



GEOLOGY AND PETROGRAPHY OF ROCKS AROUND BUTAWA, KAFIN MAGAJI AND ENVIRONS, PART OF SHEET 79NE NORTHWESTERN NIGERIA

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ABSTRACT

The geology and petrography of rocks of the Nigerian Basement Complex around Butawa–Kafin Magaji, Northwestern Nigeria, were investigated using geological mapping at a scale of 1:25,000, GIS-based digitization, and petrographic analysis, to map the lithological units and their structures and study their mineralogical compositions. The geologic mapping of the study area identified two rock units; granite gneiss covering about ($\approx 70\%$) and coarse-grained granite occupied about ($\approx 25\%$), with minor pegmatites and quartz veins occupied about ($\approx 5\%$). Petrographic study revealed that, the granite gneiss exhibits a well-defined foliated texture and is composed of quartz ($\approx 30\%$), plagioclase ($\approx 35\%$), microcline ($\approx 7\%$), and biotite ($\approx 10\%$), reflecting medium grade metamorphism associated with the Pan-African orogeny. The coarse-grained granite contains orthoclase ($\approx 15\%$), quartz ($\approx 25\%$), plagioclase ($\approx 35\%$), biotite ($\approx 7\%$), microcline ($\approx 5\%$), and fluorite ($\approx 6\%$), consistent with a felsic plutonic origin and late-stage magmatic evolution. Structural mapping documents NNE–SSW trending joints, quartz veins, and minor faults that align with regional Pan-African stress fields. The occurrence of xenoliths within the coarse-grained granite suggests partial assimilation of country rock during emplacement, while pegmatite and quartz veins represent later-magmatic and hydrothermal activity. The integrated lithological, petrographic, and structural data indicate that the area records multiple episodes of deformation, metamorphism, and granitoid magmatism typical of the Pan-African tectonic cycle. These findings improve understanding of Basement Complex evolution in northwestern Nigeria and highlight the area's potential for industrial mineral and construction materials and the structures that hold potential for mineralization.

Keywords: Basement Complex, Granite Gneiss, Petrography, Structural Geology, Pan-African Orogeny

INTRODUCTION

Globally, the Pan-African orogeny and other Neoproterozoic tectono-metamorphic events played a crucial role in reorganizing crustal architecture and assembling Gondwana (Stern, 2008). In Africa, regional metamorphism, magmatic intrusions, and crustal reworking were driven by the Trans-Saharan/Pan-African Mobile Belt, which sutured older cratonic blocks to younger terranes. The Nigerian Basement Complex lies within this mobile belt, situated between the Congo and West African cratons, and records a polycyclic history of intrusive magmatism, anatexis, metamorphism, and deformation (Ajibade & Woakes, 1984; Ominigbo, 2022). The Basement Complex is composed of three major lithotectonic units: the Neoproterozoic Schist Belts, the Migmatite–Gneiss Complex, and the Pan-African Older Granites that intruded them along major structural zones (Rahaman, 1988; Okpoli et al., 2020). The Older Granites range in composition from granodiorite to syenite, are typically potassic, and reflect mixed crustal and mantle sources, as supported by recent petrographic studies across Nigeria (Chukwu & Obiora, 2021; Olusola & Akinola, 2024).

Despite extensive regional knowledge, the complex interactions among granitization, syn- to post-tectonic intrusion, metamorphic overprinting, and structural controls remain incompletely understood at local scales (Ominigbo, 2022). In particular, detailed petrographic and structural documentation of rocks within the Butawa–Kafin Magaji area is limited, creating a need for further investigation to clarify their formation history, structural evolution, and tectonic significance. The Nigerian Basement Complex hosts economically important mineral deposits including gold, gemstones, and industrial minerals, and also provides essential construction materials such as granite and laterite (Oyawoye, 1972). Therefore, this study aims to characterize

the rock types present—both macroscopically and microscopically—and to document the structural features that define the geological history of the area. Understanding this framework is essential for resource exploration, geotechnical assessment, and geohazard mitigation. The findings contribute to the regional geological database and provide a foundation for future mineral exploration, engineering planning, and academic research within the Nigerian Basement Complex.

Overview of the Nigerian Geology

Over 2.5 billion years of crustal history influenced by various orogenic, magmatic, and sedimentary processes reflects the Nigeria's geology and forms part of the global events that brought Gondwana together and reshaped most of West Africa. Nigeria is located inside the Pan-African Mobile Belt, a tectono-metamorphic province that was created during the Pan-African Orogeny ($\sim 600\text{--}550$ Ma) (Caby *et al.*, 1981, Rahaman, 1988 and Obaje, 2009). The Precambrian Basement Complex, the Jurassic Younger Granites, and the Cretaceous to Recent Sedimentary Basins are the three main lithological units that make up the country's geological framework. During several Precambrian orogenies, most notably the Pan-African ($\sim 600 \pm 150$ Ma), the Basement Complex, which makes up roughly half of Nigeria's landmass, saw several deformations and transformations. The three main units includes:

- i. The Migmatite–Gneiss Complex represents the oldest and most reworked crustal segment, forming the core of Nigeria's basement geology and serving as a framework upon which other lithological units (Schist Belts and Older Granites) are emplaced. These high-grade metamorphic rocks, including migmatites, banded gneisses, and amphibolites, dominate southwestern and north-central Nigeria (McCurry, 1976). Their characteristic alternating light (quartz-feldspar)

and dark (mafic minerals) bands testify to intense metamorphism and partial melting.

- ii. The Schist Belts of Nigeria also called metasediments (sedimentary rocks that have undergone metamorphism) examples of metasedimentary rocks are the schist, quartzites, banded iron formation (BIF) and marble. They are a prominent component of the Precambrian Basement Complex, particularly well-developed in the western and northwestern regions of the country.
- iii. The Older Granites comprise Pan-African granitoids intruding the Basement Complex (Ajibade, 1982). These granites, granodiorites, and syenites frequently form large plutonic bodies associated with mineral deposits including tin, tantalite, and gemstones (Rahaman, 1976). The Basement Complex displays folds, faults, shear zones, and joints with dominant NE-SW, NW-SE, and NNE-SSW

trends (Turner, 1983). These structures primarily resulted from compressional and transgressional forces during the Pan-African Orogeny (Burke and Dewey, 1972). During the Jurassic (~160-140 Ma), Nigeria experienced igneous activity linked to Gondwana breakup and Atlantic opening (MacLeod, 1971). The Younger Granites occur as ring complexes, particularly on the Jos Plateau (Jacobson et al., 1958). These alkaline complexes differ from Older Granites in composition and structure, consisting mainly of biotite granites, rhyolites, and syenites with characteristic ring-dyke structures (Bowden et al., 1987). Economically, they host significant tin (cassiterite) and columbite deposits (Wright & McCurry, 1970). Overlying these basement rocks are Cretaceous to Recent sedimentary basins formed during Atlantic rifting (Petters, 1978). Major basins include The Benue Trough, Niger Delta Basin, Sokoto Basin, Chad Basin among others.

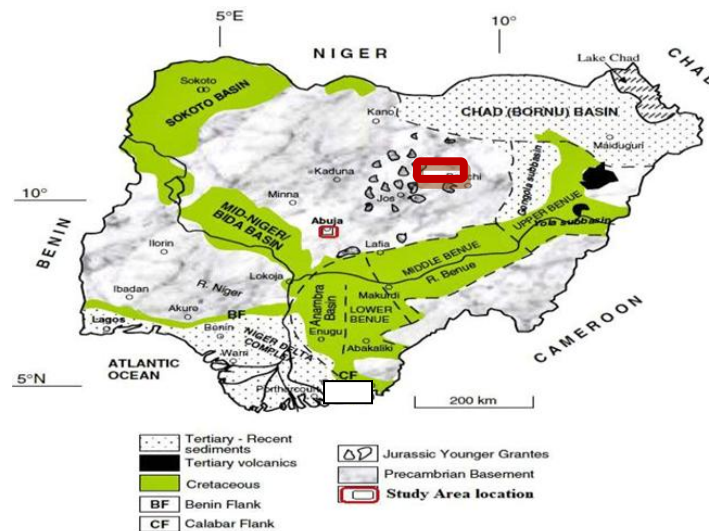


Figure 1: Geological Map of Nigeria (Modified after Obaje et al., 2006)

Study Area Description

The study area, covers approximately 40 km² within Sheet 79 NE of northwestern Nigeria and lies between latitudes 11°53'42.9"N–11°58'6.9"N and longitudes 7°57'13.7"E–8°00'00"E. It features a gently undulating terrain with elevations of 450–520 m above sea level, characterized by low relief, scattered inselbergs, and lateritic soils typical of the Nigerian Basement Complex. The region experiences a tropical continental climate with distinct wet (May–October) and dry (November–April) seasons, annual rainfall of 900–1,200 mm, and temperatures ranging from 18°C to above

35°C. Seasonal streams exhibiting dendritic to sub-dendritic drainage patterns dominate the hydrology, controlled by underlying fractures, joints, and foliation planes. These ephemeral channels enhance erosion and expose fresh rock outcrops crucial for field mapping and petrographic sampling. The area falls within the Northern Guinea Savanna vegetation zone, characterized by grasses, shrubs, and scattered drought-resistant trees such as *Daniellia oliveri* and *Isoberlinia doka*, reflecting the influence of the seasonal climate and soil development on the landscape.

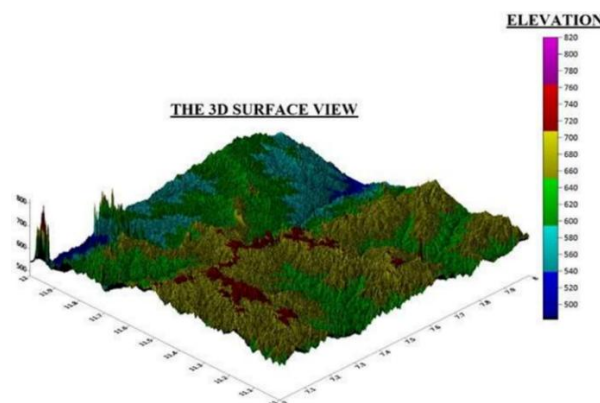


Figure 2: 3D Digital Elevation Model (DEM) Of the Study Area

Methodology

Field investigations involved geological mapping preceded by initial study of topographic maps of the study area on a scale of 1:100,000. The study area was gridded into six quadrants for easy mapping which consisted of reconnaissance and detailed mapping of outcrops and rock exposures along streams, rivers and road cuts. The area was systematically divided into ten quadrants for detailed field examination. Traverses were planned using topographic maps and natural routes such as footpaths, farm tracks, and dry stream channels. Fieldwork involved studying and recording outcrops, measuring structural features (strikes and dips of foliations, joints, veins, and faults) with a compass clinometer, and collecting GPS coordinates and elevation data for outcrops, wells, and rivers. Hydrogeological observations, including static water levels in wells and boreholes, were also recorded to complement geological interpretations. The gridded map was systematically used for navigation and rock boundary delineation. Representative rock samples,

including granite gneiss, coarse-grained granite, pegmatite, and xenoliths were consistently and evenly collected from in situ outcrops, labelled, and examined macroscopically with a hand lens in the field. In the laboratory, selected samples were prepared into thin sections and analyzed under a polarizing microscope to identify mineral composition, textures, and microstructures. Structural and petrographic data were synthesized to interpret the area's geological history and tectonic evolution. The geological map was digitized at a 1:25,000 scale using Surfer 11 software, integrating lithological boundaries, structural measurements of veins, fractures and faults were collected and plotted to provide a comprehensive geological framework.

Geology and Petrography of the Study Area

The study area, as illustrated in Figure 3 below, is underlain predominantly by granite gneiss and coarse-grained granite.

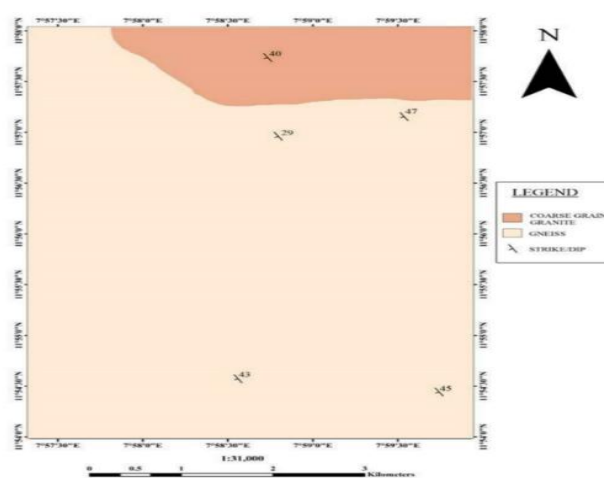


Figure 3: Geologic Map of the Study Area

Granite Gneiss

Megascopic Description

The hand samples show that the rock has a medium-grained texture with aligned quartz, feldspar, and biotite minerals, indicating strong deformation. The foliation and mineral alignment suggest recrystallization under directed pressure

during metamorphism. The area is mainly made up of highly weathered gneiss, covering about 70% of the study area, with foliation trending NE–SW and minor folds and faults. This gneiss represents the oldest rock unit in the area's geological history.



Plate I: (a) Field Occurrence of Granite Gneiss (N11° 54' 25.3" and E07°58'33.2"), (b) Hand Specimen of Granite Gneiss

Microscopic Study

Petrographic Description under Plane Polarized Light (PPL)

Under plane-polarized light (PPL), the granite gneiss sample shows a medium- to coarse-grained, equigranularity texture dominated by felsic minerals such as quartz, plagioclase, microcline, and orthoclase, with minor biotite, muscovite, and accessory sericite and perthite. Quartz is colorless and interstitial with minor fractures, while feldspars show low relief and partial alteration. Biotite appears as brown

pleochroic flakes with perfect cleavage, and muscovite is colorless with good cleavage, often intergrown with biotite. The overall texture and mineral relationships indicate moderate deformation and limited alteration.

Petrographic Description under Cross Polarized Light (XPL)

Under XPL, the granite gneiss shows a hypidiomorphic granular texture with distinct optical properties among minerals. Quartz appears light gray with low birefringence and

undulose extinction, indicating low to medium grade metamorphism. Plagioclase displays polysynthetic twinning and patchy extinction, while microcline shows characteristic cross-hatched twinning with low birefringence. Orthoclase exhibits simple Carlsbad twinning and weak interference colors. Biotite and muscovite display bright interference

colors with parallel and straight extinction, respectively. Accessory minerals like sericite show low birefringence, and perthite reveals exsolution lamellae. The features of the minerals suggest a coarse-grained rock that crystallized slowly and later experienced tectonic stress during Pan-African orogenic events.

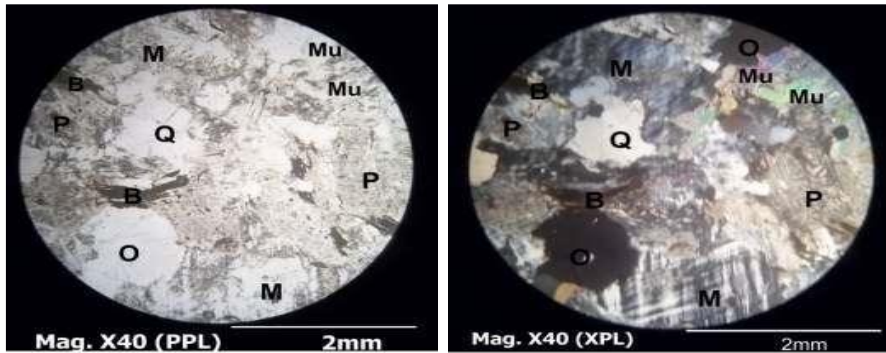


Plate II: Photomicrograph of Gneiss under Plane Polarized light (PPL) and CROSS polarized Light (XPL). Key: Mu = Muscovite; P = Plagioclase; M = Microcline; Q = Quartz; B = Biotite; O = Orthoclase

Modal Composition of Granite Gneiss

The mineral composition in granite gneiss is presented in Table 1.

Table 1: Modal Composition (%) of Minerals in Granite Gneiss

S/N	MINERAL	%
1	Quartz	30
2	Orthoclase	15
3	Plagioclase	35
4	Biotite	3
5	Muscovite	10
6	Microcline	7
Total		100

Coarse Grained Granite

Megascopeic Description

The Coarse-grained granite is a leucocratic, medium to coarse-grained rock dominated by felsic minerals. It forms low-lying

whale-back outcrops and elevated ridges, covering about 25% of the study area. The rock contains quartz, alkali and plagioclase feldspars, biotite, and muscovite, with common pegmatite and quartz vein intrusions.



Plate III: (a) field Occurrence of Coarse-grained granite (11°57' 59.1" and 07°58' 7"), (b) Hand Specimen of Coarse-grained Granite

Microscopic Study

The coarse-grained granite exhibits a porphyritic texture, with phenocrysts of feldspar and quartz set in a medium-grained

groundmass. The estimated modal composition (Table 4.2) includes orthoclase (40%), quartz (28%), plagioclase (10%), biotite (10%), microcline (6%), and fluorite (6%).

Table 2: Modal Composition (%) of Minerals in Granite Gneiss

S/N	MINERAL	%
1	Quartz	25
2	Orthoclase	15

S/N	MINERAL	%
3	Plagioclase	30
4	Biotite	7
5	Muscovite	5
6	Microcline	5
7	Fluorite	2
8	Opaque minerals	11
Total		100

Microscopic Description under Plane Polarized Light (PPL)

Under PPL, quartz displays undulose extinction, plagioclase shows polysynthetic twinning, and microcline exhibits characteristic cross-hatched twinning. The mineralogy and textures confirm a felsic, deep-seated intrusive origin with minor post-crystallization strain.

Microscopic Description under Cross Polarized Light (XPL)

Under XPL, quartz displays undulose extinction, plagioclase shows polysynthetic twinning, and microcline exhibits characteristic cross-hatched twinning. The mineralogy and textures confirm a felsic, deep-seated intrusive origin with minor post-crystallization strain.

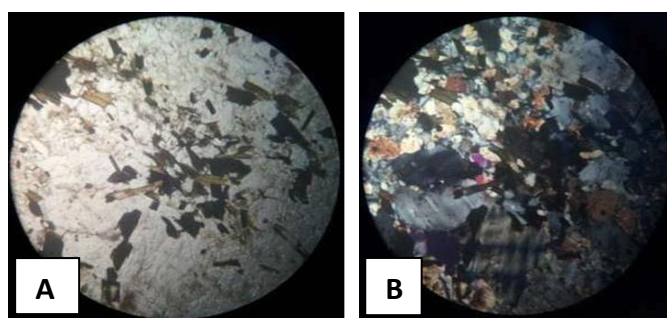


Plate IV: Photomicrographs of Coarse-grained Granite under (a) Plane Polarized Light (PPL) and (b) Cross Polarized Light (XPL)

Minor Rock Type

Pegmatite

Pegmatite occurs widely as dykes and patches cutting through the coarse-grained granite. The crystals are extremely coarse,

with phenocrysts exceeding 2 cm in length. The pegmatite forms surface exposures, indicating near-final stages of magmatic intrusion.



Plate V: Pegmatite in a Granite host Rock (N11°57'30.8" and E007°59'0.5")

Structural Geology

Within the study area, different types of structures were encountered which are displayed majorly on the Gneiss and Coarse grain Granite. The structures noticed on the field include joints and faults.

Joints

The dominant joint trend is NNE–SSW, with additional NW–SE and ENE–WSW sets. Cross-cutting relationships indicate multiple deformation phases. Plate VI, shows a typical rock joint fracture as observe in the field.



Plate VI: Fracture in the Coarse-grained Granite (N11⁰ 57' 10.8 " and E007⁰ 52' 0.5 ")

Faults

Minor localized faults were observed in the study area. Plate VII is a normal fault visible on a coarse-grained granite. These

features suggest minor sinistral and dextral movements consistent with the Pan-African tectonics.



Plate VII: Quartz Vein in A Faulted Coarse-Grained Granite (N11⁰ 57'58.7" and E07⁰ 58'32.5")

Veins

Plate VIII showed a quartzo-feldspathic vein occurring as thin to moderately thick veinlets cutting across the coarse-grained granite and granite gneiss outcrops. They range from a few

millimeters to several centimeters in thickness and are resistant to weathering. The veins generally trend NE-SW, consistent with Pan-African tectonic stress directions.



Plate VIII: Outcrop of Granite showing Quartz Vein (N11⁰ 57' 59.1" and E07⁰ 58' 7.3")

Xenolith on Coarse-grained Granite

Xenoliths occurred within the coarse-grained granite as rounded to elongate fragments, ranging from a few

centimeters up to 40 cm in length. They display NNE-SSW alignment, suggesting partial assimilation and magmatic flow during granite emplacement.



Plate IX: Xenolith on Coarse-grained Granite (N11^o 57' 59.1" E07^o 58' 7.3")

Summary

The geology and petrographic study of Butawa-Kafin Magaji showed that the area is primarily composed of coarse-grained granite ($\approx 25\%$) and granite gneiss ($\approx 70\%$), with pegmatites and structures like quartz veins, and xenoliths ($\approx 5\%$). This lithological and structural assemblage is entirely consistent with numerous studies of the Nigerian Basement Complex (Rahaman 1988; Ajibade and Woakes 1984), where migmatite-gneiss complexes and Pan-African granitoids commonly dominate. (Olade, 1976; Christopher *et al.* 2022; Ekeleme *et al.* 2024) reported similar granite to gneiss proportions and the common occurrence of pegmatites and quartz veins in areas influenced by late-to post-tectonic granitic emplacement. Thus, the overall lithologic proportions at Butawa-Kafin Magaji reinforce the interpretation of a typical basement domain affected by magmatism and subsequent deformation resulting to emplacement of the coarse-grained granite and the granite gneiss indicating medium metamorphism. In accordance with the Pan-African tectonic framework, gneiss has a significant foliation with NE-SW trends, with accessory biotite and muscovite, it is mostly constituted of quartz and feldspars (microcline and plagioclase), according to petrographic investigation. This indicates medium-to high-grade metamorphism and recrystallization which matches a classical description of Pan-African migmatite-gneiss terrains by (Odeyemi, 1993; Rahaman 1988). In the NE part of the study area, coarse-grained granite is visible as a low-lying outcrop. It is leucocratic, and rich in orthoclase, quartz, plagioclase, and biotite. Late-stage magmatic crystallization and hydrothermal activity are indicated by pegmatitic and quartz veins that pierce the granites.

Assimilation activities during magma emplacement are indicated by gneissic xenoliths found within the granites. Faults that locally displace quartz veins and joints that trend NNE-SSW dominates the study area. The documentation of joints, faults, and crosscutting veins is therefore consistent with a multi-phase deformation history recorded in the Nigerian Basement. The Pan-African orogeny, which profoundly influenced the region's tectonic architecture, exerted regional stresses that are compatible with these structural patterns.

CONCLUSION

The geological and petrographic investigation of the Butawa-Kafin Magaji area has provided a comprehensive understanding of the lithological assemblages, structural framework, and metamorphic evolution of this part of the

Nigerian Basement Complex. The study area is dominated by gneiss and coarse-grained granite, with minor occurrences of pegmatites, quartz veins, xenoliths, and fault-related rocks. Field observations and petrographic analyses show that the gneiss has undergone medium- to high-grade metamorphism, while the granite represents a later intrusive phase that cuts across the older basement units. The presence of pegmatite dykes and quartz veins indicates late-stage magmatic and hydrothermal activity associated with the final phases of granitoid emplacement. Structural analysis reveals a dominant NNE-SSW structural trend, with additional NW-SE and ENE-WSW joint sets, reflecting the regional tectonic imprint of the Pan-African Orogeny. The occurrence of gneissic xenoliths within the granite also demonstrates magma-country rock interaction during intrusion. Generally, the results show that the geological evolution of the area is marked by multiple deformation episodes, regional metamorphism, and granitoid magmatism characteristic of the Pan-African crustal reworking in northern Nigeria. These findings contribute to a broader understanding of the basement geology of the region and provide valuable information relevant to future mineral exploration, engineering geology, and academic research.

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