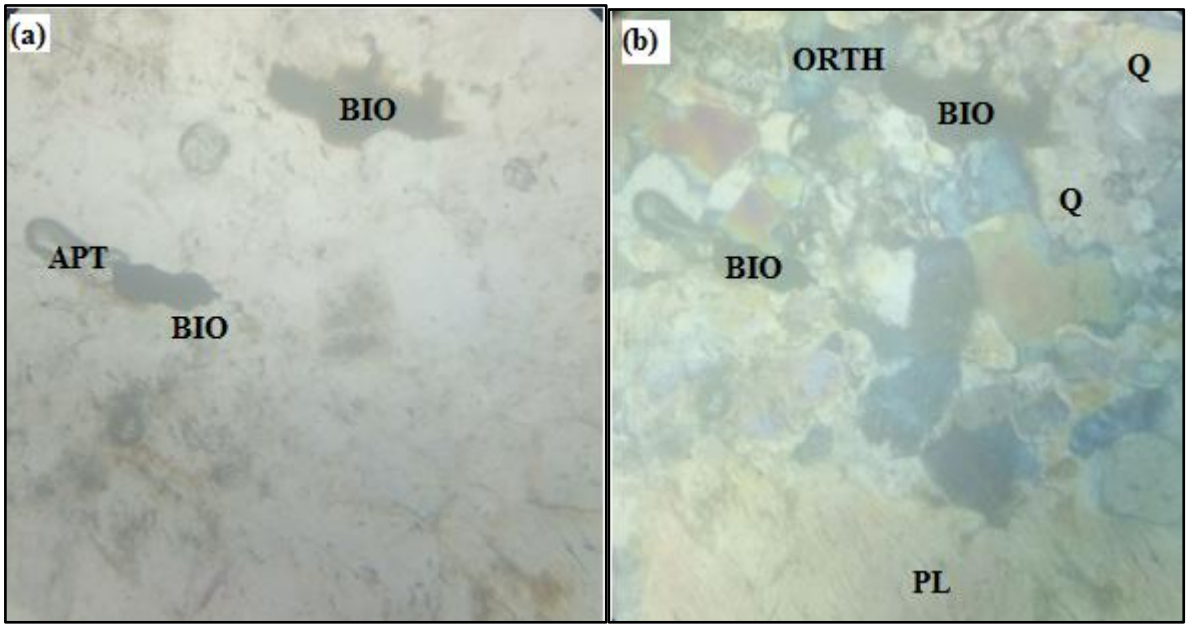

Figure 7. Photomicrograph of coarse-grained granite, (a)PPL, (b)XPL showing Q= quartz, BIO= Biotite, APT= Apatite, PL= Plagioclase and ORT= Orthoclase feldspar. Mg. =X40

Table 2: Visual estimate of minerals in coarse grained granite

Minerals	Composition (%) by visual estimation
Quartz	38
Orthoclase	32
Plagioclase	15
Biotite	11
Apatite	4
Total	100

4.1.3 Metasandstones

This unit is poorly exposed in the study area. They appear along large fractures and at low-lying hill tops where they show intense ferritization. The outcrops along large fractures appear to be low-grade psammites due to conspicuous quartz crystal forms which cannot be fully classed as quartzites (Figure 8). They are therefore referred here as quartz ridges. They

extend northward from a deep fracture around TivMambilla in the southern part of the study area and further exposed around Bambado with some sinistral displacement within the gneisses in the area. Although further investigations need to be conducted on the Mambilla-Bambado Quartz Ridge to determine its petrogenesis, the occurrence of other metasediments such as paragneisses makes it plausible to classify it as a geologic unit here.



Figure 8. Outcrop of quartzite exposed about 1km NNW of TivMambillashowing crystals of quarts and intense fractures

4.1.4 Pegmatite

The pegmatites in the study area form an important unit due to their occurrences within both the granites and gneisses. They are exposed as low-lying features or large dykes (up to 200 cm) (Figure 9) within the oldergneiss in the area or as medium-sized dykes (up to 70 cm) (Figure 10) within the granites. In hand specimen, they are generally leucocratic with conspicuously large mineral grains of orthoclase feldspar (slightly pinkish) and quartz. The occurrence of very large grains is commonly associated with late-stage magmatic activity is typically associated with the Older Granite Suites of the Nigerian Basement Complex as reported around wamba in North-Central Nigeria (Jatau et al., 2016) and parts of the Northwestern basement units.



Figure 9. An outcrop of low-lyinglargepegmatite associated with the gneisses in the study area.



Figure 10. An exposure of large pegmatite dyke occuring within granite. The width of the pegmatite is approximately 65 cm.

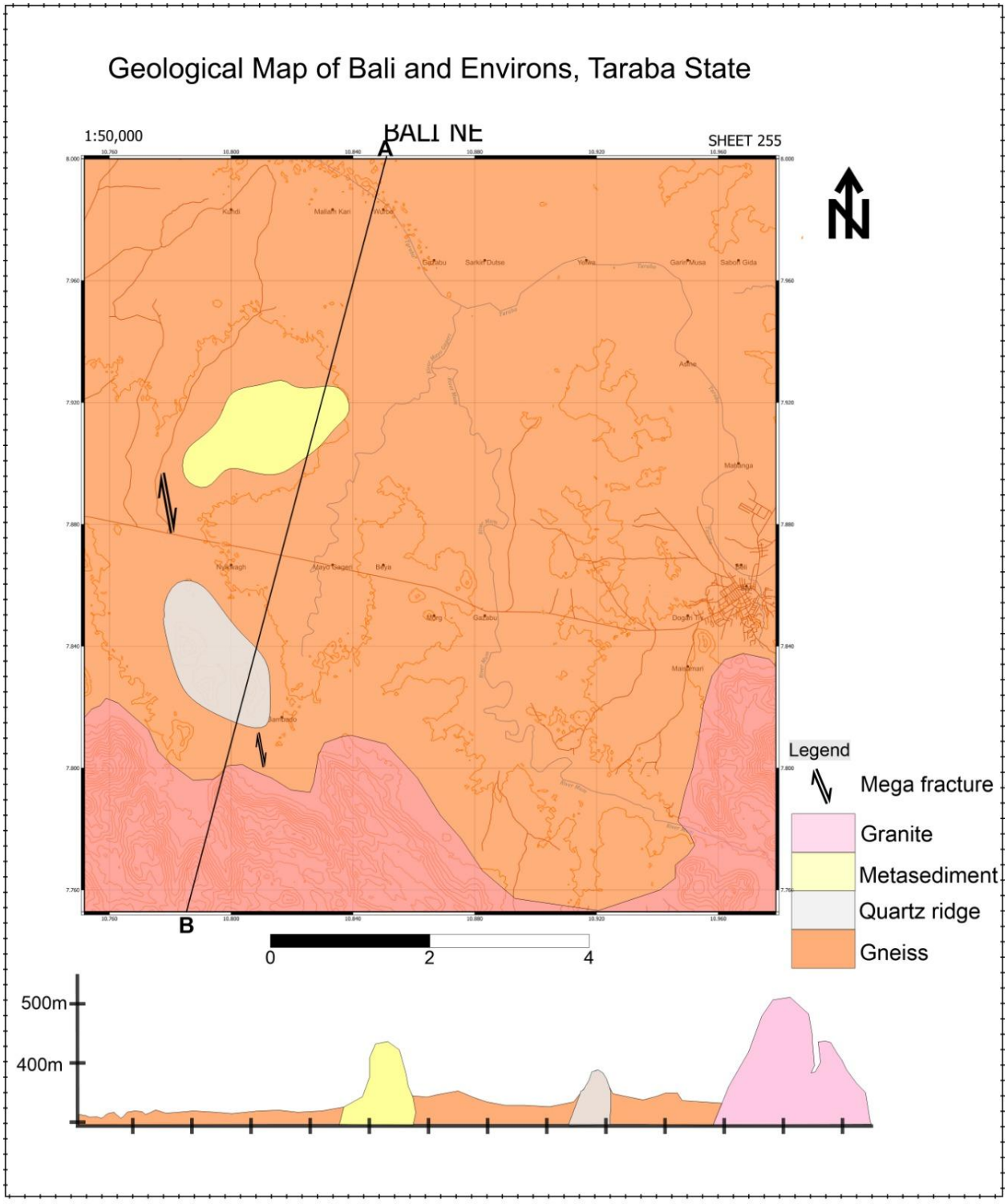

Figure 11. Geological map showing the different lithological units in the study area, cross-section A-B and the orientation of mega structures

5. Conclusion

Mapping and analyses of rocks in Bali and environs were undertaken to delineate the rock units and determine their geologic history. The four rock types identified in the area, which include gneiss, granite, metasediments and pegmatites are typical of the Older Granite Suites found in other parts of the Nigerian Basement Complex. The ortho- and para-gneisses, together with metasediments are the oldest units in the area, followed by the granites. There appeared to be older pegmatites associated with the gneiss and younger pegmatites occurring within the granites as dykes. The orientation of structures are dominantly NE/SW and N-S which show imprint of Pan-African Orogeny. Although further studies are required to fully determine the absolute ages of the rocks, evidence from this study reveals typical Cambrian rocks associated with magmatic activity.

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