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Petrology And Structural Geology Of Gneissic Rocks In Bansan-Osokom And Its Environs, Southeast Nigeria

U. B. Abia[1], V. U. Ukaegbu[2], N. Egesi[2]
Geology Department, Akwa Ibom State University, Nigeria
Geology Department, University Of Port Harcourt, Nigeria

Abstract:
This study examines the petrology and structural characteristics of gneissic rocks around Bansan-Osokom and its environs to clarify their metamorphic evolution and deformational history. Fourteen representative samples of medium- to coarse-grained migmatite gneisses (9) and granite gneisses (5) were analyzed petrographically. Modal composition indicates biotite–cordierite–garnet migmatite gneiss and biotite–cordierite granite gneiss as the major lithologies. The gneissic rocks display granoblastic to lepidoblastic textures defined by biotite, while garnet shows porphyroblastic growth with inclusion trails of biotite and quartz. Cordierite rims around garnet indicate pinitization. Three metamorphic events are inferred in this study: deformation, peak metamorphism, and retrogression. The coexistence of quartz, plagioclase, and cordierite with polygonal 120° triple junctions suggests stability at peak temperature conditions. Well-developed foliations defined by biotite record ductile deformation, whereas pinitization of cordierite and sericitization of feldspar indicate retrogression due to fluid infiltration. Structural data show dominant NE–SW-trending fold limbs with minor NW–SE directions. Foliations in granite gneiss show dominant trend mainly in E–W with subordinate NE–SW and NW–SE sets, while that of migmatite gneiss trends nearly N–S with minor E–W and NE–SW directions. Quartzofeldspathic veins are dominantly NE–SW, pegmatite veins mainly N–S, and fractures trend NW–SE. These integrated results indicate high-grade metamorphism, subsequent retrogression from upper amphibolite to lower granulite facies, and multiple deformational episodes associated with Pan-African tectonism, with remnants of pre-Pan-African structures still preserved.

Keywords: *Bansan Osokom; Cordierite; Peak metamorphism; Polyphase deformation; Retrogression.*

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I. INTRODUCTION

The research area, Bansan-Osokom and its environs is a part of Boki Local Government Area of Cross River State, Southeastern Nigeria. The area is situated within the northeast quadrant of the Bansara Sheet (304NE), bounded by latitudes 6°15′–6°30′N and longitudes 8°45′–9°00′E and bordered by the Obudu Plateau to the north, the Benue Trough to the northwest, Ikom to the south, and Mukuru to the east (Agbebia and Egesi, 2020). Bansan-Osokom area forms part of the Precambrian Basement Complex of southeastern Nigeria, a significant component of the reactivated Pan-African Mobile Belt which occupies the region between the West African and Congo craton, extending southwards into the Tuareg Shield (Figure 1). The reactivation is suggested to have resulted from the collision between the passive continental margin plate of the West African Craton and the active plate of Pharusian belt (Black *et al.,* 1979; Burke and Dewey., 1972; Caby *et al*., 1981; Leblanc, 1981; Dada, 2006).

The Precambrian Basement Complex of Nigeria is dominated by four major petro-lithological units namely, the Migmatite–Gneiss-Quartzite Complex considered to be the most widespread unit (Udensi *et al.,* 1986; Ogezi, 1988), the Schist Belt, said to be NNE-SSW elongated supracrustal belts composed mainly of greenschist to amphibolite facies metasediments, (Oyawoye 1972; Rahaman 1976; Grant 1978; Obaje 2009), the Older Granites made up of granites, charnockite, syenites, gabbro and granodiorite, intruding the Migmatite–Gneiss Complex and the Schist Belt and the undeformed acid dykes made up of pegmatites, aplites and basic dykes of dolerite (Dada, 2006; Obaje, 2009). The Basement complex has suffered multiple deformation and metamorphism due to orogenic activities with the most recent one being the activities of the Pan African event. According to McCurry, (1971) and Rahaman (1988), these rocks were significantly reworked by the Pan African event (600 ± 150Ma), which overprinted signatures of the earlier events such as Liberian (2700 ± 200 Ma), Eburnean orogeny (2000 ± 200Ma), and Kibaran orogeny (1100 ± 200Ma). However, Grant, (1971); Onyeagocha and Ekwueme (1982); Oluyide (1988); Ukaegbu (2003); Egesi and Ukaegbu (2010) argued that relics of the earlier events are still in existence.

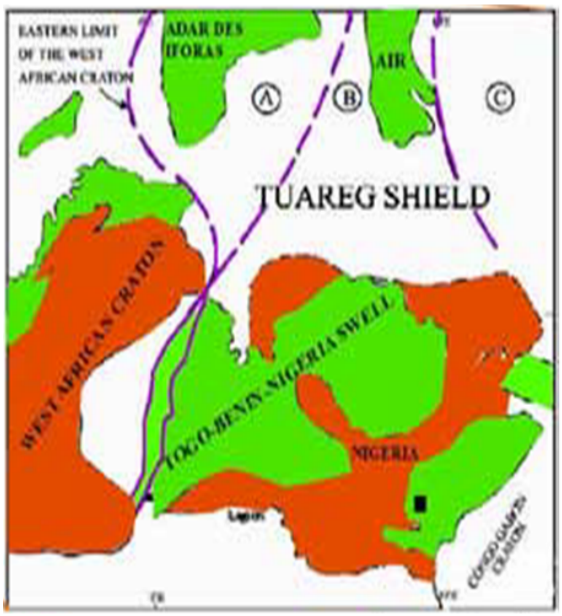

Fig 1: The location of the Nigeria Basement Complex in between the West African craton, the Congo-Gabon Craton and the southern part of the Tuareg shield (after Ibe and Obiora 2019).

Bansan Osokom area is predominantly gneisses and is usually intruded by quartzofeldspathic veins and undeformed acid and basic (pegmatite and dolerite) dykes. They are the most ubiquitous rock type constituting about 70% of the basement rocks in the area, occurring as boulders and low lying exposures. The rocks are characterized by such structures as folds, foliations, fractures, faults, joints, and veins. The metamorphic evolution and the deformational activities in the study area have been under-reported, hence, the reason for this investigation.

II. METHODOLOGY

Geological fieldwork was conducted using standard field equipment and base map of 1:50,000 (Bansara Sheet 304NE). Outcrops were studied along major and minor roads, footpaths, river channels (semi-dry and active), and within farmlands. Each outcrop was carefully examined to distinguish rock units and establish their structural relationships. Structural features such as foliations, folds, fractures, joints, veins, dykes, and faults were documented. Strike and dip measurements were taken using the compass-clinometer. Hand specimen descriptions of the rocks included colour, textural characteristics, morphology, and mineral composition.

Petrographic analysis of fourteen (14) rock samples comprising migmatite gneisses and granite gneisses was carried out at the Petrology laboratory, Chukwuemeka Odumegwu Ojukwu University, Uli. Samples were cut into thin slabs with a rock-cutting machine, and thin sections were prepared using the method of Reed and Mergner (1953). Thin sections were examined with a polarizing microscope under both plane-polarized light (PPL) and cross-polarized light (XPL) to identify the mineralogical composition of the rocks, their textural relationships, and microstructural features. Photomicrographs of characteristic mineral assemblages and textures were also taken for documentation.

III. RESULTS AND DISCUSSION

Petrology and Petrography

Migmatite Gneiss

Migmatite gneisses are widely distributed in the northeastern part of the study area (Fig. 2) and typically occur as medium to coarse grained, grey to dark-grey outcrops with well-developed banding displaying alternating leucocratic and melanocratic minerals (Fig. 3a). The leucocratic bands are composed of quartz and feldspars while the melanocratic bands are dominantly ferromagnesian minerals (Adegbuiyi et al., 2018). They are commonly intruded by quartzofeldspathic veins and dykes of pegmatite and dolerite. In hand specimen, the migmatite gneisses in the area is composed of quartz, biotite, garnet, and feldspars.

Results of the microscopic studies of the migmatite gneisses in the study area are presented in table 1 showing dominance of quartz (20-40%), biotite (15-35%), cordierite (10-38%), garnet (5-30%), plagioclase (8-15%), K-feldspar (2-10%), and opaque (2-5%). This mineral assemblage reveals biotite - cordierite - garnet bearing migmatite gneisses in the study area.

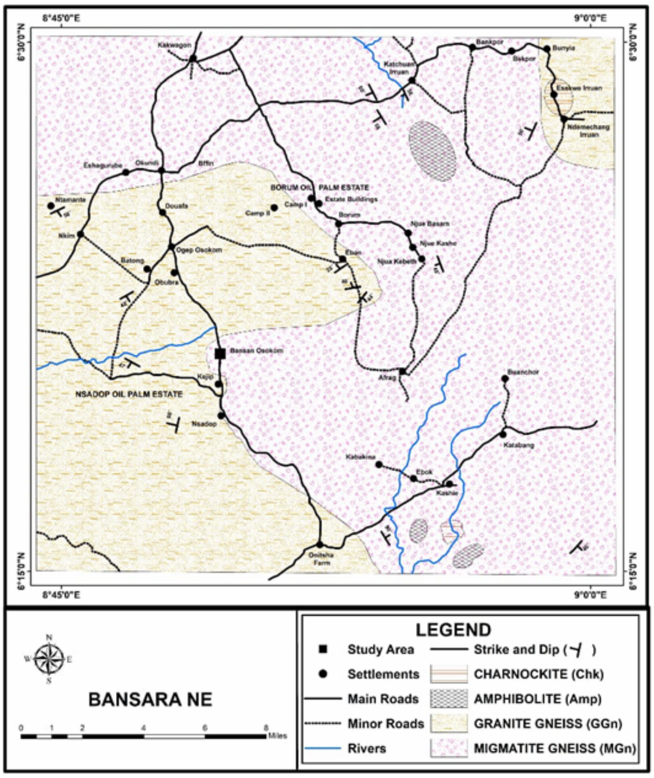

Fig. 2: Geology Map of the Study Area

Fig. 3a: Field Photograph of Migmatite Gneiss at Nwup River

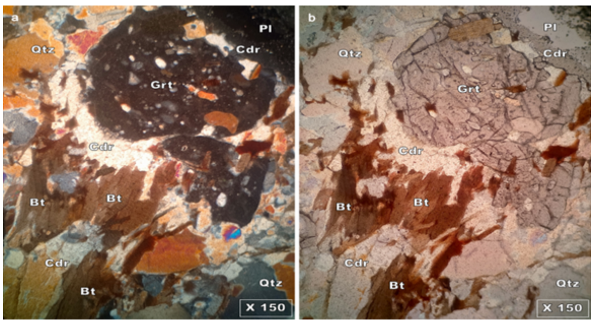

Fig. 3b: Photomicrography of Migmatite Gneiss (a=XPL, b= PPL) quartz (Qtz), biotite (Bt), garnet (Grt), cordierite (Cdr), and plagioclase (Pl)

In Fig 3a, garnet is porphyroblastic with inclusion trails of biotite and quartz. These inclusion trails are not random, they signify that there was an earlier metamorphic assemblage trapped during the growth of the garnet porphyroblast (Bell and Rubenach, 1983; Wang et al, 2023). Garnet is believed to be remnant from peak metamorphism, even when it exhibits fractures and alteration to cordierite (Wu et al., 2025).

Cordierite in Fig. 3b rims around garnet showing mottled cloudy colours typical of pinite alteration and seems to have grown at the expense of garnet and suggests it formed as an outcome of garnet decomposition during peak metamorphism to retrograde metamorphic evolution (Oyeshomo et al., 2025). The coexistence of garnet and cordierite in the rocks indicates upper amphibolite to lower granulite facies (Oyeshomo et al., 2025). According to Waters (2001), intergrowths and coronas are very common in migmatites especially, the complex ones. Biotite exhibits brown pleochroic laths around the garnet, defining strong foliation bands in the NE-SW direction as a result of compressional NW-SE stress. The foliation bands of the biotite bends around the garnet porphyroblast as seen (Fig. 3b). This suggests that garnet was unaltered during deformation and became an obstacle to the biotite. Quartz show interstitial grains with weak birefringence and sutured boundaries as a result of dynamic crystallization.

TABLE 1: Modal Composition of Migmatite gneiss and Granite gneiss around Bansan Osokom (%)

				Migmatite Gneiss						Granite Gneiss				
Minerals	MGn1	MGn2	MGn3	MGn4	MGn5	MGn6	MGn7	MGn8	MGn9	GGn1	GGn2	GGn3	GGn4	GGn5
Quartz	25	20	25	35	25	35	40	25	25	30	55	30	40	15
Muscovite										5				
Biotite	20	20	25	25	23	15	30	35	35	25	10	4	15	5
Garnet	25	30	10	5	10	15	10					1		
Cordierite	10	15	25	25	22	15	10	38	40	20	15	40		50
Plagioclase	15	10	10	10	10	10	8				15	10	30	10
K-Feldspars	5				10	10	2			10	5	15	10	8
Perthite													5	
Microcline										10				10
Sphene														2
Opaque		5	5					2						
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Granite Gneiss

Granite gneisses are predominantly exposed in the western portion of the Bansara sheet (Fig. 2), particularly at Ugep Osokom, Kato Uwire, Eban Borum, and Bansan-Osokom. They are medium to coarse grained and generally exhibit dominant light brown to yellowish-brown colour with minor greyish patches. In hand specimen, the rock is made up of quartz, biotite, and feldspar. Granite gneisses are somewhat different from migmatite gneiss in the study area as they exhibit weak foliation banding (Fig. 4a). Cordierite - biotite bearing granite gneisses are encountered in Kato Uwire, Ugep Osokom and Bansan Osokom and along Nsadop-Boje road while biotite granite gneiss is found in Eban Borum. They are generally low lying outcrops and intruded by quartzofeldspathic mineral veins characterized by a range of structural features, including fractures, xenoliths, pinch-and-swell structures, and folds.

The following modal composition result was revealed for the granite gneisses (Table 1) quartz (15-55%) is mostly anhedral with granoblastic texture showing undulose extinction in XPL (Fig. 4b). Cordierite (15-50%) is subhedral to anhedral, slightly cloudy in PPL due to incipient pinitization. Plagioclase (10-30%) shows granoblastic texture with quartz, exhibiting albite twinning and microfractures in some grains. Biotite (4-15%) is subhedral, shows lepidoblastic textures and kink bands lying in between quartz and feldspar grains, K-feldspar (5-15%) exhibits granoblastic textures interlocked quartz and plagioclase with mild alteration. Muscovite (5%) perthite (5%), sphene (5%) and garnet (1%) are seen as accessory minerals.

The mineral assemblage shown in Fig. 4b reveals three major events in the research area. These events are deformation, peak metamorphism, and retrogression. The interlocking grains, smooth Y-boundaries at 120^{0} of quartz, plagioclase and cordierite, and absence of strain suggest that these minerals were undeformed and stable together at high temperature. Well-formed foliation and kink bands defined by the biotite signify ductile deformation (Lin, 1997), and partial pinitization of cordierite and feldspar sericitization indicates retrograde metamorphism due to fluid infiltration (Spruzeniece, 2016).

Fig. 4a: Field Photograph of granite gneisses at Ugep Osokom

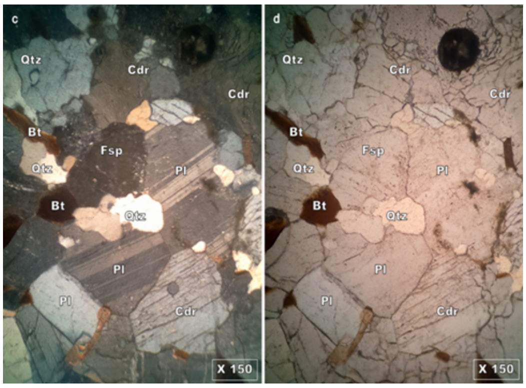

Fig. 4b: Photomicrograph of granite gneiss at Ugep Osokom (a=XPL, b= PPL) quartz (Qtz), biotite (Bt), garnet (Grt), cordierite (Cdr), and plagioclase (Pl), and K-Feldspar (Fsp)

Structural Geology

The area of study have undergone multiple episodes of deformation as of result of tectonic activities, which gave rise to different structural features to include folds, foliations, fractures, joints, faults, and pinch-and-swell structures.

Fold

Folds represent one of the most common structural features developed in the Earth's crust as a result of recurrent tectonic stresses acting over geological time (Garg, 2012). In the study area, folds constitute the most dominant deformational structures, particularly within the gneissic rocks. Migmatite gneiss exposure in Njua Kaku (Fig. 5) exhibits asymmetrical fold showing strong attenuation of the limbs and marked thickening in the hinge regions, defined by quartzofeldspathic minerals. Observing the fold from the edges, it appears to be an angular fold and also seems to be an open to closed fold. This is suggested to be evidence of progressive ductile deformation under high-grade metamorphic conditions. The combination of granoblastic and lepidoblastic textures in the rock of the research area is indicative of high-grade metamorphism and recrystallization.

Fig. 5: Showing an asymmetrical fold in the migmatite gneiss at Njua Kaku

Fig. 6: Showing intrafolial fold in Migmatite Gneiss at Katchuan Irruan

Intrafolial fold mapped at Katchuan Irruan is developed within the leucocratic bands of migmatite gneiss (Fig. 6). The fold hinges are preserved, while the limbs are truncated and aligned parallel to the dominant foliation. They typically develop where earlier structures are reoriented and incorporated into later foliations during progressive deformation (Passchier and Trouw, 2005). The alignment of these folds with the main gneissic layering indicates that the fabric in the rock is not a primary feature but the result of structural transposition, whereby earlier fold generations were rotated, thinned, and flattened into a pervasive foliation (Ukaegbu and Oti, 2005; Obiora, 2006).

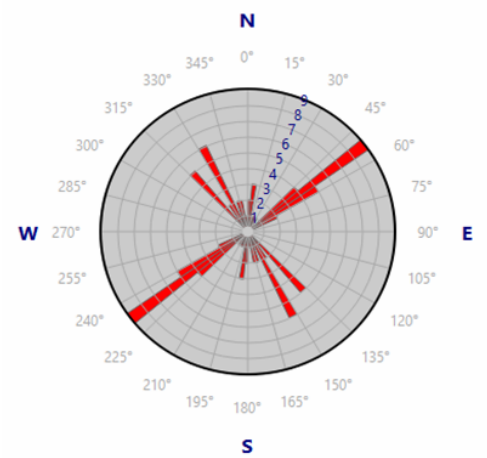

Fig. 7: Rose plot showing fold limbs trending NE-SW in the study area

The recognition of intrafolial folds in the outcrop of the study area provides clear evidence of a polyphase deformational history in the Ugep Osokom and its environs. Measurements of left and right limbs of folds plotted on a rose diagram reveals trend direction in the NE-SW with minor NW-SE, N-S direction, typical of Pan African activity. Pinch and swell structures is noticed in the granite gneiss at Ugep Osokom (Fig. 4a). It is characterized by the stretching of a competent quartzofeldspathic vein within an incompetent host matrix. Thus, this structure has undergone ductile deformation. The width of the swell structure is about 20cm while the pinch structure is about 7cm, trending N-S.

Foliations

The earliest penetrative structure recognized in the area is foliation, which represents a planar fabric formed during regional deformation of the gneisses and schist (Kolawole *et al.*, 2017). They are marked by the alignment of quartzofeldspathic and ferromagnesian minerals (Fig.5). They are more penetrative in the migmatite gneisses than the granite gneisses. In the migmatite gneiss, rose diagram (Fig. 8a) reveal two dominant orientation sets of foliation with the major one trending N-S (170°-350°), and a minor trend in the E-W (90°–270°)**.** The subordinate E–W orientation reflects that earlier structure**s** due to Pre-Pan African activities are still very much preserved and this conforms to the work of Kolawole et al., (2017). The coexistence of these two foliation sets indicates polyphase deformation in the migmatite gneiss of the study area. Foliation trend for granite gneiss in the area plotted on rose diagram (Fig. 8b) reveals a dominant NE-SW structural trend with a subordinate NW-SE trend.

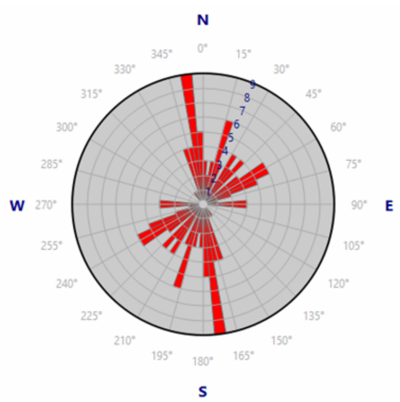

Fig. 8a: Rose plot of foliations trends in migmatite gneiss in Ugep Osokon area

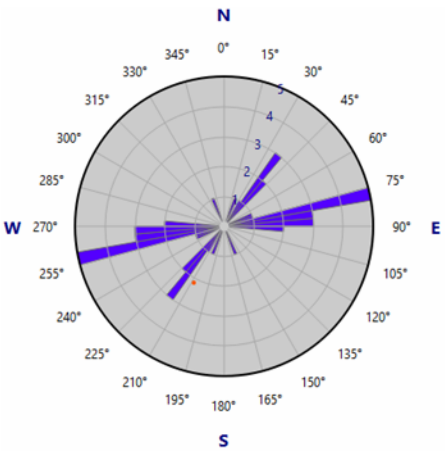

Fig. 8b: Rose plot of foliations trends in granite gneiss in Ugep Osokon area

Veins and Dykes

Quartzofeldspathic and pegmatite veins are widespread in the study area, intruding host metamorphic rocks (Fig. 6). Quartzofeldspathic veins are predominantly quartz and feldspars, hence the name. They often characterize the fold structures within the rock and exhibit thickness of about 0.5cm to 10cm. The rose diagram of quartzofeldspathic vein (Fig. 9a) indicates a dominant NE–SW trend with a subordinate E–W direction while pegmatite vein made up of coarse grain minerals trend mainly in the N-S but subordinate NE-SW direction, clearly typified Pan African event (Fig 9b).

Highly fractured pegmatite and dolerite outcrops also appear as dykes in the study area intruding migmatite gneiss (Fig 9c). The pegmatite dyke is coarse grained, pink to whitish rock, composed of quartz, mica and feldspar cross cutting migmatite gneiss along Nwup river channel. It is about 0.8 – 1.35m wide and length of about 2.9 - 3.9m, trending NE-SW. It is in sharp contact with a dark grey to black, fine grained dolerite dyke, measuring 3.6m in length, 20-30m thick, and trending in the E-W direction. Pegmatite and dolerite dykes trend in different directions confirming multiple deformations in the rocks of the study area.

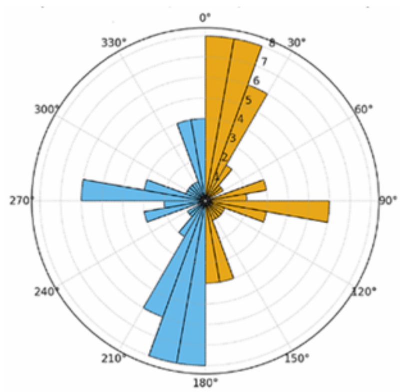

Fig. 9a: Showing a Rose diagram of quartzofeldspathic veins in the study area

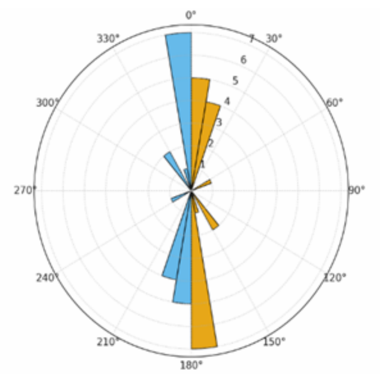

Fig. 9b: Showing a Rose diagram of Pegmatite veins in the study area

Fig. 9c: Showing highly fractured pegmatite and dolerite dykes intruding migmatite gneiss at Boje

Fig. 10: Showing a normal fault along a fracture plane in granite gneiss at Ogep Osokom

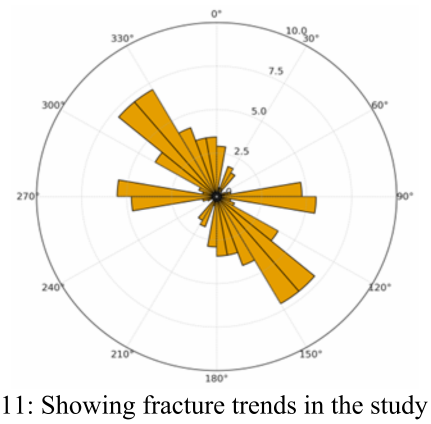

Fig. 11: Showing fracture trends in the study area

Fractures and Fault

Field observations within the study area reveal an instance where brittle faulting exploits pre-existing fracture planes. A representative example is shown in Fig.10 where a distinct planar fracture in granitic gneiss at Ogep Osokom exhibit normal displacement along the same surface. The fractures within the migmatite gneiss and the granite gneiss trend dominantly in the NW-SE direction with minor E – W trend (Fig 11), indicative of pre-Pan African event with compressive stress from NE-SW direction.

REFERENCES

[1] M. A. Agbebia And N. Egesi. "Lineament Analysis And Inference Of Geological Structures In Bansara-Boki Area, Southeastern Nigeria," Asian Journal Of Environment And Ecology, Vol. 13, Issue 1, Pp. 28–44, 2020.

[2] R. Black, R. Caby, J. M. Bertrand, A. M. Boullier, R. Dars, And J. Lameyre. "Evidence For Late Precambrian Plate Tectonics In West Africa," Nature, Vol 278 Issue 5704 Pp. 223–227, 1979.
[3] K.C. Burke And J.F. Dewey "Orogeny In Africa," In Tectonophysics, Vol. 14, Issue 1–2, Pp. 93–112, 1972.
[4] M. Leblanc. "The Late Proterozoic Ophiolites Of Bou Azzer (Morocco): Evidence For Pan-African Plate Tectonics" In A. Kröner (Ed.), Precambrian Plate Tectonics, Amsterdam: Elsevier, Pp. 435-451, 1981.
[5] S. S. Dada. "Proterozoic Evolution Of Nigeria" In: Oshi, O. (Ed.), The Basement Complex Of Nigeria And Its Mineral Resources (A Tribute To Prof. M. A. O. Rahaman). Akin Jinad And Co., Ibadan, Pp. 29–44, 2006.
[6] R. Caby, J.M. Bertrand, And R. Black. "Pan-African Closure And Continental Collision In The Hoggar-Iforas Segment, Central Sahara," In Precambrian Research, Vol. 14, Issue 1, Pp. 1–23, 1981.
[7] E.E. Udensi, S.B. Ojo, And D.E Ajakaiye. "A Three-Dimensional Interpretation Of The Bouguer Anomalies Over The Minna Batholith In Central Nigeria," Precambrian Research, Vol. 32 Issue 1, Pp. 1-15,1986.
[8] A.E. Ogezi. "Geological Evolution Of The Basement Complex In Nigeria," In: Kogbe, C. A. (Ed.), Geology Of Nigeria (2nd Ed.). Rock View (Nigeria) Limited, Jos, Pp. 45–58. 1988
[9] M. O. Oyawoye, "The Basement Complex Of Nigeria," In T. F. J. Dessauvagie & A. J. Whiteman (Eds.), African Geology Ibadan, Nigeria: University Of Ibadan Press, Pp. 67–99, 1972.
[10] P. Mccurry, "Pan-African Orogeny In Northern Nigeria," Bulletin Of The Geological Society Of America, Vol. 82, Issue 11, Pp. 3251–3262. 1971.
[11] M.A. Rahaman. 1988. "Recent Advances In The Study Of The Basement Complex Of Nigeria," In Precambrian Geol. Of Nigeria, (Oluyide, P. O., Mbonu, W. C., Ogezi, A. E., Egbuniwe, I. G., Ajibade, A. C., And Umeji, A. C.) (Eds.), A Publication Of Geological Survey Of Nigeria. Pp. 11-41.
[12] N.K. Grant, "The South Atlantic Benue Trough And Gulf Of Guinea Cretaceous Triple Junction," Geological Society Of America Bulletin, Vol. 82, 2295-2298, 1971
[13] N. K. Grant, "Structural Distinction Between A Metasedimentary Cover And An Underlying Basement In The 600 M.Y. Old Pan-African Domain Of Northwestern Nigeria, West Africa," Geological Society Of America Bulletin, Vol. 89, Issue 1, Pp. 50–58, 1978.
[14] N.G. Obaje, "Geology And Mineral Resources Of Nigeria," Berlin: Springer, Pp. 221 2009.
[15] A. C. Onyeagocha And B. N. Ekwueme,"The Pre-Pan-African Structural Features Of North-Central Nigeria," Nigerian Journal Of Mining And Geology, Vol. 19, Issue 2, Pp. 74-77, 1982.
[16] P.O. Oluyide, "Structural Trends In The Nigerian Basement Complex," In: P.O Oluyide, W. C. Mbonu., A. E. Ogezi., I. G. Egbuniwe., A.C. Ajibade And A.C. Umeji (Eds), Precambrian Geology Of Nigeria, Geological Survey Of Nigeria, Kaduna, Pp.93-98, 1988.
[17] V. U. Ukaegbu, "The Petrology And Geochemistry Of Parts Of Southern Obudu Plateau, Bamenda Massif Southeastern Nigeria," Unpublished, Ph.D. Dissertation, Univ. Of Port Harcourt, Rivers State, Nigeria, Pp. 321, 2003
[18] N. Egesi And V.U. Ukaegbu, "Petrologic And Structural Characteristics Of The Basement Units Of Bansara Area, Southeastern Nigeria," Pacific Journal Of Science And Technology (Pjst), Vol. 11, Issue 1 Pp. 510 – 525, 2010.
[19] C. U. Ibe And C. S. Obiora, "Geochemical Characterization Of Granitoids In Katchuan Irruan Area: Further Evidence For Peraluminous And Shoshonitic Compositions And And Post-Collisional Setting Of Granitic Rocks In The Precambrian Basement Complex Of Nigeria," Acta Geochemical, Vol. 38, Issue 5, Pp. 734-752, 2019.
[20] O. Adegbuyi, A. C. Ogunyele and O. M. Akinyemi, "Petrology And Geochemistry Of Basement Gneissic Rocks Around Oka-Akoko, Southwestern Nigeria," Malaysian Journal Of Geosciences, Vol. 2 Issue 2, Pp. 11–16. (2018).
[21] F. S. Reed and J. L, Mergner, "Preparation Of Rock Thin Sections." American Mineralogist, Vol. 38, Issue, 11–12, Pp. 1184–1203, 1953
[22] T.H. Bell and M.J Rubenach, "Sequential Porphyroblast Growth And Crenulation Cleavage Development During Progressive Deformation," In: M. Etheridge And S. Cox (Editors), Deformation Processes In Tectonophysics. Tecronophysics, Vol. 92 Issue 17, Pp. I-194, 1983
[23] H.H. Wang, L. Tang, M. Santosh, L.H. Jia, T. Zeng and Y.M. Sheng, "Metamorphic Evolution Of Garnet Amphibolites From The Fuping Complex," Implications For The Paleoproterozoic Subduction–Collision History Of The Trans-North China Orogen. Geological Journal, Vol. 59, Issue 2, Pp. 366–380, 2024
[24] S. Wu, Y. Su, Q. Wang And H. Qiao H, "Timing Of Retrograde Metamorphism In Medium-Pressure Pelitic Granulites Of The Qianlishan Complex: Insights From Monazite-Zircon U-Pb Geochronology And Phase Equilibria Modelling. Front. Earth Sci. 13: 2025. 1602565. Doi: 10.3389/Feart.2025.1602565
[25] A. V. Oyeshomo, C. C. Okpoli, U. Altenberger, A.S. Akingboye, D. Harlov, And A.T. Bolarinwa, "Retrograde Equilibration Conditions Of Garnet-Sillimanite-Cordierite Migmatitic Metapelites Around Ikare-Akoko, Southwestern Nigeria": Insights From Petrology And Mineral Chemistry. Journal Of African Earth Sciences, 231, 2025. Article 105538
[26] D.J. Waters, "The Significance Of Prograde And Retrograde Quartz-Bearing Intergrowth Microstructures In Partially-Melted Granulite-Facies Rocks," In: Kriegsman, L. (Ed.) Prograde And Retrograde Processes In Crustal Melting, Lithos, 56, Pp. 97-110, 2001.
[27] A. Lin, "Ductile Deformation Of Biotite In Foliated Cataclasite, Iida-Matsukawa Fault, Central Japan," Journal Of Asian Earth Sciences, Vol. 15, Issues 4–5, 1997, Pages 407-411, 1997. Issn 1367-9120,
[28] S. K. Garg, "Physical and Engineering Geology," Delhi, India: Khanna Publishers. Pp. 360-417, 2012
[29] C. W. Passchier and R. A. J. Trouw, "Microtectonics". Springer-Verlag, Berlin, Pp. 366, 2005
[30] V. U. Ukaegbu and M. N. Oti, "Petrography And Structural Relationships Of Precambrian Rocks Of Ugep And Its Environs, Southeastern Nigeria." Global Journal Of Geological Sciences, Vol. 3, Issue 1, Pp. 1–12, 2005
[31] S. C. Obiora, "Petrology and Geotectonic Setting Of The Metamorphic Rocks Around Obudu Plateau, Southeastern Nigeria." Journal Of Mining And Geology, Vol. 42 Issue 2, Pp. 121–130, 2006.
[32] F. Kolawole, H. Fossen, and A. Oluwakemi, "Structural Evolution Of Precambrian Basement Rocks In Nigeria: Implications For Pan-African Tectonics." Journal Of Structural Geology, Vol. 95, Pp. 1–17, 2017.