Geology, Field Relationship and Petrography of Rocks Around Luchi and Environs Part of Toro Sheet 148 Se, Toro L.G.A Bauchi State

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Abstract
The study area Luchi and environs lies between latitude 10 00 ' 00" to 10 02' 17" and longitude 9 17' 14" to 9 19' 38.3", part of Toro sheet 148 SE. It is part of the Basement complex of Northeastern Nigeria and is accessible through Bauchi-Jos Road. Field mapping and petrographic studies revealed the area is underlain by banded orthogneiss, stromatic metatexite, biotite granite, with occurrence of dolerite and pegmatitic dykes, and leucosome within the stromatic metatexite. The change in lithology is due to change in partial melting. The field relationship suggests a progressive partial melting, from anatexis of the banded orthogneiss to form stromatic metatexite, with eventual partial melt extraction and crystallization to form the biotite granite, and occurrence of dolerite and pegmatite dykes cross-cutting the stromatic foliation, indicating emplacement along brittle fractures, representing the youngest magmatic phase. The presence of ptygmatic folding, foliations, pegmatitic leucosome within banded orthogneiss and stromatic metatexite indicate partial melting and recrystallization, ductile deformation under high-temperature conditions, and compressional tectonic regimes that affected the study area. Petrography studies, revealed presence of minerals quartz, biotite, muscovite, plagioclase, microcline, hornblend, sanidine, and opaque minerals. Preferred orientation of platy biotite + muscovite + hornblend indicate ductile foliation, while undulose extinction in quartz indicate crystal deformation under tectonic stress. Structures observed include: joints, dykes, sills, foliations, and ptygmatic folding, and field measurements revealed the main structural trend in the study area to be NE-SW, NNW-SSE.

Introduction

The study area form part of the Northeastern Sector of the Nigeria Basement Complex. The North-eastern Nigeria (where the study area is located) comprises of Precambrian basement rocks, represented by migmatites-gneiss complex, older granite suites, and cretaceous to recent sedimentary rocks (Hamman and Haruna, 2023). The study area has migmatites that belong to Migmatites-Gneiss-Complex as major rock types, with dolerite and pegmatitic dyke intrusions. Migmatites-Gneiss-Complex, are polymorphic units believed to have formed from a complex association of deformation, shearing and folding, granitization and migmatization, involving crust-forming processes (Ahmed, 2022). Migmatites are widely developed within the Precambrian Basement Complex of Nigeria, especially in regions affected by the Pan-African Orogeny. These rocks are commonly associated with pegmatites and granitic intrusions, which may host economically valuable minerals. (Babatunde, 2021). The Basement Complex rocks around the study area have received attention from researchers as recorded in available

literatures. Some works have been carried out around the study area which forms part of the Basement Complex of Northeastern Nigeria, but there is not specific characterization to Luchi area. This study therefore, aim to carryout detailed geological mapping and petrographic studies of rocks around Luchi and its environs, which all together will be use to ascertain the geology and petrography characterization of rocks of the study area.

Location of The Study Area

The study area Luchi and its environs lies between latitude 10° 00'00'' to 10° 02'17'' and longitude 9°17'14'' to 9° 19'38.37'' Part of Toro sheet 148 S.E. The area is located in Toro LGA, Bauchi State, Northeastern Nigeria. It covers a total area of about 16km and is accessible through Bauchi Jos Road, the major road linking Bauchi to Rimin Zayam, and outcrops accessible through stream channels and footpaths used by local inhabitants to farm.

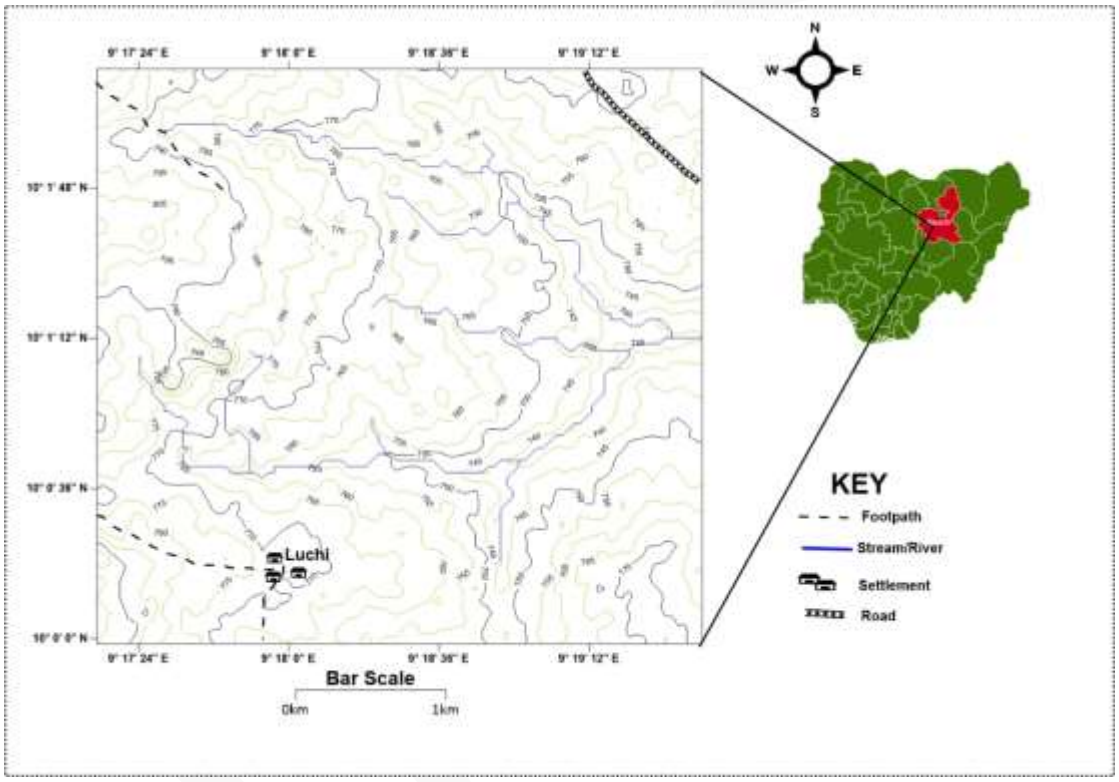


Figure 1: Topographical map of the study area

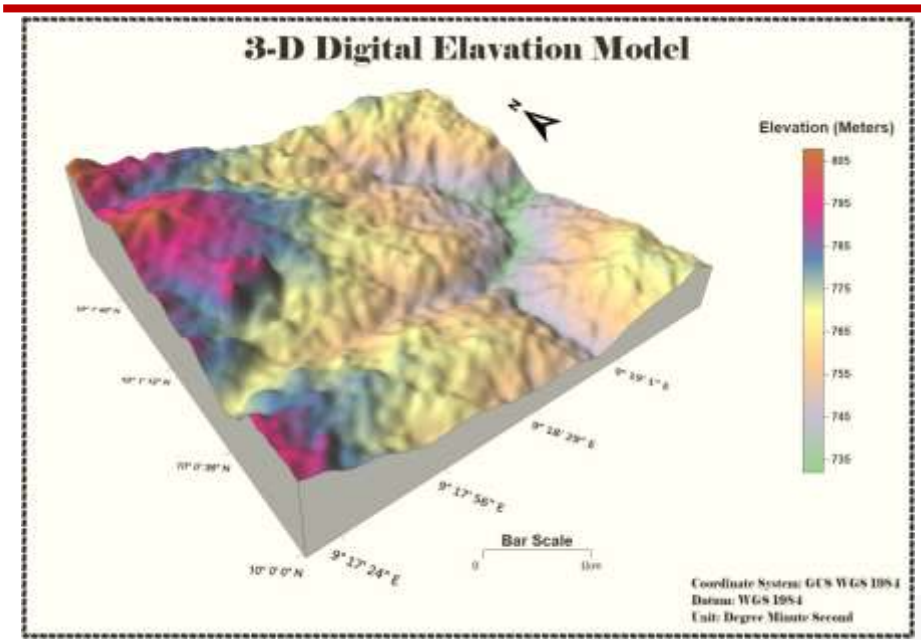


Figure 2: Relief map of the study area

Regional Geology

The study area is part of the Basement complex of Nigeria. The Nigerian basement complex forms a part of the Pan-African mobile belt, and lies between the West African and Congo Cratons, and south of the Tuareg Shield (Black, 1980). The rocks of the Precambrian Basement Complex are the most abundant and widespread of the group of crystalline rocks. They underlie nearly half of the surface of the country (Tijani, 2023), which were intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. Ajibade, et al., (1989), geologically divided the Nigerian Basement Complex into the Western and Eastern Provinces, they can be geographically divided into three viz: The Western Nigerian Basement Complex, the Eastern Nigerian Basement Complex and the Northern Nigerian Basement Complex. The Eastern Nigerian Basement Complex, believed to be a westward extension of the Cameroon basement complex into Nigeria, occupies three regions (Hawal Massif, Adamawa Massif and the Oban Massif.) along the country's eastern border with Republic of Cameroon. North-eastern Nigeria (where the study area is located) comprises of Precambrian basement rocks, represented by migmatites-gneiss complex, older granite suites, and cretaceous to recent sedimentary rocks (Hamman and Haruna, 2023). Migmatites-Gneiss-Complex, are polymorphic units believed to have formed from a complex association of deformation, shearing and folding, granitization and migmatization, involving crust-forming processes (Ahmed, 2022). The Migmatite – Gneiss Complex has ages ranging from Pan-African (900–450 Ma) to Eburnean (2000 ± 200 Ma), and it is the most widespread, constituting about 60% of the Nigerian Basement Complex. It has a heterogeneous assemblage comprising migmatites, orthogneises, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. Petrographic evidence indicates that the Pan-African reworking led to recrystallization of many of the constituent minerals of the Migmatite – Gneiss Complex by partial melting with majority of the rock types displaying medium to upper amphibolite facies metamorphism (Rahaman and Ocan 1978). These rocks in Nigeria have some petrological and geochemical characteristics of a primary igneous origin (Dada, 1999; 2008).

Previous Studies

Some work has been carried out around the study area which forms part of the Basement Complex of Northeastern Nigeria, but there is not specific characterization to Luchi area. Falconer carried the first geological survey in 1911, which was centered on the general geology and geography of Northern Nigeria, where granitic rocks were grouped as Older Granites and Younger Granites, based on field relations. Haruna (2016) discussed the lithology and field relationships of Granitoids of Bauchi district. He identified migmatite gneisses, granites and bauchite of various texture, largely compose of hornblend, pyroxene, plagioclase, biotite, microcline and accessory apatite, zircon, and sphene. He further stress that these Granitoids are probably S-type genetically related to a common source by fractional crystallization of hornblend. Aluwong et al., (2017) carried out a mineral prospect around Toro and environs with the used of remote sensing and GIS, of which this study is partly concerned with. He revealed that the major structural trend are NE-SE and NW-SE and that the rivers and vegetation of Toro and environs are structurally controlled. He identified cassiterite, topaz, aquamarine, zircon and columbite within the area. Adamu et al., (2024) established the petrography, field relationship of migmatites around Gada Biu Maiturare. He identified banded orthogneiss, stromatic metatexite, schlierene and nebulite, with ryolitic dykes/ridges. Petrography studies revealed presence of metamorphic minerals, garnet, silimanite, hornblend, cordierite, with presence of inclusion within the garnet indicating there is economic prospect in the area.

Materials and Method

Materials

Topographic (Base), map Global Positioning System (GPS), compass clinometer, hand lens, measuring tape, geological hammer, field notebook, pen, sample bags, permanent marker, masking tape, camera, and petrographic microscope.

Field Method

The field work for this research was carried out to ascertain the geology and petrography of Luchi and its environs, Northeastern Nigeria. A total area of about 16Km2 was covered, using traverse compass mapping technique. Stream channels and footpaths were used as means of accessing outcrops. Rocks were carefully observed and described on the field notebook based on the following macroscopic feature; color, texture, mineral composition, and foliation. Coordinates. Global Positioning System (GPS) was used to record positions, outcrop coordinates and elevations, (coordinates of sample points were plotted on the base map), which will help in delineating rock, boundaries and their distribution in the study area. Careful measurements of structural features such as strike, dip, dip directions, faults, joints, veins, foliations, dykes, sills folds were taken and recorded to get the tectonic and deformational history of the study area. Representative fresh rock samples were collected systematically from all available rock exposures in the study area with the use of a sledge hammer, labeled respectively in a sequential order using a permanent marker and masking tape and were assembled into the sample bags.

Laboratory Work

Petrography analysis is method used to study the mineralogical composition and textures, and modal percentage of minerals in rocks. After a systematic collection of samples, careful selected samples were taken to the laboratory and thin section slides were produced. The slides were studied using the petrographic microscope under Plane Polarized Light (PPL) and Cross Polarized Light (XPL) to view minerals optical properties such as, colour, relief, form, pleochroism and cleavage, interference colour, twinning and extinction angles.

Photomicrographs of the thin sections were also produced by the used of phone camera. The thin section slides used for laboratory analysis were produced at the "Thin Section Laboratory of Department of Applied Geology, Abubakar Tafawa Balewa University (ATBU), Bauchi.

Result and Discussion

Geology of The Area

Field observation and petrography studies of twelve (12) labelled B7, B1, B4, B2, B5, B2B, B6, B8B. B3A, B4B, B3B, and B5B, shows that the study area is underlain by different lithology, which include: banded orthogneiss stromatic metatexite, pegmatitic leucosome, biotite granite, with minor occurrence of dolerite dyke intrusions within the stromatic metatexite (fig 3). The structures observed within the study area include: joints, dykes, sills, gneissic foliations, and ptygmatic folding, provide insight into the deformational history of the area.

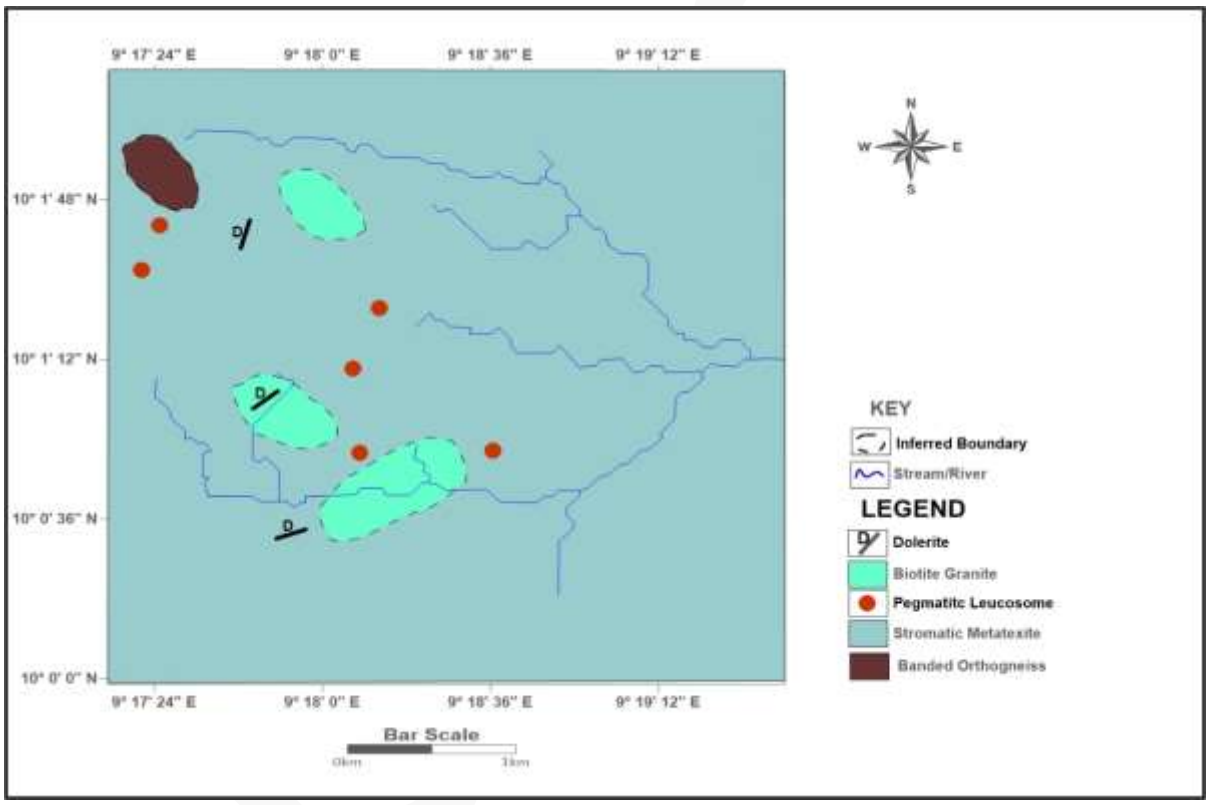


Figure 3: Geological map of the study area

FIELD OBSERVATION

Banded orthogneiss occur in minor amount, as low lying outcrops and along stream channels. Its outcropping mainly at the Northwestern portion of the study area. The rock appears medium to coarse grained, mesocratic (light to dark gray), foliated, with quartz, feldspar and biotite composition in hand specimen. The stromatic metatexites is the dominant rock unit in the study area by areal extent, and it occupies approximately 80% of the study area It is well foliated, medium to coarse grained, mesocratic to melanocratic (light to dark gray), with quartz, feldspar and biotite composition in hand specimen. The occur as low lying and also as range of high hills, generally elongated along the strike of foliations, with general trend of foliations NNW-SSE, parallel to region Pan African deformation. Pegmatitic leucosomes were also observed occurring within the stromatic metatexites, it is coarse grained, having predominantly quartz

and feldspar composition in hand specimen. The biotite granite occurred in the middle NW and SW portion of the study area, occurring as highly elevated and as massive outcrops. It appears medium to coarse grained in texture, mesocratic (light grey), with quartz, feldspar and biotite composition in hand specimen. The dolerite occurred in the study area in form of dykes (discordant bodies), cross cutting the foliations of stromatic metatexites, with width ranging from 40 centimeters to 2.5 meters, trending predominantly NNE-SSW direction. It appeared melanocratic (dark gray), fine grained in texture.

Field Relationship

The banded orthogneiss which is the oldest rock in the study area represents the protolith of the stromatic metatexite and biotite granite, from which melting begins. It grades into stromatic metatexite with increasing degree of partial melting, characterized by development of leucosome (quartz-feldspar) and melanosomes (biotite, hornblend), bands, with bands appearing parallel to gneissic foliation and some exhibiting ptygmatic folding (*plate I*). The biotite granite occurred as massive bodies within the stromatic, mesocratic (light grey), with quartz, feldspar and biotite composition in hand specimen. Formed through magma mixing, during partial melting of stromatic metatexite, (hybridization). The transformation is marked by the destruction of the stromatic structure, leading to textural homogeneous rock. Pegmatitic leucosomes were also observed within the stromatic metatexites, is coarse grained and composed mainly of quartz and feldspars (*plate III A*). The pegmatitic leucosome represents a later stage of volatile-rich melt segregation and migration from the metatexite source. Dolerite occurred cross-cutting the stromatic banding and foliation, indicating emplacement along brittle fractures, representing the youngest mafic magmatic phase (*plate III B*). This crosscutting relationship indicate that the intrusion post-dates the Pan-African migmatization.

Plate I: field occurrence of stromatic metatexite, showing (A) leucosome band occupying foliation, (B) ptygmatic folding in the study area.

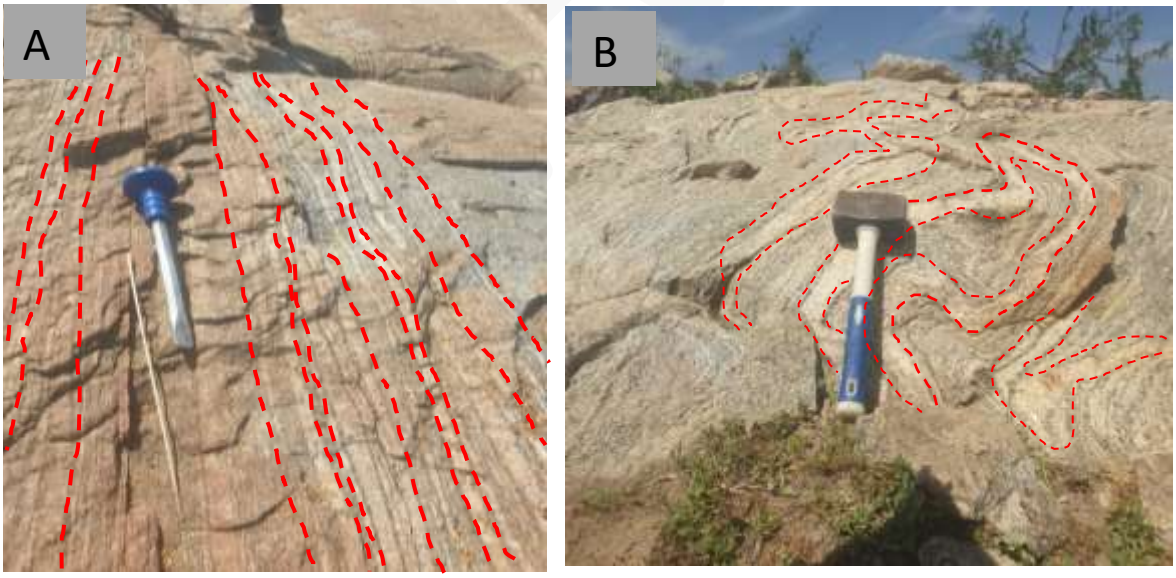


Plate II: field occurrence of (A) Banded Orthogneiss (B) Biotite granite in the study area.



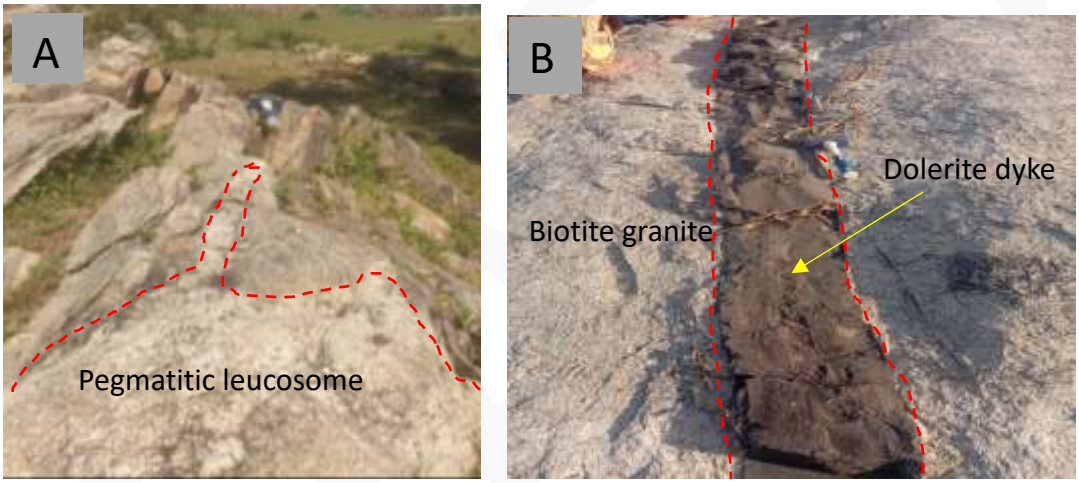


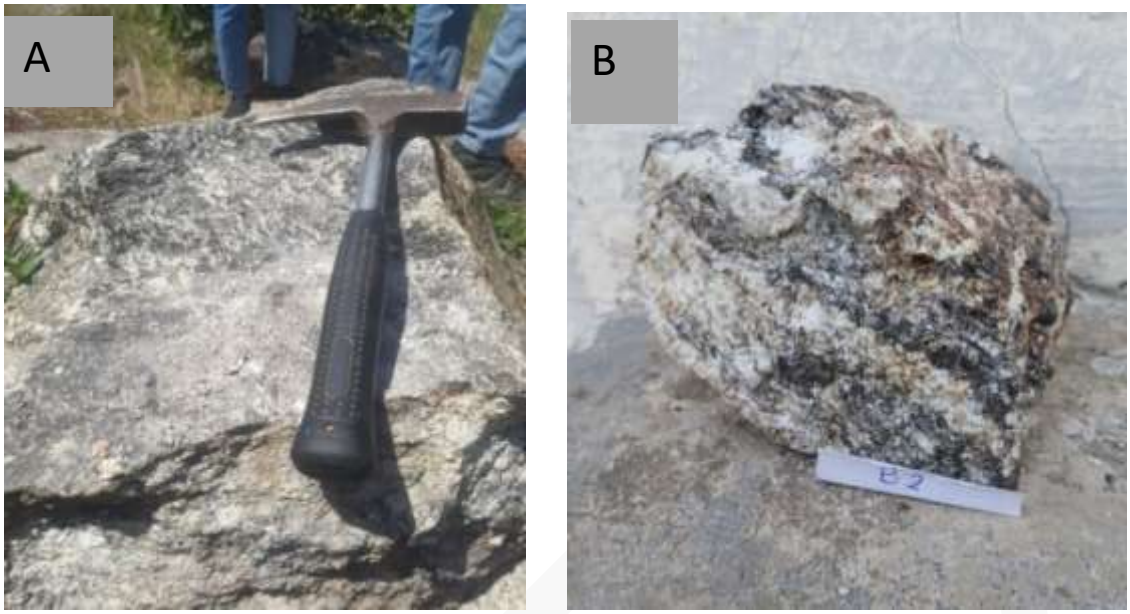
Plate III: Field View Showing (A) Pegmatitic Leucosome (B) Dolerite dyke in the study area.

Petrography Studies

Banded Orthogneiss

In banded orthogneiss, quartz appears colourless, anhedral shape, with low relief, under plane polarized light and showing undulose extinction under cross polarized light. The biotite appears brown, euhedral (elongated platy) shape, with high relief, displaying one directional perfect cleavage under plane polarized light. It appears dark brown with no twining under cross polarized light. Muscovite occur colorless subhedral (tabular) shape, moderate relief, with one directional perfect cleavage under plane polarized light. exhibiting second to third order green, red, blue, purple interference colour under cross polarized light. Opaque minerals aligning within the muscovite and biotite, appearing black under both plane polarized light and cross polarized light.

Plate IV: (A) field occurrence (C) hand specimen banded orthogneiss in the study area.



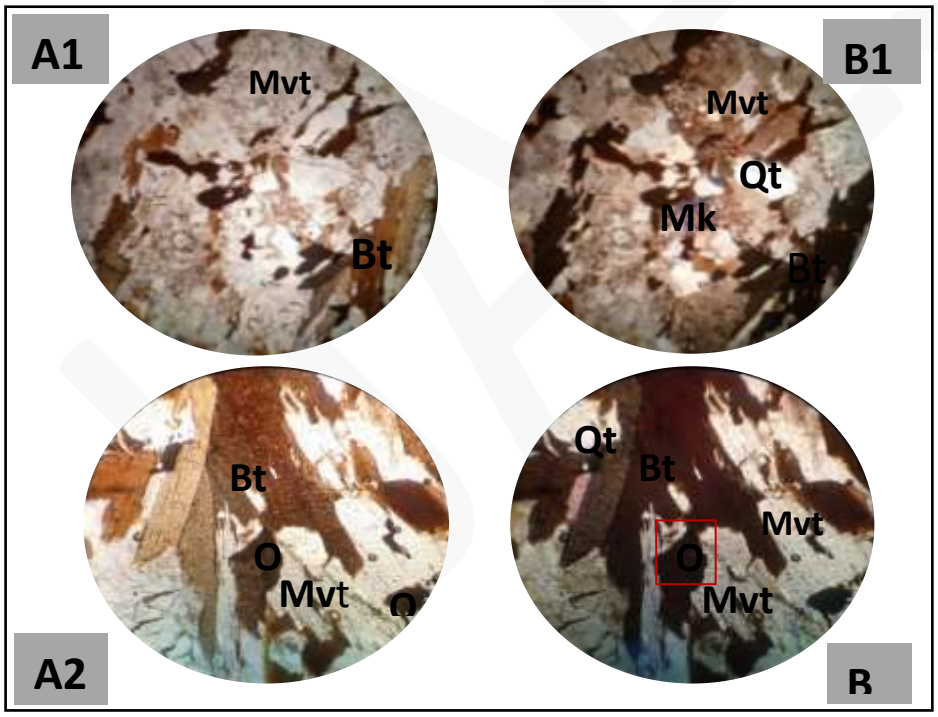


Plate V: photomicrograph of banded orthogneiss (A1 and A2) under PPL (B1 and B2) under XPL. (Qt=Quartz, Bt=Biotite, Pg=Plagioclase, Mvt=Muscovite, O=Opaque, Mk=Myrmekite.), (Magnification A1 and B1=X40, A2 and B2= X100).

Stromatic Metatexite

The quartz appears colourless, anhedral shape, with low relief, under plane polarized light, showing undulose extinction under cross polarized light. Biotite appears brown, euhedral (elongated platy) shape, with moderate to high relief with strong pleochroism, displaying one directional perfect cleavage under plane polarized light. Muscovite appears colorless subhedral (tabular) shape, low to moderate relief under plane polarized light. It exhibits second to third order blue and purple interference colour under cross polarized light. Hornblend appears green to brownish yellow, subhedral shape, medium to high relief, showing strong pleochroism under plane polarized light. Exhibit first to second order interference colour, masked by its dark colour, under cross polarized light. Some of the hornblend appear as tabular crystals, while others as prismatic elongated crystals, with little biotite. Plagioclase appears colorless, anhedral to subhedral shape, with cleavage and low relief under cross polarized light. Exhibit first to second order gray to slightly brown interference colour and exhibit albite twinning under cross polarized light.

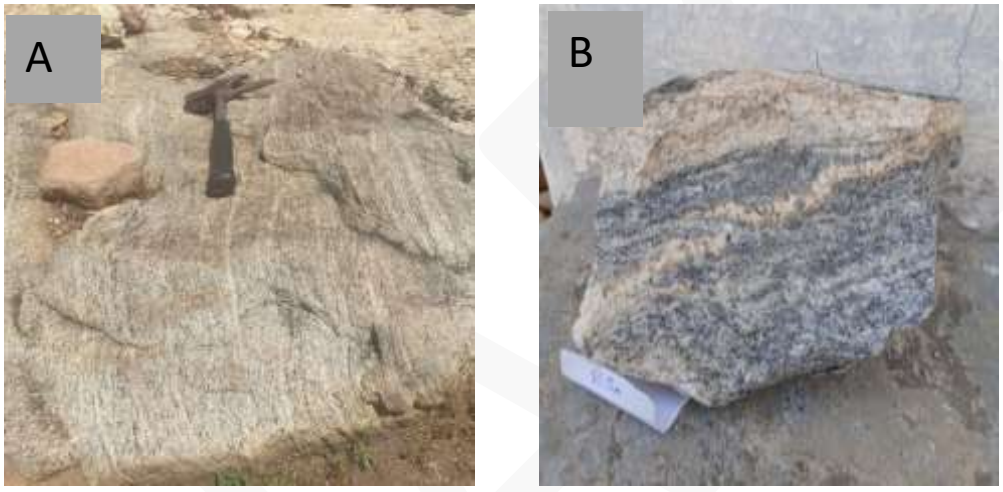
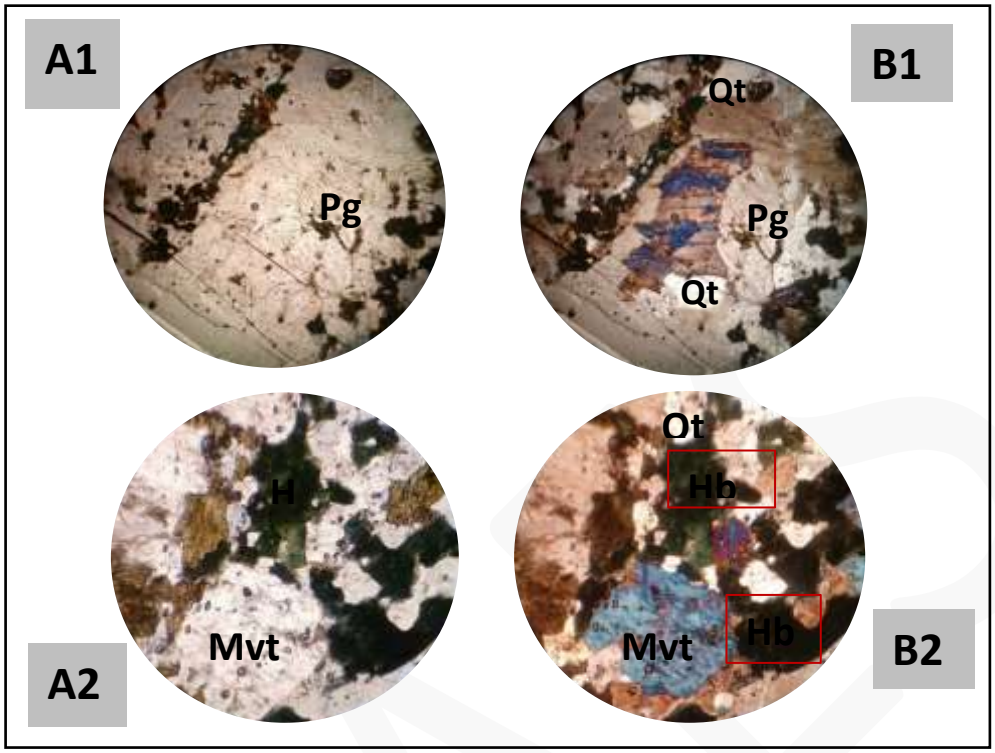


Plate VI: (A) field occurrence (B) hand specimen of stromatic metatexite in the study area.

Plate VII: photomicrograph of stromatic metatexite (A1 and A2) under PPL (B1 and B2). (Qt=Quartz, Bt=Biotite, Pg=Plagioclase, Mvt=Muscovite, Hb=Hornblend.) (X100 Magnification).



Pegmatitic Leucosome

Quartz in pegmatitic leucosome appears colourless, anhedral shape, low relief, with interference colour of pale yellow. Biotite appears brown, euhedral (elongated platy) shape, moderate to high relief, with strong pleochroism, and displaying one directional perfect cleavage under plane polarized light. Microcline appears colourless, anhedral shape, with low relief under plane polarized light. It appears colourless, exhibiting crosshatch twining under cross polarized light.

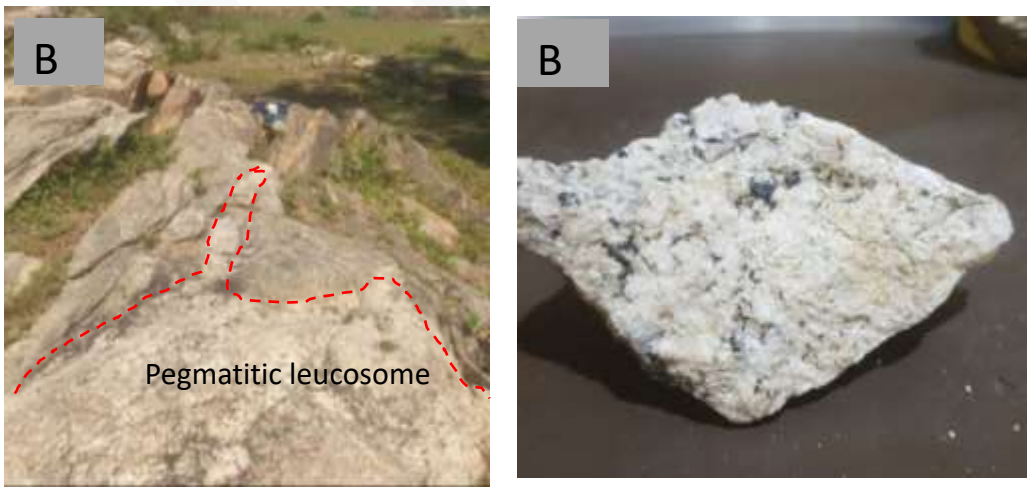
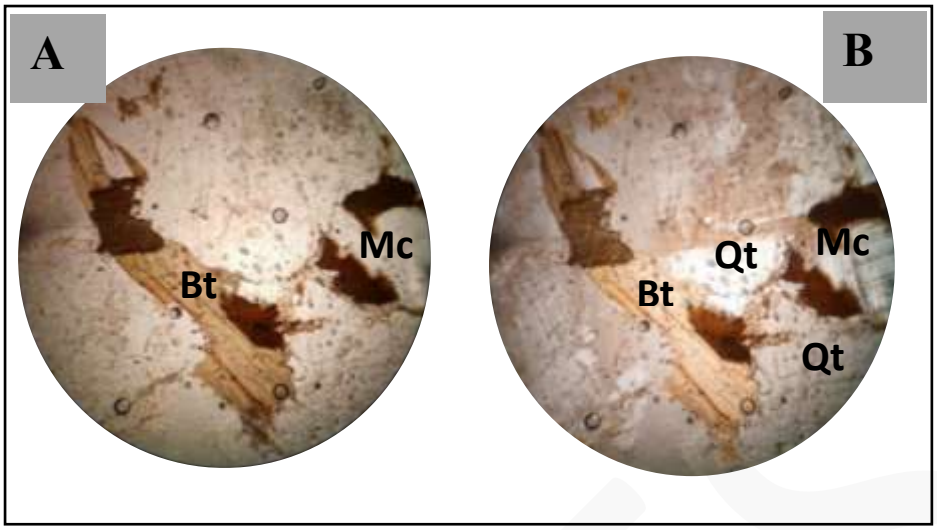


Plate VIII: (A) field occurrence (B) hand specimen of pegmatitic leucosome in the study area.

Plate IX: photomicrograph of pegmatitic leucosome (A) under PPL (B) under XPL (Qt=Quartz, Bt=Biotite, Pg=Plagioclase, Mc=Microcline). (X100 Magnification)



Biotite Granite

In biotite granite Microcline appears colourless, anhedral shape, with low relief, and exhibiting crosshatch twining under cross polarized light. Quartz appears colourless, low relief, with absence of cleavage under plane polarized light. Biotite appears brown, euhedral (elongated platy) shape, with high relief and strong pleochroism, displaying one directional perfect cleavage under plane polarized light. It appears dark brown with no twining under cross polarized light. Opaque minerals appear shapeless and black under both plane polarized light and cross polarized light.

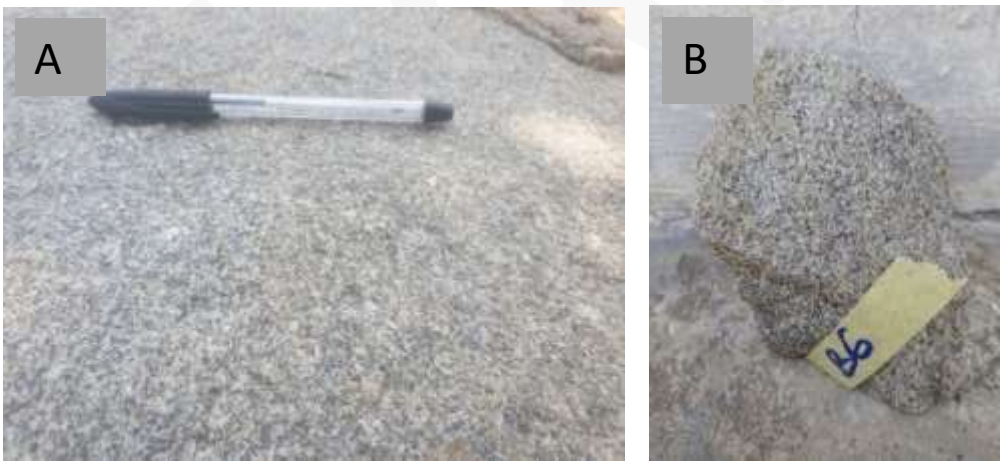


Plate X: (A) field occurrence (B) hand specimen of biotite granite in the study area.

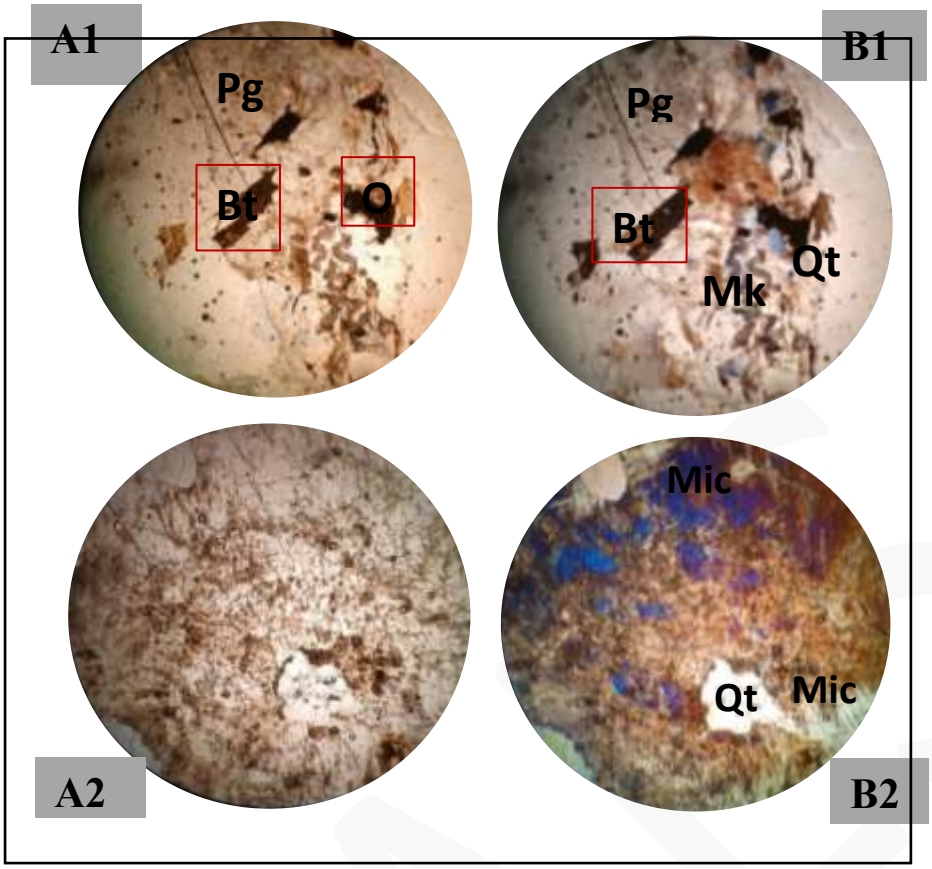


Plate XI: photomicrograph of biotite granite (A1 and A2) under PPL (B1 and B2) under XPL. (Qt=Quartz, Bt=Biotite, Pg=Plagioclase, Mc=Microcline, Mk=Myrmekite, O=Opaque). (Magnification A1 and B1=X40, A2 and B2= X100).

Dolerite

Plagioclase appears colorless, as elongated tabular crystals with low relief under plane polarized light. And second order white to gray interference colour under cross polarized light. Pyroxene appears pale green to brown, subhedral in shape with high relief shape under plane polarized light. And it displays first to second order green under cross polarized light. With dark opaque minerals.

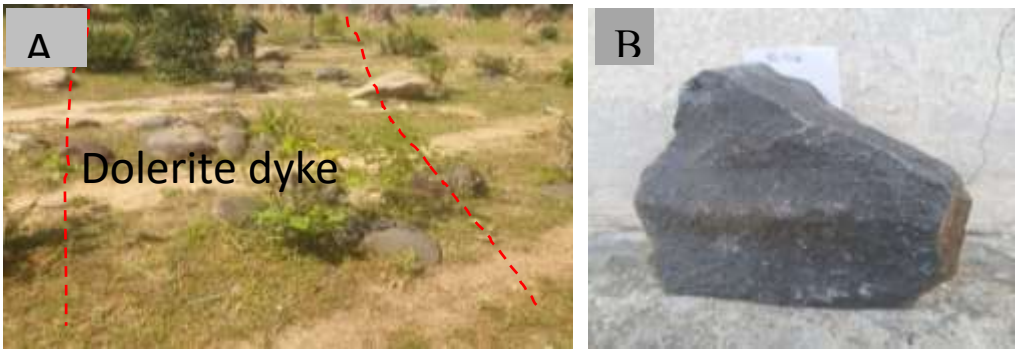


Plate XII: (A & B) field occurrence (C) hand specimen of dolerite in the study area.

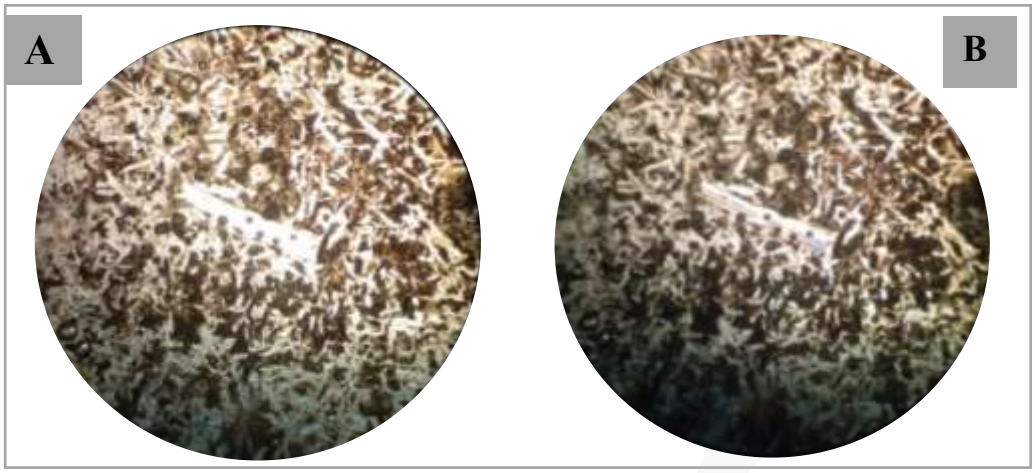


Plate XIII: photomicrograph of dolerite (A) under PPL (B) under XPL. (X40 Magnification).

Discussion

The study area is part of the Basement complex of Nigeria. Field mapping and petrographic studies provide insight into the texture, composition and other characteristics of rocks within the study area. Field mapping and petrography revealed the area is underlain by different lithological units, including: banded orthogneiss, stromatic metatexite, pegmatitic leucosome, biotite granite, with minor occurrence of dolerite dykes. The field relationship suggests a progressive partial melting, from anatexis of the banded orthogneiss to form stromatic metatexite, with eventual partial melt extraction and crystallization to form the biotite granite, and occurrence of dolerite dykes cross-cutting the stromatic foliation, indicating emplacement along brittle fractures, representing the youngest magmatic phase. The texture differences between pegmatitic leucosome and dolerite suggest the rate and depth at which the magma crystallized. Pegmatitic leucosome (very coarse-grained) crystallized very slowly beneath the earth's crust often from volatile- rich magma, while dolerite (fine-grained) crystallized rapidly on the earth surface. The structures observed within the study area include: joints, dykes, sills, gneissic foliations, and ptygmatic folding, which provide insight into the deformational history of the area. Field measurements revealed the main structural trend in the study area to be NNE-SSW, NNW-SSE. The presence of ptygmatic folding, foliations (banding), pegmatitic leucosome within banded orthogneiss and stromatic metatexite indicate partial melting and recrystallization, ductile deformation under high-temperature conditions, and compressional tectonic regimes (shearing) that affected the study area. Petrography studies, revealed presence of quartz, biotite, muscovite, plagioclase, microcline, hornblend, orthoclase, and opaque as dominant minerals in rocks. The abundance of quartz and feldspar especially in pegmatitic leucosome shows the felsic nature of the rocks, while the presence of high temperature minerals like biotite and hornblend indicates medium to high metamorphic grade. Preferred orientation of platy biotite + muscovite + hornblend indicate ductile foliation, undulose extinction in quartz indicate crystal deformation under tectonic stress.

Conclusion

In conclusion, the study area is part of the Basement complex of Nigeria, underlain banded orthogneiss, stromatic metatexite, pegmatitic leucosome, biotite granite, and dolerite dykes. The field relationship suggests a progressive partial melting, intense deformation during the

Pan-African orogeny and emplacement of youngest magmatic phase along brittle fractures. Petrography studies, revealed presence of quartz, biotite, muscovite, plagioclase, microcline, hornblend, orthoclase, and opaque as dominant minerals in rocks.

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