Petrography of Rocks Around Rudibida Ganjuwa, Bauchi State, Part of Sheet 128 Se,

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Abstract
This research investigates the geology and petrography of the basement rocks around Rudibida in Ganjuwa LGA, Bauchi State, Nigeria, within coordinates N10° 30′ 56″–N10° 32′ 56″ and E9° 56′ 42″–E10° 0′ 00″. Field mapping identified a migmatite-gneiss complex displaying classic anatectic structures - stromatic banding, pinch-and-swell boudinage, ptygmatic folding and penetrative gneissic foliation - intruded by concordant, syn-tectonic pegmatite sills/dykes and later, discordant, post-tectonic east-west trending basaltic dykes. Petrographic study of seven representative thin sections (BL1, BL2A, BL3, BL6, BL16, BL20 and BL22) confirmed a dominantly granitoid (hornblende/biotite granite and granodiorite) mineralogy, with one sample (BL2A) recording a sillimanite-muscovite metasedimentary signature, one (BL22) recording an orthopyroxene-cordierite granulite-facies assemblage, and one (BL3) confirmed as an olivine basalt. The area is hence part of the pan African Migmatite terrain of the basement complex of Nigeria.

Keywords: *petrography, migmatite, metasedimentary*

Introduction

Understanding the geology, petrography, and geochemistry of any region provides critical insight into its tectonic evolution, mineralization potential, and resource development prospects. Basement Complex terrains of northern Nigeria part of the Pan-African mobile belt are characterized by diverse lithologies, structural imprints, and varied mineral assemblages resulting from multiple orogenic cycles (Ajibade & Wright, 1989; Rahaman, 1988). Detailed geological studies of such terrains enhance knowledge of lithological variations, deformation history, and geochemical signatures that guide mineral exploration and regional geological interpretations.

The geological evolution of the Earth's crust has resulted in the distribution of diverse rock types, tectonic features, and mineral resources across continents. Understanding the geology of a specific area requires situating it within broader global, continental, and regional geological frameworks. The study area around Rudibida in Ganjuwa LGA, Bauchi State, lies within the Nigerian Basement Complex, which forms part of the extensive Pan-African Mobile Belt a major tectonothermal province that extends across West, Central, and East Africa (Kennedy, 1964; Windley, 1995).

The Nigerian Basement Complex occupies the western part of the Pan-African Mobile Belt, sandwiched between the West African Craton to the west and the Congo Craton to the southeast.

It comprises Precambrian to Lower Paleozoic rocks that have undergone repeated deformation, metamorphism, and magmatism during the Liberian (~2700 Ma), Eburnean (~2000 Ma), Kibaran (~1100 Ma), and Pan-African (~600 Ma) orogenies (Rahaman, 1988; Wright, 1985).

The literature on Nigeria's Basement Complex spans over five decades, beginning with foundational studies such as McCurry (1971), Turner (1983), Rahaman (1988), Ajibade & Wright (1989), Garba (2002), and Dada (2008), which established the structural, sedimentological, metamorphic, and geochronological framework of the terrain, including the Pan-African Belt and its schist belts. More recent work has focused intensively on the migmatites and charnockites of the Hawal Massif in Bauchi State, using integrated field mapping, petrography, and whole-rock geochemistry. Studies such as Ahmed et al. (2017), Yahuza et al. (2020), Jibrin et al. (2021), Magaji et al. (2021), and Hassan et al. (2025) have characterized lithologies ranging from banded orthogneisses and metatexites to diatexites and anatectic granites, documenting ferroan, peraluminous compositions, granulite-facies assemblages, and a west-to-east metamorphic gradient consistent with Pan-African orogenesis (450–750 Ma).

Collectively, these studies highlight polyphase deformation, CO_2-rich fluid conditions, and partial melting of mixed sedimentary–igneous protoliths as key petrogenetic processes, while debates persist over the origin of Bauchi charnockites—specifically whether they formed by granulite-facies dehydration of biotite gneiss or as Pan-African lower-crustal partial melts. Economic implications are increasingly emphasized, with widespread fracturing, alteration, and weathering suggesting significant mineralization and groundwater potential; pegmatites in Kariya have yielded tantalite, lithium-mica, and beryl, and elevated Zr and V in migmatites hint at untapped resources. However, gaps remain, including limited whole-rock geochemistry in some areas and unresolved fluid-inclusion data, prompting recommendations for targeted geochemical profiling, fluid-inclusion analyses, and detailed exploration across the region, including work such as Abubakar Ahmed Maikudi et al. (2026) on Lafiyari and environs.

The study area around Rudibida in Ganjuwa Local Government Area of Bauchi State falls within the Kafin Madaki Sheet 128 SE, representing part of the Northern Nigerian Basement Complex, composed predominantly of migmatites, granites, and various supracrustal units (Oyawoye, 1972). Despite its geological significance, the area remains largely under-studied, with scarce petrographic and geochemical data. A systematic investigation is therefore necessary to map the lithologies, characterize their mineral contents, and determine the geochemical processes responsible for their evolution.

Materials methods

Study Area

The study area is located in Ganjuwa Local Government Area, southeastern Bauchi State, on the Kafin Madaki topographic/geologic sheet (128 SE). It lies between Latitude: 10° 30′ 56″ N to 10° 32′ 56″ and Longitude: 9° 56′ 42″ E to 10° 00′ 00″ E. The mapped area covers approximately 25 km² and lies at an average elevation of ~584 m above sea level.

The area is accessible through a road about 15km off Bauchi – Kano Federal highway adjacent to ATBU Gubi Campus. The study area Rudibida is easily accessible by motor vehicle, motorcycle, and footpaths that give access to the remote areas where these outcrops area locate with high- and low-level elevations.

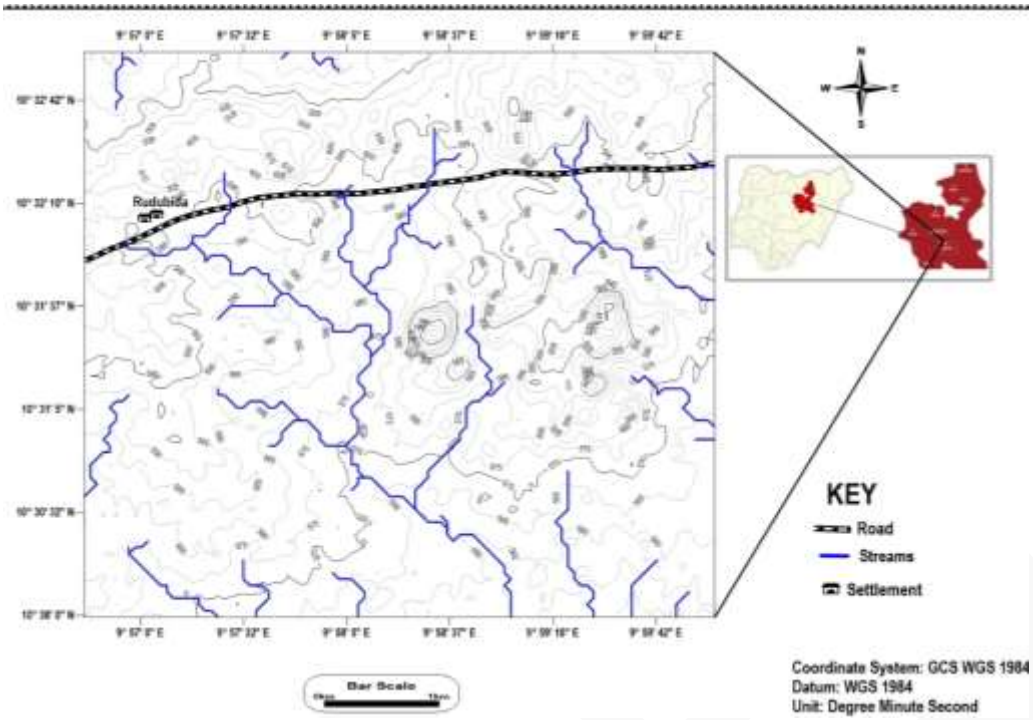


Figure 1: Location Map of the Study Area

The study area lies at an average elevation of ~584 m, characterized by gently undulating topography typical of the Northern Basement Complex terrains (McCurry, 1971). The relief consists of:

- Low-lying hills composed of stromatic and granitoids rocks.
- Broad plains with thin soil cover.
- Occasional inselbergs and isolated rock exposures.

Drainage is predominantly dendritic, controlled by structural features and rock types. Seasonal streams flow during the rainy season and empty into larger tributaries linked to the River Benue system. The drainage pattern reflects the influence of jointing and foliations in the basement rocks.

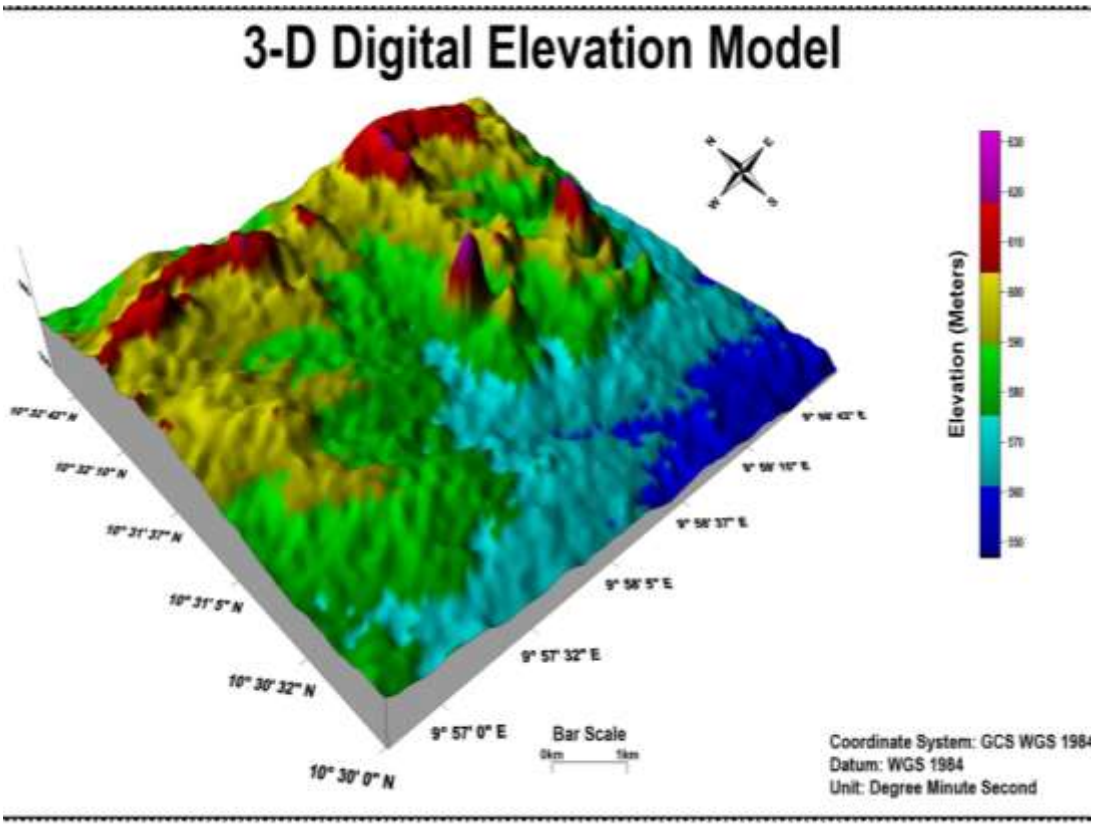


Figure 2: Relief Map of the Study Area in 3D

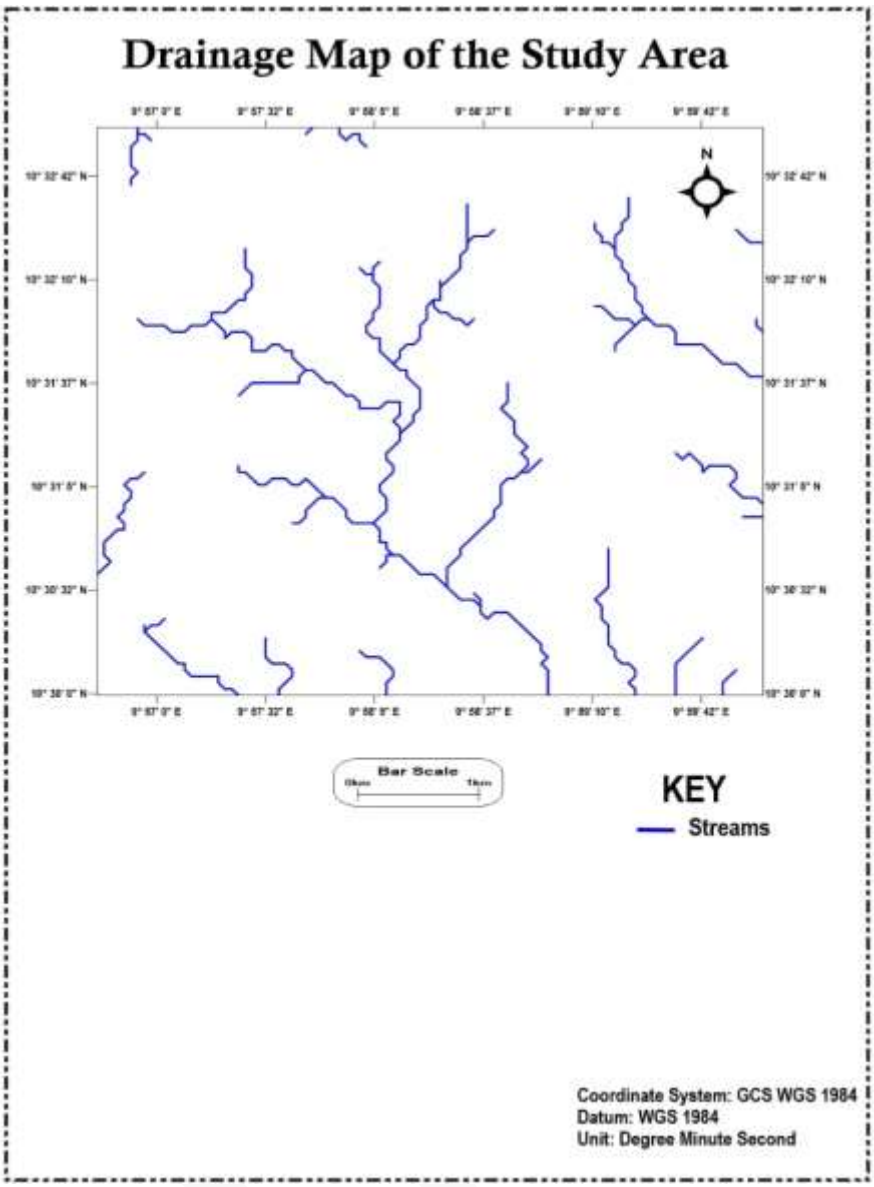


Figure 3: Drainage Map of the Study Area

Fieldwork

Fieldwork formed the foundation of this study and involved reconnaissance surveys, detailed geological mapping, structural measurements, and systematic sampling of representative lithological units across the mapped area. Emphasis was placed on identifying lithologic boundaries, recording rock-textural features, describing mineral assemblages, and documenting structural elements such as foliations, fractures, joints, and fold patterns. All field observations were recorded in a field notebook, and coordinates of sampling stations were captured using a GPS receiver.

Geological Mapping

Geological mapping was conducted at an appropriate scale to identify, delineate, and document the spatial distribution of lithological units. Mapping activities included:

Determining the rock types and their boundaries
Identifying primary and secondary structures (foliation, lineation, joints, quartz veins, folds)
Describing textures, mineralogy, and weathering profiles
Establishing the relationships among mapped units
Recording strike and dip measurements using a Compass–clinometer
Topographic Sheet 128 SE served as the base map for field navigation and plotting of geological features. Mapping traverses followed natural exposures along road cuts, river channels, farmlands, and rocky outcrops.

Field Equipment

The following tools and instruments were employed during the field study:
Geological Hammer**:** For breaking rocks to obtain fresh surfaces for lithological identification.
Compass/Clinometer**:** Used for measuring strike, dip, and orientation of planar and linear geological features.
Global Positioning System (GPS): For obtaining accurate coordinates of sampling points and key geological features.
Sample Bags & Markers**:** For labeling and storing collected samples.
Field Notebook and Camera**:** For recording detailed observations and capturing photographic evidence.

Field Procedures

The field procedures followed systematic steps to ensure accuracy and reliability:
Survey**:** Identification of the major rock exposures and access routes.
Mapping**:** Conducted along predefined lines to ensure total coverage of lithological units.
Geological Descriptions**:** Each outcrop was described in terms of color, grain size, texture, mineralogy, weathering, and structural attributes.
Structural Measurements**:** Documentation of strike, dip, joint orientations, and vein patterns.
Boundary Delineation**:** Lithological boundaries were traced and marked on the base map.
Sample Labeling**:** Each collected sample was assigned a unique code, geo-referenced, and stored appropriately.

Sample Collection

A total of 25 rock samples were collected from different lithological units across the study area. Out of these, 10 samples were selected for petrographic and geochemical analyses based on:
Freshness
Representativeness of lithological units
Textural and mineralogical diversity
Each sample was labeled with:
Sample code
GPS coordinate
Lithology and field description
The systematic sampling ensured wide coverage of the study area's major rock types.

Laboratory Work

Laboratory investigations were conducted to determine the mineralogical, and textural characteristics of the collected samples. These include petrographic (thin-section preparation and microscopic analysis) analysis.

Petrographic studies involved preparing thin sections of selected samples and examining them under a polarizing microscope. The aim was to identify mineral constituents, assess textural relationships, and classify the rocks based on mineralogical criteria.

Two modes of microscopic observation were used:

Plane Polarized Light (PPL): For observing color, pleochroism, habit, cleavage, relief, and transparency.

Cross Polarized Light (XPL): For identifying interference colors, twinning, extinction angles, and birefringence.

These observations provided key information on the crystallization history, metamorphic grade, and deformation features of the rocks.

Laboratory Procedure for Thin Sectioning

Thin section preparation followed the standard steps:

Cutting: Samples were cut into billets using a diamond saw.

Mounting**:** Billets were mounted onto glass slides using epoxy resin.

Grinding**:** The mounted samples were ground to reduce thickness using progressively finer abrasives.

Polishing**:** Final polishing ensured a smooth surface.

Thinning**:** Samples were ground further to the standard thickness of ~30 µm.

Final Inspection: Finished thin sections were inspected for cracks, inclusions, and uniformity.

3.3.3 Precautions in Thin Section Production

Precautions taken during thin-section preparation include:

Ensuring that equipment (cutting and grinding machines) were properly cleaned to avoid contamination.

Avoiding overheating samples during grinding.

Maintaining uniform thickness throughout each section.

Using clean resins and adhesives to prevent inclusion of foreign particles.

Proper labeling of samples to avoid mix-ups.

Checking for air bubbles during mounting.

Slide Viewing Technique under the Optical Microscope

Thin sections were examined using a polarizing microscope following these guidelines:

Starting with low magnification to gain a general overview.

Switching between PPL and XPL to compare optical properties.

Rotating the stage to observe extinction angles, birefringence, and pleochroism.

Documenting mineral proportions, grain boundaries, alteration features, and textures.

Photographing important mineral relationships for documentation.

Results

Field Relationship

Field mapping of the study area revealed a basement terrain dominated by migmatite-gneiss complexes intruded by pegmatite, aplite and basaltic bodies (Figure 4). The rocks display a variety of primary and secondary structures that record a polyphase history of partial melting (anatexis), deformation and later brittle-ductile intrusive events. These structures are documented in Plates below.

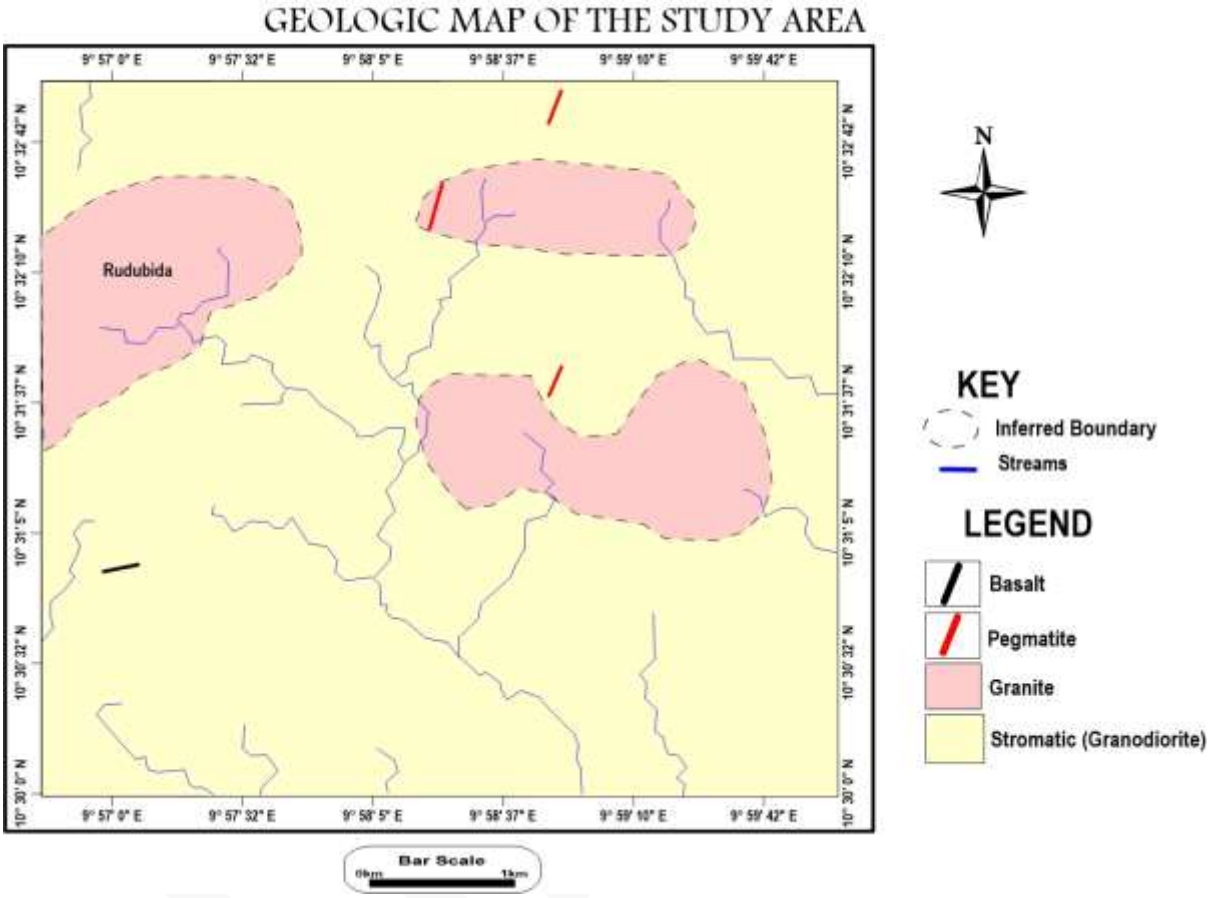


Figure 4: Geologic map of the study area

Migmatites



Plate I: Field photographs showing the characteristic stromatic banding of the migmatites, with the melanosome (biotite/hornblende-rich, mafic, dark band) and leucosome (quartzo-feldspathic, felsic, light-coloured band) delineated by the dashed red lines

Plate 1 illustrates the classical anatectic banding that characterises the migmatites of the study area. The alternating melanosome and leucosome bands define a stromatic (layered) migmatite structure produced by partial melting (anatexis) of a pre-existing gneissic protolith under upper amphibolite- to granulite-facies conditions. The melanosome, rich in refractory ferromagnesian minerals (biotite ± hornblende), represents the residuum (restite) left after the felsic melt fraction was extracted, while the leucosome represents the crystallised product of the in-situ partial melt (neosome), dominated by quartz and feldspar. The sharp, planar to gently undulating contacts between the two domains, together with the parallelism of the banding with the regional foliation, indicate that melt segregation occurred syn-tectonically, with melt migrating along foliation planes under active deformation. The presence of well-developed stromatic migmatite is diagnostic of medium- to high-grade regional metamorphism.

Pegmatite Dykes and Sills



Plate II: Field views of pegmatitic leucosome occurring as a concordant sill/vein within the migmatite-gneiss

Plate 2 shows coarse-grained, essentially monomineralic to bimineralic pegmatitic leucosome bodies occurring both as discordant dykes and as concordant sills within the host migmatite. The pegmatites are interpreted as the last, most evolved and volatile-rich fraction of the anatectic melt, which migrated along zones of structural weakness (foliation planes, joints and fold hinges) before crystallising in situ. Structurally, the concordancy of most pegmatite bodies with the host foliation suggests emplacement was controlled by, and broadly synchronous with, the last stages of regional deformation, whereas cross-cutting bodies represent slightly later, more discordant injections.

Pinch-and-Swell Structures



Plate III: Pinch-and-swell structure exhibited by a competent leucosome layer within stromatic migmatite

The boudin-like pinch-and-swell structure in (Plate 3) developed where a rheologically competent (more viscous) quartzo-feldspathic layer, embedded within a less competent, more ductile matrix, was subjected to layer-parallel extension. Because the competent layer could not accommodate the imposed strain by flow to the same degree as its host, it necked down at regular intervals to produce alternating thin (pinch) and thick (swell) segments without complete rupture into isolated boudins.

Ptygmatic Folds



Plate IV: Ptygmatic (disharmonic) folding of a felsic (leucosome) vein within stromatic migmatite

Ptygmatic folding (Plate 4) is produced when a rigid, competent vein embedded in a much less competent (more ductile/mobile) host is shortened parallel to its length. The competent vein buckles internally into tight, irregular, disharmonic fold forms that appear to float freely within the more homogeneously deforming matrix, because the surrounding incompetent material behaves near-elastically and simply flows to accommodate the volume changes at fold hinges, rather than folding sympathetically itself. As noted in the field description, the folded material occupying the ptygmatic structure is felsic leucosome, consistent with its interpretation as a partial melt vein that was still sufficiently mobile (or rheologically distinct) at the time of folding to buckle independently of its host.

Foliation Planes



Plate V: In-situ gneissic foliation planes defined by the alignment of felsic and mafic mineral bands

The gneissic foliation illustrated in Plate 5 is defined by the parallel alignment and segregation of felsic (quartz-feldspar) and mafic (biotite-hornblende) bands into a penetrative planar fabric. This fabric records the regional metamorphic/tectonic grain of the basement complex and formed through a combination of solid-state recrystallisation, mimetic growth of phyllosilicates, and transposition of earlier layering during progressive deformation. The foliation is an essential structural marker used throughout the mapping programme to establish the regional strike and dip of the basement fabric, to which the pegmatite sills (Plate 2) and other intrusive sheets are largely concordant, confirming a late syn- to post-tectonic timing for their emplacement relative to the main fabric-forming event.

Basaltic Dykes

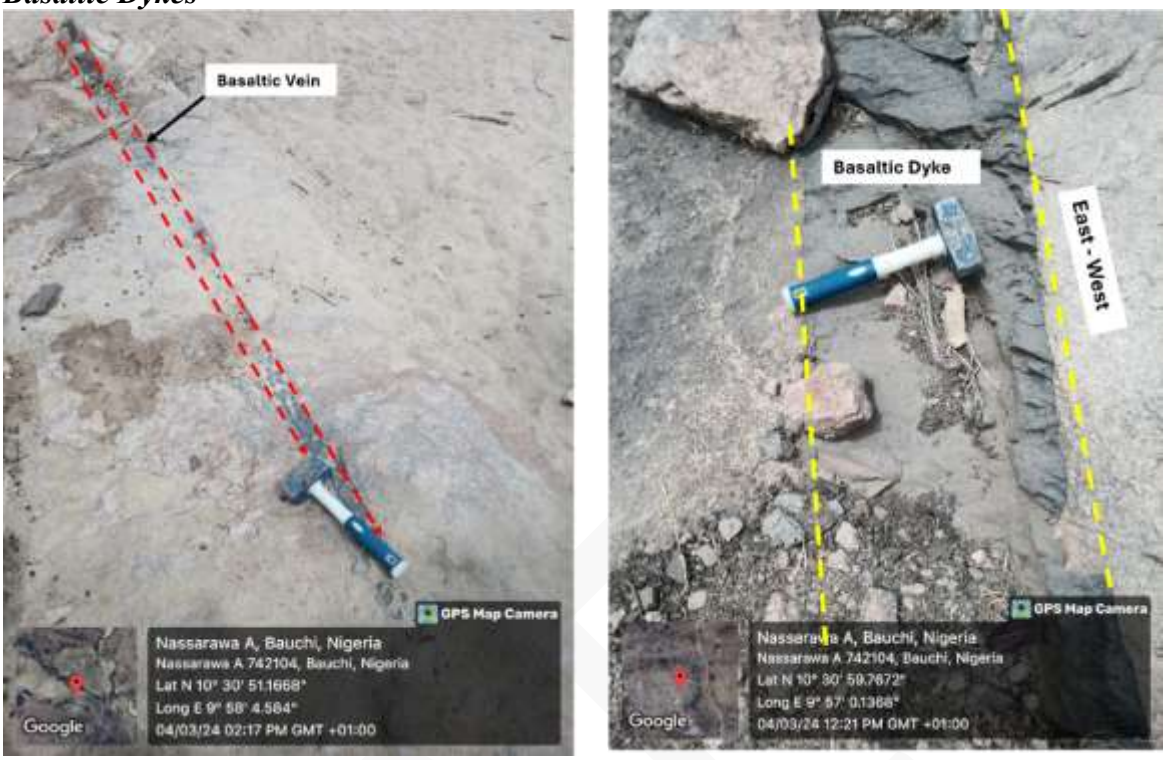


Plate VI: Field views of discordant basaltic dykes/veins cross-cutting the migmatite fabric, trending broadly east-west, Nassarawa A, Bauchi State

In contrast to the concordant, syn-tectonic pegmatites, the basaltic bodies in Plate 6 are sharply discordant, cross-cutting the gneissic/migmatitic foliation at a high angle and trending approximately east-west. This relationship demonstrates that the basaltic magmatism represents a distinctly younger, post-tectonic (and probably post-Pan-African) event, most plausibly related to a later phase of extensional fracturing and mafic dyke swarm intrusion that is widely recognised cutting the Nigerian basement complex. The east-west trend is consistent with regional extensional dyke swarms recorded elsewhere in the basement complex of Nigeria.

Migmatite Morphology: Metatexite

The metatexite migmatites constitute the most abundant rock morphology mapped in the study area. They are characterised by stromatic (layered) banding of alternating felsic and mafic bands, which frequently shows evidence of folding (Plates 3 and 4) which is attributed to syn-anatectic deformation. Additionally, these metatexites form the principal host to the pegmatite bodies of the area, which occur dominantly as sills and subordinate dykes broadly concordant with the regional foliation.

Petrography

Sample BL 1



Plate VII: (a) Field view of sample BL1; (b) hand specimen view of BL1; (c) photomicrographs of BL1 under plane polarised light (c1, c3) and crossed polarised light (c2, c4)
Hbl = hornblende, Qtz = quartz, Alb = albite, Mus = muscovite.

In hand specimen, sample BL1 is a coarse-grained, leucocratic to mesocratic, pinkish-grey rock with a granitic aspect. Under the microscope, the sample displays a holocrystalline, medium- to coarse-grained, inequigranular, granular texture. Hornblende occurs as anhedral to subhedral, ragged, interstitial to poikilitic patches (c1, c3) enclosing and intergrown with the felsic framework of quartz and albite (c2), which display an allotriomorphic, interlocking mosaic typical of a granitoid. The dominance of quartz + albite + hornblende, with only minor muscovite, together with the granitic hand-specimen texture, is consistent with the classification of BL1 as a hornblende-bearing granite.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Hornblende	Pale-green to brownish-green, strongly pleochroic, anhedral to subhedral, ragged/poikilitic grains; two cleavages intersecting at ~56°/124°; moderate to high relief.	Second-order green to yellow-green interference colours; inclined extinction (15°-30° to cleavage traces); occasional simple twinning.
Albite	Colourless, subhedral to anhedral, low relief, no obvious alteration.	Low first-order grey interference colour; fine polysynthetic albite twinning diagnostic of plagioclase near the albite end-member.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Quartz	Colourless, anhedral, low relief, no cleavage, interlocking mosaic texture with feldspar.	First-order grey-white interference colours; weak undulose extinction indicating minor post-crystallisation strain.
Muscovite	Colourless, platy, high relief, one perfect cleavage; minor accessory phase.	High-order (third/fourth order) bright interference colours; straight extinction parallel to cleavage traces.

Sample BL 2A

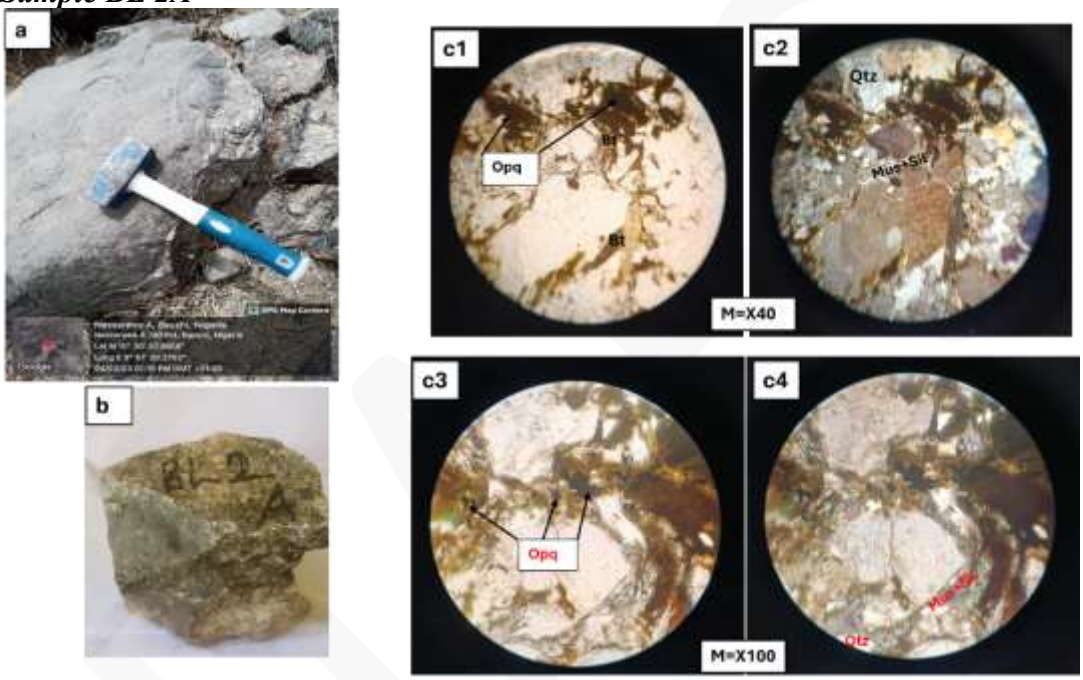


Plate VIII: (a) Field view of sample BL2; (b) hand specimen view of BL2; (c) photomicrographs of BL2 under plane polarised light (c1, c3) and crossed polarised light (c2, c4)
Qtz= quartz, Mus= Muscovite, Sil= Silliminite, Bt= Biotite, Opq = opaque mieral

Sample BL2A is a medium- to coarse-grained, foliated, grey granodioritic gneiss in hand specimen. In thin section it shows a foliated, lepidoblastic-granoblastic texture defined by the preferred orientation of biotite (Bt) laths intergrown with fibrous sillimanite (c1, c3) wrapped by a coarser muscovite + sillimanite (Mus+Sil) intergrowth (c2, c4), set in a granoblastic quartz matrix. Disseminated opaque (Opq) minerals occur as small anhedral grains associated with the biotite-rich domains, likely representing Fe-Ti oxides exsolved during biotite breakdown.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Biotite	Reddish-brown to dark-brown, strongly pleochroic, elongate lath-like grains defining the foliation; one perfect cleavage.	Masked, "tobacco-brown" to near-opaque high interference colours often obscured by mineral colour (anomalous birefringence); straight extinction along cleavage.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Sillimanite	Colourless, fibrous to prismatic habit (fibrolite), moderate relief, commonly intergrown with muscovite.	Second-order interference colours; parallel extinction and positive elongation (length-slow), diagnostic of the Al2SiO5 polymorph sillimanite.
Muscovite	Colourless, platy to flaky, high relief, perfect basal cleavage; intergrown with sillimanite (Mus+Sil domains).	Bright, high-order (3rd-4th order) interference colours; straight extinction parallel to cleavage; often shows mica "birds-eye" texture where fine-grained.
Quartz	Colourless, anhedral, granoblastic, low relief, no cleavage.	First-order grey interference colours; undulose extinction reflecting solid-state recrystallisation/strain.
Opaque mineral	Black, opaque, anhedral, associated with biotite domains.	Remains opaque (isotropic) under crossed polars.

Sample BL 3

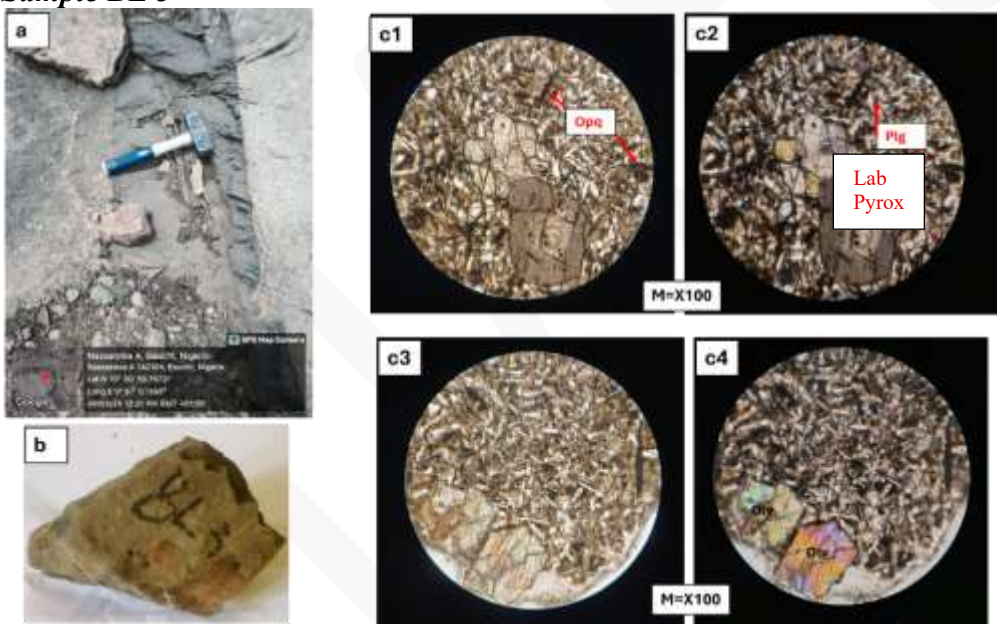


Plate IX: (a) Field view of sample BL3; (b) hand specimen view of BL3; (c) photomicrographs of BL3 under plane polarised light (c1, c2) and crossed polarised light (c3, c4). Plg = plagioclase, Olv = olivine, Opq = opaque mineral

Sample BL3, corresponding to the discordant basaltic dyke of Plate 6, is a dark grey-black, fine-grained, aphanitic rock in hand specimen. Petrographically, it displays a fine-grained, intergranular to intersertal, holocrystalline texture typical of a rapidly cooled hypabyssal rock. Small, partially resorbed olivine phenocrysts/microphenocrysts (c4) are set in a groundmass dominated by a felted network of plagioclase laths with interstitial opaque minerals

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Plagioclase	Colourless, lath-shaped, low relief, forming a felted (intergranular) groundmass texture.	Low first-order grey interference colours; well-developed albite and combined albite-Carlsbad lamellar twinning diagnostic of plagioclase.
Olivine	Colourless to very pale green/yellow, high relief, generally euhedral to subhedral, commonly fractured no cleavage.	High second- to third-order (anomalous, vivid) interference colours owing to high birefringence (~0.036); mottled/patchy extinction where partially altered.
Opaque mineral	Black, anhedral to subhedral, interstitial to the plagioclase framework, likely Fe-Ti oxide (magnetite/ilmenite).	Isotropic; remains opaque under crossed polars.

Sample BL 6

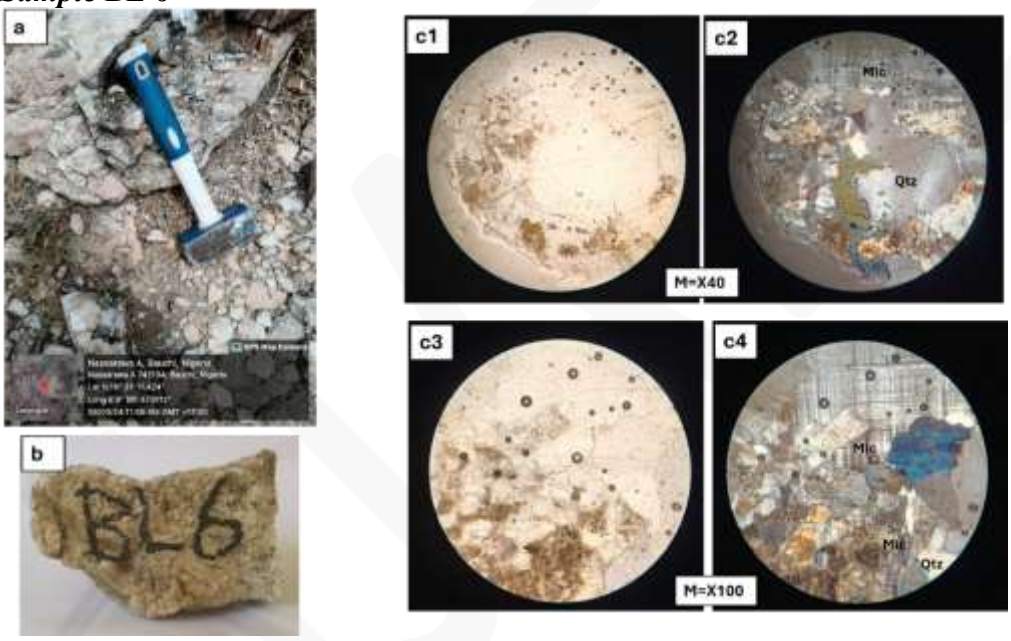


Plate X: (a) Field view of sample BL6; (b) hand specimen view of BL6; (c) photomicrographs of BL6 under plane polarised light (c1, c3) and crossed polarised light (c2, c4). Qtz = quartz, Mic = microcline

Sample BL6 is a coarse-grained, leucocratic, pinkish-white pegmatitic rock. In thin section it is holocrystalline, medium- to coarse-grained and hypidiomorphic-granular, dominated by an interlocking framework of anhedral quartz and microcline with only trace mafic minerals, consistent with its highly evolved.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Microcline	Colourless, subhedral to anhedral, low relief; commonly perthitic (fine	Diagnostic cross-hatched twinning (combined albite and pericline

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
	exsolution lamellae may be visible).	twins); low first-order grey interference colours.
Quartz	Colourless, anhedral, low relief, interlocking mosaic with microcline, no cleavage.	First-order grey-white interference colours; weak undulose extinction.

Sample BL 16



Plate XI: (a) Field view of sample BL16; (b) hand specimen view of BL16; (c) photomicrographs of BL16 under plane polarised light (c1, c2) and crossed polarised light (c2, c4)
Qtz = quartz, Mic = microcline, Bt = biotite

Sample BL16 is a medium-grained, pinkish-grey granite in hand specimen. Petrographically, it comprises a hypidiomorphic-granular intergrowth of microcline (Mic) and quartz (Qtz) with a subordinate, ragged biotite (Bt) that appears embayed and partially resorbed by the surrounding quartzo-feldspathic matrix.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Microcline (Mic)	Colourless, subhedral, low relief.	Characteristic tartan (cross-hatched) twinning; low first-order grey interference colour.
Quartz (Qtz)	Colourless, anhedral, low relief, forms interlocking mosaic with microcline.	First-order grey-white interference colours; weak undulose extinction.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Biotite (Bt)	Brown, pleochroic, ragged/embayed anhedral flakes, one perfect cleavage.	Masked/high-order interference colours; straight extinction along cleavage traces.

Sample BL 20

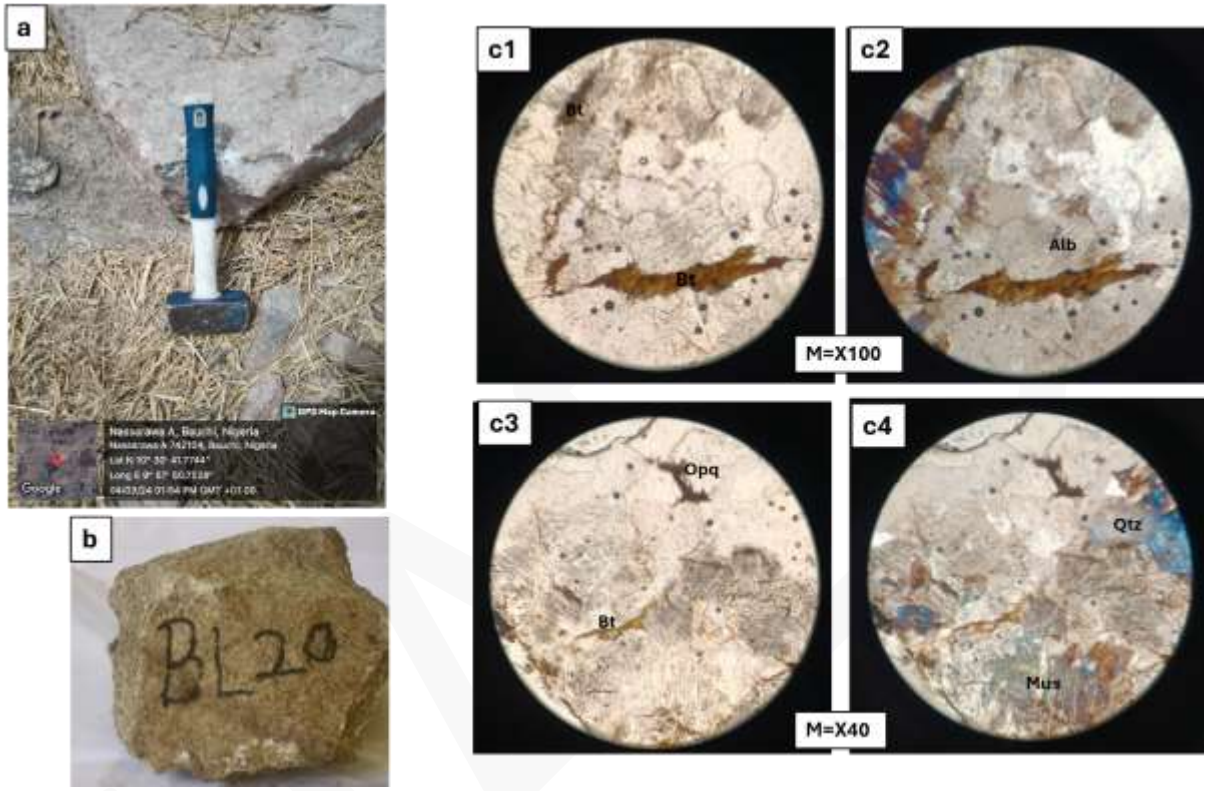


Plate XII: (a) Field view of sample BL20; (b) hand-specimen view of BL20; (c) photomicrographs of BL20 under plane polarised light (c1, c3) and crossed polarised light (c2, c4). Alb = albite, Qtz = quartz, Opq = opaque mineral, Mus = muscovite; Bt = biotite

Sample BL20 is a pale, leucocratic granodioritic rock. The thin section shows a fine- to medium-grained granoblastic matrix of quartz and albite (c4) containing ragged, elongate biotite laths (c1, c3) and disseminated opaque grains, with muscovite (Mus) intergrown with quartz at grain boundaries (c4). The presence of garnet noted in the accompanying field description points to a metamorphic (rather than purely igneous) overprint on this sample.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Biotite	Brown, strongly pleochroic, elongate/ragged flakes, one perfect cleavage.	Masked, anomalous high interference colours; straight extinction along cleavage.
Albite	Colourless, anhedral to subhedral, low relief.	Low first-order grey interference colour with fine polysynthetic albite twinning.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Quartz	Colourless, anhedral, low relief, granoblastic mosaic.	First-order grey-white colours; undulose extinction.
Muscovite	Colourless, platy, high relief, perfect cleavage, intergrown with quartz.	High-order bright interference colours; straight extinction.
Opaque mineral	Black, anhedral, disseminated within biotite-rich domains.	Isotropic; opaque under crossed polars.

Sample BL 22

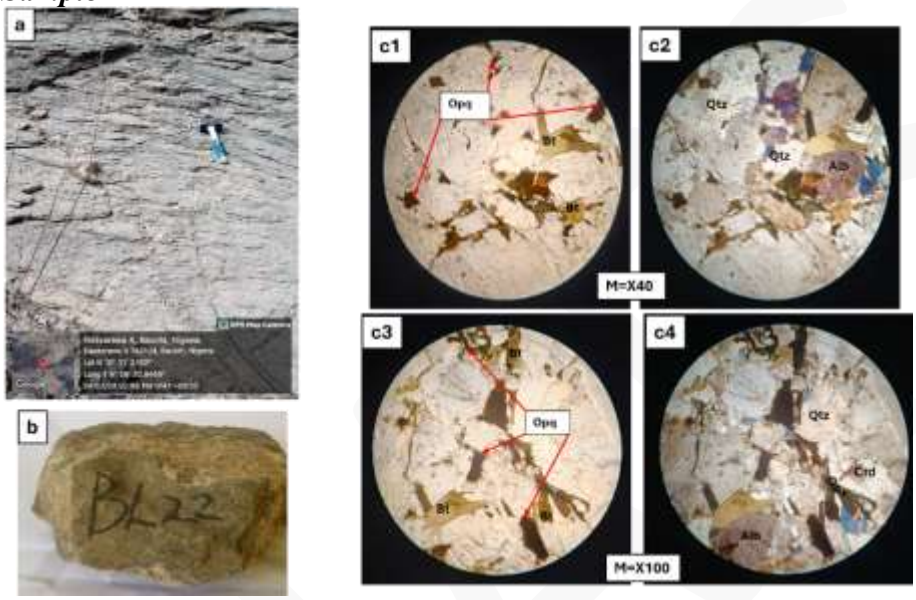


Plate XIII: (a) Field view of sample BL22; (b) hand specimen view of BL22; (c) photomicrographs of BL22 under plane polarised light (c1, c3) and crossed polarised light (c2, c4). Alb= albite, Bt= biotite, Opx= orthopyroxene, Crd= cordierite, Qtz= quartz, Opq= opaque mineral

Sample BL22 is a coarse-grained, greenish-grey granodioritic gneiss. It is the mineralogically most distinctive sample of the suite, containing orthopyroxene (Opx) and cordierite (Crd) in addition to quartz (Qtz), albite (Alb) and biotite (Bt), an assemblage that is diagnostic of granulite-facies metamorphic conditions.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Orthopyroxene	Colourless to very pale pink/green, weakly pleochroic, subhedral, two cleavages intersecting at ~90°; high relief.	Low first-order grey to yellow interference colours; straight (parallel) extinction to cleavage traces.
Cordierite	Colourless to very pale blue, low-moderate relief; may show incipient pinitisation (alteration to fine mica).	Low first-order grey interference colours; may display polysynthetic/sector twinning; pleochroic haloes around included zircon/monazite are common where present.

Mineral	Plane Polarised Light (PPL)	Crossed Polarised Light (XPL)
Biotite	Brown, pleochroic, ragged flakes associated with opaque exsolution products.	Masked, high-order interference colours; straight extinction.
Albite	Colourless, subhedral, low relief.	Low first-order grey colour with fine albite twin lamellae.
Quartz	Colourless, anhedral, low relief.	First-order grey-white colours; undulose extinction.
Opaque mineral	Black, anhedral, associated with biotite.	Isotropic; opaque under crossed polars.

Discussion

1. Lithological assemblage and regional geological context

From the field mapping and petrographic observations, the Rudibida area is underlain by a heterogeneous crystalline basement, consisting of foliated, stromatic migmatite-gneiss, with granitoid-looking lithologies, quartz–feldspar-rich pegmatitic bodies and younger, discordant mafic dykes. This association is in line with the polycyclic nature of the Nigerian Basement Complex which was variably deformed, migmatised and intruded by successive tectonothermal events (Ajibade, 1987; Dada, 2008). The intimate relationship of lithologically and texturally distinct rock types within the mapped area is thus best considered as a reflection of a complicated basement history rather than a single, uniform magmatic or metamorphic event.

This is manifested at the sample scale in the seven described thin sections. BL1 has hornblende, quartz and albite, with minor muscovite; BL16 is dominated by microcline and quartz with subordinate biotite; and BL20 is composed of quartz, albite, biotite and muscovite in a granoblastic matrix. BL6 is a course pegmatitic quartz–microcline-rich rock, while BL2A and BL22 have mineral assemblage's indicative of the presence of more strongly metamorphosed components. These contrasts are generally similar to the diverse metatexite, diatexite and granitoid groups reported in Mararraban Liman Katagum and Miya in Bauchi State (Ahmad et al., 2022; Kariya et al., 2024). However, the use of the term granite and granodiorite as petrographic working groups is retained here due to the lack of modal quartz, alkali feldspar and plagioclase proportions for formal QAPF classification.

2. Migmatization, partial melting and deformation

The most compelling evidence for the migmatization is the alternating light quartz–feldspar-rich and dark ferromagnesian-rich outcrops in the stromatic type and the presence of deformed felsic layers and veins. Leucosome typically corresponds to the melt-rich domain of the neosome, while darker domains can be either residuum or other mafic-rich material, but dark colour is not proof of a strictly residual origin (Sawyer, 2008; Pawley et al., 2015). The presence of preserved recognisable layering and coherent host rock fabrics argue for a description of the principal migmatitic morphology as metatexite rather than pervasive diatexis. The observed structures are in turn compatible with the process of spatially heterogeneous partial melting and segregation of felsic material during high-grade metamorphism.

The pinch-and-swell structures (Plate III), ptygmatic folds (Plate IV) and penetrative gneissic foliation (Plate V) offer a structural framework for the interpretation of the melt-related structures.

Pinch-and-swell geometry reflects strain partitioning between varying competence layers, and ptygmatic folding documents mechanical contrasts between the variously competent felsic veins and their host during deformation. The presence of deformed leucosome-like material indicates that at least some of the felsic segregation was synchronous with, or predates, the deformation, but geometry of the folds does not prove exact synchronicity for all. Deformation can promote melt migration and melt can overprint crystallised leucosomes, as demonstrated in experiments (Gardien et al., 1995) and in the field (Pawley et al., 2015). In this context, the ages of the Rudibida structures reflect a complex history of metamorphism, partial melting and ductile strain, and do not, on their own, constrain the timing of these events in absolute terms or their number.

3. Metamorphic mineral assemblages and possible protoliths

Sample BL2A is especially informative, as it has been reported to contain quartz–biotite–sillimanite–muscovite, which is suggestive of an aluminous component, most likely from a metasedimentary precursor. The presence of sillimanite is consistent with relatively high temperature metamorphism of rocks of appropriate bulk-composition, and the relationship to domains containing mica is consistent with known relationships in pelitic systems (Vernon & Clarke, 2008; Gardien et al., 1995). The fact that muscovite is present together with sillimanite does not necessarily indicate a peak-metamorphic equilibrium, however, because mica may survive or be produced during a later fluid-assisted retrogression. A metapelitic contribution is therefore a reasonable interpretation, although an exclusively sedimentary protolith and a specific pressure–temperature path cannot be established without the help of mineral chemistry and reaction textures and whole-rock compositional data.

The orthopyroxene, cordierite, quartz, albite and biotite reported in BL22 give the most petrographic evidence of a possibly high-temperature domain. The presence of orthopyroxene and cordierite, when correctly identified and when part of a coherent equilibrium assemblage, are consistent with granulite-facies or granulite-related conditions at the correct bulk composition. This similarity is regionally significant: Ferré and Caby (2007) described orthopyroxene-bearing rocks and high-temperature metamorphism related to charnockite formation in northern Nigeria, though also warned that the high-temperature metamorphics can be localised, such as around plutonic heat sources. The same association of orthopyroxene-, cordierite- and sillimanite-bearing has been reported elsewhere from Bauchi migmatites (Ahmad et al., 2022; Kariya et al., 2024). The optical data in Rudibida are consistent with a high temperature component of a heterogeneous terrane, but they do not necessarily indicate that the whole area has reached the granulite facies and they are not used to derive a quantitative pressure–temperature estimate. Therefore, the use of the term 'charnockitic' as a label should be viewed more as an affinity to be confirmed than as a rock type which is fully validated.

4. Granitoid and pegmatitic components

The quartz–feldspar-rich nature of BL1, BL6, BL16 and BL20 is evidence of the presence of significant amounts of felsic rocks in the local assemblage, although they do not necessarily have the same origin. BL6 in particular exhibits the characteristic coarse quartz–microcline intergrowth typical of a pegmatitic or very coarse level of a felsic body. Pegmatitic sheets and veins are found both parallel and locally transecting the host migmatitic fabric in the field (Plate II). Emplacement along concordant geometry could have occurred along pre-existing foliation or melt-migration pathways and discordant contacts show that at least some injections are younger than the structures

they cross. Geometrical evidence alone can not be used to verify direct crystallization of anatectic melt, and to demonstrate syn-tectonic emplacement of all pegmatites.

Felsic melts can form by partial melting of mica-bearing crustal rocks, and segregation and subsequent migration of these melts can lead to the formation of leucosomes, veins and, under favorable circumstances, larger granitoid bodies (Gardien et al., 1995; Brown, 2013). This offers a feasible conceptual model for the Rudibida felsic components but other contributions from externally derived granitoid or pegmatitic magmas are possible. Contacts would need to be documented more closely and modal data and whole-rock or mineral geochemistry of the quartz–feldspar body in question to determine if it is a segregated leucosome, a mobilized anatectic vein, or an independent intrusion. Similarly, the pegmatite fertility and rare-metal enrichment reported in the petrography cannot be sustained in the absence of geochemical data.

5. Relative chronology and significance of the mafic dykes

The most obvious relative-age constraint in the field is the discordant mafic bodies which cut the gneissic fabric (Plate VI). Sample BL3 has a fine-grained plagioclase-rich groundmass, and contains microphenocrysts of olivine and opaque minerals consistent with an olivine-bearing basaltic dyke. From the evidence, these dykes are younger than the foliation and host rocks that they cross-cut and also, they belong to a different magmatic event from the one represented by the migmatisation of the gneisses. The east–west trend could be an exploitation of fractures, but does not alone indicate the stress regime.

It should be emphasized that a post-foliation age does not necessarily imply a post-Pan-African/Mesozoic age of emplacement. The evolution of the regional basement is long and has many events and cross-cutting relationships give relative, not numerical, dates (Dada, 2008). Thus, the timing, source and tectonic affinity of the Rudibida dykes are still open questions, until they are investigated by whole-rock major- and trace-element data and by an appropriate geochronological study. Chemical analysis would be desirable, especially if a firm designation of basaltic composition and classification in a tectonic context were desired.

6. Regional synthesis, significance and limitations

The observations as a whole point to a relative chronology in which a compositionally variable basement was foliated and migmatised, experienced localized felsic segregation and deformation and was intruded by some pegmatitic bodies and by the discordant mafic dykes. This sequence is a working reconstruction, not a unique tectonic model because the relative timing of foliation development and partial melting and concordant pegmatite emplacement may overlap, and the temporal extent of multiple metamorphic and/or intrusive events cannot at this time be resolved. The pattern is, however, consistent with the general trend in the Nigerian Basement Complex where crustal reworking, metamorphism, mylonitization and anatexis and granitoid magmatism have been part of a long lasting tectonothermal evolution (Ajibade, 1987; Dada, 2008; Saleh et al., 2025). The Rudibida results are best viewed as a regional petrographic and structural input for the increasingly well-documented Bauchi basement province and not as a newly recognized regional metamorphic event. The migmatitic morphologies and high-grade mineral associations reported here are comparable with that of Ahmad et al. (2022) and Kariya et al. (2024) at other localities in Bauchi, and the U–Pb and Lu–Hf study of zircon from Halilu et al. (2025) reveals that crustal recycling and multiple magmatic–metamorphic histories can be resolved where isotopic data are available. These age restrictions are useful for providing regional context, but should not simply be used as transfer ages to Rudibida without first dating the local rocks. The present study has

therefore documented for the first time stromatic metatexites, compared the petrographic assemblages and mapped relative cross-cutting relationships in the mapped exposures of Rudibida. Interpretations are hampered by limited numbers of described thin sections (7), no reported quantitative mineral modes or mineral-chemical analyses, and a lack of whole rock geochemistry and geochronology, and the lack of a structural-orientation dataset presented for the region to assess regional kinematics. These restrictions have a particular impact on definitive granitoid classification, peak metamorphic conditions, protolith discrimination and intrusive ages. Given these limitations, the research offers a logical field and microscopy framework for future integrated petrological/geochronological studies and does not result in a unique pressure–temperature–time path.

Conclusion

On the basis of the field and petrographic evidence presented, it is concluded that, the study area is underlain by a polydeformed migmatite-gneiss complex that experienced upper amphibolite- to granulite-facies (BL22) regional metamorphism and at least one phase of syn-anatectic ductile deformation, recorded by stromatic banding, boudinage and ptygmatic folding, prior to being intruded by concordant pegmatites and, much later, by discordant, post-tectonic basaltic dykes. Petrographically, the basement complex comprises hornblende- and biotite-granites and granodiorites, a sillimanite-bearing metasedimentary-derived gneiss, an orthopyroxene-cordierite-bearing charnockitic gneiss, and a discrete olivine basalt, reflecting a heterogeneous protolith assemblage subjected to variable peak metamorphic grade.

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