

Geology and Petrography of Migmatites Around Kundun Durum, Sheet 128 Kafin Madaki Se, Bauchi, Bauchi State, Nigeria

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Abstract

The Kundun Durum area, within Sheet 128 Kafin Madaki SE of the Nigerian Basement Complex, is underlain by a migmatite-gneiss suite formed through Pan-African high-grade metamorphism and crustal anatexis. This study presents the field relationships and petrography of the migmatite suite in order to characterize its morphological units, mineral assemblages, and metamorphic grade. Geological mapping, field observations, and petrographic analyses were carried out on representative rock samples collected across the study area. Five lithological units were identified in the field, which include the relict biotite-sillimanite-muscovite schist, banded orthogneiss, a compositionally heterogeneous leucosome inseparable in outcrop from its melanosome, trachyte and pegmatite, with stromatic metatexite as the dominant host rock. Petrographically, the rocks are dominated by quartz, biotite, muscovite, microcline, plagioclase, hornblende, sillimanite, amphibole and opaque minerals. Quartz shows wavy undulose extinction, biotite is strongly aligned, microcline displays cross-hatch twinning, and myrmekite occurs at microcline-plagioclase contacts within the leucosome, indicating recrystallization under amphibolites to granulite facies conditions. Field relationships, including the intimate and inseparable association of leucosome and melanosome, the compositional banding of the orthogneiss, and the discordant, non-foliated character of the pegmatite, place the sequence within a single, progressive in-situ anatectic system. The Kundun Durum migmatites evolved through progressive partial melting, deformation, and recrystallization of a dominantly metasedimentary crust with a subordinate meta-igneous component during the Pan-African tectono-metamorphic event.

Introduction

The Nigerian Basement Complex forms part of the Pan-African Trans-Saharan Mobile Belt, situated between the West African Craton, the Congo Craton, and the East Saharan Block, and preserves evidence of at least four tectono-metamorphic episodes, the Liberian, Eburnean, Kibaran, and Pan-African orogenies (Caby et al., 1981; Ferré & Caby, 2006). Migmatites constitute the Migmatite Gneiss Complex, the oldest and most widespread of the three principal lithological units of the Basement Complex alongside the Schist Belts and the Pan-African granitoids or Older Granites, and make up an estimated sixty percent of the exposed basement (Rahaman & Ocan, 1978; Rahaman, 1988). Despite this areal dominance, migmatites remain the least studied unit of the Nigerian basement, with most petrological attention historically directed at the granitoid rocks (Rahaman & Ocan, 1978).

Migmatites are heterogeneous, medium to high grade metamorphic rocks formed by partial

melting, or anatexis, of pre-existing crust, and are characterized by the intimate coexistence of a melt derived leucosome and a residual melanosome (Sawyer, 2008). Around Bauchi, in the Jos-Bauchi transect of the Nigerian basement, migmatites, gneisses, and their associated charnockitic and granitoid rocks record a single, monocyclic Pan-African metamorphic history dated to between 638 ± 3 Ma and 585 ± 7 Ma (Dada & Respaut, 1989; Ferré et al., 1993), attaining amphibolite to granulite facies conditions consistent with a Barrovian-type metamorphic path (Ferré & Caby, 2006). Recent petrographic and field based studies across the wider Bauchi basement, at Bagel (Abdulhameed & Haruna, 2021), Dungulbi (Zailani et al., 2021), Miri and Wuntin Dada (Sabo et al., 2021), Lallangi (Bunyaminu et al., 2020), Rimin Zayam (Mohammed et al., 2024), Kariya (Kariya et al., 2024), Kadage (Mayana et al., 2024), and Dungal (Ali et al., 2023), consistently describe a metatexite to diatexite progression, with mineral assemblages of quartz, biotite, feldspar, and sillimanite pointing to amphibolites to granulite facies anatexis and an in-situ to in-source mode of melt generation. The Kundun Durum area lies in this same basement terrain but has not previously been the subject of detailed geological or petrographic investigation. This paper presents the field relationships and petrography of the migmatite gneiss suite exposed around Kundun Durum, with the aim of establishing the lithological units present, their mineral assemblages and metamorphic grade, and their bearing on the mode of melt generation during the Pan-African orogeny.

Location and Accessibility

The study area lies between latitudes $N10^{\circ}32'8.57''$ and $N10^{\circ}33'25.7''$ and longitudes $E9^{\circ}45'00''$ and $E9^{\circ}46'00''$, forming part of Sheet 128 Kafin Madaki SE and covering approximately 4.3 km² at a scale of 1:25,000 (Figure 1). It is accessible via the major road linking Bauchi to Ningi, with outcrops in the more remote parts of the area reached through minor roads and footpaths.

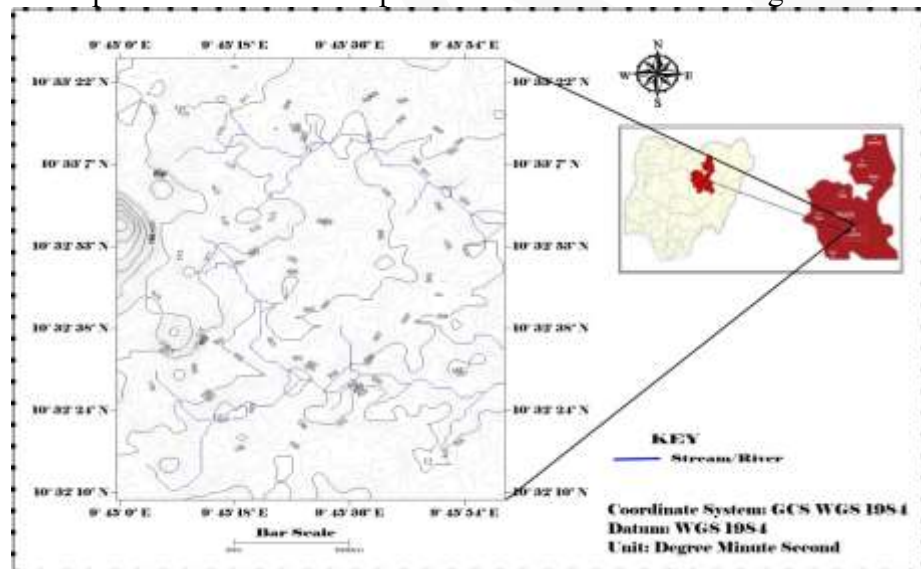


Figure 1: Topographic Map of the Study Area (Source; Google Earth).

Geological Setting

Regional Geology

Nigeria is situated within the Pan-African mobile belt, flanked by the West African Craton to the west, the Tuareg Shield to the north, and the Congo Craton to the southeast (Black, 1980), with the Precambrian Basement Complex underlying roughly half of the country's land area (Kogbe,

1989). The Basement Complex comprises three principal units, the Migmatite Gneiss Complex, the Schist Belts, and the Pan-African granitoids or Older Granites (Rahaman, 1988). Basement rocks record evolution through the Liberian, Eburnean, Kibaran, and Pan-African orogenic cycles (Caby et al., 1981), the first three marked by intense deformation and isoclinal folding under regional metamorphism, and the Pan-African by renewed regional metamorphism, migmatization, and extensive granitization and gneissification producing syntectonic granites and homogeneous gneisses (Abaa, 1983).



Figure 2: Geological Map of Parts of West Africa Showing the Position of Nigeria and its Pan-African Basement, the Congo-Gabon Craton, the West African Craton and the Tuareg Shield
Source: Adapted from Wright et al., (1989).

Local Geology

The Bauchi basement is dominated by migmatite gneiss, the oldest unit of the Nigerian Basement Complex (Rahaman, 1988), historically described as agmatitic in character (Mehnert, 1968) and dated at around 618 Ma (Dada et al., 1993). The area additionally hosts porphyritic biotite-hornblende granite, biotite-muscovite granite, quartz-diorite, and the locally distinctive fayalite-quartz monzonite named Bauchite after the town (Oyawoye, 1965). Mineral assemblages in the metasedimentary gneisses and associated anatexites indicate a Barrovian-type, amphibolite to granulite facies metamorphic history (Ferré & Caby, 2006). The Kundun Durum area and its environs are predominantly underlain by migmatites, with stromatic metatexites as the dominant lithology, with subordinate relict schist, banded orthogneiss, leucosome, trachyte and pegmatite. Petrographically, the rocks are composed predominantly of quartz, plagioclase feldspar, microcline, biotite, hornblende, amphibole, muscovite, with accessory opaque minerals. This assemblage is consistent with the high-grade metamorphism and anatexis recorded across the Bauchi basement (Ferré & Caby, 2006). The schist occurs as a residual lithology within the migmatite terrain, while pegmatites occur along foliation planes and fractures and record late-stage melt movement. Similar lithological associations of banded orthogneiss, stromatic migmatite, leucosomes, schist and pegmatite have been documented in nearby areas such as Gubi and Filin Shagari within the Bauchi Basement Complex (Muhammad et al., 2022; Wada et al., 2024).

Materials and Methods

Materials

Field mapping and sample collection made use of a topographic map, a Global Positioning System (GPS) unit, a compass clinometer, a geological hammer, a measuring tape, masking tape, and standard field-writing materials and a camera.

Methods

Fieldwork combined systematic traverse mapping along outcrop to outcrop profiles, guided by a topographic base map enlarged to 1:25,000, with GPS located sampling and megascopic description of rock colour, texture, and composition at each station, using the first and second order morphological classification of Sawyer (2008). A total of twenty-four samples were collected across the mapped units, from which thirteen were selected for petrographic study. Thin sections were prepared at the petrography laboratory of Abubakar Tafawa Balewa University (ATBU), Bauchi, and examined under plane and cross polarized transmitted light. Properties recorded under plane polarized light included colour, pleochroism, relief, and cleavage; those recorded under crossed polars included birefringence, interference colour, extinction angle, and twinning. Photomicrographs of representative textures were captured with a camera mounted on the petrographic microscope.

Result and Discussion

The study area forms part of the Migmatite Gneiss Complex, characterized by high-grade metamorphism and crustal anatexis. Field mapping identified stromatic metatexite as the dominant basement rock type, hosting subordinate schist, banded orthogneiss, leucosome, trachyte, and pegmatite, with a thin surficial laterite capping. The stromatic metatexite consists of leucosome occurring as compositionally variable interbanded material representing crystallized anatectic melt, the bands ranging from quartzofeldspathic light layers to darker biotite-hornblende rich layers, with sharp and diffuse contacts between them. The biotite-sillimanite-muscovite schist occurs as relict enclaves within the migmatite, dark in colour, patchy, foliated and schistose (Plate IX), and represents a metasedimentary paleosome that escaped complete partial melting. Scattered restite patches (Plate I) preserve hints of the original parent lithology prior to migmatization, and metamorphic contortions, complex folds and swirls formed under intense heat and pressure, were also observed in the field (Plate II).

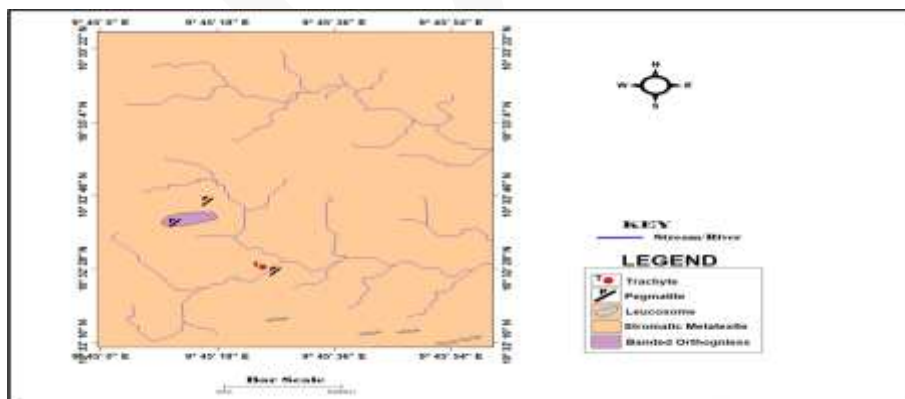


Figure 3: Geologic Map of the Study Area (Source: Field Work, 2025)

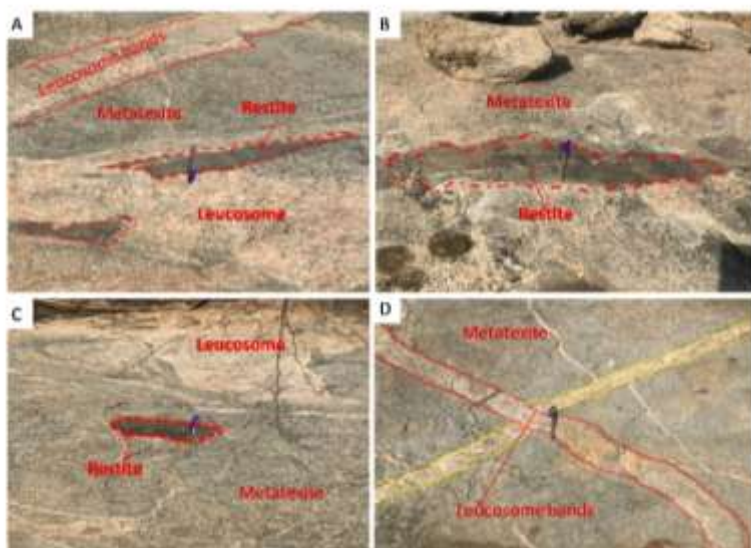


Plate I: Field occurrence and morphology of the metatexite showing small scattered patches of restites enclosed by melanosomes and leucosomes (A, B, C), and leucosome bands cross cutting one another (D)

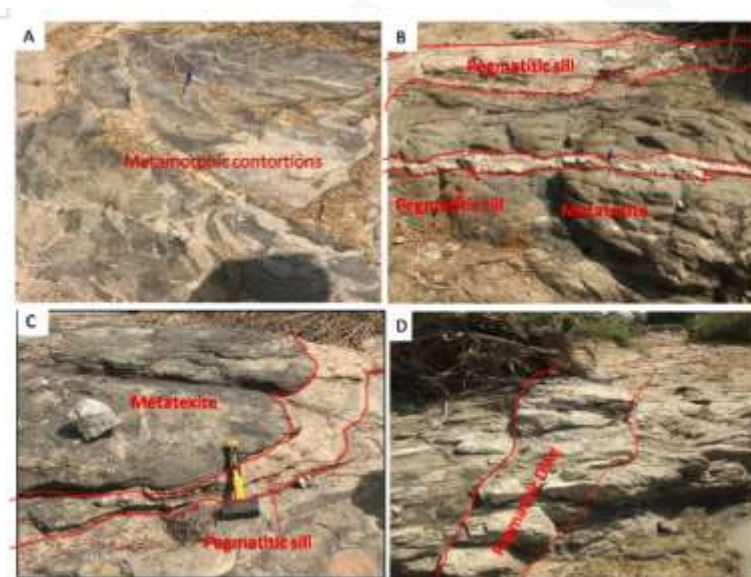


Plate II: Field occurrence and morphology of the metatexite showing metamorphic contortions (A), and pegmatitic sills and dike (B, C and D), occurring within the metatexite

Banded Orthogneiss

The banded orthogneiss occurs as boulders and low-lying outcrops, characterized by distinct compositional banding of alternating felsic and mafic layers. The felsic bands are coarse grained and composed of quartz, plagioclase, biotite, and opaque minerals (Plate III), while the dark-grey mafic bands are medium grained and composed of quartz, hornblende, and strongly oriented biotite with opaque minerals aligned parallel to the fabric. The preferred orientation of the biotite

(Plate IV) suggests a gneissic foliation reflecting tectonic alignment under directed stress during the Pan-African collisional event, with recrystallization and rotation of platy biotite into an orientation perpendicular to the principal stress.

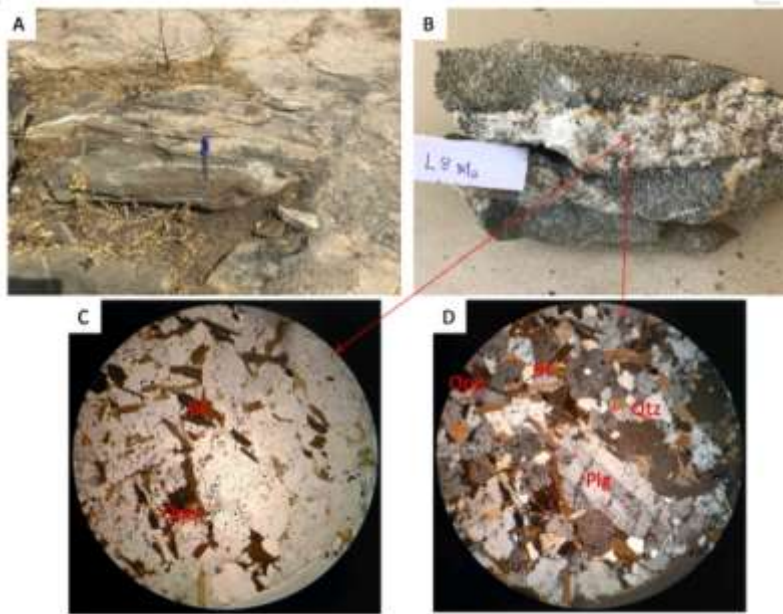


Plate III: Field and hand Sample of the banded orthogneiss (A and B) and Photomicrograph of Metatexite under both PPL and XPL (C and D). Qtz: Quartz, Bt: Biotite, Opq: Opaque, Pl: Plagioclase. (Mag. X40)

Table 1: General Optical Properties of the Banded Orthogneiss (L8M2B) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Colourless with low relief.	Wavy undulose extinction.
Biotite	Elongated platy biotite.	Dark brown elongated biotite with high relief.
Plagioclase	Colourless and not visible.	Visible albite twinning with 1 st order interference colour.
Opaque	Black opaque minerals.	Black opaque minerals.

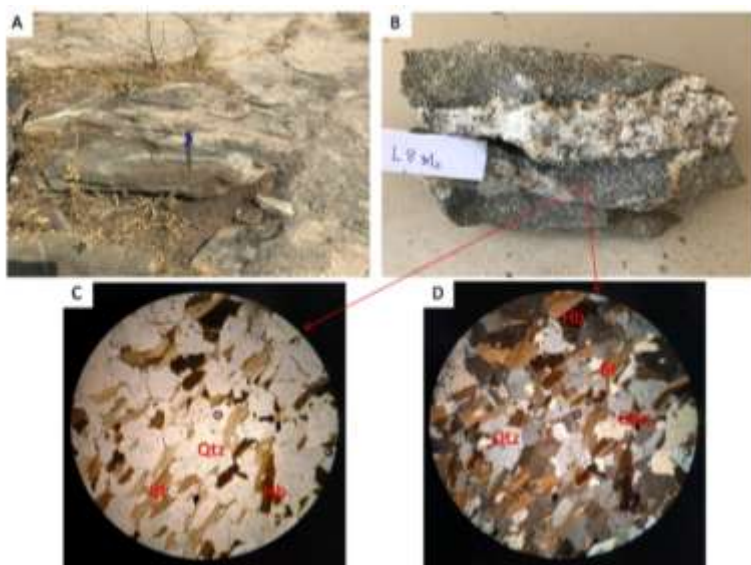


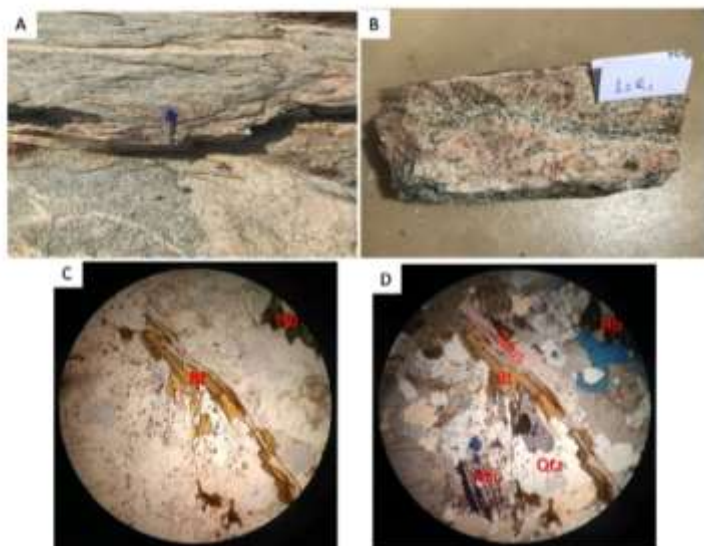
Plate IV: Field and hand Sample of banded orthogneiss (A and B) and photomicrograph under both PPL and XPL (C and D). Qtz: Quartz, Bt: Biotite, Hb: Hornblende, Opq: Opaque. (Mag. X40)

Table 2: General optical Properties of the Banded Orthogneiss (L8M2A) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Quartz is colourless.	Wavy undulose extinction.
Biotite	Elongated platy biotite with high relief.	Aligned elongated brown biotite with high relief and one directional cleavage.
Hornblende	Dark green-brown colour with moderate relief	Very dark green colour with simple one directional cleavage.
Opaque	Black opaque minerals.	Black opaque minerals.

Leucosome

Leucosomes are a prominent component of the migmatite complex, occurring as concordant sills along foliation planes and as discordant, light-coloured veins, dikes, patches, and segregations cross cutting the host foliation. In the field, the leucosome occurs side by side with the melanosome as a single, laterally continuous unit; the two could not be reliably differentiated as discrete lithologies, either in outcrop or in thin section, consistent with their genetic pairing as melt and residuum from partial melting. Quartz and feldspar grains show sutured grain boundaries and weak preferred orientation, indicating recrystallization from melt. Petrographically, the samples are leucocratic, non foliated, and coarse to medium grained, dominated by euhedral to subhedral quartz, K-feldspar, biotite, hornblende, and myrmekite



microstructure.

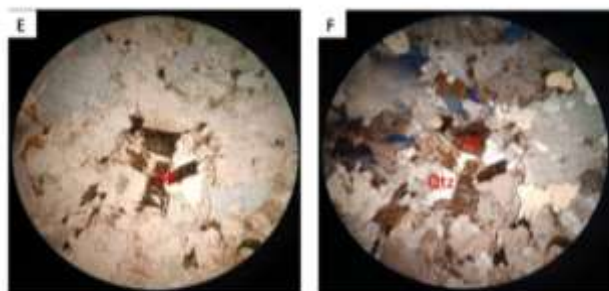


Plate III: Photograph of Field and Hand Sample of Leucosome (A and B) and Photomicrograph under both PPL (C and E) and XPL (D and F). Qtz: Quartz, Bt: Biotite, Mus: Muscovite, Mic: Microcline, Hb: Hornblende. (Mag. X40)

Table 3: General optical Properties of the Leucosome (L2R1) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Quartz is colourless with low relief.	Gray to white, showing wavy undulose extinction.
Biotite	Platy brown with high relief.	Dark brown biotite showing one directional cleavage.
Microcline	Microcline show colourless.	Cross hatch twinning visible.

Muscovite	Colourless to pale with low relief.	Shows 2 nd -3 rd order interference colours, bright pinks, greens and yellows.
Hornblende	Dark green-brown colour with moderate relief	Very dark green colour with simple one directional cleavage.

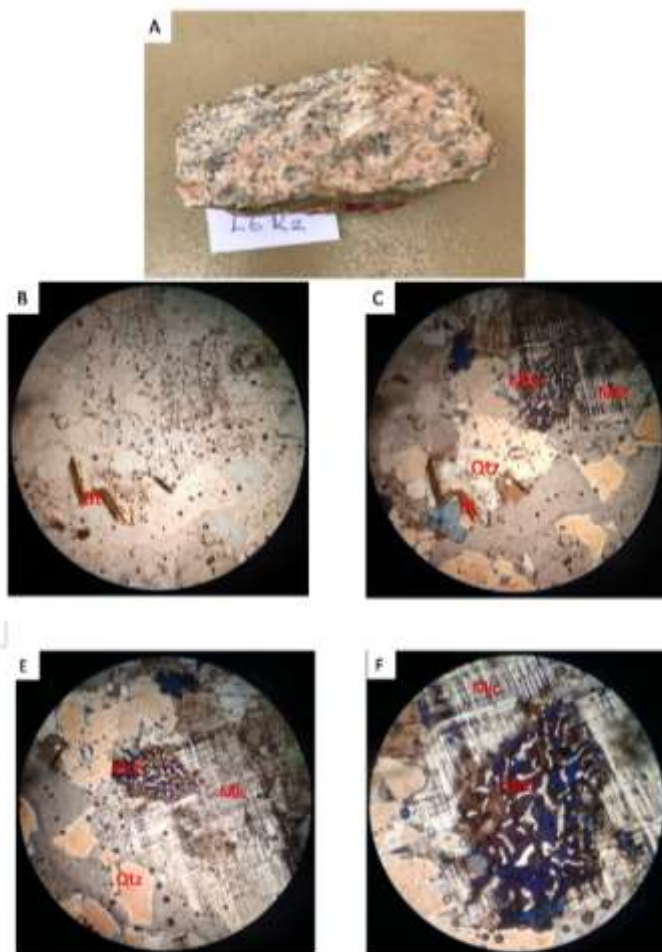


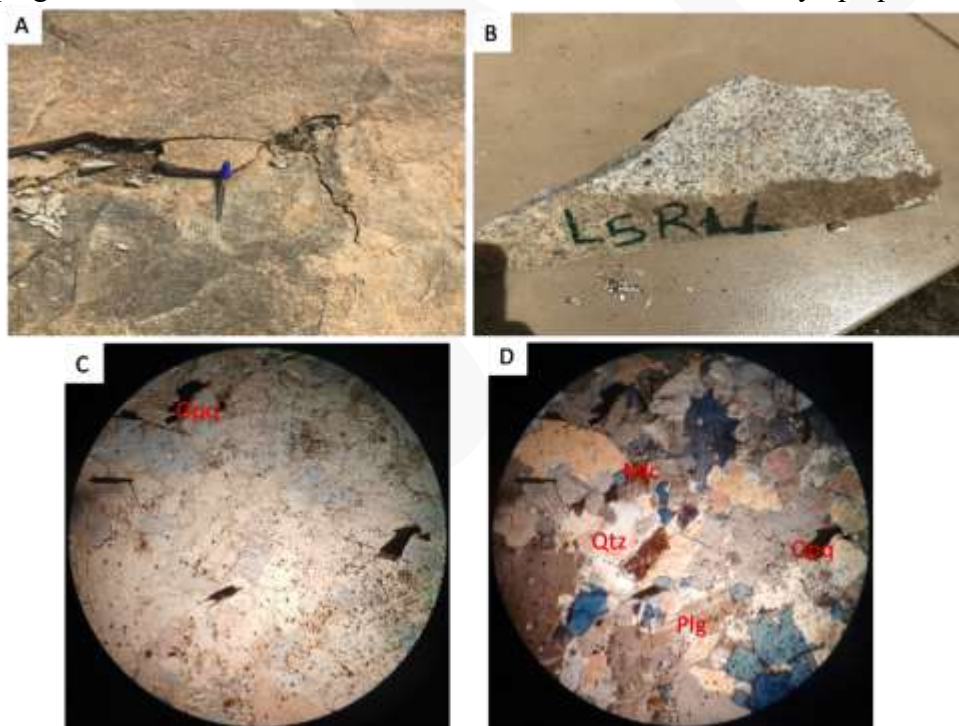
Plate VI: Photograph of hand Sample of Leucosome (A) and Photomicrograph under both PPL and XPL (B and C). Qtz: Quartz, Bt: Biotite, Mrk: Myrmekite, Mic: Microcline. (Mag. X40; F=X100)

Table 4: General Optical Properties of the Leucosome (L6R2) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Colourless with low relief.	Wavy undulose extinction.
Biotite	Platy brown with one directional cleavage.	Elongated platy brown biotite.
Microcline	Microcline is colourless.	Shows cross hatch twinning.
Myrmekite	Myrmekite is not visible.	Myrmekite microstructure visible.
Hornblende	Dark green colour with high relief	Dark green-brown colour with simple one directional cleavage.

Trachyte

The trachyte occurs as light coloured, felsic segregations within the migmatite, medium grained and associated with the granitic leucosomes. It is characterized by a trachytic texture defined by aligned laths of K-feldspar and plagioclase in a quartz-dominated groundmass with minor biotite, is leucocratic, equigranular, and generally non-foliated. Petrographically, it comprises quartz, plagioclase, muscovite, microcline, minor biotite, and accessory opaque minerals.



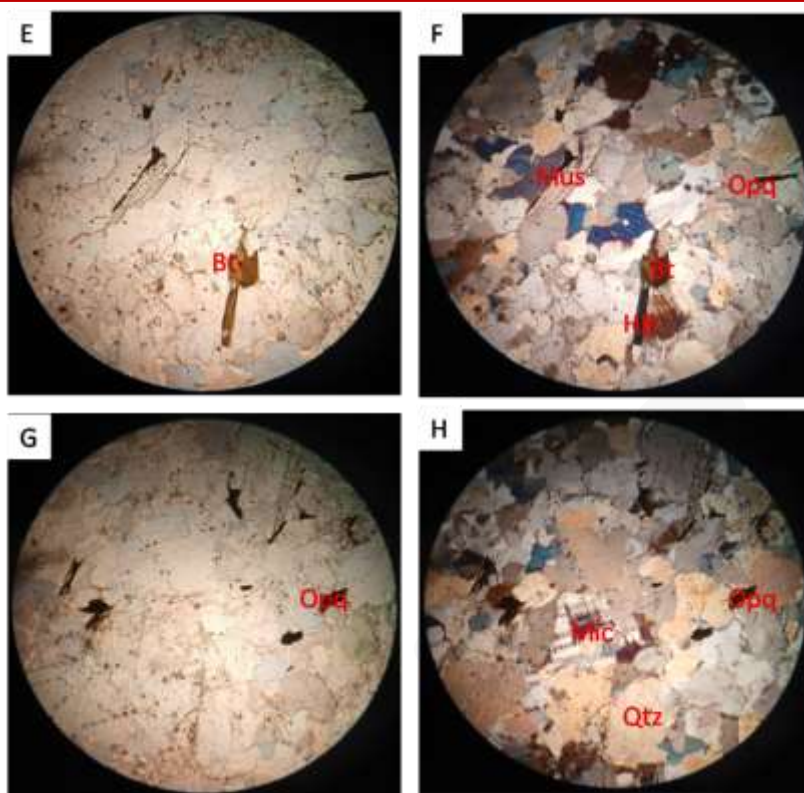


Plate VII: Photograph of Field and Hand Sample of Trachyte (A and B) and Photomicrograph under both PPL (C, E, and G) and XPL (D, F and H). Qtz: Quartz, Bt: Biotite, Mus: Muscovite, Mic: Microcline, Plg: Plagioclase, Opq: Opaque. (Mag. X40)

Table 5: General optical Properties of the Trachyte (L5R4) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Quartz is colourless.	Shows wavy undulose extinction.
Biotite	Elongated brown biotite with moderate relief.	Dark brown biotite with high relief showing one directional cleavage.
Microcline	Microcline is colourless.	Visible cross hatch twinning.
Muscovite	Colourless to pale with low relief.	Shows 2 nd order interference colours, bright pinks, blue, green.
Plagioclase	Colourless with low relief.	Visible albite twinning, parallel black and white stripes.
Opaque	Black opaque minerals.	Black opaque minerals.

Pegmatite

Pegmatites occur as intrusive bodies and irregular veins and lenses along foliation planes cutting across the migmatite, and as a dike exposed along a stream channel. They display sharp, discordant contacts with the host rock, are very coarse grained, and are composed predominantly of quartz, K-feldspar, plagioclase, muscovite, and occasionally biotite. The pegmatites are non-foliated and show no evidence of penetrative deformation, consistent with their interpretation as the final product of fractional crystallization of anatectic melts and exsolution of volatile-rich fluids.

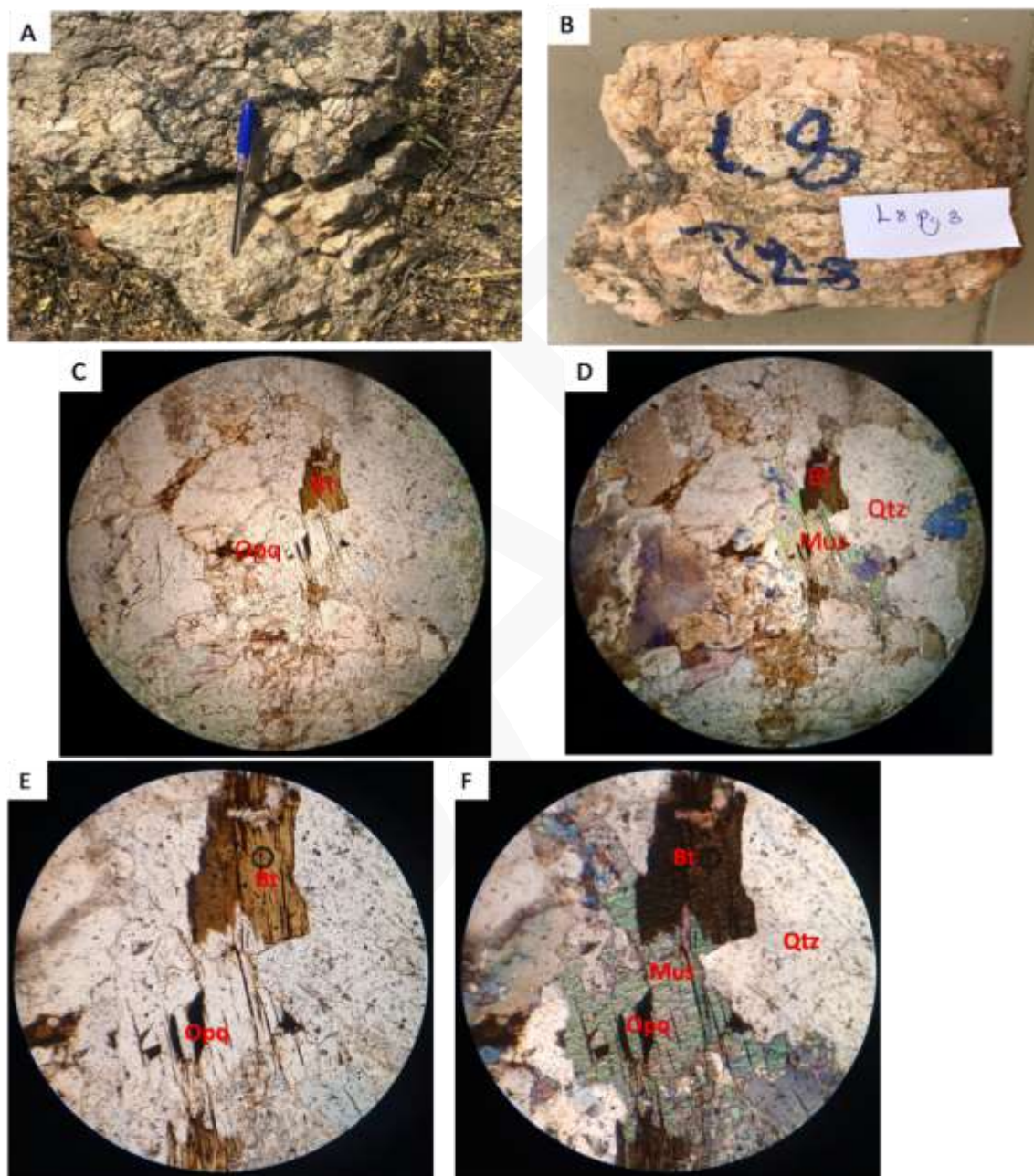


Plate IV: Photograph of Field and Hand Sample of Pegmatite (A and B) and Photomicrograph under both PPL and XPL (C and D). Qtz: Quartz, Bt: Biotite, Mus: Muscovite, Opq: Opaque. (Mag. X40; E, F=X100)

Table 6: General optical Properties of the Pegmatite (L8Pg3) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Quartz is colourless.	Gray, wavy undulose extinction.
Biotite	Elongated platy with high relief.	Dark brown biotite with one directional cleavage.
Muscovite	Colourless with low relief.	2 nd -3 rd order interference colours, pinks, blue, greens, yellows.
Opaque	Black opaque minerals.	Black opaque minerals.

Schist

The schist occurs as scattered, relict patches within the migmatite terrain, representing portions of the original metasedimentary rock that escaped complete partial melting. It is dark grey, fine to medium grained, and displays a well-developed schistosity defined by the parallel alignment of platy and prismatic minerals. Mineralogically, it is dominated by biotite and amphibole, with quartz, muscovite, sillimanite, and opaque minerals.

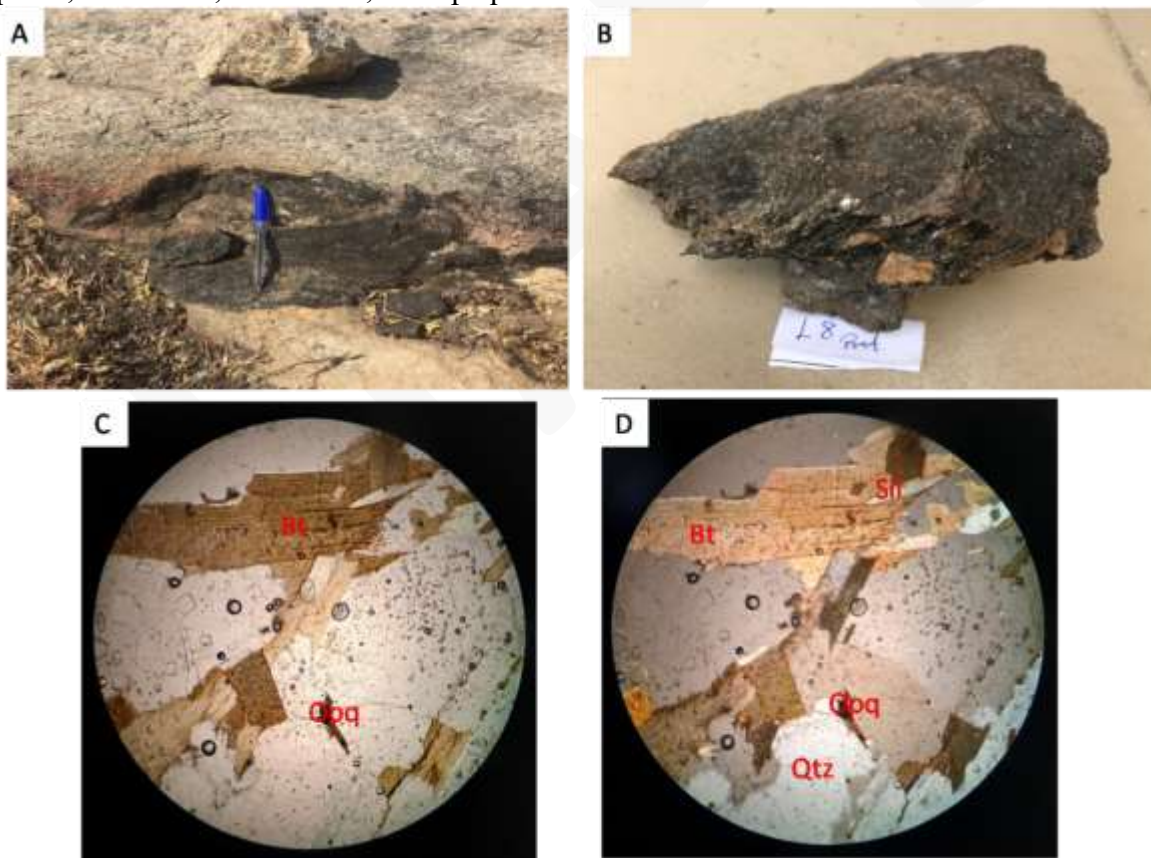




Plate V: Photograph of Field and Hand Sample of Schist (A and B) and Photomicrograph under both PPL and XPL (C, D, E and F). Qtz: Quartz, Bt: Biotite, Mus: Muscovite, Opq: Opaque, Sil: Silimanite. (Mag. X40; E, F=X100)

Table 7: General optical Properties of the Schist (L8R1) under Plane and Crossed Polarised Light

Minerals	PPL	XPL
Quartz	Colourless with low relief.	Wavy undulose extinction.
Biotite	Elongated dark brown with high relief.	Platy brown biotite with high relief with one directional cleavage.
Sillimanite	Colourless to tan under PPL.	Shows 2 nd order interference colour with cleavage along its prismatic length.
Muscovite	Colourless to pale with low relief.	2 nd -3 rd order interference colours, pinks, bright blue, greens, yellows.
Amphibole	Pale brown with high relief, perfect cleavage.	2 nd -3 rd order interference colours, bright pinks, dark greens, high relief with simple twinning.
Opaque	Black opaque minerals.	Black opaque minerals.

Microstructure: Myrmekite

Myrmekite forms through the collection and expulsion of quartz by plagioclase, typically at the contact between microcline and plagioclase, where it appears as inflated, cauliflower-like masses intruding into the microcline (Oyawoye, 1958, as cited in Bunyaminu et al., 2020). This texture is developed in K-feldspar-bearing rocks such as the leucosome (Plate IV). The microcline commonly shows evidence of strain and appears to be replacing the plagioclase, whereas the plagioclase itself shows no such deformation; the myrmekite is in all cases subordinate in size to

the associated microcline.

Discussion of Results

The field relationships and petrography of the Kundun Durum migmatite suite are interpreted within a purely metamorphic, anatectic framework. Starting from the relict schist through banded orthogneiss, leucosome, trachyte and, finally, pegmatite, the sequence describes a metatexite dominated terrane in which granitic material is generated in place rather than intruded from elsewhere (Kariya et al., 2024). The schist is the anchor of this sequence. Its biotite-sillimanite-muscovite-amphibole-quartz assemblage (Table 7; Plate IX) is the mineralogical signature of an aluminous metasedimentary rock carried to upper amphibolite to granulite facies conditions, and its dark colour and brittle, biotite dominated fabric mark it as the least melted material in the study area, the residue left behind once a lighter, quartzofeldspathic fraction was extracted during partial melting. The presence of sillimanite indicates the temperature regime required for this melting to proceed, and restite of this mineralogy is the expected residual product of fluid-absent partial melting in pelitic migmatite terranes (Sawyer, 2008). The banded orthogneiss (Plate III and IV; Tables 1 and 2) preserves compositional banding, its felsic bands of quartz, plagioclase, and biotite, and its mafic bands carrying hornblende and strongly oriented, elongated biotite. The preferred alignment of biotite indicates gneissic foliation developed under the directed stress of the Pan-African collisional event, with platy biotite recrystallizing and rotating into an orientation perpendicular to the principal stress. The leucosome samples (Plates V and VI; Tables 3 and 4) give the clearest petrographic evidence that melt actually moved locally within the host rock, occurring as discordant, light coloured, non-foliated segregations that cut across the stromatic metatexite and showing sutured quartz-feldspar grain boundaries with only weak preferred orientation, features consistent with recrystallization from a melt phase. The myrmekite developed at microcline-plagioclase contacts in sample L6R2 (Plate IV) follows the original description of this intergrowth in Nigerian basement rocks (Oyawoye, 1958, as cited in Bunyaminu et al., 2020); the strained microcline visibly replacing unstrained plagioclase indicates a late-stage exchange reaction at the mineral scale. In the field, the leucosome occurs as a single, texturally and compositionally continuous unit, closely juxtaposed with the melanosome such that the two could not be reliably differentiated as discrete lithologies, either in outcrop or in thin section. This intimate spatial association is consistent with their genetic relationship as complementary products of partial melting, the leucosome representing the melt-derived, quartzofeldspathic fraction and the melanosome the residual, biotite- and hornblende-rich fraction left after melt extraction, the two occurring side by side rather than as separable rock types. The leucosome is further found in direct field association with the banded orthogneiss and stromatic metatexite that underlie much of Kundun Durum, occurring interlayered with and grading into these lithologies. The trachyte (Plate VII; Table 5) and the pegmatite (Plate VIII; Table 6) close the sequence at its most evolved end. The trachytic leucosome has lost essentially all trace of the original banding; its aligned laths of K-feldspar and plagioclase in a quartz-dominated groundmass reflect a melt fraction large enough to disaggregate and homogenise the earlier metatexite fabric. The term "trachytic" used here is purely descriptive of this texture, since the sample remains compositionally continuous with the other leucosome material rather than being a true volcanic rock. The pegmatite, by contrast, is defined by its very coarse grain size and its quartz-, K-feldspar and muscovite dominated mineralogy with only minor biotite, and by field relationships, occurring both as sills concordant with the metatexite foliation and as discordant veins and a dike exposed along a stream channel (Plate II), that place it as the last

melt fraction to crystallise, after volatile exsolution had already removed much of the remaining biotite from the system. This relationship between a disaggregated, homogenised leucosome and a discordant, late pegmatite has been described as the terminal stage of melt evolution in the Bauchi metatexite-diatexite suite (Magaji et al., 2021). The field relationships and petrography indicate that the Kundun Durum migmatites record progressive, in-situ partial melting and deformation of a dominantly metasedimentary crust with a subordinate meta-igneous component, during the Pan-African tectono-metamorphic event, rather than a suite of unrelated intrusions emplaced from elsewhere.

Conclusions

- The Kundun Durum area is underlain mainly by migmatite (stromatic metatexite hosting leucosome), relict schist, banded orthogneiss, trachyte, and pegmatite, with a thin surficial laterite capping.
- The rocks belong to the Precambrian Basement Complex of northeastern Nigeria and record progressive, in-situ partial melting of a dominantly metasedimentary protolith represented by relict schist, together with a meta-igneous orthogneiss component, during high grade Pan-African metamorphism.
- Melt segregation produced a compositionally heterogeneous leucosome, with lighter and darker bands reflecting local segregation heterogeneity rather than two genetically distinct rock types, while the pegmatite represents the final, most fractionated product of this anatectic system, emplaced along pre-existing foliation and fracture planes.
- Petrographic properties, including undulose extinction in quartz, aligned elongated platy biotite, the metamorphic mineral sillimanite, and the myrmekite microstructure, indicate that the study area is a metamorphic terrain that has undergone shearing, with metamorphic grade increasing from the schist protolith through the banded orthogneiss to the leucosome and pegmatite. The presence of sillimanite, particularly, is consistent with amphibolite to granulite facies metamorphism.

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