

The geology and petrography of Dangkan and environs, Kanke lga, North-central Nigeria, (Wase sheet 191 NW)

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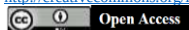
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ABSTRACT

A detailed geologic survey was conducted in Dangkan and its environs, located between latitude 09° 16' 00" N to 09° 18' 00" N and longitude 09° 43' 00" E to 09° 46' 30" E within Kanke Local Government Area of Plateau State North-central Nigeria. Field studies on the rocks revealed the presence of migmatite and porphyritic biotite granite as primary rocks intruded by minor intrusions of Pegmatites and dolerites. Petrographic studies revealed the presence of muscovite, plagioclase, quartz, and biotite as the minerals in migmatite and porphyritic biotite granite rocks of the study area, with feldspars, hornblende, and other opaque minerals in pegmatite and dolerite with their distinctive optical properties both in plane-polarized and cross-polarized lights. The geological structures observed include foliations, banding, folds, joints, and veins (especially quartz veins). The general orientation of structural elements is in the NE-SW, NNE-SSW, N-S, and minor NW-SE directions, which have undergone a tectonic evolution that evolved into two distinct episodes the flexible NE-SW & minor N-S layer and the brittle phase that formed the NW-SE quartz veins. The Migmatite and Porphyritic biotite Granite encountered are peculiar to the Nigerian Basement Complexes, and more research needs to be carried out to ascertain the economic geology of these rock types and the characteristic economic minerals contained in them. A more detailed geologic map of the study area should also be created to ascertain the quantity and quality of this mineral deposits and good roads should be created for accessibility.

Introduction

Nigeria's geological landscape is linked to its position within the dynamic Pan-African mobile belt of Africa. The Pan-African orogeny remodeled this region some 600 million years ago. This major event led to extensive sedimentary deposits, rock folding, and widespread metamorphism, fundamentally altering the area's geology. While detailed geological and structural studies in Nigeria remain limited, geochronological data available up to 1982 Ogezi, (2002) revealed a polycyclic history for the Basement Complex, these include; the, Pan-African Orogeny (600 ± 150 Ma): This major orogenic event, responsible for the formation of the Pan-African mobile belt, profoundly impacted the Nigerian Basement Complex through intense deformation, metamorphism, and the emplacement of granitic intrusions.

The Eburnean (2000 ± 200 Ma) and Kibaran (1100 ± 200 Ma) orogenies are the two major orogenic events contributing to the Basement Complex. The Eburnean's orogeny is well-established, while the extent of the Kibaran orogeny's influence remains an active area of research. The Liberian Orogeny (2800 ± 200 Ma) provides evidence of ancient crustal formation and deformation within the Nigerian Basement Complex. The region has also experienced other, less dramatic geological processes. During the Mesozoic era (252-66 Ma), the emplacement of the Younger Granites contributed

significantly to the diversification of the geological landscape in Nigeria. This event was characterized by processes of cauldron subsidence, ring faulting, and volcanism.

Structural analysis reveals the dominant lineaments in Nigeria, the consistent orientations of northeast-southwest (NE-SW) and northwest-southeast (NW-SE) reflecting deep-seated crustal discontinuities (Ogezi, 2002). These lineaments are essential conduits for fluid flow and exert a primary control on the spatial distribution of mineral resources. Petrography analysis is an in-depth investigation of the microscopic features of a particular rock sample, including the macroscopic investigations of the rock sample. To ascertain these rocks petrogenesis, a detailed mineralogical characterization that includes optical mineralogy of thin sections and comprehensive micro-textural, and structural analysis, is required.

The Basement Complex represents one of the three major litho-petrological components that underpins Nigeria's geological framework. It comprises a diverse assemblage of metamorphic and igneous rocks, intruded in places by the Younger Granites of the Jos Plateau and overlain unconformably by Cretaceous and younger sedimentary sequences. The Nigerian Basement Complex bears the imprint of the Pan-African Orogeny, a major tectonic event that occurred around 600 million years ago, triggered when the passive continental margin of the West African Craton collides with the active Eurasian continental margin. Burke and Dewey, (1972), Dada, (2006), resulted in extensive deformation, metamorphism, and magmatism within the region. The Basement Complex is composed of four principal petro-lithological units:

Undeformed Acid and Basic Dykes: These dykes, representing relatively young intrusions, cut across the older rocks of the Basement Complex. They include a variety of rock types, ranging from acid dykes (e.g., tourmaline and beryl-bearing pegmatites, muscovite-rich aplites, and syenites) to essential dykes (e.g., dolerites, lamprophyres, and basalts).

Older Granites (Pan-African Granitoids): This unit encompasses many granitic rocks, including granites, granodiorites, porphyritic granites, syenites, gabbros, and charnockites. These rocks crystallized from magma generated during the Pan-African Orogeny signifying a significant component of the Basement Complex.

Schist Belts: consist of metamorphosed sedimentary and volcanic rocks, such as phyllites, schists, pelites, quartzites, marbles, and amphibolites. The initial stones during the Pan-African Orogeny were subjected to intense heat and pressure, leading to their transformation into new mineral textures and assemblages.

Migmatite-Gneiss Complex: This signifies the most highly metamorphosed rocks within the Basement Complex. It is made up of migmatites and gneisses. These rocks have undergone partial melting and extensive recrystallization, resulting in complex textures and mineral assemblages.

The undeformed acid and essential dykes represent a relatively young suite of intrusive rocks within the Nigerian Basement Complex, emplaced during the late to post-tectonic stages of the Pan-African Orogeny. These dykes characteristically cross-cut the older units of the Basement Complex, including the migmatite-gneiss complex, the schist belts, and the older granites.

Felsic Dykes: They exhibit a range of compositions, from muscovite-rich aplites and microgranites to tourmaline and beryl-bearing pegmatites and syenites, they are related with the Pan-African granitoid (Dada, 2006). They provide valuable insights into the late-stage magmatic activity related to the orogeny.

Essential Dykes: These dykes, composed predominantly of dolerite, with less common occurrences of basalt, felsite, and lamprophyre, are often considered the youngest units within the Nigerian Basement Complex. Rb-Sr whole-rock studies suggest an age range of 580 to 535 Ma for the felsite dykes Dada, (2006), while the essential dykes are estimated to be around 500 Ma (Grant, 1970).

Dykes have often been overlooked in Nigerian geological studies (Dada, 2006). The cross-cutting relationships of these dykes within the basement units are crucial for reconstructing the region's geological timeline, enabling us to determine the relative ages of metamorphic structures and rock suites, potentially identifying older basement windows, and providing essential samples for isotope geochemistry. The data obtained allows for detailed studies of the region's rock formation and tectonic evolution (Dada, 2006). The term "Older Granites" was introduced by Falconer (1911) to distinguish these deep-seated, typically concordant or semi-concordant granitic rocks of the Basement Complex from the younger, highly discordant, tin-bearing granites found in northern Nigeria (Obaje, 2009).

These Older Granites believed to represent a complex and prolonged magmatic cycle associated with the Pan-African Orogeny, span a wide range in age (750-450 Ma) and composition. They intrude into both the migmatite-gneiss-quartzite complex and the schist belts, suggesting their emplacement occurred during various stages of the orogenic event - pre-, syn-, and post-tectonic. The Older Granites are associated with the Migmatite-Gneiss Complex and the Schist Belts, this spatial relationship highlights the close link between their formation, the broader tectonic and metamorphic processes that shaped the Basement Complex. While generally lacking in associated mineralization, the thermal effects of the Older Granites may have played a role in the remobilization of mineralizing fluids, potentially contributing to ore formation in other parts of the Basement Complex (Obaje, 2009).

The Schist Belts, also referred to as the metasedimentary belts, are structurally controlled by elongated zones within the Nigerian Basement Complex, characterized by a general north-south (N-S) to north-northeast-south-southwest (NNE-SSW) trend. These belts are primarily of low-grade metamorphosed sedimentary rocks with subordinate metavolcanic components. The Schist Belts are believed to represent Upper Proterozoic subcrustal rocks that were deposited on the older migmatite-gneiss complex and subsequently enfolded into it during the Pan-African Orogeny. Their lithological diversity encompasses coarse- to fine-grained clastic rocks, pelitic schists, phyllites, banded iron formations, carbonate rocks (marbles and dolomitic marbles), and mafic metavolcanic (amphibolites).

Some researchers also suggest the presence of fragments of oceanic crust, potentially derived from small back-arc basins. The origin and evolution of the Schist Belts have been the subject of considerable debate. While Rahaman, (1976) and Grant, (1978) proposed multiple basins of deposition, Oyawoye (1972) and McCurry (1976) favored a single supracrustal cover. Olade and Elueze (1979) interpreted the Schist Belts as fault-controlled rift-like structures Grant (1978), and Turner (1983) suggested the presence of sediments of different ages within the belts, based on structural and lithological associations. However, Ajibade et al., 1987 challenged this conclusion, demonstrating that both series experienced similar deformational histories. The structural relationship between the Schist Belts and the basement has also been examined.

While Truswell and Cope (1963) considered them to represent conformable metamorphic fronts, Ajibade et al., (1987) were the first to map a structural break between the two units. The nation's mining industry benefits substantially from the Schist Belt's, rich.

Valuable mineral deposits such as gold, limestone, manganese, marble, quartzite, and gneiss. Migmatite-Gneiss Complex (MGC) constitutes the most extensive and dominant unit, constituting about 60% of its exposed surface area within the Nigerian Basement Complex (Rahaman and Ocan, 1978). This complex assemblage encompasses a diverse array of rock types, including migmatites, orthogneisses (derived from metamorphosed igneous rocks), paragneisses (derived from metamorphosed sedimentary rocks), and a variety of metamorphosed basic and ultrabasic rocks.

Petrographic evidence reveals that the Pan-African Orogeny profoundly impacted the MGC, leading to extensive recrystallization of its constituent minerals through partial melting. Most rock types

within the complex display medium to upper amphibolite facies metamorphism, indicative of the high temperatures and pressures associated with this tectonic event. The MGC is widely distributed across Nigeria, covering significant portions of the northern, western, and eastern regions. Notable areas where rocks of the MGC are exposed include: Northern Nigeria: Abuja, Keffi, Akwanga, Bauchi, Kaduna, Kano, Funtua, Okenne, Egbe, and Ajaokuta. Western Nigeria: Ibadan, Ile-Ife, Akure, and Ikerre. Eastern Nigeria: Obudu and the Oban Massif areas. The widespread occurrence of the MGC underscores its fundamental role in the geological architecture of the Nigerian Basement Complex.

The study area lies within the Wase sheet 191 NE (1:100,000) in Dangkan, Kanke Local Government Area of Plateau State, Nigeria, part of the Basement Complex and Older Granites. Little is known, and a lot of unpublished work has been done about the area's geology, owing to the limited work that has been done in the area. Recent work carried out indicates that the area is made up of basement Complex rocks that have been intruded by pegmatitic and dolerite dykes as a result of intensive deformation due to tectonic activities. This research is to describe the types of rocks that make up the area of study, their structural patterns, and mineral composition, to also carry out detailed geological mapping of the different lithological units of the study area by producing an updated geologic map of the area on a scale of 1: 12,500, to propose possible productive areas for siting economic minerals in the area and to produce a database for future research.

Study Area

Location, Extent, and Accessibility

The study area is extracted from Wase Sheet 191 NE on a scale of 1: 100,000 and enlarged to a scale of 1: 12,500 with a total area of about 30 km². It lies between Longitudes 09° 43' 00" E and 09° 46' 30" E and Latitudes 09° 16' 00" N and 09° 18' 00" N. The study area is accessible in rainy and dry seasons due to a network of tarred roads from Jos to Pankshin, Amper, and down to Kanke.

Relief and Drainage

The study area is defined by two relief features: highlands and lowlands. The highlands with a peak of about 600m above sea level extend towards the West of the study area. Some of the hills are conical in shape, but most have no well-defined morphological features. Some of the plains and hills have been widely eroded, resulting in very rough terrains. The streams in the area were observed to flow from higher regions through different channels (Figure 1), it has a dendritic drainage pattern. The rivers in the study area retain water and flow only after torrential rainfall in May, June, July, and August, with corresponding low flow during the dry seasons.

Climate and Vegetation

The climate in Langtang North features a distinct dry season spanning November to March. During these months, rainfall diminishes, and temperatures rise. Despite the reduced precipitation, the area experiences relatively high humidity, the region transitions into its wet season from April to October, with June and September experiencing the heaviest rainfalls. This period of significant precipitation is essential for maintaining the area's vibrant green landscape and agricultural productivity.

Dangkan and its environs have vegetation similar to the Guinea Savannah Vegetation (Figure 2). Surface water schemes are inadequate due to the prolonged dry season. The inhabitants, therefore depends on subsurface water for domestic and irrigation activities. It is distinguished by sparse vegetation including: grasses, shrubs, few trees like; Moringa, Neem trees known as Dogon yaro, and few Mango trees. Vegetation is thicker along stream channels due to the availability of water.

People, Settlement, and Land Use

The study area is a nucleated and dispersed settlement mainly dominated by mud houses situated close to fertile soils and others around the minor roads. The settlements are surrounded by cultivated

fields and flat grasslands at the foot of the hills. The dominant ethnic group is Tarok. On the other hand, the minor languages spoken in the study area are Boggom and Ngas. The primary use of land in the area is for agriculture which is conducted on a subsistence level involving the cultivation of crops such as millet, Guinea corn, beans, groundnut, Bambara nut rice, and maize. Vegetables such as okra, pumpkin, onions, spinach, and hibiscus are also farmed in the study area. Apart from farming, the inhabitants are engaged in trading and cattle rearing as a result of low-lying plains with well-growing grasses which serve as grazing fields.

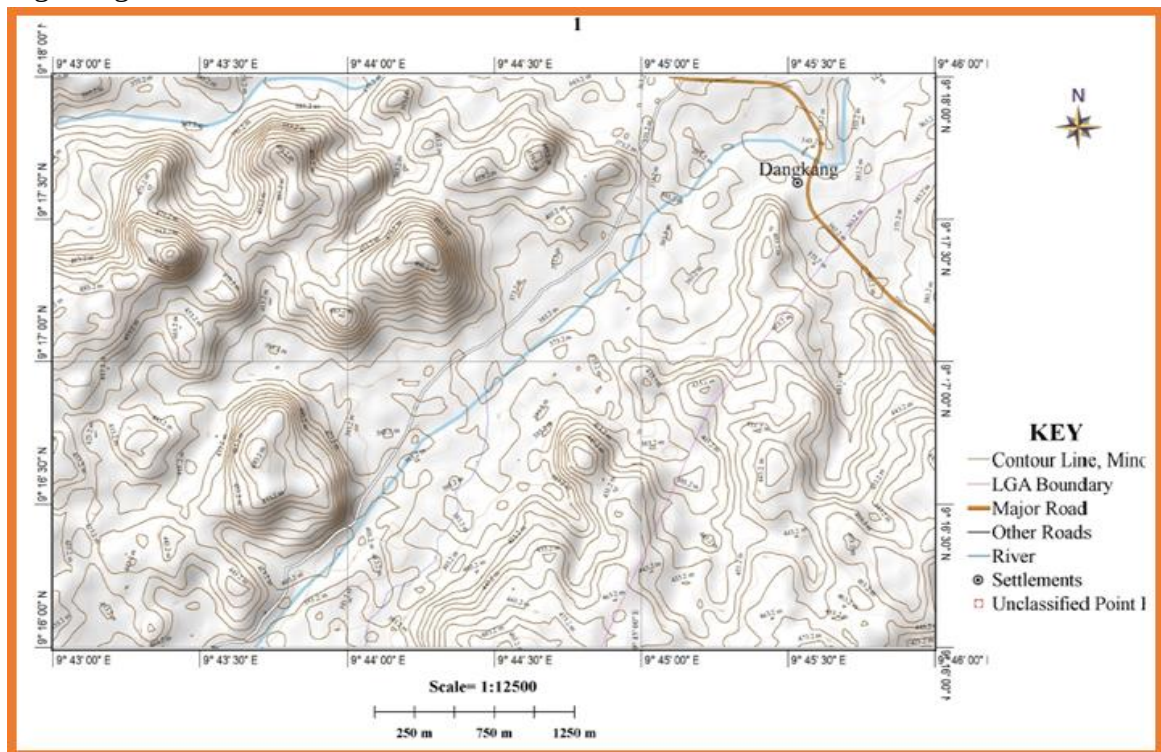


Figure 1. Topographic Map of the Study Area (Nigerian Geological Survey Agency, 2006)

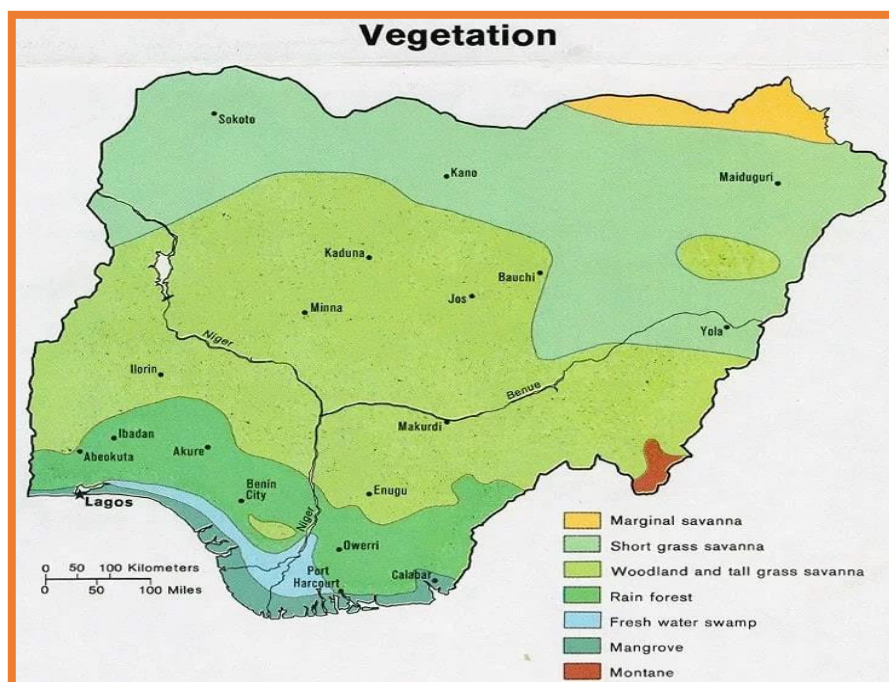


Figure 2. Vegetation Map of Nigeria (NCRS Jos, accessed, 12/02/2025)

Geology of Jos Plateau

Jos Plateau is characterized by a geological sequence consisting of both plutonic and volcanic types of igneous rocks (Table 1). This rock assembly shows the history of volcanic eruptions and magma emplacement. MacLeod and Berridge, (1971) revealed the foundational stratigraphic framework, outlining major rock groups and their chronological relationships, that is essential for understanding the geological development on the Jos Plateau.

Table 1. The geological sequence of the Jos-Plateau

S/N	Age	Rock type	Description
1	Precambrian – Lower Palaeozoic	Crystalline Basement	Migmatite-gneiss, Pan-African Granite
2	Jurassic	Younger Granites	Granite, Porphyries
3	Cretaceous	Sedimentary Rocks	Sediments
4	Quaternary	Quaternary	Lava flows and volcanic cone

2. Methodology

A foot-based survey of the Dangkan area was conducted to document its geological diversity comprehensively, researchers systematically observed and recorded outcrops, structures, and other significant features across varied terrains, including river valleys and rugged hills Using both traditional and modern techniques. A detailed analysis of rock types, textures, grain sizes, and anomalies was conducted to identify the minerals present. These minerals diagnostic optical properties were also conducted to determine their color, pleochroism, extinction angle, cleavage, twinning and birefringence, these properties identify the mineral constituents present in each thin section.

To ensure precision and accuracy in the data collected and documented, a range of scientific instruments and equipment were used: Spatial Data (Topographic maps and GPS units for accurate location and elevation measurements), Geological Tools (Geologic compass-clinometers for structural measurements and geologic hammers and a sledgehammer for rock sampling), Measurement and Documentation (Measuring tapes, cameras, field notebooks, markers, pencils, pens, sample bags, and masking tape for detailed recording and sample preservation) and Laboratory Petrographic Analysis (Collected rock samples underwent detailed petrographic analysis using a polarizing petrographic microscope. This technique allowed for the identification and description of minerals based on their optical properties under polarized light). By integrating petrographic analysis with established literatures, the origin, evolution, and classification of rock types in Dangkan and its environs were interpreted.

3. Results and discussion

A comprehensive petrographic study vital for classification of rocks accurately, involves a two-tiered approach this includes, estimating mineral proportions (mafic/felsic), classifying texture (grain size and arrangement), examining the color index as a proxy for mineralogy, and identifying foliation in metamorphic samples. The microscopic analysis of thin sections provides detailed and precise characterization that allows for accurate mineral identification, determination of mineral percentages quantitatively, in-depth textural analysis, and interpretation of the rock's geological history.

Geology of The Study Area

Dominant Rock Types

The study area is formed by the crystalline rocks predominantly of the Nigerian Basement Complex. This complex comprises of different metamorphic rocks, with migmatite and gneiss being the most abundant in the region. The area also features intrusive bodies like basalts and quartz veins.

Intrusive Activity

Observed to intrude on the basement rocks are non-columnar basalts and quartz veins, leveraging pre-existing fractures. Their NNE-SSW trend aligns with the dominant structural grain of the Basement Complex, suggesting a possible structural control on their emplacement.

Field Identification and Classification

A detailed megascopic examination was performed to characterize the various rock types encountered in the field. The primary rock units identified were migmatite and Porphyritic biotite granite, distinguished based on their textural and mineralogical attributes (Figure 3). Quartz veins, commonly observed as discordant features intersecting the Migmatite and Porphyritic biotite granites, were also recorded. Pegmatite and dolerite, though less abundant, were recognized by their distinctive textures and mineral assemblages.

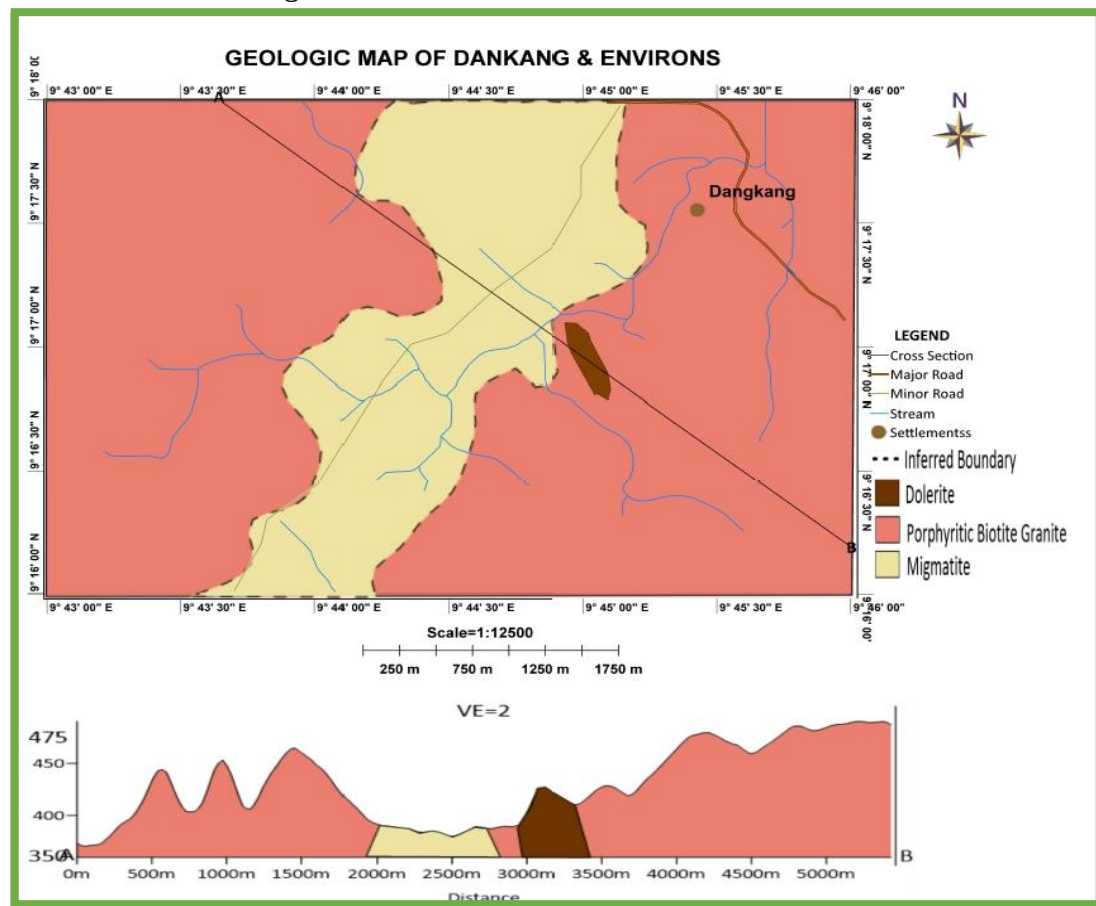


Figure 3. Map of the Study Area

Megascopic Descriptions

Migmatites, exhibits a heterogeneous appearance and displays a foliated texture, with alternating layers of light-colored (felsic) and dark-colored (mafic) minerals. This rock type is indicative of partial melting and recrystallization,

Porphyritic Biotite Granite, rock type was distinguished by its porphyritic texture, with larger phenocrysts (most likely feldspar and quartz) embedded in a finer-grained groundmass. The presence of biotite mica was also confirmed.

Dolerite, Identified by its fine-grained, dark-colored appearance.

Pegmatite: This rock type is readily recognizable by its exceptionally coarse-grained texture, with large interlocking crystals of quartz, feldspar, and mica.

Field Observations

Outcrop Morphology and Lithological Units

Outcrops ranged from prominent hills and ridges formed by massive exposures to scattered boulders and weathered, often vegetation-obscured, isolated outcrops, revealing a diverse landscape of rock outcrops, their forms varying significantly due to differences in rock type and ongoing geological processes. The size and distribution of these outcrops were directly influenced by the specific rock type and the local geomorphological setting. Field observations and megascopic descriptions confirms, lithological units were seen within the study area, and categorized into: Migmatite, porphyritic biotite granite, dolerite, and pegmatite.

Migmatite

Migmatites are identified by a striking banded appearance defined by the felsic and mafic layers. They are often intricately folded, visually demonstrating the partial melting these rocks have undergone (Plate 1). A key component of the Nigerian Basement Complex, the origin of these migmatites is credited to either the injection of granitic magma into host rock or the pervasive action of metamorphic fluids that induce partial melting and recrystallization. In the Dangangk area, migmatites are closely associated with gneisses, suggesting a shared metamorphic history. They are predominantly granitic in composition, exhibiting a dark gray to dark green coloration with contrasting white patches. The texture is generally medium to very coarse-grained, with occasional quartz porphyroblasts standing out against a finer-grained matrix. A preliminary assessment indicates the presence of feldspar, biotite, quartz, and other accessory minerals.

The complex texture of the migmatite can be explained further by its constituent components: Leucosome, Palaeosome, Melanosome and Neosome



**Plate 1. Migmatite in the study area at 9° 17' 40.8" N and 9° 45' 36.2" Elevation 368m
Porphyritic Biotite Granite**

The porphyritic biotite granite outcrops in the study area display a distinct texture characterized by larger phenocrysts (up to a few millimeters to one centimeter in size) embedded in finer-grained groundmass (Plate 2). This texture suggests a two-stage cooling history, with initial slow cooling at

depth allowing for the growth of phenocrysts, followed by more rapid cooling near the surface or in shallow intrusions, resulting in the finer-grained matrix. These granites are typically light-colored (leucocratic) to intermediate in color (mesocratic), reflecting their mineralogy dominated by felsic minerals. Mineral samples such as feldspar (likely both K-feldspar and plagioclase), quartz, muscovite mica, and biotite mica are readily observable.

The biotite mica imparts a distinctive speckled appearance to the rock. The granitic outcrops exhibit an NW-SE orientation, confirming a possible structural control on their emplacement deformation. Field observations also indicate the presence of structural features such as faults and joints. This may be related to regional tectonic events. The granites in the study area were seen to be cross-cut by pegmatite intrusions. This cross-cutting relationship unequivocally establishes the relative age of the two rock types, demonstrating that the granites are older than the pegmatites that intruded on them.



Plate 2. Porphyritic biotite granite in the study area at N09° 17' 25.1" E09° 45' 32.2" Elevation 390m

Dolerite

Dolerite is a dark, fine-grained rock found next to the pegmatite and granite rocks. It runs north-south, forming a line of boulders about 200 meters long. The rock shows signs of rapid cooling, with small holes from gas bubbles and cracks that formed later (Plate 3). Its location and direction suggest link between other rocks and the area's overall geological structure.

Pegmatite

Pegmatites originated from volatile-rich, residual magmatic melts. They are coarse-grained igneous rocks defined by their large interlocking crystals of quartz, feldspar, and mica. They crystallized slowly within fractures of the older granitic host rock, a process known as igneous differentiation. Evidenced by their cross-cutting, east-west trending dykes, the pegmatites are not older than the granites they intrude. Field observations reveal sharp contacts and crystals ranging in size from centimeters to decimeters (Plate 4). The presence of these pegmatites not only adds complexity to the area's geological history but also points to potential late-stage magmatic activity and associated rare-element mineralization, as pegmatites are known to host valuable minerals like lithium, beryllium, tantalum, and gemstones.



Plate 3. Dolorite in the study area at N09° 17 32.2' E09° 45 49.9' Altitude 381m



Plate 4. Pegmatite in the study area at N09° 17 40.8' E09° 45 36.3' Elevation 368m

Petrographic Analysis

Using microscopy to identify and classify rocks is referred to as the cornerstone of geology. Petrographic analysis is achieved by slicing and polishing rock samples of about 0.03 mm thick under a polarizing microscope, allowing light to pass through for detailed observation. The polarizing microscope, with its specialized filters, magnifies the thin section, revealing the rock's mineral

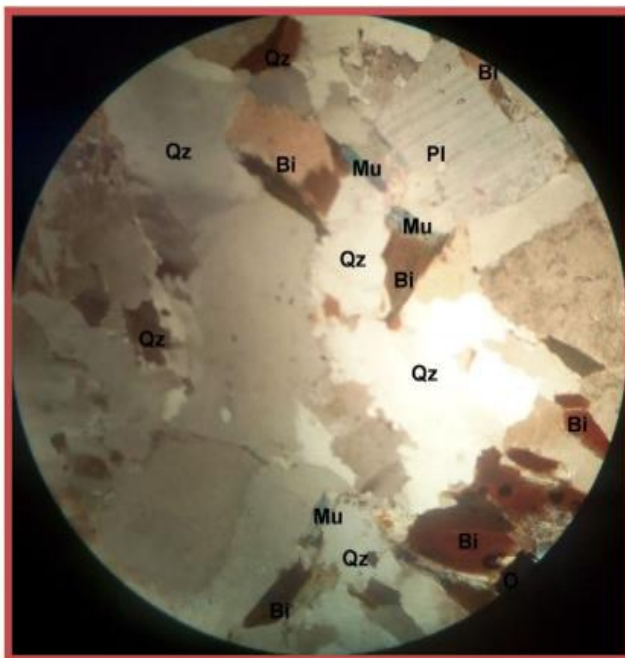
composition by observing distinct optical properties under plane-polarized light (PPL) and cross-polarized light (XPL).

Microscopic Description of Rock Samples

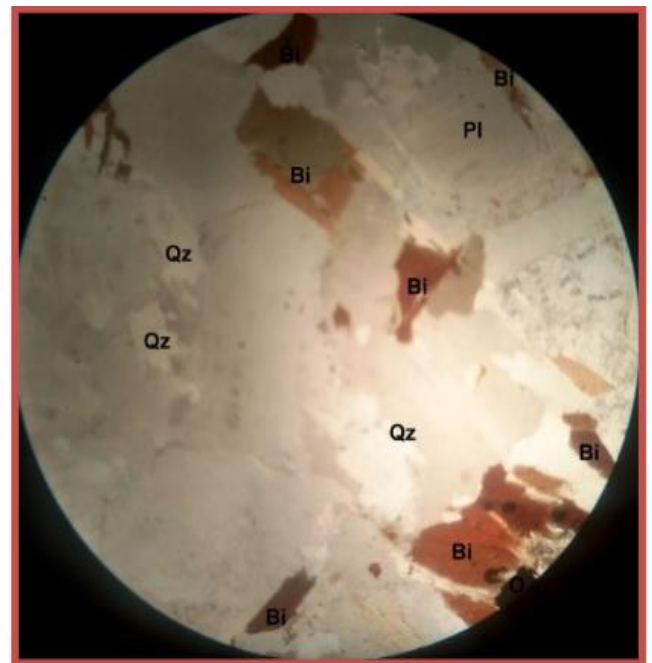
Field observations and hand specimen analysis guided the selection of representative rock samples (migmatite, porphyritic biotite granite, pegmatite, and dolerite) for detailed petrographic study. Four samples (JM 1-4) were prepared as 30-micrometer thin sections and examined using plane-polarized (PPL) and cross-polarized light (XPL) microscopy, revealing the following mineral assemblage: plagioclase (characterized by polysynthetic twinning), quartz (low relief, gray/white interference), muscovite (perfect cleavage, bright interference), biotite (brown/black, mica-like), hornblende (prismatic, two cleavages, distinctive interference), and opaque minerals (black/dark in both PPL and XPL).

Results from The Petrographic Examination of Rock Samples Under Plane-Polarized Light (Ppl) And Cross-Polarized Light (Xpl)

Migmatite



(a)XPL



(b) PPL

Plate 5. Photomicrographs of Migmatite (JM 1) - Magnification $\times 10$

B – Biotite, Qz - Quartz, Mu – Muscovite, Pl – Plagioclase

Microscopic Observations (Plate 5)

Under plane-polarized light, the migmatite thin section presents a complex and heterogeneous texture characteristic of its partially melted origin.

Plagioclase are abundant, colorless, tabular crystals with anhedral (irregular) shapes. Many display polysynthetic twinning, appearing as parallel, fine-scale twin lamellae. Plagioclase grains are often interwoven with other minerals, indicating their growth during or after partial melting.

Biotite, are Brownish flakes with well-developed cleavage parallel to the basal plane. Strong pleochroism is observed, with colors ranging from light brown to dark brown or reddish-brown, depending on the orientation. Some biotite grains show alteration to greenish chlorite along their cleavages or margins.

Muscovite are Colorless to pinkish-green flakes with perfect cleavage parallel to the basal plane and low relief. Muscovite often occurs in close association with biotite, sometimes forming intergrowths.

Quartz are Colorless, anhedral grains with low relief and no discernible cleavage, the grains are often interstitial, filling spaces between other minerals.

Opaque Minerals: Scattered throughout the matrix, these minerals, likely iron oxides, appear black and do not transmit light.

Under cross-polarized light, the optical properties of the minerals become more diagnostic.

Plagioclase are Exhibits first-order gray-to-white interference colors and inclined extinction. Polysynthetic twinning is even more readily visible, aiding in the identification of plagioclase.

Biotite ranging from bright reds and blues to greens and yellows, and exhibits parallel extinction.

Muscovite they, displays bright, high-order interference colors, often showing vivid pinks, greens, and yellows, and also exhibits parallel extinction.

Quartz; They are colorless with low relief exhibiting first-order pale yellow to gray interference colors and undulate extinction. confirming that the quartz crystals have experienced deformation or strain during or after partial melting.

Interpretation

Texture and Composition: The heterogeneous texture, with evidence of partial melting and recrystallization, along with the presence of both igneous-like (e.g., plagioclase, quartz) and metamorphic (e.g., biotite, muscovite) minerals, confirms the rock's migmatitic nature with an estimated modal composition of plagioclase (40-50%), biotite (20-30%), muscovite (10-20%), quartz (10-20%), and opaque minerals (<5%). Migmatite originated from a granitic protolith that underwent partially melted during the Pan-African Orogeny. The presence of biotite and muscovite suggests medium-grade metamorphic conditions. The alteration of biotite to chlorite indicates subsequent hydrothermal alteration or retrograde metamorphism. The undulate extinction in quartz suggests the rock also underwent deformation during or after partial melting. Under plane-polarized light, the porphyritic biotite granite thin section displays a distinct porphyritic texture, characterized by larger phenocrysts embedded in a finer-grained groundmass (Plate 6).

Phenocrysts

Quartz: Large, anhedral (irregularly shaped) grains, often exhibiting embayments or rounded outlines. They appear colorless and transparent with low relief.

K-feldspar (likely Orthoclase): Large, subhedral to euhedral (somewhat well-formed) crystals, often displaying Carlsbad twinning. They may show a faint pink or beige coloration.

Porphyritic Biotite Granite

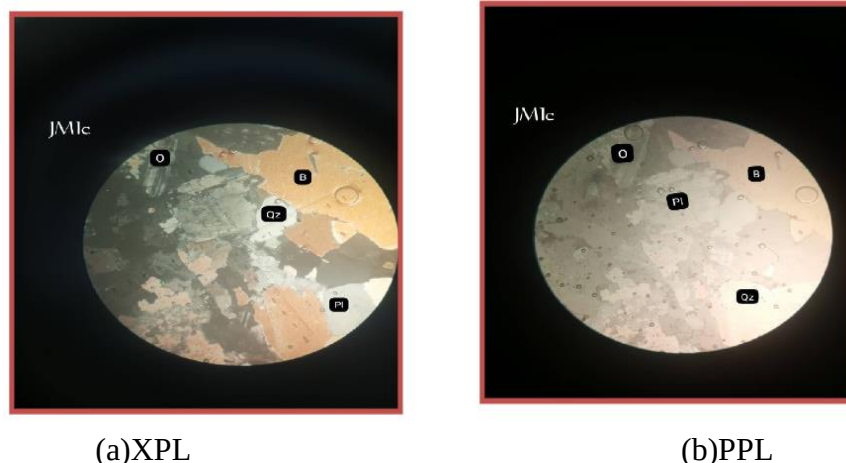


Plate 6. Photomicrographs of Porphyritic Biotite Granite (JM 2) - Magnification $\times 10$

B – Biotite, Qz - Quartz, Mu – Muscovite, Pl – Plagioclase

Groundmass

Quartz: Smaller, anhedral grains, similar to the phenocrysts but significantly smaller than phenocrysts.

K-feldspar: They are smaller grains, often intergrown with quartz form a granophyric texture.

Plagioclase: Present in varying amounts, typically as smaller, tabular crystals with polysynthetic twinning.

Biotite: Brown to reddish-brown flakes with well-developed cleavage parallel to the basal plane. Pleochroism may be observed, with colors changing from light to dark brown upon rotation.

Muscovite: Present in minor amounts as colorless flakes with perfect cleavage and low relief.

Opaque Minerals: Scattered throughout the matrix, these minerals, likely iron oxides, appear black and do not transmit light.

Under cross-polarized light, the optical properties of the minerals become more distinct.

Quartz: Remains colorless with low relief and exhibits first-order pale yellow to gray interference colors. It may display undulose extinction, indicative of strain or deformation.

K-feldspar; Typically shows first-order gray interference colors and may exhibit simple twinning (Carlsbad twinning) or tartan twinning (characteristic of microcline).

Plagioclase; They exhibits first-order gray-to-white interference colors and inclined extinction, meaning the crystal goes dark at an angle to its cleavage planes. Polysynthetic twinning is readily visible, confirming its plagioclase nature.

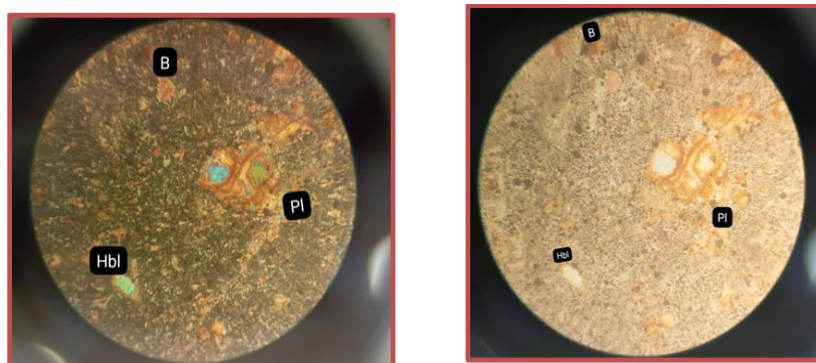
Biotite: Shows third to fourth-order interference colors, ranging from bright reds and blues to greens and yellows, and exhibits parallel extinction.

Muscovite; Displays bright, high-order interference colors, often showing vivid pinks, greens, and yellows, and exhibits parallel extinction.

Interpretation

Texture and Composition; Porphyritic texture, with larger phenocrysts of quartz and K-feldspar set in a finer-grained groundmass, suggests a two-stage cooling history. The initial slow cooling allowed for the growth of the larger phenocrysts, followed by more rapid cooling that resulted in the finer-grained rocks. The mineral assemblage is consistent with a granite composition. **Modal Composition:** Quartz: 30-40%, K-feldspar: 30-40%, Plagioclase: 15-25%, Biotite: 5-10%, Muscovite: <5%, Opaque minerals: <5%. Porphyritic biotite granites are typically associated with intrusive igneous activity, often emplaced at relatively shallow depths within the crust. The presence of larger phenocrysts suggests that the magma underwent some degree of crystallization at depth before intruding into its final position.

Dolerite



(a)XPL

(b) PPL

Plate 7. Photomicrographs of Dolerite (JM 3) - Magnification ×10

B – Biotite, Qz - Quartz, Hbl – Hornblende, Pl – Plagioclase

Microscopic Observations (Plate 7)

Under plane-polarized light, the dolerite thin section exhibits a fine-grained, interlocking texture, indicative of relatively rapid cooling from a melt.

Hornblende; Appears as greenish, prismatic crystals with distinct cleavage planes intersecting at approximately 120° and 60°. Some crystals display a subtle color variation from pale green to deeper green (pleochroism) as the stage is revolved.

Biotite: Presents as brownish flakes with well-developed cleavage parallel to the basal plane. The flakes show strong pleochroism, changing from light brown to dark brown or reddish-brown, depending on the orientation.

Plagioclase: Occurs as white to gray, tabular crystals, exhibiting both anhedral and euhedral shapes. Many plagioclase crystals showcase polysynthetic twinning, parallel fine-scale twin lamellae that appear as alternating light and dark bands under PPL.

Quartz: Present in minor amounts as colorless, anhedral grains with low relief and no discernible cleavage.

Muscovite: Sparse, pinkish-green flakes with perfect cleavage parallel to the basal plane and low relief.

Opaque Minerals: Scattered throughout the matrix, these minerals, likely iron oxides or sulfides, appear black and do not transmit light.

Under cross-polarized light, the optical properties of the minerals become more pronounced.

Hornblende: They displays second-order blue and green interference colors and parallel extinction, where the crystal goes dark when its cleavage planes are positioned with the polarizer. This verifies its amphibious nature.

Biotite: Shows third to fourth-order interference colors, typically ranging from bright reds and blues to greens and yellows, and exhibits parallel extinction.

Plagioclase: Exhibits first-order gray-to-white interference colors and inclined extinction, meaning the crystal goes dark at an angle to its cleavage planes. Polysynthetic twinning is even more readily visible under XPL, aiding in the identification of plagioclase.

Quartz: Remains colorless with low relief and exhibits first-order pale yellow to gray interference colors. It also displays undulate extinction, characterized by a wavy or irregular pattern of darkness as the stage revolves. This confirms that the quartz crystals have experienced some deformation or strain.

Muscovite: Displays bright, high-order interference colors, often showing vivid pinks, greens, and yellows. It also exhibits parallel extinction.

Interpretation

Texture and Composition: Fine-grained, interlocking texture, along with the presence of laths of plagioclase feldspar, suggests a subvolcanic emplacement environment where the magma cooled relatively quickly. The mineral assemblage, dominated by plagioclase, clinopyroxene, and biotite, with minor quartz and accessory minerals, is typical of dolerite. The alteration of pyroxene to hornblende and biotite to chlorite confirms that the rock has experienced some degree of hydrothermal alteration. The undulose extinction observed in quartz suggests that the rock has also been deformation.

Pegmatite

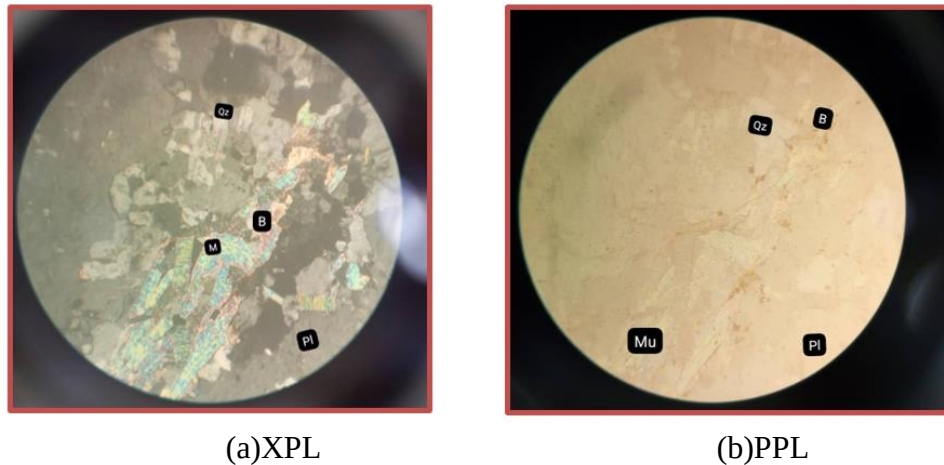


Plate 8. Photomicrographs of Pegmatite (JM 4) - Magnification $\times 10$

B – Biotite, Qz - Quartz, Mu – Muscovite, Pl – Plagioclase

Microscopic Observations (Plate 8)

Under the plane polarized light, the pegmatite's assemblage is visible, they have a strikingly coarse texture due to slow crystallization from a volatile-rich melt.

Quartz: Abundant, large, clear, anhedral grains with irregular boundaries, low relief and lack of cleavage.

Microcline (K-feldspar): Equally prominent, large subhedral to euhedral crystals, cross-hatched twinning is discernible, often accompanied by a subtle pink or beige hue.

Muscovite: Large, platy, colorless to pale brown crystals exhibiting perfect basal cleavage and low relief, contributing to the rock's shimmering quality.

Biotite (if present): Less frequent, appearing as brown to reddish-brown flakes with visible cleavage and pleochroism.

The Cross-Polarized Light reveals the optical properties of the minerals, enhancing the pegmatite's visual complexity:

Quartz: Shows first-order gray to pale yellow interference colors and may exhibit undulose extinction, indicating strain.

Microcline: Has a distinct grid pattern, the cross-hatched twinning is dramatically highlighted.

Muscovite: Vibrant high-order interference colors and parallel extinction, emphasizing its platy form.

Biotite (if present): Exhibits third to fourth-order interference colors, ranging from intense reds and blues to greens and yellows.

Interpretation

Their reflecting slow cooling, volatile enrichment and coarse interlocking texture confirms pegmatitic origin, the dominant mineral assemblage (quartz, microcline, and muscovite) also confirms they are granite pegmatite. Estimated modal composition for Quartz (30-40%), Microcline (30-40%), Muscovite (20-30%), and Biotite (< 5%). Pegmatites represent the final stages of magmatic differentiation forming from residual, volatile-rich melts. Their coarse crystals and rare elements make them both geologically significant and economically valuable. This pegmatite's presence enriches the region's geological history.

Structural Geology of Dangangk and Environs

The Dangangk study area is within the Nigerian Basement Complex, characterized by migmatite, gneiss, and quartzite. Evidence of past tectonic activity is abundant, including joints, foliations with

mineral lineations, veins, and micro-folds (Plate 9). These structures reveal the region's complex deformational history.

Observed Structures

Joints (fractures): These are planar discontinuities in the rock mass, often resulting from brittle deformation under stress. They are particularly well-developed in the migmatite and quartzite units of the study area.

Folds (minor folds): These are wave-like bends in the rock layers caused by ductile deformation under compressional stress. While minor folds were detected, larger-scale folding was also present in the study area.

Foliation: Common feature in the migmatite units, providing evidence of past tectonic activity. This planar fabric results from the alignment of minerals and compositional banding during metamorphism.

Veins: These are infilled fractures. The ones encountered during this research were quartz minerals precipitated from hydrothermal fluids.

Structural Analysis of Joints in the Danggang Area

Significant structural features in rock in the Danggang area are fractures with minor displacement. These fractures, present in competent and incompetent rocks, are vital for understanding the region's deformational history. Their orientation, defined by their strike, provides insights into the stress regimes that have shaped the landscape. Joints form primarily due to extensional stress in brittle rocks, driven by:

Cooling and Contraction: Volumetric reduction in cooling igneous rocks.

Pressure Release: Unloading due to erosion leading to rock expansion.

Tectonic Stresses: Regional or local forces associated with folding and faulting.

These features influence geological processes by:

Providing pathways for fluid circulation, enhancing weathering and erosion.

Acting as conduits for hydrothermal fluids, potentially leading to mineralization.

Joints in the Danggang Area

Rose diagrams were drawn from field measurements of joint orientations analysis, shows that the Joints observed in the study area were abundant in migmatites, indicating a complex deformation history. These trends align with the regions structural patterns documented Rahaman, (1976) and Ogezi, (2002), confirming a consistent tectonic influence. The observed joint orientations also confirm the cumulative effects of multiple tectonic events that have impacted the region.



Plate 9. Observing Joints on Migmatite

Rock Bending

Those mesmerizing wave-like bends in rock layers, are a hallmark of ductile deformation, particularly in metamorphic rocks. These structures arise when initially flat rock surfaces are squeezed by compressional forces, causing them to buckle and warp into complex shapes, imagine a rug forced out from both ends, the resulting wrinkles are analogous to folds in rock. Metamorphic rocks forged under this extreme condition deep within the Earth are prone to folding due to their increased flexibility. Migmatite rocks in the study area with mingled igneous and metamorphic components showcase this. Deformed quartz veins within these migmatites provide valuable clues about the strength and direction of the deforming forces. By analyzing their shape and arrangement, we can reconstruct past stress fields and understand a region's tectonic history. Furthermore, folds can trap oil and gas, making them crucial for hydrocarbon exploration.

Foliations

Foliation, features in metamorphic rocks, it is the parallel alignment of elongated minerals, formed due to uniform deformation during metamorphism, where mineral grains recrystallize perpendicular to the direction of maximum stress, this process creates a planes of weakness that influence its mechanical behavior by permeating the entire rock, (Plate 10). In the Dangkan region, foliation is readily seen in migmatites as banding – alternating layers of light and dark minerals. This banding reflects the intense deformation and recrystallization these rocks underwent deep within the Earth. The migmatites in the study area exhibit well-developed foliation, indicating a high-grade metamorphic history. The abundance of mica and hornblende minerals contributes to this prominent fabric.



Plate 10. Foliation

Veins: Indicators of Geological Processes

Veins, sheet-like mineral bodies filling rock fractures are prominent features in the study area. They form through the precipitation of minerals, primarily quartz, feldspar, and muscovite, from hydrothermal fluids circulating within this opening. Two key processes drive vein formation, they include: Open-Space Filling (Hydrothermal fluids enter open fractures, and as they cool and lose

pressure, dissolved minerals crystallize, filling the void) and Crack-Seal Growth (Repeated cycles of fracturing and mineral precipitation occur. Stress creates a small crack, allowing fluid entry and mineral deposition. Subsequent sealing is followed by renewed fracturing, enabling further mineral growth and often resulting in comb-structured veins).

Veins in the Danggang Area

Quartz veins, formed by silica-rich fluid precipitation, were observed across mapped outcrops. These veins consistently trend NE-SW to NNE-SSW, suggesting alignment with pre-existing structural features (Plate 11). They host economically significant mineral deposits, including gold and silver. The consistent vein orientation points to potential structural controls on fluid flow and mineralization, which increases the economic potential of the study area.



Plate 11. Quartz vein

Structural Measurements and Rose Diagrams

The dominant structural rock features, include: Veins, joints and foliations in the study area revealed by field observations of the basement complex. Joint strike measurements, primarily from migmatite outcrops, used to create rose diagrams illustrating joint orientations (Figure 4). A strong NNE-SSW joint strike trend was confirmed, suggesting control by local stress, possibly related to faults. Subsidiary NE-SW and NW-SE trends indicate a more complex structural history.

Rose Diagram Interpretation: Veins

Quartz veins, the most abundant vein type in the study area, were predominantly observed in the migmatite units. The rose diagram for quartz vein strikes (Figure 5) demonstrates a distinct NE-SW orientation. This alignment suggests a potential structural control on the emplacement of these veins, possibly related to the reactivation of pre-existing fractures or the development of new fractures during deformation.

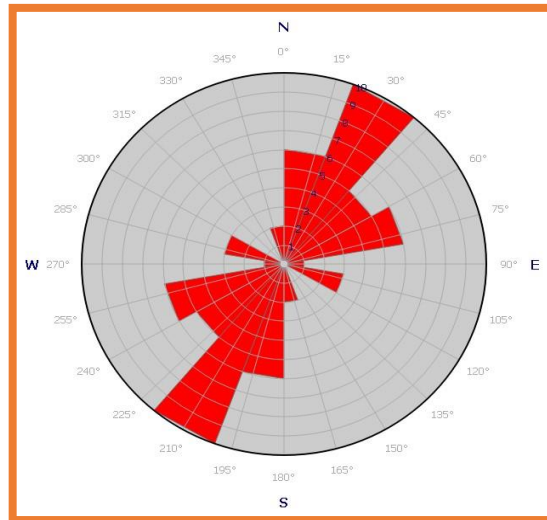


Figure 4 Rose Diagram of Strikes for Joints on Migmatite in the Study Area (GeoRose, 2024)

Number of data = 64

Dominant trend = NNE-SSW

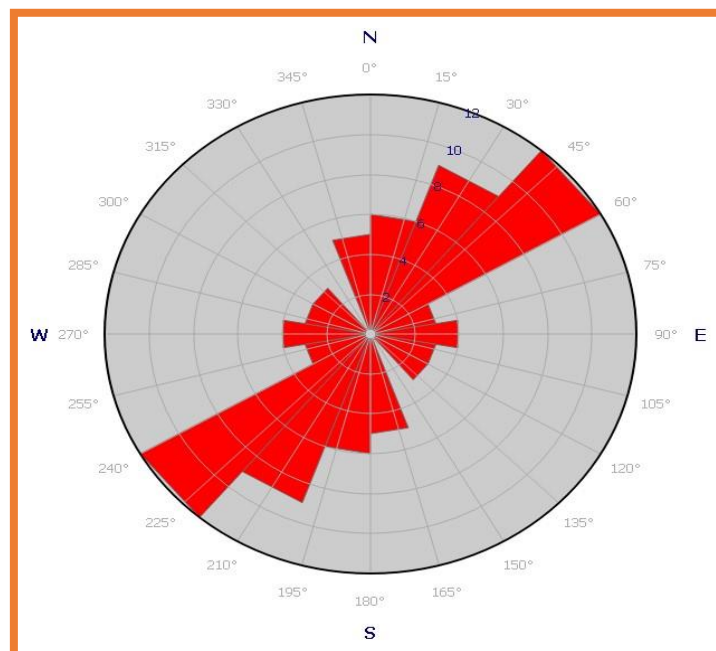


Figure 5 Rose Diagram of Strikes for Quartz Veins on Migmatite in the Study Area (GeoRose, 2024)

Number of data = 41

Dominant trend = NE-SW

Implications and Further Research

The structural measurements and rose diagrams offer valuable insights into the deformational history and tectonic evolution of the Dangkan area. The dominant NNE-SSW joint trend and the NE-SW vein trend is linked to major regional structures and stress fields, while the subsidiary joint orientations reflect local variations in stress.

Geological History of the Dangkan Area

The Dangkan region's geological framework are developed upon the Precambrian Basement Complex, a foundation of migmatite-gneiss, quartzite, and later-intruded dolerite dykes. The presence of these dykes, cutting across the older gneissic rocks, indicates a late to post-tectonic Pan-African

magmatic episode following the primary deformational phase (Obaje, 2009). The area's tectonic history is detaily recorded in the orientations of joints, veins, and foliations. A dominant NNE-SSW structural trend revealed through rose diagrams points to a significant NNW-SSE directed compressional. This stress field shaped the regional structural grain with the consistent orientation of foliation, suggesting an NW-SE maximum stress direction during deformation. These structural features overprint the pre-existing rock fabric of the Basement Complex, confirming their later formation, this confirms the intense metamorphism and ductile deformation seen in the foliated migmatite-gneiss and gneiss units. The alignment of minerals and gneissic banding reflect recrystallization and reorientation under high temperatures and pressures. Quartz and veins aligns with regional structural trends suggesting fluid flow and mineralization associated with tectonic activity. These fractures resulted from stress release following the ductile deformation phase. The Dang Kang area's geological history is a complex sequence of magmatic, metamorphic, and tectonic events spanning billions of years.

The ancient Precambrian Basement Complex was significantly altered during the Pan-African orogeny. Subsequent dolerite dyke intrusions and the development of joints and veins mark later magmatic and tectonic episodes. Future research, including detailed structural and geochronological studies, is crucial for a more precise understanding of the timing and sequence of these deformation events. However, investigating the potential link between the observed structures and mineralization could reveal the region's economic potential.

Discussion

The study area is dominated by Porphyritic Biotite Granite and Migmatite. Accessible by road via the Pankshin-Langtang, this region reveals a landscape sculpted by the interplay of these rock types and their associated structural features. The Migmatite, indicative of partial melting, is a key feature, hosting economically significant minerals such as micas (muscovite and biotite), plagioclase, and quartz. A pervasive network of geological structures, primarily joints, veins, and foliations trending NNE-SSW, demonstrates significant deformation. The drainage patterns and weathering processes in the study area is influenced by these geological. This research provides a more detailed understanding of the Dang Kang area's geology, refining previous regional studies, earlier research recognized migmatites in the broader region. This investigation specifically delineates their occurrence and extent within the study area, a detail missing from the 2004 geological map of Nigeria. Observed structural features, such as microscopic mineral lineation in the Migmatite, suggest a dynamic mineral re-adjustment during metamorphism. The abundance of joints indicates brittle deformation associated with the Pan-African orogeny and subsequent tectonic events, the consistent NE-SW and NNE-SSW trends, in foliations and veins align with the regional tectonic fabric, reflecting maximum stress directions during these events. Furthermore, analyzing joint orientations with dominant NE-SW and NNE-SSW trends, is crucial for engineering and hydrological planning. Petrographic analysis revealed four distinct rock units: Migmatite, porphyritic biotite granite, dolerite, and pegmatite, highlighting a previously undocumented petrographic diversity.

4. Conclusion

The Dang Kang area is a deformed terrain. It features metamorphic rocks, including gneiss and migmatite with characteristic banding, interspersed with quartzite ridges and basaltic intrusions. The region's structural fabric, defined by NNE-SSW trending joints, quartz veins, and foliations, reflects the influence of tectonic forces, particularly the Pan-African orogeny. This structural grain reflectsthe orientation of streams and rivers, and the rocks exhibit brittle and ductile deformation. Petrographic analysis identified a mineral assemblage comprising micas, quartz, feldspar, hornblende, and microcline, providing evidence of the rocks' metamorphic history and the impact of the Pan-African orogeny.

Structural elements like mineral lineation, foliation, minor folds, joints, and veins manifest these tectonic events.

The Dangangk area holds economic potential through its basement rocks, suitable for construction materials. Local communities utilize these rocks for aggregates and hardcore, and abundant sharp sands are available along river channels. The confirmation of quartz, micas, and feldspar in the study area, enhances resource and economic potential for various industries. Sustainable management of limited water resources is also vital. A detailed geological map at a scale of 1:12,500 was developed to provide valuable insight into rock unit distribution, age relationships, and structural framework. This map is essential for resource exploration, environmental management, land-use planning, and infrastructure development.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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