iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VII **Month of publication:** July 2026

DOI: https://doi.org/10.22214/ijraset.2026.83763

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

Geology, Petrography, Hydrogeology and Structural Analysis of Basawa and Its Environs, Part of Zaria Sheet 102 SW, Kaduna State, Northwestern Nigeria

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Abstract: ***This study presents the geology, petrography, hydrogeology, structural characteristics, and economic significance of Basawa and its environs within Zaria Sheet 102 SW, Kaduna State, Northwestern Nigeria. Detailed geological mapping at a scale of 1:25,000, complemented by petrographic analysis of representative rock samples, was undertaken to characterize the lithological units and reconstruct the geological history of the area. The area is predominantly underlain by Precambrian Basement Complex rocks consisting mainly of gneiss and granitic intrusions, with minor occurrences of quartz veins, laterite, and alluvial deposits. Field observations reveal extensive structural features including joints, veins, dykes, foliations, and ptygmatic folds. Petrographic studies indicate that the gneiss is composed predominantly of quartz, plagioclase, orthoclase, microcline, biotite, and muscovite, whereas the granites consist mainly of quartz, feldspar, biotite, and muscovite. Structural analysis indicates dominant N–S to NE–SW trends consistent with regional Pan-African tectonism. Field relationships and petrographic evidence suggest that the gneiss constitutes the oldest lithological unit and was subsequently intruded by granitic bodies during the Pan-African orogeny. Although no economically significant metallic mineralization was identified, the abundance of granitic and gneissic rocks, lateritic materials, and alluvial deposits provides substantial potential for construction materials, groundwater development, and agricultural activities. The study contributes to the understanding of the geology and tectonic evolution of the Nigerian Basement Complex in the Zaria region.***

Keywords: Basawa, Gneiss, Granite, Petrography, Pan African Orogeny, Rose diagram.

I. INTRODUCTION

The Nigerian Basement Complex forms part of the Pan-African Mobile Belt situated between the West African and Congo Cratons. The Basawa area, located within Zaria Sheet 102 SW, is underlain by crystalline basement rocks that preserve evidence of multiple episodes of deformation, metamorphism, and magmatism. Despite several regional studies on the Nigerian Basement Complex, detailed geological information on Basawa remains limited. This study aims to document the lithological units, petrographic characteristics, structural framework, and geological evolution of Basawa and its environs. The Study Area is located in Sabon Gari Local Government Area of Kaduna state, within latitudes 11°10′44.51″N and 11°13′15.49″N and longitudes 7°39′23.74″E and 7°43′51.00″E covering an approximate area of about 40Km^2. The studied area was mapped on a scale of 1:25000. The studied area falls within the basement complex of Nigeria. The rock types found in the basement complex of Nigeria includes migmatites, gneisses, schists, quartzites, marbles and a series of basic, intermediate plutonic rocks-charnockitic suites, gabbros, diorites, granites, granodiorites and syenites (Rahaman, 1988). Northern Nigeria is underlain by gneisses, migmatites and metasediments of Precambrian age which have been intruded by a series of granitic rocks of late Precambrian to lower Paleozoic age. These rocks have been variably metamorphosed and granitized through at least two tectono-metamorphic cycles so that they have been largely converted to migmatites and granite gneiss (Mc Curry, 1971). The Northern Nigeria is perhaps the most interesting area of basement geology, because all the major rock units are present, including extensive belts of younger metasediments.

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II. REGIONAL GEOLOGICAL SETTING

The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria (Danbatta, 1999). The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo cratons and south of the Tuareg Shield (Falconer, 1911; Black 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian basement was affected by the 600 Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Danbatta, 1999). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma). The first three cycles were characterized by intense deformation and isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional metamorphism, migmatization and extensive granitization and gneissification which produced syntectonic granites and homogeneous gneisses (Danbatta, 1999). Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing (Gandu et al., 1986; Burke and Dewey, 1972). The Nigerian Basement Complex comprises Migmatite–Gneiss Complexes, Schist Belts, Older Granites, and minor intrusive bodies. These rocks record the effects of Liberian, Eburnean, Kibaran, and Pan-African tectono-metamorphic events. The Pan-African Orogeny (~600 Ma) produced widespread deformation, regional metamorphism, granitization, and emplacement of syn- to late-tectonic granitoids. Basawa lies within this basement province and exhibits lithological and structural features characteristic of Pan-African reworking.

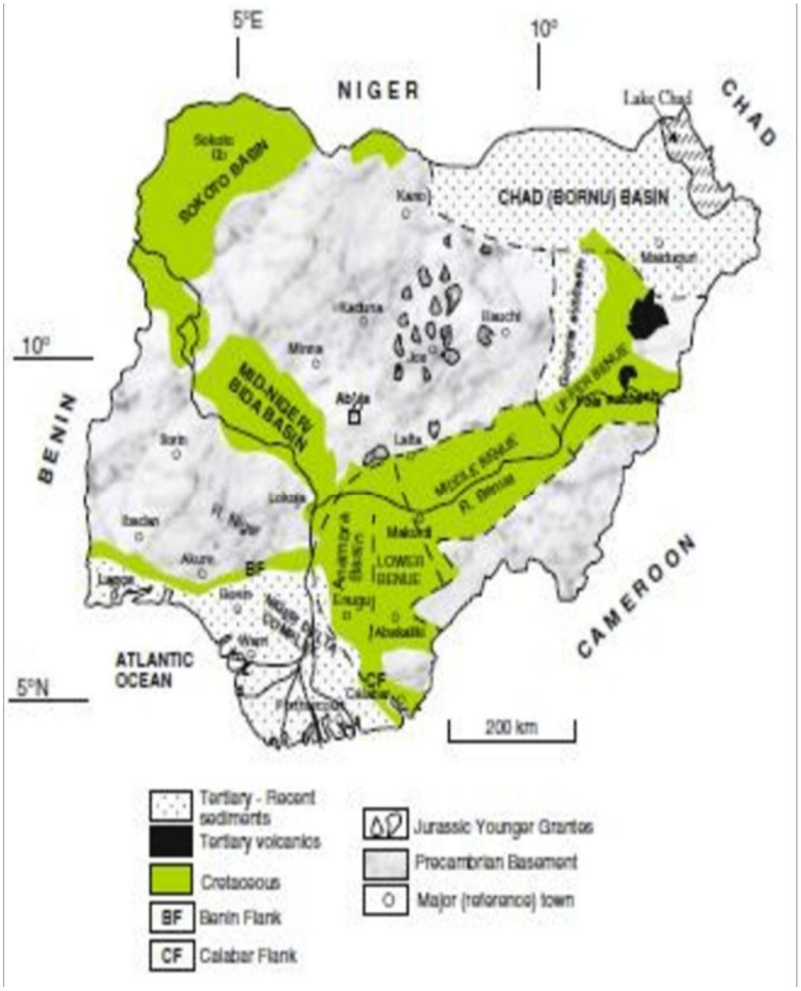


Fig. 1: Generalized Geological Map of Nigeria (Adapted from Obaje, 2009)

Table 1: Generalized Geochronology of the Basement Complex Rocks of Nigeria

Age/Period	Geological History	Rock Type
Recent to 135+-20 Ma	Superficial deposition	Alluvium, loam and laterite
Mid-Cambrian 540+_40Ma	Uplift, cooling, fracturing, fault, high level migmatitc activity	
Lower –Cambrian 580-650Ma	Granite intrusion, pegmatite and aplite development	Older granites
Pan-African 650-850Ma	Orogenesis, deformation, metamorphism, migmatisation and reactivation of pre-existing rocks	Older granite, syenite, granodiorite, granite gneiss, cataclasites, etc
Katanga 800-1000Ma	Geosyncline deposition, intrusion of hypersthene bearing rocks	Katangan metasediments
Eburnean 1900+_ 250Ma	Granite intrusion, orogenesis, folding, metamorphism and reactivation of pre-existing rocks	Eburnean granites
Birimian 2500Ma	Geosyncline deposition	Birimian metasediments
Liberian cycle 2800+_200	Possible formation of banded gneiss near Ibadan (Grant 1970)	Migmatite gneiss, granulite gneiss

III. MATERIALS AND METHOD

Geological mapping was conducted using compass traversing techniques on a scale of 1:25,000. Field equipment included a GPS, compass-clinometer, geological hammer, hand lens, measuring tape, sample bags, and field notebooks. Structural measurements of strike and dip were recorded systematically. Representative rock samples were collected from major lithological units for petrographic examination. Thin sections were prepared and studied under plane-polarized and cross-polarized light using a polarizing microscope. Rose diagram was used to conduct the structural analysis and hydrogeological data were taken to develop the hydrogeological map of the area. Details of the method have been described by Sa'ad and Baba (2017); and Muhammad, et al, (2022).

IV. RESULTS

The principal lithological units identified include gneiss and granite, with subordinate quartz veins, laterite, and alluvial deposits. Gneiss occupies the majority of the exposed basement terrain and exhibits well-developed foliation and compositional banding. Granitic bodies occur as intrusive units forming dome-shaped and whaleback outcrops. Petrographic analysis of gneiss reveals quartz, plagioclase, orthoclase, microcline, biotite, and muscovite. The mineral assemblage and foliation indicate medium- to high-grade metamorphism. Granites are characterized by quartz, feldspar, biotite, and muscovite, displaying hypidiomorphic granular textures typical of felsic intrusive rocks.

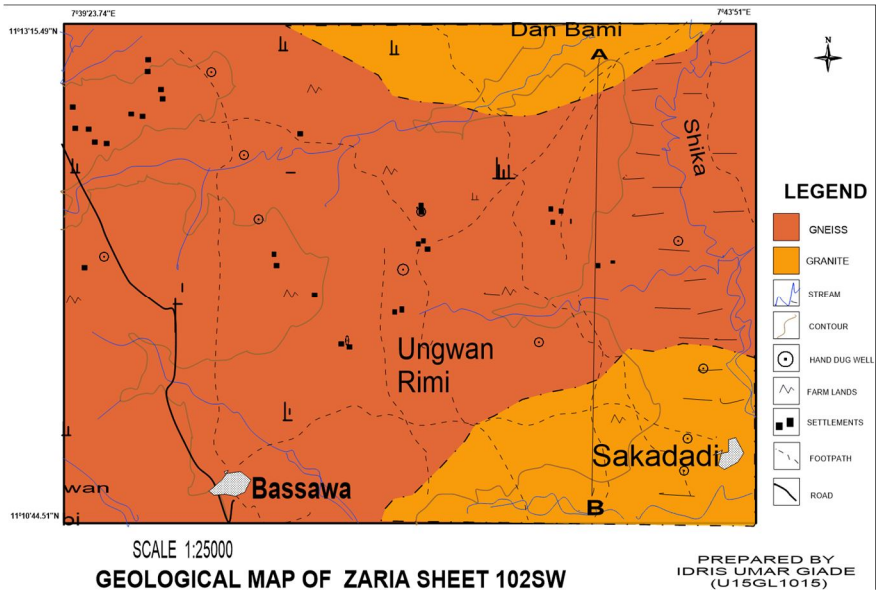
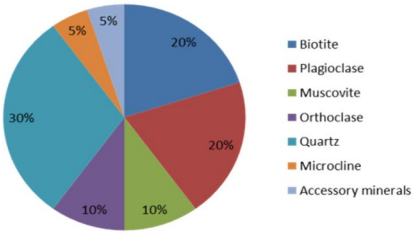


Fig. 2: Geological map of the Study Area

The gneiss occupies almost 45% of the total exposed lithology of the mapped area but constitutes about 75% of the basement rock. The gneiss is recognized by the alignment of mafic and felsic minerals (foliation) in a preferred direction, this phenomenon is known as gneissic banding or gneissosity. Exfoliation is observed on the rock which is an evidence of physical weathering effect on the rock.



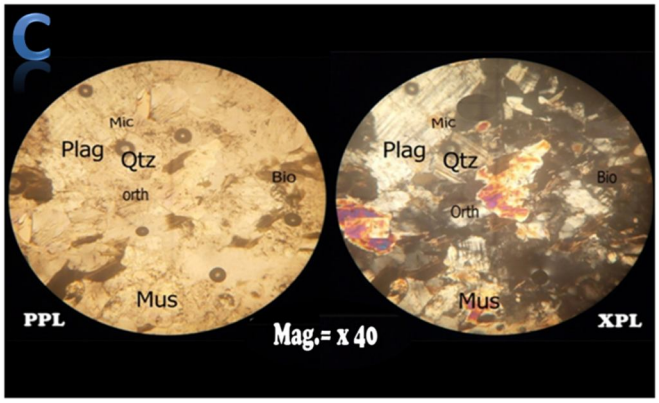


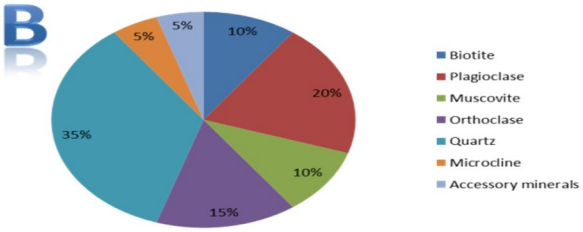
Plate 1 a: A Gneiss exposure western part of the Study Area (11°11'13.2"N, 7°39'32.8"E)

b: Pie chart showing modal mineral composition of Gneiss.

c: Photomicrograph of Gneiss showing mineral composition in PPL and XPL view. (Plag= Plagioclase, Qtz=Quartz, Orth= Orthoclase, Bio= Biotite, Mic= Microcline, Mus= Muscovite)

Plate 1: Field, modal and photomicrograph of Gneiss

The Granite exposures appeared to be a large granitic body, whaleback/ dome shaped and occupies less than 20% of the Study Area, occurring as an intruding rock into the basement rock of the study area and generally trending NW-SE. The Coarse to Medium Grain Granite has a variation in colour from light to dark, due to the differences in abundance of biotite in different parts of the outcrop. In terms of the texture, the rock is medium grained with average grain size 3-5mm.



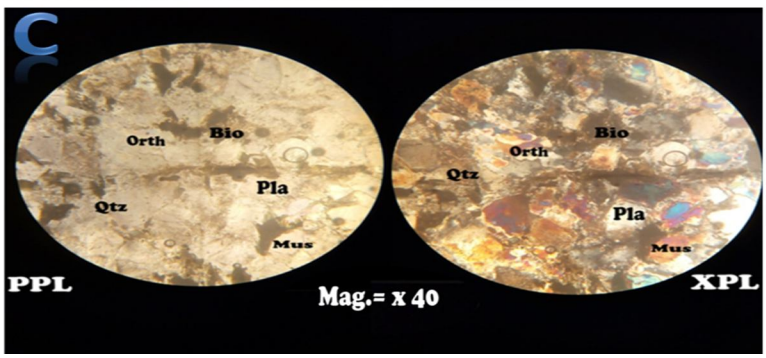


Plate 2 a: A Granite exposure in the Study Area (11°11'4.508"N,7°43'20.38"E)

b: Pie chart showing modal mineral composition of Granite

c: Photomicrograph of Coarse to Medium Grain Granite showing mineral composition in PPL and XPL view. (Plag= Plagioclase, Qtz=Quartz, Orth= Orthoclase, Bio= Biotite, Mus= Muscovite)

Plate 2: Field, modal and photomicrograph of Granite

Structural features include joints, fractures, veins, dykes, foliations, and ptygmatic folds. The dominant structural trend is N–S to NE–SW, reflecting the influence of Pan-African deformation.

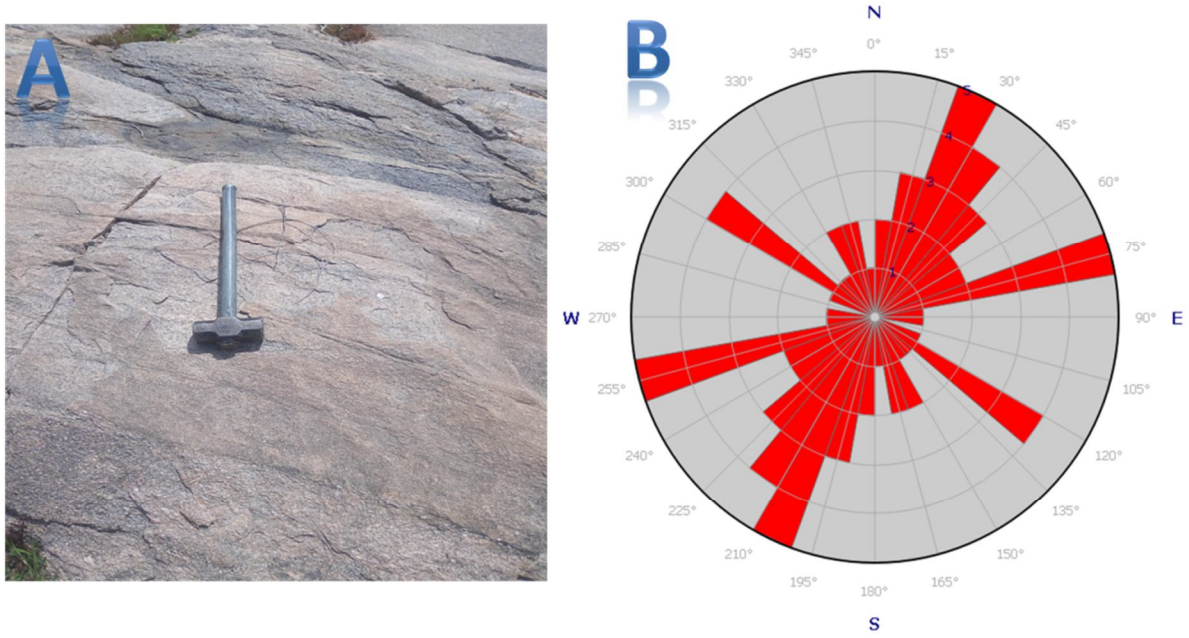


Plate 3 a & b: Field and Rose diagram of a joint and joint set (N11º11'13.2", E7º39'32.8“)

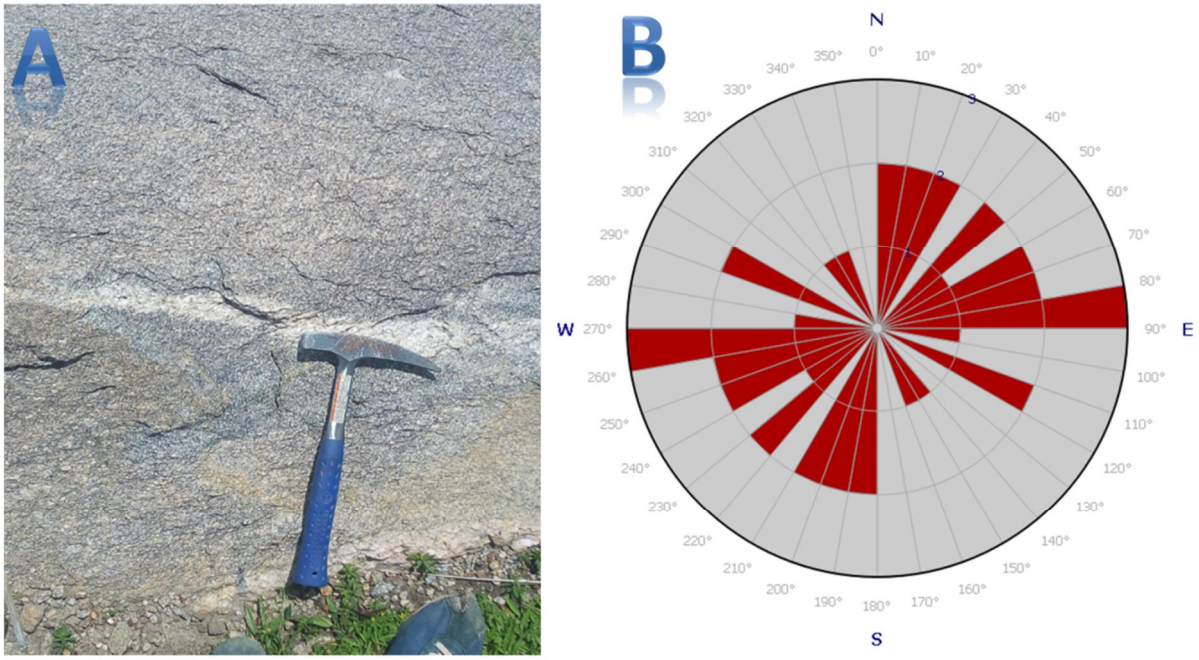


Plate 4 a & b: Field and Rose diagram of a vein (11^{0}13$'$5.8$"$N,7^{0}41$'$35.028$"$E)

Plate 5 a & b: Field photograph of a ptygmatic fold (11^{0}11'7.974"N,7^{0}43'27.204"E) and Aplite dyke (11^{0}13'6.354"N, 7^{0}41'35.58"E)

The hydrogeology of the Study Area comprises of both groundwater and surface water from the River Shika which runs from Northwest to Southeast serving as a source of water for consumption and irrigation. Crystalline rocks like gneiss are generally non-porous and impermeable holding no prospects for groundwater, but when they are fractured, fissured or weathered, can contain groundwater. Importantly metamorphic rocks forming the upper layer may have better chances of being an aquifer than those buried deeply because the fractured zones gets closed and disappear with depth. Moreover the upper layer is invariably weathered to a greater or lesser extent which adds to the original permeability.

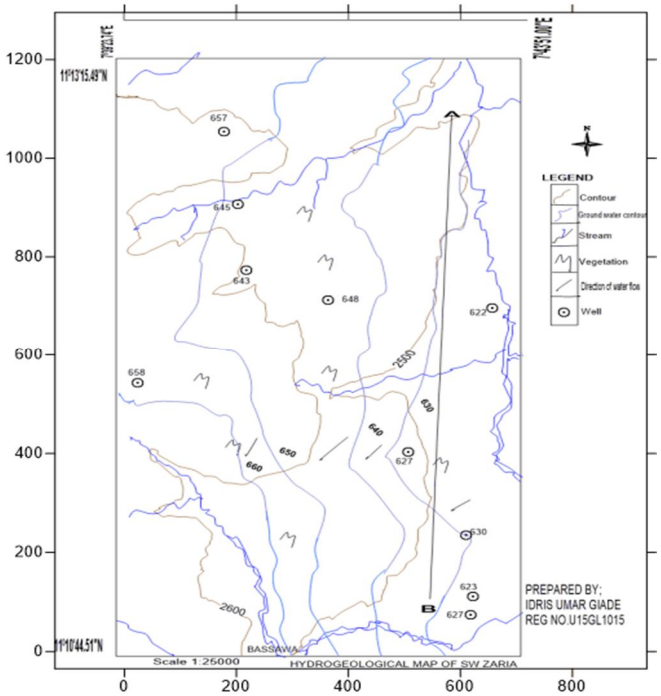


Fig. 3: Hydrogeological map of the study area showing the groundwater table

V. DISCUSSION

Field relationships demonstrate that the gneiss predates the granitic intrusions. The occurrence of gneissic xenoliths within granitic bodies supports emplacement of granitoids into older metamorphic basement rocks (Ajibade, 1976 and 1980). The observed structural trends correspond with regional Pan-African deformation patterns documented across northwestern Nigeria (Adekoya, 1977). The mineralogical composition and textures of the granites indicate slow cooling at depth, consistent with emplacement as plutonic bodies. Distortion of feldspar twins and mineral alignment within the gneiss suggest deformation under directed stress. The widespread occurrence of joints and fractures likely reflects brittle deformation during the late stages of the Pan-African tectonic cycle. The geological evolution of the area involved formation of basement gneisses, regional metamorphism, deformation, granitoid intrusion, and subsequent weathering leading to the development of lateritic profiles and alluvial deposits. The granites and gneisses represent valuable construction materials suitable for quarrying and aggregate production. Lateritic materials may serve as road construction materials, while alluvial deposits support agricultural activities. Weathered and fractured basement rocks constitute potential groundwater reservoirs. Groundwater occurrence is expected within weathered regolith and fracture systems, with water levels varying according to topography and seasonal recharge.

VI. CONCLUSION

Basawa and its environs are underlain predominantly by Precambrian basement rocks comprising gneiss and granitic intrusions. Petrographic and field evidence indicate that the gneiss represents the oldest rock unit, subsequently intruded by Pan-African granitoids. Structural features, including joints, veins, dykes, and foliations, display dominant N–S to NE–SW orientations consistent with regional tectonic trends. The area possesses considerable potential for groundwater development based on the well readings and depth analysis, thus, it can be established that the water table will be approximately met at depths of 3- 9meters during the rainy season (from east-west) relative to the topographical contour of the area for hand dug wells. This should aid and facilitate future water exploration studies. Economically, the area has prospect for construction materials and agricultural utilization. The study enhances understanding of the lithological, structural, and tectonic evolution of the Northwestern Nigerian Basement Complex.

VII. ACKNOWLEDGEMENTS

The authors acknowledge the Department of Geology, Ahmadu Bello University, Zaria, for providing laboratory facilities and technical support during fieldwork and petrographic investigations.

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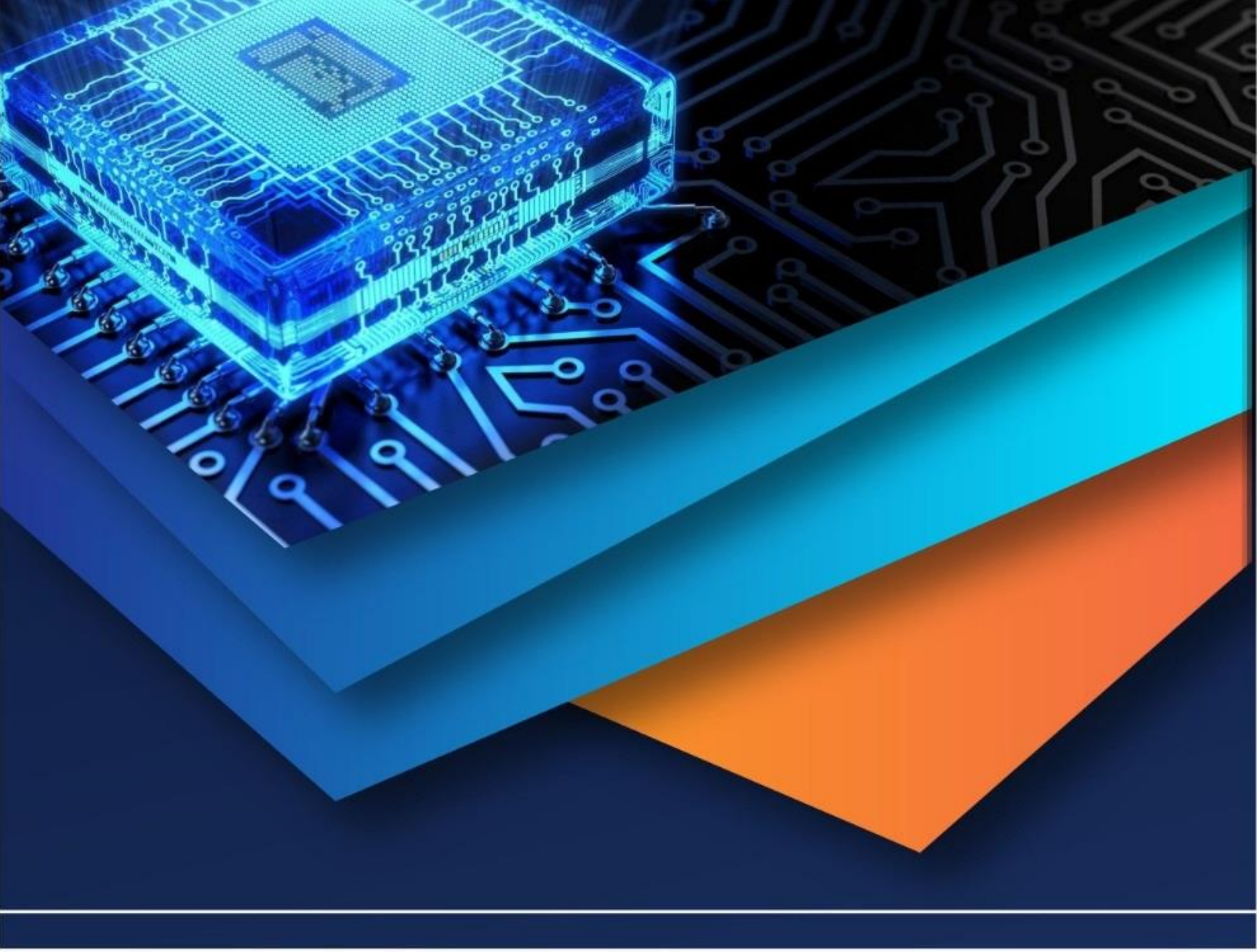

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