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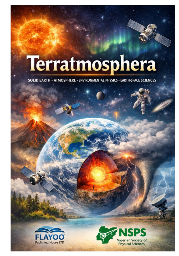

Geology and petrographic studies of basement complex rocks in Damaga and environs, northwestern Nigeria

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ABSTRACT

The geology and petrography of basement complex rocks in Damaga and environs were studied to identify the underlying rock types and determine their spatial coverage and mineralogical characteristics. Geological field mapping was conducted, fresh representative rock samples were collected during the field exercise, and petrographic analysis was performed on selected samples using a polarizing microscope. The major mapped rock units are granodiorite, phyllite, and amphibolite schist. Granodiorite accounts for about 38% of the total lithology and is divided into two textural groups: medium- to coarse-grained and porphyritic. It generally occurs as low-lying exposures and boulders. Phyllite is characterized by the alignment of light and dark minerals and constitutes about 34% of the total lithology, occurring mainly as low-lying outcrops exposed along river channels. Amphibolite schist covers about 20% of the total lithology and occurs largely as flat-lying outcrops. Petrographic investigations revealed that the mapped rocks are composed chiefly of felsic minerals, such as quartz, muscovite and feldspars (plagioclase and orthoclase), mafic minerals (biotite and amphibole), and minor opaque minerals. The minor lithologies, which account for 8%, consist of xenolith, aplite, and quartz veins. Structural readings revealed a dominant NE–SW trend that is consistent with Pan-African deformation.

1. INTRODUCTION

The geological investigation of an area is a structured process that delineates various litho-petrological units, including their mineral composition, structures, and deformational dynamics [1]. This process can be achieved through field mapping to acquire the necessary data and produce a detailed geological map showing the distribution and characteristics of the various rock units underlying the area [2, 3]. The traverse mapping technique is an effective method that complements and ensures the success of field mapping activity [4]. This approach essentially records the geology along predefined locations on a topographic base map [4]. Petrographic studies involve the analysis of rock thin sections at the microscale with the aid of a polarizing microscope

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[5–8].

The Basement Complex of Nigeria, where the study area is located, is part of the Pan-African mobile belt situated within the West African and Congo cratons [9]. The Basement Complex was affected by polyphase deformation, with the Pan-African Orogeny recognized as the prominent event [10]. This sequence of deformation led to episodes of recrystallization and significant intrusion of granitic rocks [10, 11]. The basement geology of Nigeria consists of four petro-lithological units: the Migmatite-Gneiss Complex, Schist Belt (metasedimentary and metavolcanic), Older Granites, and undeformed acid and basic dykes [11]. The Migmatite-Gneiss Complex is strictly the Basement Complex *sensu stricto*, covering slightly more than half of the Nigerian Basement Complex [11–13]. It chiefly comprises schist, migmatite, gneiss, and granite-gneiss [11, 14, 15]. The Maru Schist Belt is one of the most prominent schist belts [11]. Generally, the Nigerian schist belts consist of upper Proterozoic supracrustal rocks that have been folded into the migmatite-gneiss-quartzite complex [11, 16]. Phyllites, interlaminated slates, banded iron formation, amphibolite schist, granodiorite, granite, and gabbro are various litho-compositional units common in the schist belts [11, 17]. The Pan-African granitoids of Ref. [13], commonly known as the Older Granite Suites, host syngenetic rock units that are believed to have intruded the Migmatite-Gneiss Complex and the schist belts [11, 18].

The northwestern portion of the Nigerian Basement Complex has been the subject of several regional geological studies [19–21]. However, these studies did not show the diversity of rock units in the study area, which is critical for interpreting the petrogenesis and evolution of the Basement Complex. Therefore, this research aims to characterize the basement rocks in Damaga and its environs through geological field mapping and petrographic investigations. This research fills the existing gap in the diversity of rocks around Damaga and environs, northwestern Nigeria.

1.1. STUDY AREA

The study area is located in the Maru district, Maru Local Government Area of Zamfara State. It covers about 40 km^2, bounded by latitudes 12°19′45″N to 12°23′00″N and longitudes 006°20′30″E to 006°23′00″E (Figure 1) within the Federal Survey Map Sheet 53NW. Geologically, this area lies within the Maru Schist Belt in the northwestern Basement Complex of Nigeria (Figure 1). The Sokoto–Gusau road and other well-established minor roads, which intersect the Maru Schist Belt, facilitate access to the area.

The climate is typical of a tropical savanna pattern characterized by two distinct seasons: the rainy season starts in May and lasts through October/November, while the dry season extends from November through April. The vegetation is typical of tropical savanna and consists of shrubs, thorny bushes, and grasses. The area is characterized by hilly terrain with a few low, undulating topographic surfaces and a dendritic drainage pattern drained by the River Sokoto and its seasonal tributaries (Figure 1).

2. MATERIALS AND METHODS

2.1. FIELD MAPPING

Detailed geological field mapping was carried out to systematically investigate the geology of the study area using a gridded topographic map on a scale of 1:25,000, extracted from the Federal Topographic Map of Nigeria, Sheet 53NW. The field mapping exercise focused primarily on detailed on-site descriptions, including mode of occurrence, structural analysis, and megascopic examinations. Descriptions of the shapes, textures, and proportions of individual mineral grains in hand samples were made with the aid of a hand lens where applicable. A handheld Global Positioning System (GPS) receiver was used to record outcrop coordinates, and a Brunton compass was used to measure the strike and dip of structural features. A measuring tape was used to measure rock dimensions.

Fresh representative rock samples were obtained from the studied outcrops during the field mapping with the aid of a geological hammer. All sample locations were plotted on the base map, and each collected sample was appropriately labeled with masking tape and marker pens. Geological boundaries between distinct rock units were also delineated accordingly. All other information related to field observations was duly noted in the field notebook. Figure 1 shows the locations of samples collected during field mapping.

2.2. THIN-SECTION AND PETROGRAPHIC STUDIES

Representative samples of rocks in the area were selected for thin sectioning and petrographic analysis. The rock thin sections were prepared in line with the procedure of Ref. [23]. The procedure involves cutting a hand specimen of about 0.1 m thickness in a regular pattern using a diamond-coated blade. The cut hand specimen, known as a rock slice, is then rubbed against an abrasive and glued onto a glass slide using an epoxy solution. The other surface is then ground to a thickness of about 30 μm and subsequently covered with a thin glass slip. This process produced the rock slides for petrographic analysis.

Petrographic analysis facilitates the study of rock constituents at a fine scale [18]. In this study, the constituent minerals were identified based on their optical properties under plain-polarized light (PPL), including color, habit, pleochroism, and cleavage, and cross-polarized light (XPL), including interference, color, and extinction. These properties enable the accurate determination of rock mineralogy [18, 24]. Using a digital camera, the photomicrographs of all samples were taken to obtain the percentages of each mineral constituent. The results of petrographic investigations, together with field geological mapping data, were used collectively to delineate the rock units underlying the area.

2.3. ROSE DIAGRAM AND MAP PRODUCTION

A rose diagram is a two-dimensional tool used to represent directional data visually [18, 25, 26]. The strike values of structures were plotted using GeoRose software, from which the dominant trends were identified. The geological map of the area was produced using a combination of Google Earth and Surfer 11 software.

3. RESULTS AND DISCUSSION

3.1. DISTRIBUTION AND DESCRIPTION OF ROCK UNITS

Three main rock units underlie the study area: granodiorite, phyllite, and amphibolite schist (Figure 2). Other lithologies, such as aplite dyke, quartz veins, and xenolith, occur as intrusions,

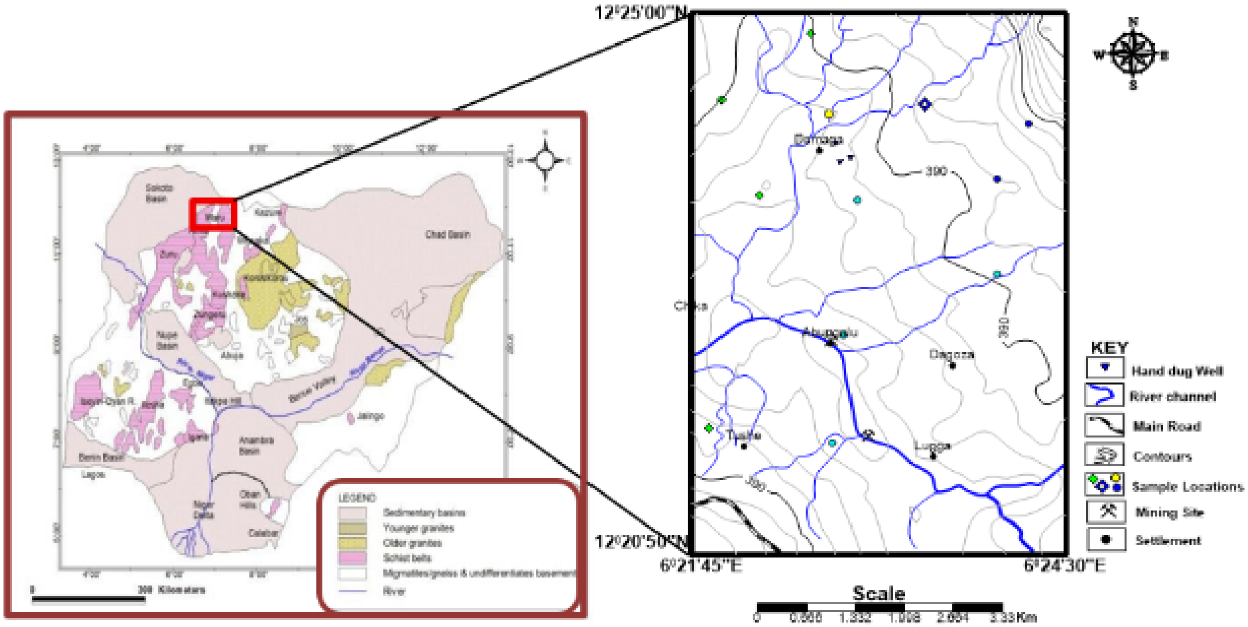

Figure 1. Simplified geological map of Nigeria (modified from Ref. [22]), showing the location of the study area.

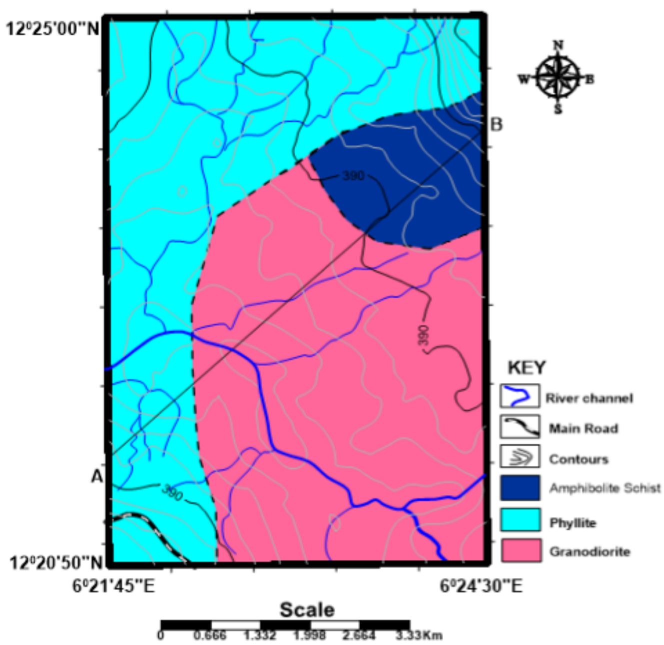

Figure 2. Geological map of Damaga and environs.

hydrothermal veins, and inclusions in the major rock units, respectively. The following sections discuss detailed descriptions of lithological characteristics, field occurrences, relationships among the various rock units, and the physical properties of constituent minerals.

3.1.1. Medium- to coarse-grained granodiorite

The medium- to coarse-grained granodiorite covers the southern to somewhat northeastern portion of the study area, accounting for about 20% of the total granodiorite lithology (Figure 3A). In the field, most of the medium-grained granodiorite outcrops are highly deformed and fractured, occurring as low-lying boulders that trend northeast–southwest. In hand specimen, the medium-grained granodiorite is a granular, holocrystalline rock dominated by quartz, plagioclase feldspar, orthoclase feldspar, and biotite (Figure 3B). Quartz appears glassy and rigid. Plagioclase appears whitish, whereas orthoclase has shades of pink and red. Biotite is black and crumbles into flakes when scratched. In general, the sample is leucocratic, characterized by its sparkling appearance and distinctive mineral grains.

A massive, leucocratic aplite dyke intruded the medium- to coarse-grained granodiorite at N12°21′38.5″, E006°22′42.6″ (Figure 3C). The aplite dyke is medium-grained, although relatively finer than the host rock. The hand specimen showed the dominance of plagioclase feldspar, with quartz and biotite occurring in different dimensions (Figure 3D).

3.1.2. Porphyritic granodiorite

The porphyritic granodiorite covers the entire Lugga village (Figures 1 and 2). It dominantly appears as flat-lying outcrops and medium-sized domes. At some locations, it occurs as boulders and ridges trending in the N–S direction (Figure 3E). Most of the mapped porphyritic granodiorite outcrops are also highly weathered and fractured, contacting the amphibolite schist toward Damaga to the south. The hand specimen is leucocratic, holocrystalline, and porphyritic, with vitreous to pearly-lustrous blocky albite grains of about 3–13 mm as phenocrysts surrounded by quartz and biotite groundmass (Figure 3F).

3.1.3. Phyllite

The phyllite occurs as flat-lying outcrops, mostly exposed along river channels, and varies in appearance from dark grey to yellowish and, in some places, weathered brown (Figure 3G). In most locations, phyllite outcrops are laminated, weakly foliated,

Figure 3. Field occurrence and hand specimen of rock units: (A–B) medium- to coarse-grained granodiorite, (C–D) aplite dyke, (E–F) porphyritic granodiorite, (G) phyllite, and (H–I) amphibolite schist.

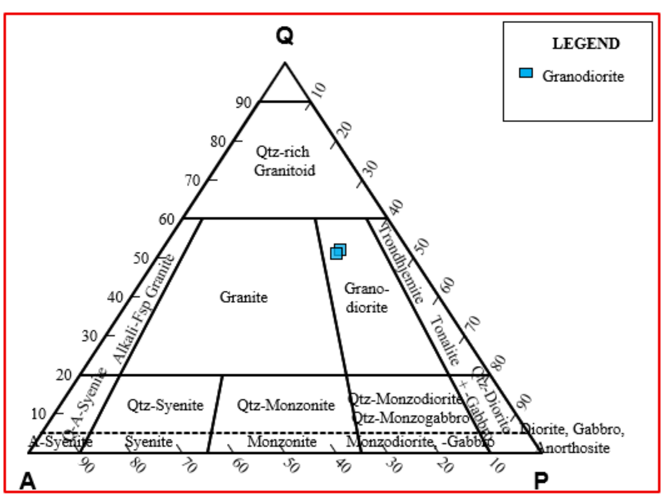

Figure 4. QAP plot of granodiorite.

highly deformed, and tectonically inclined. Significant exposures were mapped around the northwestern and southwestern portions, where they underlie major localities such as Damaga, Chika, Abungulu, and Tushe (Figures 1 and 2). In terms of overall lithology, phyllite covers about 34%. This rock unit is characterized by a parallel alignment of light and dark minerals.

3.1.4. Amphibolite schist

Amphibolite schist occurs as low-lying outcrops and boulders that are about 2 m above the ground in some locations (Figure 3H). It constitutes about 20% of the total lithology and covers the northeastern portion. The hand specimen is dark and has a fine- to medium-grained texture (Figure 3I). It is highly dense when lifted, probably because of the dominance of mafic minerals. The component grains are nearly equigranular and consist of a wide range of greenish to dark brown minerals occurring together with fine quartz.

3.2. PETROGRAPHIC AND OPTICAL CHARACTERISTICS OF ROCK UNITS

This section presents the petrographic and optical characteristics of constituent minerals found in rocks underlying the research area. The proportions of each mineral component were determined by modal analysis (point counting), following the methodology of Ref. [27]. The modal mineral composition of granodior-

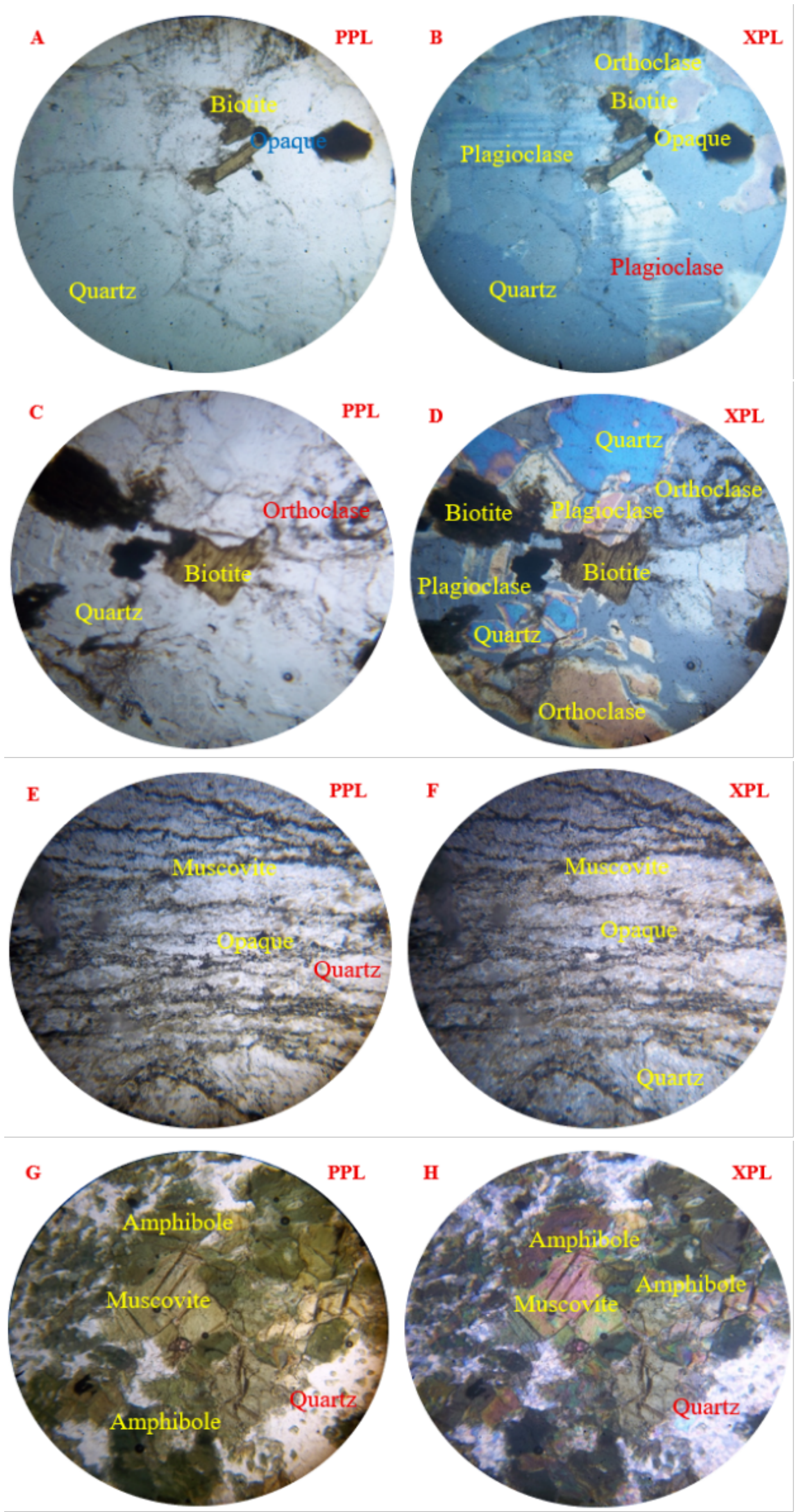

Figure 5. Photomicrograph of rock thin section: (A-B) medium-coarse grained granodiorite (C-D) porphyritic granodiorite (E-F) phyllite (G-H) amphibolite schist.

ite samples was plotted on the quartz–alkali feldspar–plagioclase (QAP) diagram [28] for further classification (Figure 4). The QAP diagram is primarily used to classify igneous rocks. Therefore, phyllite and amphibolite schist were not considered for QAP classification. Photomicrographs of the representative rock units are shown in Figure 5A–H.

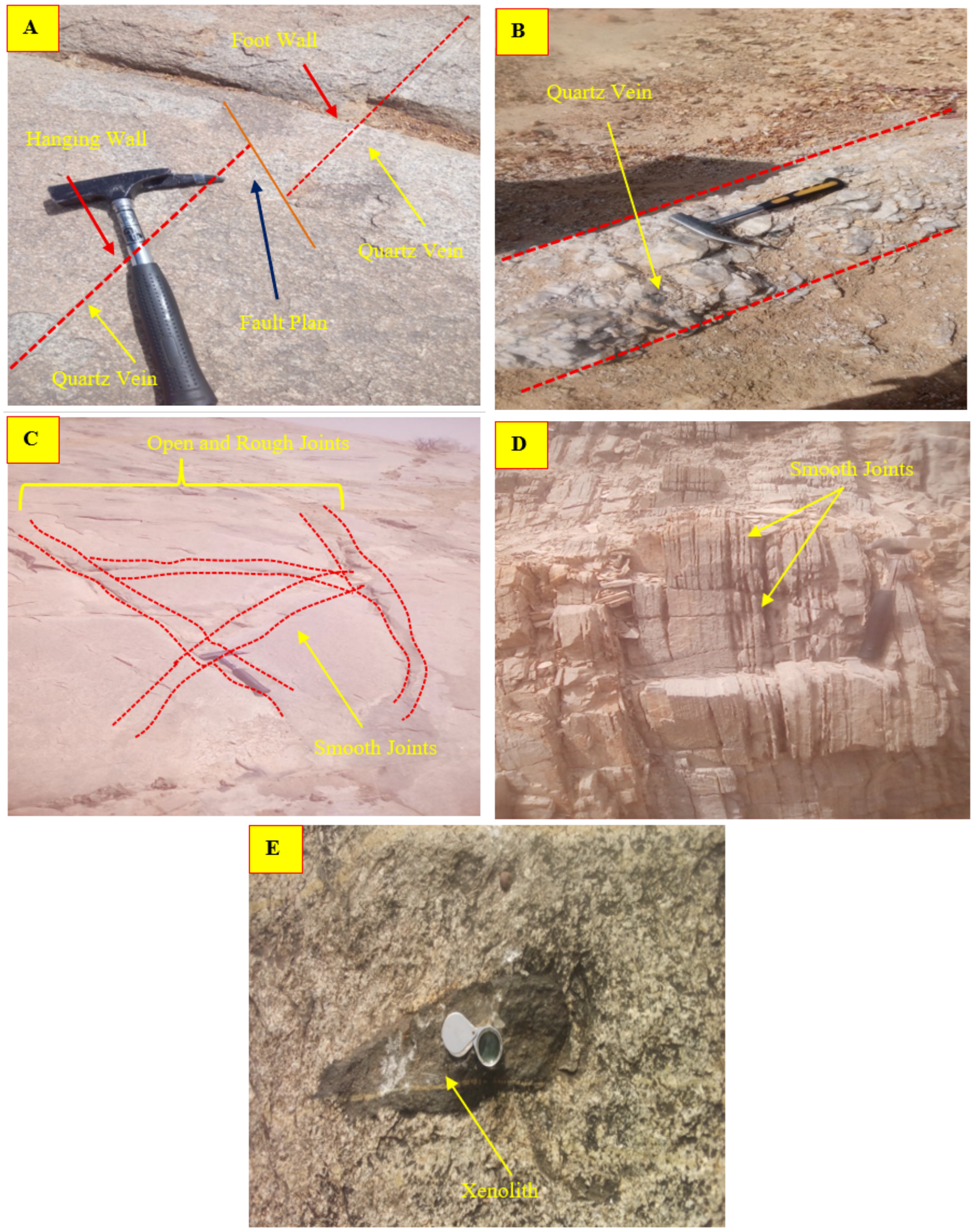

Figure 6. Structural features in the study area: (A) fault, (A and B) quartz veins, (C and D) joints, and (E) xenolith.

From the petrographic examinations, the medium- to coarse-grained granodiorite consists of quartz (44%), plagioclase (37%), orthoclase (8%), biotite (9%), and opaque minerals (2%); porphyritic granodiorite contains quartz (43%), plagioclase (30%), orthoclase (12%), and biotite (15%); phyllite is composed of quartz (45%), muscovite (47%), and opaque minerals (8%); and amphibolite schist includes quartz (30%), amphibole (hornblende) (50%), and muscovite (20%). These mineral grains are predominantly euhedral to anhedral, reflecting differential crystallization and spatial variability during the cooling and solidification of magma, particularly in granodiorite. The quartz crystals are colorless under PPL and XPL, possess very low relief, exhibit first-order birefringence, lack cleavage and twinning, show no pleochroism, and demonstrate undulose extinction. Plagioclase crystals are colorless under PPL and XPL. They exhibit low relief, parallel extinction, and notable polysynthetic twinning in medium- to coarse-grained granodiorite, whereas albite twinning and oblique extinction are prominent in porphyritic granodiorite. In medium- to coarse-grained granodiorite, orthoclase feldspar appears bluish-pink under XPL, with significant variation in porphyritic granodiorite as a result of twinning and biotite inclusions. The crystals are characterized by very low relief, Carlsbad twinning, low birefringence (first order), and a patchy and thread-like perthitic texture. Biotite under PPL and XPL ranges from dark brown to brownish green and light brown to dark brown in medium- to coarse-grained granodior-ite and porphyritic granodiorite, respectively. The crystals exhibit strong pleochroism, have moderate relief, and display mica cleavage. The textural relationships among the constituent minerals in granodiorite suggest a low rate of cooling, confirming its plutonic origin. In

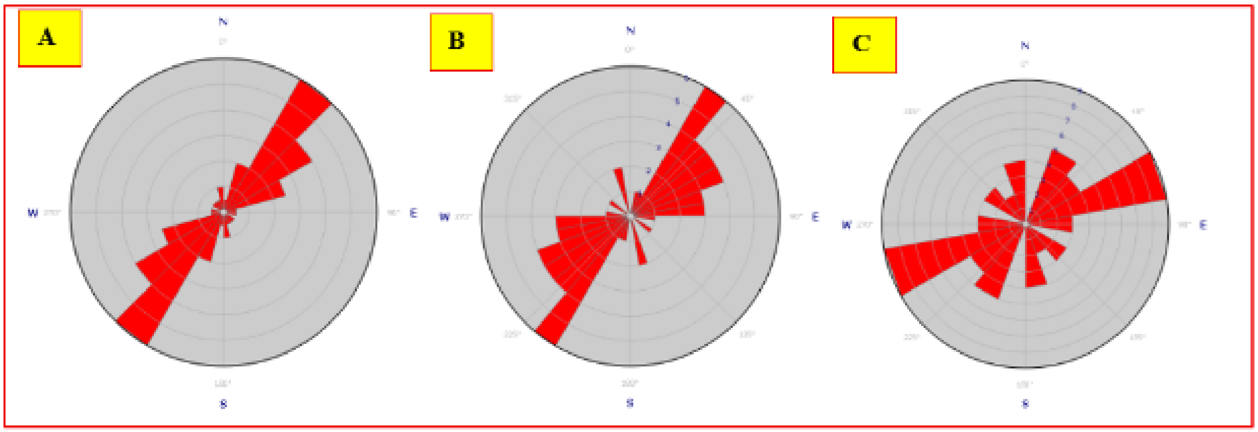

Figure 7. Rose diagrams showing (A) joint trends in granodiorite and amphibolite schist, (B) quartz vein trends in granodiorite, and (C) joint trends in phyllite.

the amphibolite schist, muscovite is greenish to pink in XPL. It shows biotite inclusions, perfect cleavage, and strong pleochroism. Amphibole is also characterized by intense pleochroism; it appears dark to greenish brown under PPL and bluish green under XPL. The presence of amphibole (hornblende) in the amphibolite schist indicates medium-grade metamorphism typical of lower amphibolite facies [29, 30]. The phyllite is characterized by a fine-grained lepidoblastic texture, defined by the preferred arrangement of muscovite (sericite), quartz, and opaque minerals. The muscovite grains in the phyllite are colorless under PPL with parallel extinction under XPL, whereas opaque minerals are dark-colored under PPL and XPL.

3.3. STRUCTURAL FEATURES

The structural features recorded in rocks of the study area consist of quartz veins, faults, joints, and xenolith. The quartz veins show variable thickness, ranging from a few centimeters to approximately 0.5 m (Figure 6A and B), and trend in the N–S direction. At one location (12°23′31.0″N, 006°22′52.7″E), the vein is distinctly prominent and well pronounced (Figure 6B). Generally, quartz veins typically form by recrystallization of silicate minerals within fractures filled with hydrothermal fluid [31, 32]. Normal faults that are occasionally filled with silicate minerals are prominent in the area (Figure 6A). However, some walls occur as barren and open (Figure 6C and D). Joints in the area are predominantly tectonic, with a general NE–SW trend (Figure 7A–C). A series of smooth and rough joint surfaces were mapped, especially across granodiorite outcrops (Figure 6C). Within the highly weathered phyllite exposures, sheet jointing is prominent (Figure 6D). A basic, lensoidal xenolith of about 0.3 m length occurred within the medium-grained granodiorite (Figure 6E). Xenoliths are inclusions that represent pieces of older rock incorporated into crystallizing magma.

4. CONCLUSION

The geology and petrography of rocks in Damaga and its environs have been investigated. Field-lithological studies and petrographic analysis of the constituent minerals established the various rock types, their relationships, associated minerals, and structural features in the study area. Three major rock units—granodiorite, phyllite, and amphibolite schist—underlie the area. The results of the petrographic analysis indicated that granodiorite is rich in quartz, feldspar (plagioclase and orthoclase), and biotite. Phyllite is dominated by quartz and muscovite, while amphibole (hornblende), quartz, and muscovite constitute amphibolite schist. The area records both igneous and low-grade metamorphic processes. Trends of structural readings in the area are in line with the regional direction of structures conforming to the Pan-African Orogeny.

DATA AVAILABILITY

The data are available on request from the corresponding author.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

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References

[1] O. G. Olisa, O. A. Okunlola & A. A. Omitogun, "Rare metals (Ta–Nb–Sn) mineralization potential of pegmatites of Igangan area, southwestern Nigeria", Journal of Geoscience and Environmental Protection **6** (2018) 67. https://doi.org/10.4236/gep.2018.64005.

[2] N. A. Yusuf, M. Abdullahi & I. S. Hassan, "Geology and petrography of basement rocks around Paki, northwestern Nigeria", International Journal of Advances in Scientific Research and Engineering **4** (2018) 257. https://doi.org/10.31695/IJASRE.2018.33027.

[3] A. I. Aliyu, C. I. Unuevho, A. Yohanna, I. M. Sanusi, S. Aliyu, N. J. Jabo, A. I. Okkoh & M. Yahaya, "Assessment of industrial potentials of marble deposits in Ugya, north-central Nigeria based on mineralogical and chemical studies", Science Forum (Journal of Pure and Applied Sciences) **23** (2023) 951. https://atbuscienceforum.com.ng/index.php/jpas/article/view/144

[4] J. W. Barnes & R. J. Lisle, Basic Geological Mapping, 4th ed., John Wiley & Sons Ltd., Chichester, United Kingdom, 2004. https://download.e-bookshelf.de/download/0000/5687/49/L-G-0000568749-0002356835.pdf

[5] I. Bunyaminu, A. I. Haruna & Y. Isah, "Geology, petrography, and microtectonic studies of rocks in Lallangi and environs, part of Bauchi Sheet 149 NE, Bauchi, northeast Nigeria", Science Forum (Journal of Pure and Applied Sciences) **20** (2020) 174. https://doi.org/10.5455/sf.84299.

[6] O. O. Akinola, A. Ghani & E. James, "Petrography and geochemical characterization of a granite batholith in Idanre, southwestern Nigeria", Sains Malaysiana **50** (2021) 315. https://doi.org/10.17576/jsm-2021-5002-04.

[7] B. Aliyu & Z. Muhammad, "Geology and petrography of Rawayya and its environs, part of Sheet 54SE, Bungudu Local Government Area of Zamfara State, Nigeria", Earth Sciences **14** (2025) 57. https://doi.org/10.11648/j.earth.20251402.12.

[8] M. A. Mohammed, O. I. Chinedu & M. Lawal, "Geology and mineralogy of Batola and its environs, southwestern Nigeria", International Journal of Science for Global Sustainability **11** (2025). https://doi.org/10.57233/ijsgs.v11i2.841.

[9] R. Black, "Precambrian of West Africa", Episodes **3** (1980) 3. https://doi.org/10.18814/epiiugs/1980/v3i4/001.

[10] P. McCurry & J. B. Wright, "Geochemistry of calc-alkaline volcanics in northwestern Nigeria, and a possible Pan-African suture zone", Earth and Planetary Science Letters **37** (1977) 90. https://doi.org/10.1016/0012-821X(77)90149-2.

[11] N. Obaje, *Geology and Mineral Resources of Nigeria*, Springer, Berlin, Germany, 2009. https://doi.org/10.1007/978-3-540-92685-6.

[12] M. Rahman, *Recent advances in the study of the Basement Complex of Nigeria*, in *Precambrian Geology of Nigeria*, Geological Survey of Nigeria, Kaduna, Nigeria, 1988, pp. 11–43. https://www.scirp.org/reference/referencespapers?referenceid=1712445

[13] S. S. Dada, "Proterozoic evolution of Nigeria", in *The Basement Complex of Nigeria and its Mineral Resources (A Tribute to Prof. M. A. O. Rahman)*, O. Oshi (Ed.), Akin Jinad & Co., Ibadan, Nigeria, 2006, pp. 29–44. https://www.scirp.org/reference/referencespapers?referenceid=1425168

[14] W. Musa, A. I. Haruna, A. S. Maigari, A. I. Jibrin, I. I. Kariya, T. Aga & H. R. Gayyemi, "Geology and economic potentials of migmatite around Filin Shagari, Kafin Madaki (Sheet 129 NW & SW), Bauchi N.E, Nigeria", IIARD International Journal of Geography & Environmental Management **10** (2024) 321. https://www.researchgate.net/publication/391156775_Geology_and_Economic_Potentials_of_Migmatite_Around_Filin_Shagari_Kafin_Madaki_SHEET_129_NW_SW_Bauchi_NE_Nigeria.

[15] O. A. OlaOlorun & O. O. Akinola, "Migmatite-gneiss-granite basement of southwestern Nigeria: Mineralogical and geochemical evidence for a possible common ancient protolith", Journal of Earth and Environmental Sciences Research **6** (2024) 1. https://www.researchgate.net/publication/382714796_Migmatite-Gneiss-Granite_Basement_of_Southwestern_Nigeria_Mineralogical_and_Geochemical_Evidence_for_a_Possible_Common_Ancient_Protolith

[16] D. C. Turner, "Upper Proterozoic schist belts in the Nigerian sector of the Pan-African Province of West Africa", Precambrian Research **21** (1983) 55. https://doi.org/10.1016/0301-9268(83)90005-0.

[17] M. T. Jimoh, A. T. Bolarinwa & T. Kolawale, "Geochemical stream reconnaissance survey of the schist belt around Igbo-Ora, southwestern Nigeria", Journal of Geology and Mining Research **7** (2015) 65. https://www.researchgate.net/publication/290472488_Geochemical_stream_reconnaissance_survey_of_the_schist_belt_around_Igbo-Ora_Southwestern_Nigeria.

[18] Y. A. Omanayin, M. Lawal, I. B. Bolaji & A. Muhammad, "Field and petrographic studies of Basement Complex rocks in Saigbe and environs, north-central Nigeria", Nigerian Journal of Basic and Applied Sciences **31** (2023) 49. https://doi.org/10.4314/njbas.v31i1.6.

[19] U. A. Dambatta, "On the evolution of the Kazaure Schist Belt of NW Nigeria: A re-interpretation", Global Journal of Geological Sciences **8** (2010) 207. https://pdfs.semanticscholar.org/07e6/6207c9447265d811b934deec1c5672ef2d38.pdf

[20] M. Abdullahi, M. A. Adediran & N. Y. Abdullahi, "Geology and petrography of basement rocks around Tsauni, northwestern Nigeria", International Journal of Advances in Scientific Research and Engineering **5** (2019) 257. https://www.researchgate.net/publication/332942781_Geology_and_Petrography_of_Basement_Rocks_around_Tsauni_Northwestern_Nigeria.

[21] M. Lawal, M. Mohamed, K. A. Alalade, H. Hamidu, A. M. Shuaibu, N. Y. Abdulmumin, Y. A. Omanayin & F. Salman-Adeniyi, "Geology of Basement Complex rocks in Kabo area, Kano, northwestern Nigeria: Insights into the trends of mineralization in the region", International Journal of Science for Global Sustainability **11** (2025) 38. https://doi.org/10.57233/ijsgs.v11i1.780.

[22] A. S. Sa'ad, I. M. Mustapha, U. Maibeti, M. K. Muhammad, J. H. Yashe, N. K. Caleb, U. Mohammed, J. I. Hassan, U. A. Usman, H. I. Kamale, A. U. Taliyawa, A. Yunusa, I. A. Yerima, A. Busuma & W. I. Suleiman, "Petrography and structures of the Precambrian basement rocks of the Kazaure Schist Belt, northwestern Nigeria", The Oil and Gas Journal of Engineering, Applied Sciences, Management and Art Research **3** (2024) 100. https://www.researchgate.net/publication/383358137_PETROGRAPHY_AND_STRUCTURES_OF_THE_PRECAMBRIAN_BASEMENT_ROCKS_OF_THE_KAZAURE_SCHIST_BELT_NORTHWESTERN_NIGERIA

[23] E. O. Rowland, "Rapid method for preparation of thin rock sections", Mineralogical Magazine **30** (1953) 254. https://www.cambridge.org/core/journals/mineralogical-magazine-and-journal-of-the-mineralogical-society/article/abs/rapid-method-for-the-preparation-of-thin-rocksections/A8EF983A1C0A0A9A0184B3EC38CB32D9

[24] J. M. El-Nafaty, "Geology and petrography of the rocks around Gulani area, northeastern Nigeria", Journal of Geology and Mining Research **7** (2015) 1. https://doi.org/10.5897/JGMR15.0222.

[25] A. T. Agbor, O. U. Shehu, S. H. Dantata, E. S. Jude & A. I. Asema, "Petrographic and structural analysis of exposed rocks of Bishini Sheet (Block 2), north-central Nigeria", Earth Science Research **2** (2013) 143. https://doi.org/10.5539/esr.v2n1p143.

[26] E. C. Ukaegbu, O. C. Okeke, U. C. Emmanuel, M. O. Okafor, T. C. Owerri, F. B. Akiang & G. A. Onwunaonyeshi, "Role of rose diagram in the interpretation of geologic structures: A review", World Journal of Innovation and Modern Technology **8** (2024) 163. https://doi.org/10.56201/wjimt.v8.vo5.2024.pg163.187.

[27] F. Chayes, "A simple point counter for thin section analysis", American Mineralogist **34** (1949) 1. https://pubs.geoscienceworld.org/msa/ammin/article-abstract/34/1-2/1/541208/A-simple-point-counter-for-thin-section-analysis?redirectedFrom=fulltext

[28] T. Age & A. I. Haruna, "The field geology and petrography of the Kofayi Younger Granite Complex, central Nigeria", International Journal of Advanced Geosciences **7** (2019) 95. https://scispace.com/pdf/the-field-geology-and-petrography-of-the-kofayi-younger-2p25gsv5sh.pdf

[29] R. N. Abbott Jr. & B. R. Bandy, "Amphibolite and blueschist–greenschist facies metamorphism, Blue Mountain inlier, eastern Jamaica", Geological Journal **43** (2008) 525. https://doi.org/10.1002/gj.1126.

[30] K. Safei, M. Ali-Arian & S. H. Moien Zadeh Mirhosseni, "Mineral chemistry and geothermometry of amphibole and plagioclase in the metabasites, located at the Tanbour Metamorphic Complex in southern Iran", Open Journal of Geology **5** (2015) 795. https://doi.org/10.4236/ojg.2015.511068.

[31] J. Mao, Y. Wang, H. Li, F. Pirajno, C. Zhang & R. Wang, "The relationship of mantle-derived fluids to gold metallogenesis in the Jiaodong Peninsula: Evidence from D–O–C–S isotopes systematics", Ore Geology Reviews **33** (2008) 361. https://doi.org/10.1016/j.oregeorev.2007.01.003.

[32] N. Mama, A. Adama, B. Ntieche, F. S. Nsang & N. Anchimbom, "Quartz veins, evidence of hydrothermalism and postmagmatic process for mineral deposit gold and sphalerite ore in KAAKA area (Adamawa-Cameroon)", ISAR Journal of Science and Technology **2** (2024) 5. https://www.researchgate.net/publication/383431025_Quartz_veins_evidence_of_hydrothermalism_and_postmagmatic_process_for_mineral_deposit_gold_and_sphalerite_ore_in_KAAKA_area_ADAMAWA-CAMEROON_Corresponding_Author .