Petrologic and Structural Characteristics of the Basement Units of Bansara Area, Southeastern Nigeria.

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ABSTRACT

Petrologic and structural features of the basement units of the Bansara area reveal regional and local changes in rock types and environmental variables of pressure, temperature, and fluid activity. Polydeformation and polymetamorphism of the rock units produced orientations in different directions. Foliation with dip of 60º-80º are in the N-S to NE-SW (0º-45º) directions in the major structures, while minor overprinted ones with dip of 58º-80º are in the NW-SE to E-W directions. Typical metamorphic textures with porphyroblastic, granoblastic, poikiloblastic, and porphyroclastic characters are present in the gneisses and schists, while porphyritic and granitic textures characterize the granitoids. Thus, deformation, metamorphism and intrusions are the dorminant geodynamic features in the area. The intense charnockitic and granitic igneous activities, which accompanied the metamorphism and deformation in the high grade terrain is genetically related to the evolution and geotectonic setting of the Basement Complex of the study area.

(Keywords: rock units, deformation, metamorphism, intrusions, geodynamic features, basement complex, southeastern Nigeria)

INTRODUCTION

The Bansara area located, west of Boki Local Government Area, Cross River State, is part of the terminus of the Bamenda highlands of Cameroon into southeastern Nigeria and it lies between latitude 6º 10¹ to 6º 30¹ N and longitudes 8º 43¹ to 9º 00¹ E with the famous Obudu Plateau in the northeastern part of the study area (Figure 1). The basement rocks in the southeastern part of Nigeria have only recently started to receive some attention. Thick equatorial rainforests of Oban Massif and Bansara area and the rugged Obudu Plateau topography have remained a barrier to detailed geological studies. In this paper, attempts are made to characterize the petrologic and structural relationships of the Bansara area with a view to presenting a preliminary petrogenetic and geotectonic history of the study area.

LOCAL GEOLOGY

The rock types are predominantly migmatite-gneiss-schist complex and granitoids, which consist mainly of granites, granodiorites, and enderbites and occur as stocks and bosses; other rock units are amphibolites, quartzites, pegmatites, aplites, cataclasites, and mylonites. Records of structural imprints in the Bansara area are scarce, except an aeromagnetic survey covering Obudu Plateau and Oban Massif which does not have ground truthing in the study area. Field evidence shows the Pan-African orogeny has left its structural imprints on the rocks of this area. Opinion has been divided on the occurrence of these structural imprints in the basement rocks of southeastern Nigeria. McCurry (1971) and Rahaman (1976), are of the view that the last tectonothermal event (Pan-African) was so pervasive that it erased all earlier structural imprints. However, Grant (1978); Onyeagocha and Ekwueme (1982); Ekwueme (1987); Oluyide (1988); Ukaegbu (2003); Ukaegbu and Oti (2005) stress that though pervasive, the Pan-African event left some traces of the earlier structures.

Toteu et al. (1990) in their study correlated structural orientations in the NW-SE directions to an older Pan-African deformation in northern Cameroon. The rocks in the Bansara area were classified as undifferentiated basement by the Geological Survey of Nigeria (1994), and granulites terrain by the Nigerian Geological Survey Agency (2006), without appropriate mapping to delineate the boundaries.

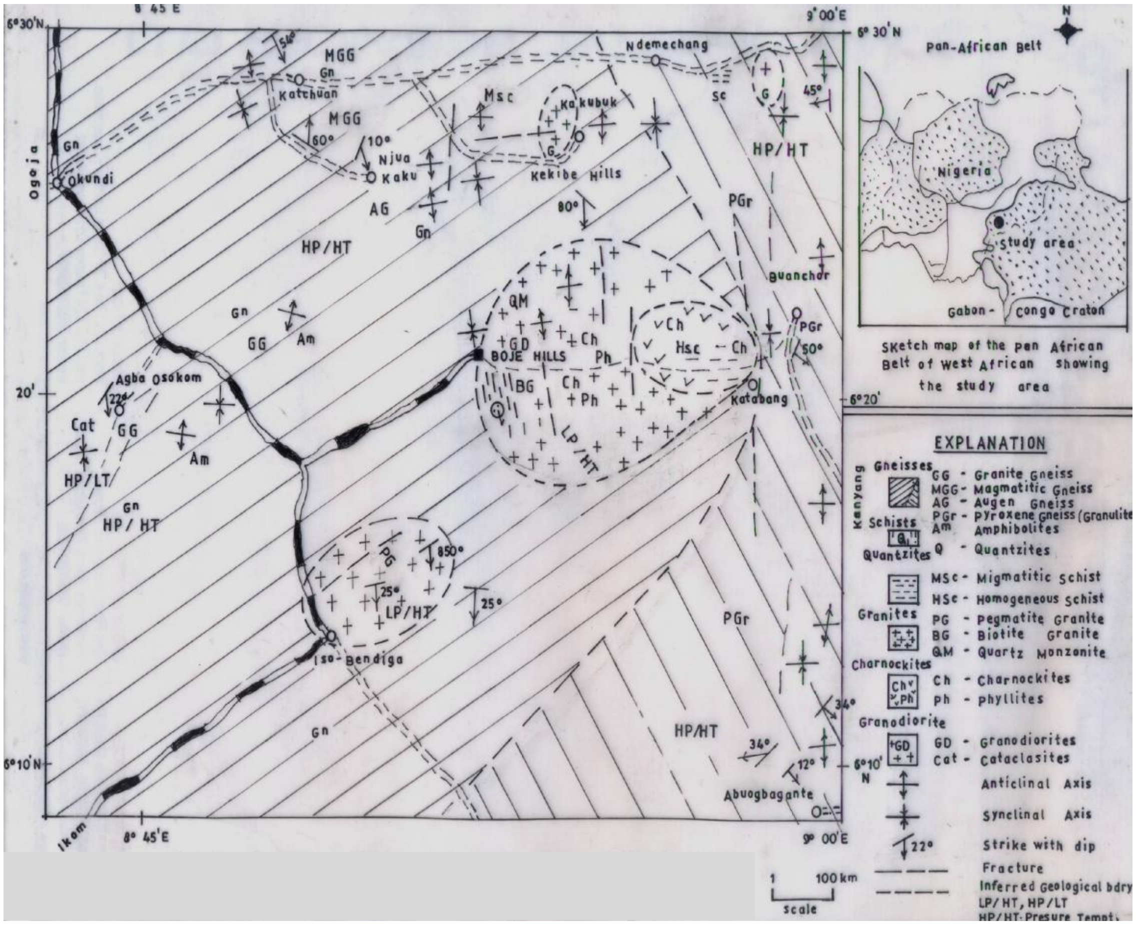


Figure 1: Structural Map of Bansara Sheet (304 NE &SE), Bamenda Massif, Southeastern Nigeria.

The only available reports are regional aeromagnetic survey of Oban and Obudu Massifs, which identified the area as Basement Complex with preponderance of NE trending anomalies Iliya and Bassey (1993) and lineament analysis which showed that high lineament densities are mapped in areas of outcropping bedrock and thin overburden Edet et al. (1994).

PETROLOGY

The Bansara sheet 304 NE and SE consist of Igneous and Metamorphic rocks (Figure 1). The metamorphic rocks are gneisses, schists, amphiboites, quartzites and phyllites.

The gneisses, which are quite extensive, include granite gneiss at Agba Osokom, augen gneiss at Njua Kaku hills, migmatitic gneiss at Katchuan and pyroxene bearing gneiss (granulites) at Buanchor (Figure 1). They form several hills, and on restricted, exposed, and eroded lowland portion, relicts of schists, which have been fractured and weathered occur.

Some migmatitic schists occur as artificial pavement; there are also few amphibolite lenses and quartzite veins in sandstones in the area. Charnockites of magmatic origin (Egesi and Ukaegbu, in press) display contact metamorphic aureoles, and show chilled margin of phyllite composition (quartz + chlorite + muscovite) undergoing spheroidal weathering (Figure 2a and 2b) along Ebbaken Community-Enyi Boje-Intraba hills-Ashuben road and massive dome features above 300m in the area.

The granites are biotite granite, quartz monzonite, and pegmatitic granite. En route Ashuben-Katabang boundary area, schists, which occur as relicts of weathered homogeneous rocks with spaced cleavage and fault plane, were mapped (Figure 3a and 3b).

Figure 2a: Charnockite Intrusives with Chilled Margin undergoing Spheroidal Weathering along Intraba Hills – Ashuben Road.

Figure 2b: Dyke Swarms with Contact Metamorphic Aureoles at Ebbaken Community.

Figure 3a: Homogeneous Schist with pegmatite along Ashuben-Katabang road.

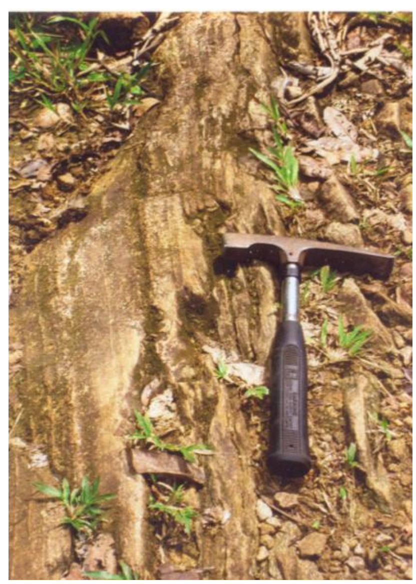


Figure 3b: Elongated Parallel Orientation of Schist Minerals at Katabang.

The granitoids include granites, granodiorites, and enderbites (charnockitic rocks). They are unmetamorphosed and display sharp contact relationships with the county rock. They intrude Pan-African granite gneisses, augen gneisses, migmatitic gneisses, migmatitic schists, and granulites, which form undulating topographic features in a regional N-S to NE-SW pattern.

Thus, metamorphic effects range from the baking of thin zones, contact aureoles around the intrusions which are within the emplaced stocks and bosses, to regional dimension. There are several swarms of contact metamorphic aureoles from Ebbaken Community-Enyi Boje-Intraba hills-to Ashuben (Figure 2b) with major intrusions as plutons and stocks and minor ones as dykes.

Lineation is present at Kekibe hills, Agba Osokom and Katchuan areas (Figure 4). A pegmatitic granites occurs at Iso Bendiga and trends 110º, with thickness of 15cm and length 4.9m (Fig.5a) and fine-grained aplite veins with of thickness 0.5-3cm, length of 5.0m trending 20º to 30º occur in several other locations. The microscopic observations of the quartz monzonites at Ebok cave (Figure 5b and 5c) showed myrmekitic texture, while porhyroblasts of orthoclase and microcline twinning are present in granite gneiss. Average modal compositions of rocks from Bansara are shown in Table 1.

Figure 4: Linear Structure on Migmatite (Agmatite) Gneiss at Katchuan Joints filled by Mineralized Vein.

Figure 5a: Coarsed-Grained Pegmatitic Granite Rock at Iso Bendiga.

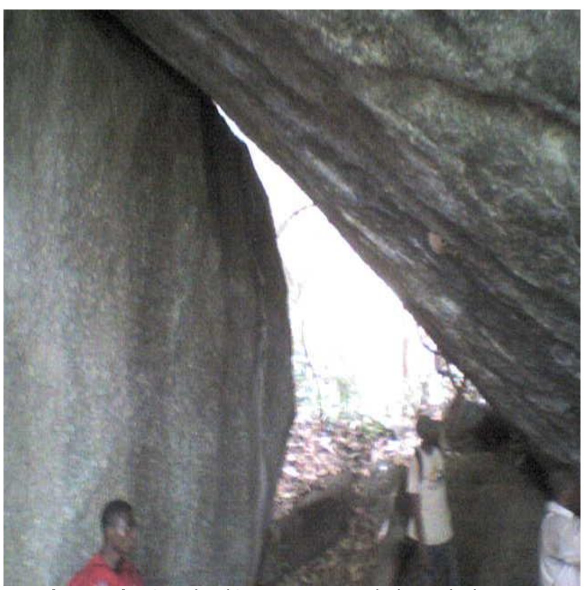


Figure 5b: Granite (Quartz Monzonite) at Ebok cave.

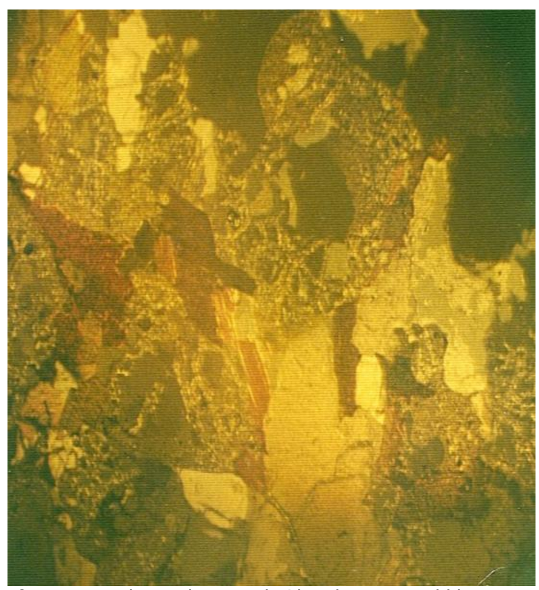


Figure 5c: Photomicrograph Showing Myrmekitic Texture.

Table 1: Average Modal Compositions of Rocks from Bansara.

Mineral	Migmatitic gneiss	Granite gneiss	Augen gneiss	Pyroxene gneiss	Schist	Amphibolite	Quartzite	Phyllite	Cataclasite	Mylonite	Granite	Pegmatite and aplite	Granodiotite	Charnockite
Quartz	25	27	31	23	30	3	94	22	37	30	30	36	25	21
K-feldspar	20	30	17	10	10	-	3	-	13	15	29	30	16.5	14
Plagioclase	22	20	20	25	25	25	-	18	28	29	15	14	42	25
Biotite	10	7	8	8	8	Trace	-	45	12	-	8	2	9	<1
Muscovite	5	5	7	-	25	-	<1	4	7	13	7	3	-	-
Chlorite	-	-	-	-	-	-	-	11	-	3	-	-	-	-
Horublende	6	6	6	3	-	60	-	-	-	-	-	-	5.5	<1
Orthopyroxene	-	-	-	15	-	-	-	-	-	-	-	-	-	27
Clinopyroxene	-	-	-	-	-	3	-	-	-	Trace	-	-	-	-
Garnet	8	-	6	6	5	5	-	-	-	-	-	-	-	-
Olivine	-	-	-	-	-	<1	-	-	-	-	-	-	-	-
Kyanite	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sillimanite		<1	-	10	<1	-	-	-	-	9	-	-	-	-
Myrmekite	-	-	-	-	-	-	-	-	3	-	7	2	-	8
Perthite	2	3	3	-	-	-	-	-	-	-	<1	10	-	2
Opaque minerals	2	2	2	1	3	4	2	<1	-	<1	3	2	2	2

STRUCTURAL GEOLOGY

The structural relationships of the Bansara area have been superimposed on the geology of the area (Figure 1). The highland in places are cliffs, which are difficult to map, while the lowland has thick forest with tall trees ranging from 30 to 60m high. There are few roads and several footpaths in the area. The Boje hills, Intraba hills, Ashuben hills, Katabang hills, Buanchor hills, Njua Kaku hills, Katchuan hills, Kekibe hills, and Ndemechang hills are parts of Afi mountain belt (Figure 1) and are characterized by rocks that are strongly deformed with extensive metamorphism, and less deformed and un-metamorphosed granitoids. Megascopic and microscopic structures were mapped in the area.

Planar Structures

Planar arrangement of dimensionally orientated minerals formed by the recrystallisation and segregation of minerals, growing under conditions of elevated pressure and shearing stress, are conspicuous structures shown by banding (Figures 6 and 7) in gneisses and schists in the Bansara area.

Figure 6a: Banded Features in Migmatitic (Injection) Gneiss at Katchuan**.**

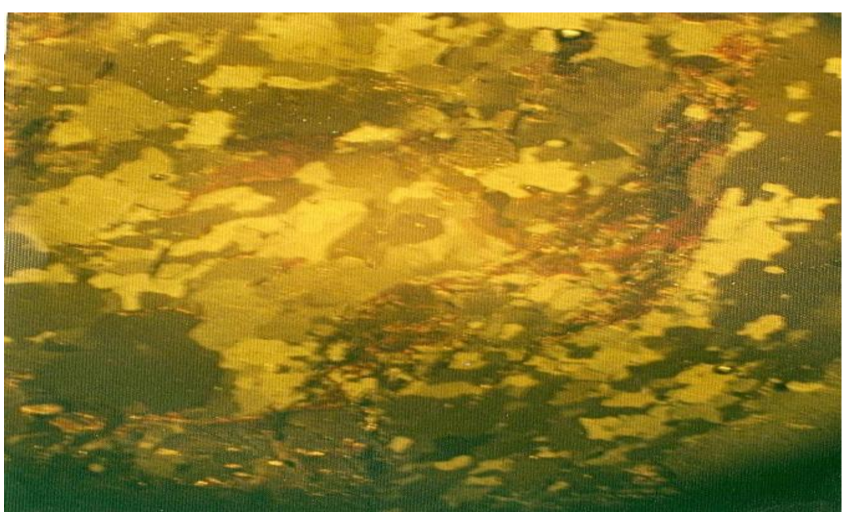


Figure 6b: S- Trails in Garnet of Migmatitic (Injection) Gneiss at Katchuan

Figure 7a: Assymmetrical Folds with M- type Boudins Structural Features in Migmatitic Schist at Kekibe Hills.

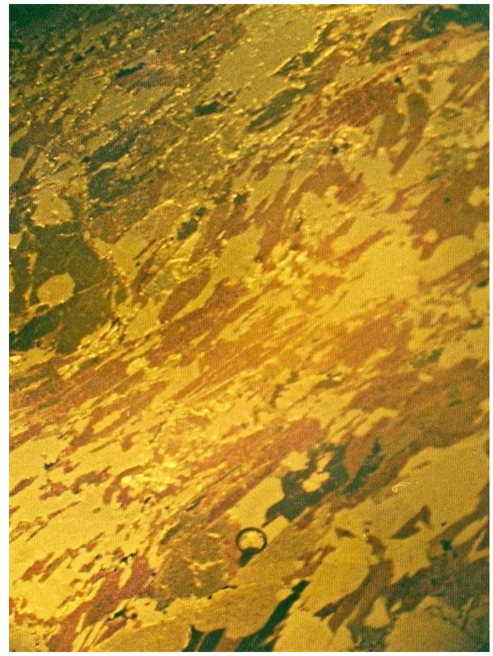


Figure 7b: Photomicrograph of Garnet Mica Schist, Garnet Squat Prism, Biotite Brown, Quartz Yellowish at Kekibe Hills (XPL 40).

Figure 7c: Garnet-Mica Schist at Kekibe Hills Occurred as an Artificial Pavement.

At Agba Osokom, folds have quartzo-feldspathic composition and are asymmetrical in granite gneiss. The granite gneisses exhibit jointing. Xenoblasts of quartzofeldpathic minerals occur in the granite gneiss (Figures 8a and 8b). Also melanosome basic xenoblasts of amphibolites occur as lens. They indicate minor reverse faults on the granite gneiss (Figures 8c and 8d). On the downthrown blocks, features of dynamic metamorphism occur, including fractured tectonic or fault brecciated rocks with slickensides along the fault plane (Figure 8e). About eight hundred and eighty seven measurements of strikes and dips foliations, fractures and folds were made in Bansara. Figures 9a and 9b are stereogram poles of foliation and physical relationships between foliations. A microtectonic station of rose diagram indicate (0º-12º) fold planes of direction, mineral lineations (0º-30º) and fractures (0º-30º) at Katchuan (Figs.9c and 9d) trend in north-south to northeast-southwest directions.

Figure 8a: Xenoblast of Quartzofeldpathic Minerals in Prismatic Granite Gneiss at Agba Osokom. (see hammer's head).

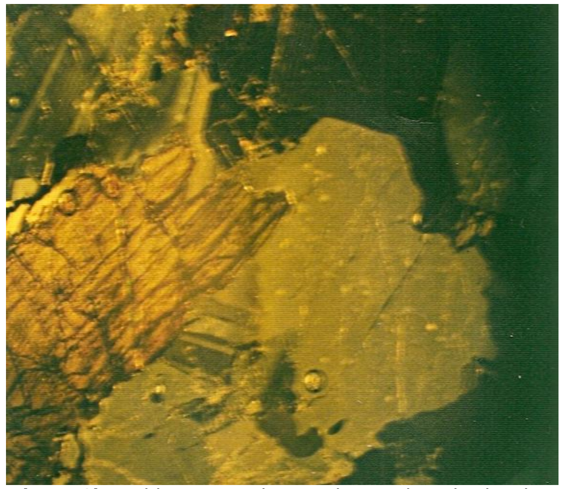


Figure 8b: Feldspars are the Dominant minerals showing Orthoclase and Cross-Hatching Microcline Twinning**.** (XPL 40).

Figure 8c: Reverse Fault in Mafic Xenoblast of Amphibolites in Granite Gneiss at Agba Osokom.

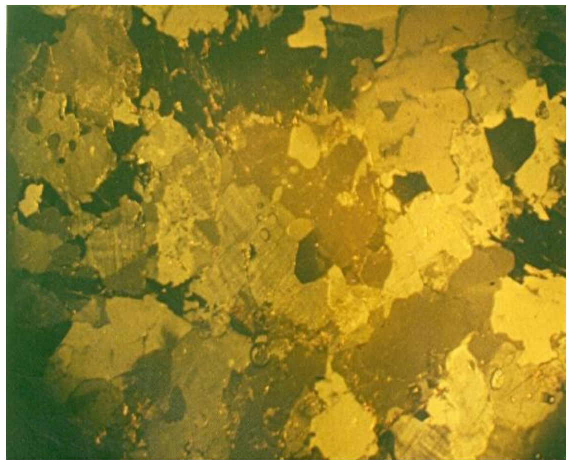


Figure 8d: Photomicrograph of Amphibolite with Hornblende Twinning (XPL 40).

Figure 8e: Slickenside Straie, Evidence of Faulting on the Downthrown Block at Agba Osokom.

At an elevation of 533.5m in Kekibe hills-Kakubuk area, there is occurrence of migmatitic mica garnet schists trending 16º to 172º with varying dips from 22º NW to nearly vertical. The planar structures mapped are asymmetrical folds with M-type banding features (Figure 7a).

The area seems to lie within the transition zone of granulites in the eastern part of the study area. A strereonet plot using Schmidt net indicate the hot zone to be in the north of the hills. Figure 9e is the mineral lineations rose diagram plot at Katchuan showing a N-S to NE-SW directions. Elsewhere schists have been fractured and weathered as relicts of the homogenous variety especially along Ashuben-Katabang boundary area still remain (Figure 3a).

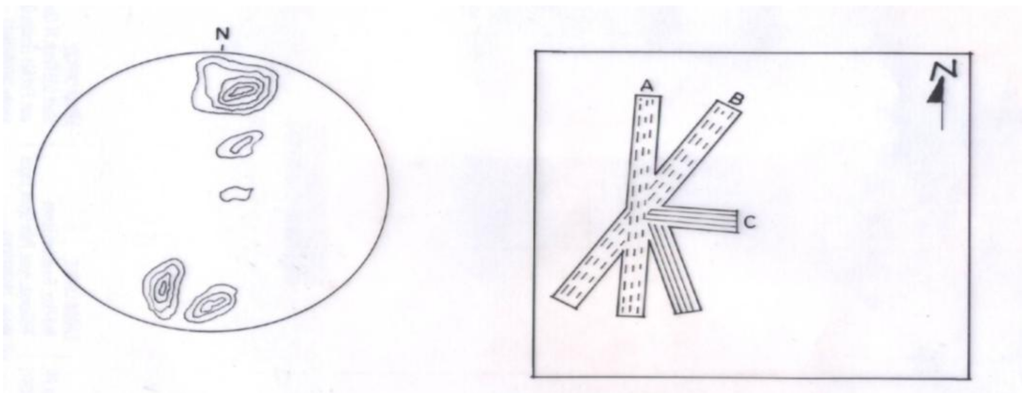
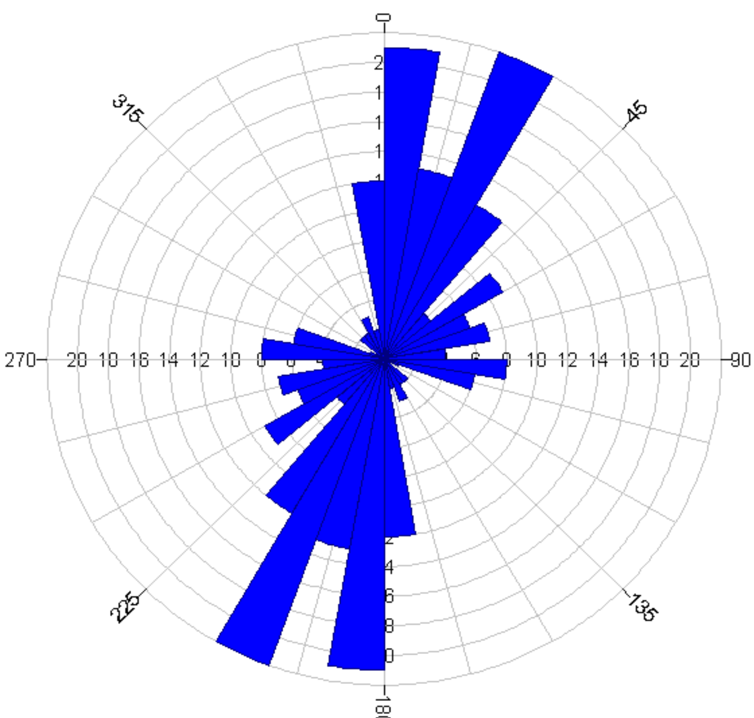


Figure 9: A – Sterogram Plot of Poles of Foliation in Bansara Area Counours in 2%, 4%, 6%, 8% per 1% Area of 100 Data Points. **B** – The Physical relationships between Foliation in Bansara. C, A, and B are the Regional and Major Directions.



Statistical Summary	
Calculation Method:	Frequency
Class Interval:	10.0 Degrees
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	134
Total Length of All Lineations:	268.0
Maximum Bin Population:	22.0
Mean Bin Population:	7.88
Standard Deviation of Bin Population:	6.26
Maximum Bin Population (%):	8.21
Mean Bin Population (%):	2.94
Standard Deviation of Bin Population (%):	2.33
Maximum Bin Length:	22.0
Mean Bin Length:	7.88
Standard Deviation of Bin Lengths:	6.26
Maximum Bin Length (%):	8.21
Mean Bin Length (%):	2.94
Standard Deviation of Bin Lengths (%):	2.33
Vector Mean:	25.1 Degrees
	205.12 Degrees
Confidence Interval:	15.1 Degrees
	(95 Percent)
R-mag:	0.43

Figure 9c: Fracture Trends N-S to NE- SW Directions at Katchuan.

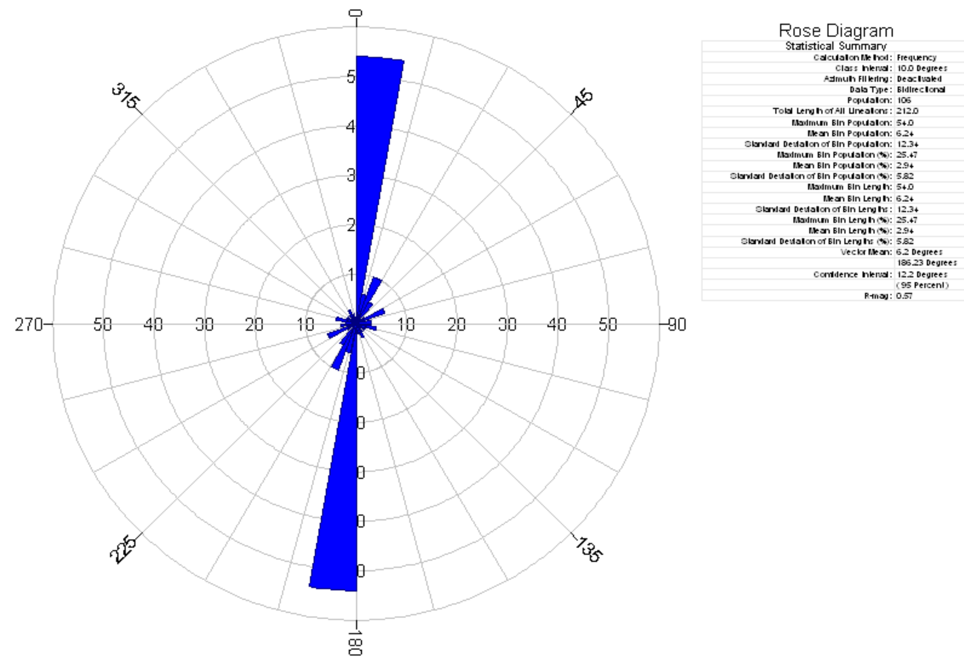


Figure 9d: Fold Axis N-S direction at Katchuan.

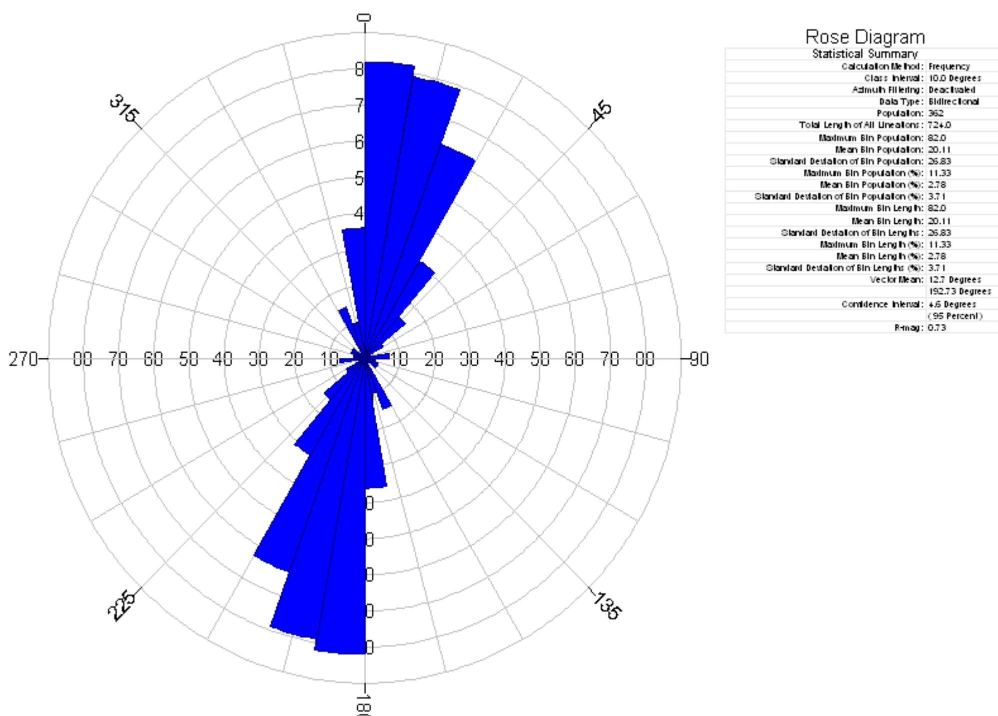


Figure 9e: Mineral Lineations N-S to NE-SW Directions at Katchuan.

In Njua Kaku area, migmatitic gneiss and augen gneiss occur. Figure 10 is open fold in augen-gneiss at elevation of 226.4m Njua Kaku hills. Metamorphic rocks of the Bansara area have been folded into anticlines and synclines, similar folds which thicken towards their hinge.

Asymmetrical type of fold is common at Kekibe hills, Agba Osokom and Katchuan areas (Figure 7a and Figure 8a). Plunge of 44º towards 10º with parasitic folds of Z- and S-types were mapped at Katchuan and Njua Kaku (Figure 10).

Other types of folds in the area are gentle, open, close, tight and isoclinal folds. In some gneisses in Njua Kaku hills two types of foliation trends are recognizable: coarsed-grained gneissose texture and porphyroblastic texture in the augen-gneiss. Complex disharmonic, drag, ptygmatitic folds, pinch and swell structures and shear zones are common features at Buanchor granulites (Figure 11).

The M-type folds at Kekibe hills (Figure 7a) display boudinage features in schists and consist of leucocratic feldspar and quartz minerals at the centre, while biotite and hornblende form the lenticular melanosome separation. Ptygmatitic structures are disharmonically folded veins in the competent layers of granulites. C

ontorted quartzo-feldspathic veins in migmatites commonly occur at Njua Kaku and Katchuan areas (Figure 10 and Figure 4). S1-S2-S3 foliation are equally present at Kanyang 2 (Figure 12), which is within the boundary area of Bansara and Mukuru sheets. Structural control stream channels are present at Enyi Boje (Figure 13). Boudinage, tension gashes, fracture cleavage and slickensides are minor structures in the metamorphic rocks.

Linear Structures

The Bansara area attained a high grade regional metamorphism with contact and dynamic metamorphism in places. The 304 NE & SE has contact with the granulites facies metamorphism of Mukuru 305 NW & SW, which lies just below southern Obudu sheet 291, which Ekwueme (1990b) and Ukaegbu (2003) reported to have attained a high grade regional metamorphism up to granulites facies metamorphism.

Figure 10: Open Folds with Syncline and Anticline Features in Augen Gneiss at Njua Kaku Hills.

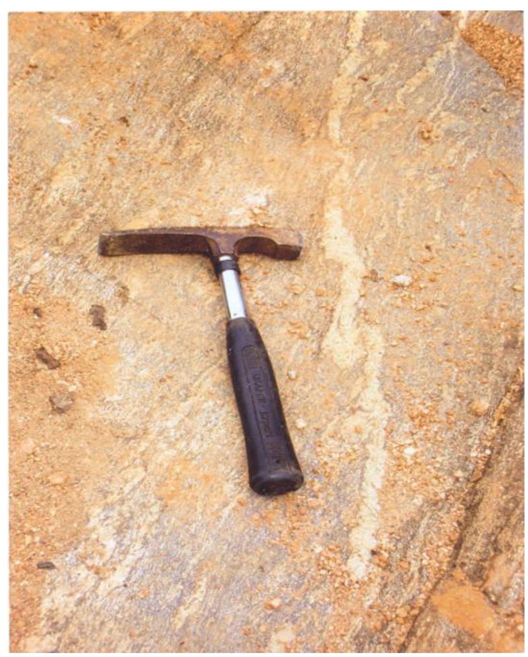


Figure 11: Drag Fold in Granulite at Buanchor Area Boundary with Mukuru Sheet.

Figure 12: Ghost Structure in Kanyang 2 Granulite. Fold Type-Isoclinal and Tight. D1,D2,D3; M1,M2,M3; S1,S2,S3. Joint: Extension Joint Shear Joint, Oblique Extension Joint (Denis 1972 ,p.291).

Figure 13: Fractured and Structurally Controlled Stream Channel, Standing on the Downthrown Block at Enyi Boje.

The metamorphism and polydeformation have largely produced new mineral grain of porphyroblasts, and destroyed the original linear structures and textures. However, relicts of lineation, fold axes, boudins, pinch-and-swell structures, as well as fractures were mapped in the area. Figure 14 and Figure 4 show linear structure on granulites and migmatitic granite gneiss at Kekibe hills and Katchuan, where low-temperature eutectic granitic melts appear as veins which intermixed with the original metamorphic rock material. The migmatites show granodioritic mineralogical composition while the granite gneisses are of granitic composition.

Figure 14: Fault and Fractures at Kekibe Hills. Normal Fault Throw 70cm, 40cm, 30cm in Granulitic Rocks.

Boudinage structures in a deformed layer and fractured artificial-like pavement features trend E-W direction in migmatitic schist. This trend at Kekibe hills was observed on aeromagnetic survey Iliya and Bassey (1993). Fractures with normal faults show throw of 70cm, 40cm, and 30cm from different points on granulites (Figure 14).

Major faults occur in igneous rocks at Iso Bendiga, Enyi Boje, Ebok and in metamorphic rocks at Agba Osokom, Kekibe hills, Katchuan, Buanchor and Katabang areas (Figure 1) with lineaments mostly in the N-S and NE-SW trends. In shear zones (Figures 8e and 15) slickenside striae are widespread.

The amphibolites show granoblastic textures with enlogate prismatic crystals of hornblende twins which have pleochroic shades of brown (Figure 8d). Schistosity is well developed in the mica schists at Kekibe hills and consists of muscovite, biotite, and garnets and variable amounts of quartz. Some stressed quartz grains become elongated within the schistosity. Lenticles of quartz and mica plates alternate in the rock; well formed almandine garnet grow as porphyroblasts, tending to push apart the micaceous layers and can be freed from the rock. The foliation under the microscope is identified by parallel arrangement of biotite and/or hornblende. Some of the garnet crystals show angular to subconchoidal fracture (Figure 7b). In the contact metamorphic aureoles at Enyi Boje and Ashuben areas biotite minerals have been largely chloritized (Figure 2a).

There are S-trails in garnets in some migmatitic rocks (Fig.6b). Also prismatic pyroxene occurs as linear aggregates parallel to the foliation plane of the granulitic rocks in Bansara area. Formation of mortar texture is common features of rocks subjected to faulting Ekwueme (1994b). At Enyi Boje granodiorites show mortar texture fracturing and brecciation and rest on the downthrown block of major fault. In Bansara area, occurrence of almandine garnet is common in gneisses and schists. The occurrence of this type of garnet is also common in the Obudu Plateau area.

Figure 15: Normal Fault in Shear Zone at Buanchor.

DISCUSSION

The Bansara area lies within the Pan-African Remobilized Basement Complex of southeastern Nigeria. Late to Post Pan-African intrusives outcropping in the area compose mainly of granitoids. The granitoids appear to be emplaced into the metamorphic Basement

Complex of Nigeria during the Pan African event (600 ± 150 Ma) Kennedy (1964), and they probably mark the terminal end of the event. The charnockitic rocks with swarms of contact metamorphic aureoles probably represent the first post-collisional stage of the wider West African belt.

On the geodynamic evolution of the Pan-African belt in West Africa, which includes southeastern Basement Complex of Nigeria, based on petrographic and structural studies, a model of continent-continent collision between the Congo Craton and West African plate can be proposed. Geodynamic disturbances and magmatic activity generated deep within the Earth's crust may have initiated faulting exploited by the granitoids. Thus, tectonism in the area seems to be so strong to have led to the emplacement of granitoids (enderbite-granodiorite-granite) series (Egesi and Ukaegbu, in press).

The evolution of the study area ends with the development of molassic basins and emplacement of high-level alkaline granitoids. The N-S fractures are more often than not attributed to brittle deformation Oluyide (1988). The intensity of structural features are higher in Obudu area than in Oban Massif and any other part of Nigerian Basement Complex Udoh (1988), Oluyide (1988), Edet et al.,(1994) and Ukaegbu and Oti (2005) including the Bansara area, which appears to be boundary zone between contrasting rock masses that probably extended as deep as the mantle, base of the crust or the contact between continental plates that have collided.

The Bansara area contact boundaries with Mukuru sheet, indicates the first appearance of granulitic rocks west of Bamenda Massif. The area is probably a geosuture zone as shown by the prominent Afi mountain and Afi river in a N-S trending direction. The linear N-S trending topographical features which reflect crustal structure in the area, probably represent a major fault line exploited by the granitoids at Enyi Boje (Figure 13).

The granulites is believed to have formed at the root of the collision zone, the base of the crust or upper mantle, resulting to exhumed granulitic rocks and the presence of extensive plutons of granitoids with composition of charnockites, granodiorite, ademellites and granites emplaced within the granulites and granite gneisses in the study area. They can be observed at Iso Bendiga, Ebok, Enyi Boje, Ashuben, Katabang and minor intrusive at Ndemechang (Figure 1). Some granitoids show unmixing with perthite development. Mesoperthites which consist of roughly equal amounts of intergrowth of alkali feldspar and plagioclase in the granulites and charnockites are diagnostic features. The post-collisional structural features, molassic deposits and metamorphic aureoles observed in the area are believed to be controlled by the movement of the Congo Craton (CC) east of the Pan-African mobile domain. The Bansara structural relationships are similar to the Adamawa-Yadé domain, west Cameroon domain and Obudu Plateau but different in having the first appearance of exhumed granulitic rocks west of the Bamenda massif and associated single massive intrusion of granitoids.

Planar arrangement of dimensionally orientated minerals formed by the recrystalisation and segregation of minerals growing under conditions of elevated pressure and shearing stress are conspicuous structures shown by banding (Fig.6a and Figure 7a). Amphibolite lens indicate minor reverse faults (Figure 8c) and fractured tectonic or fault brecciated rocks with slickensides on the downthrown block (Figure 8e). The adjacent Obudu Plateau has been observed to have experienced polytectonic and polymetamorphic activities Ekwueme, (1994) and Ukaegbu and Oti (2005).

In the Bansara area, multidirectional orientations of planar and linear structures as well as S-trails in garnets confirm that polydeformation affected the basement rocks. The deformation and metamorphism seems to be progressive with anticlines, synclines, S-type, M-type and Z-type folds. The migmatization and augen structures may be probably due to a second regional metamorphism during the Pan-African orogeny.

CONCLUSIONS

The Pan-African orogeny which was widespread deformational episode and penetrative produced major foliation directions with N-S to NE-SW and minor E-W to NW-SE trending structures in Bansara area. The area is probably a geosuture zone as shown by the prominent Afi mountain and Afi river in a N-S trending direction. The post-collisional structural features, molassic deposits and metamorphic aureoles observed in the area are believed to be controlled by the movement of the Congo Craton east of the Pan-African mobile domain.

The Bansara structural relationships are similar to the Adamawa-Yadé domain, western Cameroon domain and Obudu Plateau but different in having the first appearance of exhumed granulitic rocks west of the Bamenda massif and associated single massive intrusion of granitoids. The units of granulitic, charnockitic, and granitic rocks sequence is of both petrologic and structural significance. The contacts between the granitoids and the country rocks should be subjected to integrated studies using ground geophysics, whole rock geochemistry, drilling in overburden/bedrock, to ascertain actual or potential mineralization in the area as thick grayish minerals suspected to be cassiterite were mapped at Ebok, Enyi Boje and Ashuben.

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