

Structural and Petrologic Studies of Bumaji Area, Southeastern Nigeria

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Abstract: The study area is part of the Basement Complex of Southeastern Nigeria. The major rock units in the area comprises of intrusives (pegmatites, dolerites and charnockites), and the host metamorphic rocks are; quartzites, migmatites, schists, and biotite gneiss. Structural evidence shows that the rocks are deformed and were intruded by the magmatic rocks. The metamorphic rocks are strongly deformed in N-S to NE-SW direction. The charnockites is composed of quartz, 32%, plagioclase, 25%, K-feldspar, 20%, hornblende, 15% and other accessory minerals. The dolerite consists of olivine, 30%, biotite, 17% and hornblende, 16%. It shows ophitic texture. Schist and migmatite indicatess faults, fractures, mineral lineations and planar features. Variation in structural trend and mineralogical composition of the metamorphic rocks is due to the series of deformational activities; metamorphism and magmatism, which has affected the rocks during geologic time. The small scale geological structures which were used to interpret large scale structures, are of the size a field outcrop scale of 1cm to 10km of the district geological features.

Keywords: Rocks, Deformation, Metamorphism, Intrusions, Structures, Basement SE, Nigeria

INTRODUCTION

Nigeria lies in the Pan-African mobile belt, being sandwiched between the West African Craton to the west, eastern Saharan Craton to the northeast and the Gabon-Congo Craton to the southeast (Kroner *et al.*, 2001). It is underlain by crystalline basement and sedimentary rocks. The Precambrian Basement Complex rocks cover about 50% of Nigeria's land area and extend into neighboring countries like Benin to the west and Cameroon Republic to the east. The Pre-Pan African rocks (2.8 - 1.3 Ga) which are mainly migmatite-gneiss complexes, ancient granitic rocks and the Pan-African rocks (600 ± 150 Ma) comprising of the Older Granites and Metavolcano sedimentary series (Ekwueme, 1990).

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 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) Egesi and Ukaegbu (2010) stress that though pervasive, the Pan-African event left some traces of the earlier structures. The authors agree with second school of taught, some the rocks may be unmappable in the field depending on the scale of the map. This research work examines the petrology, and geological structures associated with the exposed rocks of Bumaji area, in Mukuru Sheet 305 boundary with Obudu Sheet 291, Southeastern Nigeria (Fig. 1).

LOCAL GEOLOGY

Two giant spurs make up the Pre-cambrian basement of southeastern Nigeria, namely the Oban massif and the Obudu Plateau (Fig. 2). These spurs are the western prolongation of Cameroon Mountains into the Cross river plains of Southeastern Nigeria. The basements are overlain by Cretaceous sediments of the Calabar Flank in the south and west but separated by a Cretaceous sediment filled graben or Mamfe rift (Embayment) in the north. Orajaka (1964), Umeji (1988), Ekwueme (1990), Ekwueme (2003), Ukwang

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(1998), Ukaegbu (2003), Ephraim (2004), Egesi and Ukaegbu (2011, 2013) and Obioha and Ekwueme, (2011) have studied in detail the Pre-cambrian basement rocks in the Obudu, Obalinku and Boki areas, which is in the north and western parts of the study area. These are composed of phyllites, schists,

gneisses, granulites and migmatites intruded by rocks of granitoids, mafic and ultramafic composition. They range in age from Neo-Archaeon to Pan-African Ekwueme and Shiling (1995) and (Ekwueme and Kroner 1997, 1998).

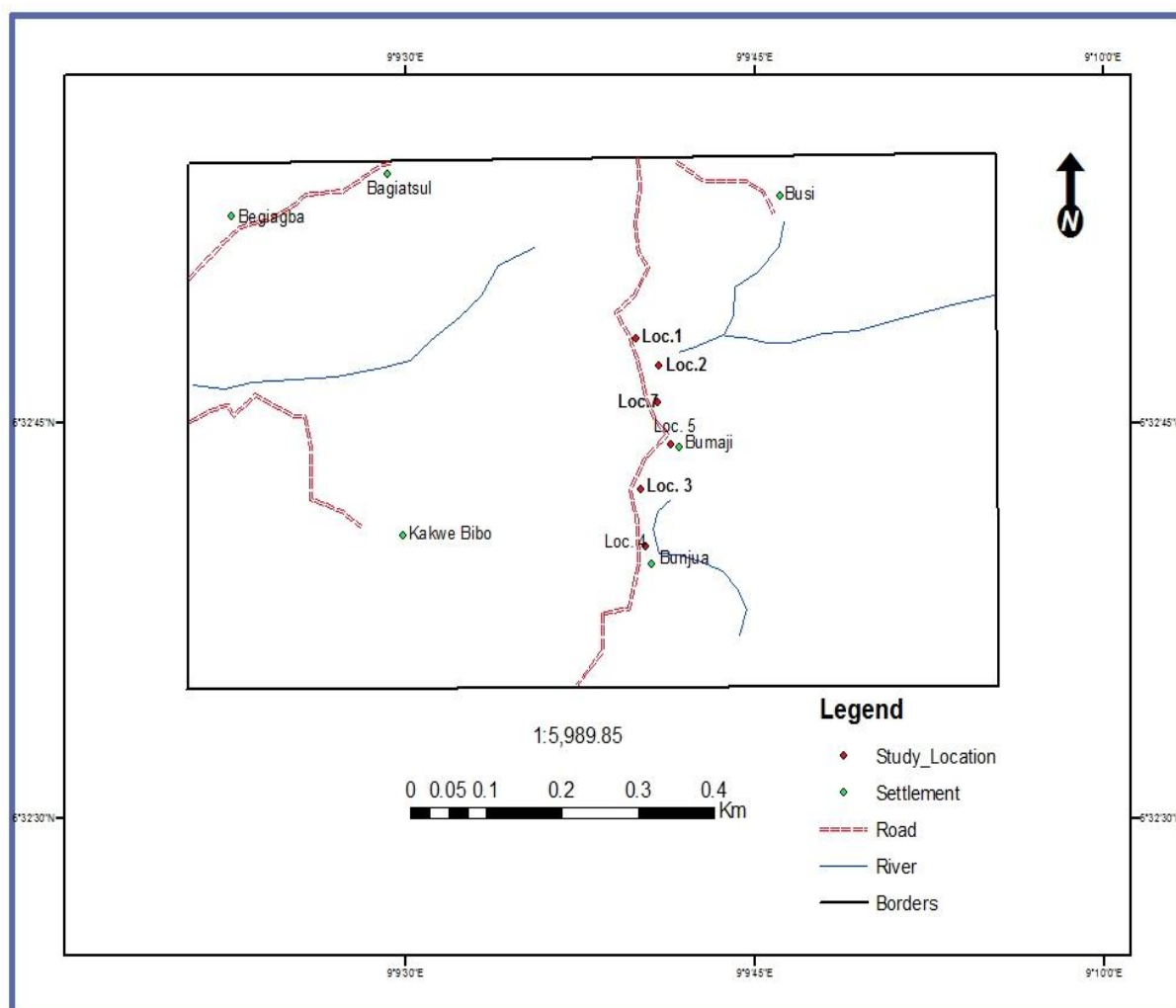
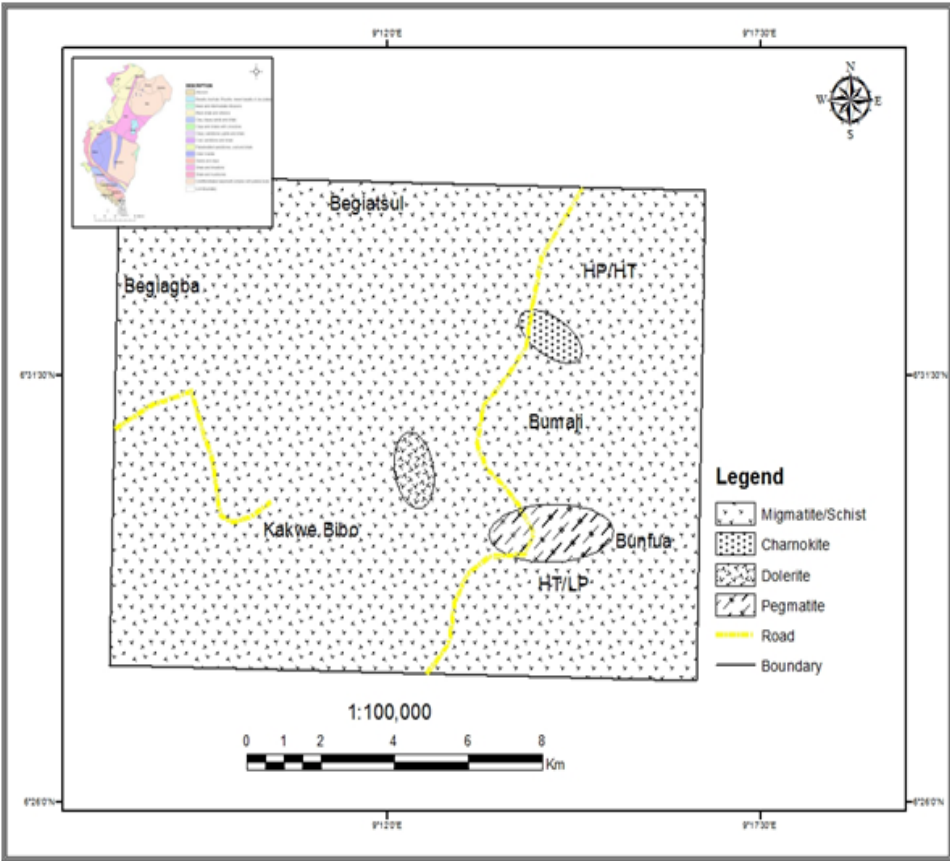


Figure1. Sample location map of the study area



The basement has undergone polyphase deformation and several generations of folding, faulting, shearing and fracturing have been reported (Ekwueme 1987, 1994). The dominant trend of the structural features comprising of planar and linear types is N-S to NE-SW (0° - 30°). Minor trends in the NW-SE and E-W

The Mukuru sheet 305 NW consist of Igneous and Metamorphic rocks. During the field mapping exercise, different rocks were observed and their physical and textural characteristics examined. The study area basically consists of five (5) main

also occur and have been interpreted as relicts of pre-Pan African deformation episodes (Grant *et al.*, 1972; Onyeagocha and Ekwueme, 1982; Ekwueme, 1994). Petters *et al.*, (1982), had suggested that the Oban massif and Obudu Plateau could have been continuous prior to the formation of the Mamfe Basin which lies between them. lithologies; charnockites, dolerites and migmatites, schists, granite gneisses, quartzites, with pegmatites occurring as vein deposits. The metamorphic rocks are gneisses, schists, quartzites, and metasediments. The schists, which are quite extensive, include migmatite schists, garnet mica schists, and intrusions are charnockites, dolerites, and granites at the northern Boki boundary areas with Obalinku LGA (Figs. 3-5). They form several hills, and on restricted, exposed, and eroded lowland portion, relicts of schists, which have been fractured and weathered occur. Charnockites of magmatic origin display contact metamorphic aureoles, and show chilled margin of granitic rock undergoing spheroidal weathering along Bunfua Community. The granites are biotite granite and pegmatitic granite.



Figure 3a: Charnockite intrusives showing metamorphic aureole over 60cm see the hammer head.

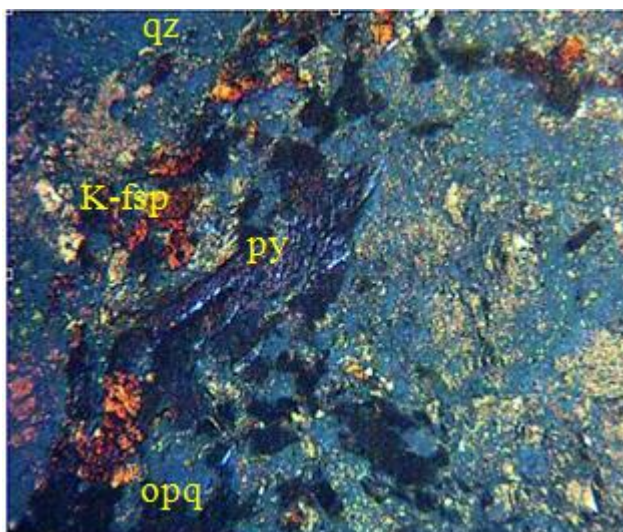


Figure 3b: Photomicrograph of Charnockite showing minerals, K-fsp = K-feldspar, qz = quartz, py = pyroxene, opq = opaque (XPL x25)



Figure 4a: Dolerite intrusion undergoing spheroidal weathering along Sankwala-Bumaji road Obanliku-Boki area boundary

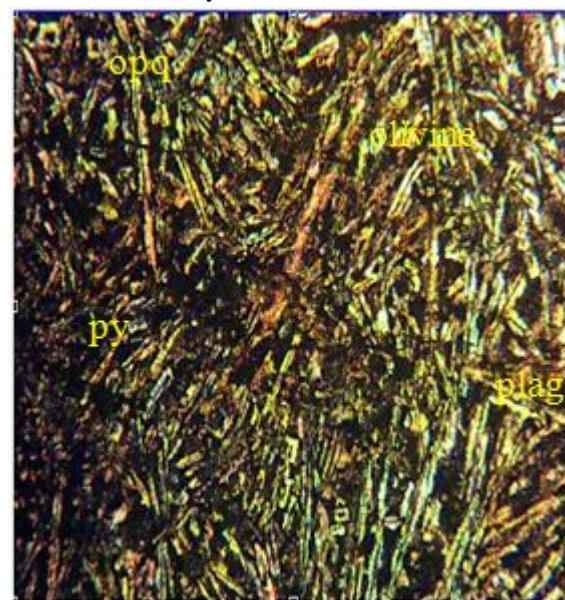


Figure 4b: Photomicrograph of Dolerite with ophitic texture and showing olivine, py = pyroxene, plag = plagioclase and opq = opaque minerals (XPL x25)

The noticeable structures encountered in the mapped area include; joints, faults, veins, and lineation. The joints range from 1m to 8.6m and the fault height observed in the migmatite schists is 90cm. Variable dip angles and direction characterize the strike joints of the migmatite schists. Genesis of these structures may be attributed to visible expressions of residual stresses released after deformation. Both quartz and pegmatitic veins are found in the rocks of the studied area. The veins are irregular. Some of them run parallel to the general structural NW-SE trend, while

others crosscut especially the quartz veins. It can be inferred that they formed at a later age.



Figure 5a: Pegmatite veins occurring in weathered schist.

Fractures (joints and faults), lineations, were the main structural elements present in the rocks. Joints were mapped by observing areas in outcrops where cohesion is lost with no relative movement of the rocks along the fracture plane. The relationship of the joints, whether parallel to the dip, strike or not in alliance with either the strike or dip of the rocks was also observed. The spacing between joints in each set, the rocks each set penetrates and the chronological sequence of sets of joints were noted.

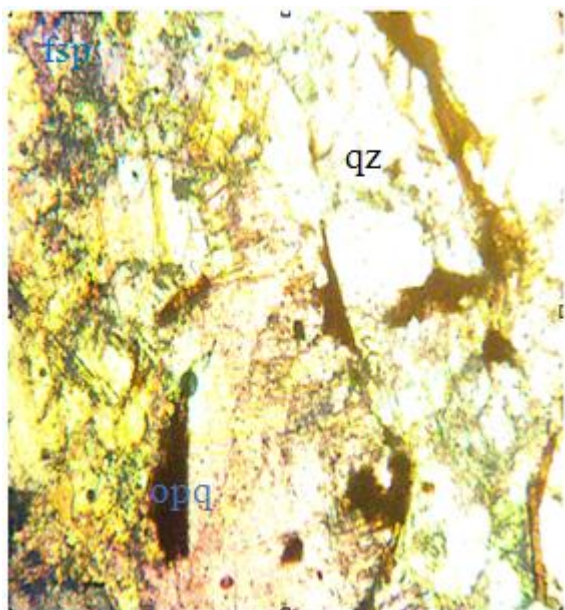


Figure 5b: Photomicrograph of pegmatite with qz = quartz, fsp = feldspar and opq = opaque minerals (PPL x25).



Figure 6a: Fractures in weathered schist along Bunfua road.

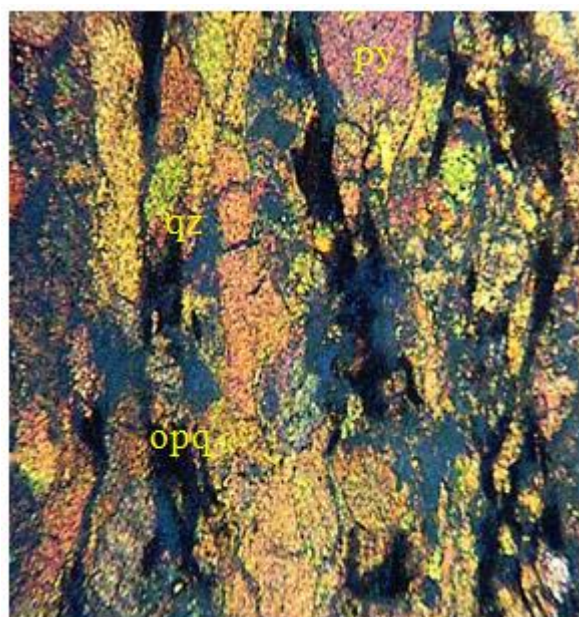


Figure 6b: Photomicrograph of schist showing qz = quartz, py = pyroxene and opq = opaque minerals (XPL x25).

METHODOLOGY

The method employed involved systematic geological mapping and sampling of the various rock outcrop occurring within the study area, followed by

petrographic and thin section studies. More than 20 fresh and uncontaminated whole rock samples were collected from the outcrops occurring within the study area. In collection of the samples, effort was made to sample mostly the central parts of the rock bodies to collect fresh samples, and a total of eleven samples, which were considered representative of the different major outcrops in the study area were eventually selected for thin section studies.

In the laboratory, petrographic analysis was done on selected representative rock samples for microscopic study. Eleven rock samples of (migmatites, schists, dolerites, quartzites, charnockites, pegmatites, and garnet mica schist) were used for thin sections preparation. The thin sections were examined using a petrological microscope under plane polarized Light (PPL) and crossed polarized light (XPL) with the aid of transmitted light and photomicrographs of the thin sections produced. The laboratory analysis was done at the laboratory and workshop of Department of Geology, University of Port Harcourt, Rivers State, Nigeria.

RESULTS AND DISCUSSION

Petrology

Ekwueme and Matheis (1995) are of the view that petrology as the science concerned with the petrography and petrogenesis of rocks.

The Bumaji area consists of igneous intrusives and metamorphic rocks. The igneous intrusives are charnockites, dolerites, granites, and pegmatites. The granites are biotite granite, and pegmatitic granite. Charnockite is a coarse-grained rock of approximately granitic composition containing feldspar, orthopyroxene and quartz. The quartz has a blue opalescence because of the presence of exsolved needles of rutile, while the feldspar is brownish in colour. The charnockites are of magmatic origin and displayed contact metamorphic aureoles, undergoing spheroidal weathering along Bumaji community road (Fig.3a). It was found to have intruded into the pre-existing rocks.

Dolerite is a medium grained mafic igneous rock that is mineralogically and chemically equivalent to basalt or of basaltic composition and commonly forms minor intrusion. Their emplacement is believed to have terminated the Pan-African Orogeny in Nigeria. In the mapped area, dolerite was found along Bunfua community going towards Obanliku occurring as intrusions, undergoing spheroidal weathering. They

displayed sharp contacts with the host rock showing no evidence of metamorphism. It is possible that dolerites occur at other locations but are buried under the surface because of their hyperbyssal nature.

Schists are strongly foliated rocks formed by regional metamorphism as they readily split into flecks. The conspicuous schistosity of all schists is attributed to mineral orientation. Schist underlies a large percentage of the total mapped area. It is found occurring in both Akase and Etikpe rivers. They are highly fractured and weathered. Schistosity is strong and trends N-S to NE-SW. There were evidence indicative of shearing and faulting that occurred as a result of deformation of rocks in the area. Minerals occurring include quartz, K-feldspar, plagioclase, pyroxene, biotite and opaque minerals (Table 1). The pyroxene content is augite and hypersthene. Dominant plagioclase is the labradorite. The opaque minerals occur as scattered grains of iron oxide along the augite partings.

In the study area, pegmatites occur mostly as veins of varying dimensions within the gneisses and schists. Quartzite veins was also seen in unmappable migmatites rocks at the Etikpe river. They cut across the whole length and width of the host rock. Their emplacement is controlled by the N-S to NE-SW regional structure of the host rock. In thin sections, pegmatites occurs as very coarse grained crystal. Minerals identified in thin sections include quartz, feldspar, hornblende, biotite and opaque minerals. Biotite is a minor constituent while muscovite occurs as flaky aggregates.

The migmatites are dark and light in colour and comprised leucocratic (leucosome) and melanocratic (melanosome) fractions. The rock displayed a migmatitic texture marked by the development of foliations and lineations. The foliations are defined by the parallel arrangement of dark and light coloured minerals while the lineations are defined by low, sub parallel ribs and furrows on the cleavage surface of the rocks. Hand specimen of the rock shows the presence of hornblende, plagioclase, biotite and quartz (Fig. 6).



Figure 6a: Field Photograph showing migmatites between Boki and Obaliku boundary along Sankwala – Bumaji road.

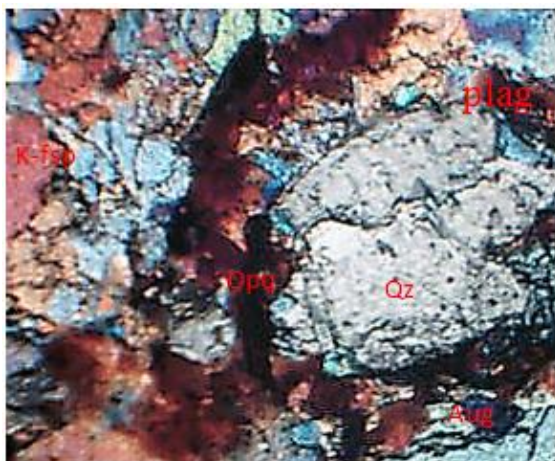


Figure 6b: Photomicrograph of Migmatite showing qz = quartz, fsp = feldspar and opq = opaque minerals(XPL x25)

Under the microscope, the rocks show euhedral, sub-hedral and anhedral crystals of dark and light coloured minerals. The dark coloured minerals are hornblende and biotite while plagioclase and quartz are the light coloured minerals. The orientation of the dark and light coloured minerals defines the foliations and lineations in the rock. The rock shows a coarse grained texture due to the development of the mineral grains into well-defined crystals though some have been deformed.

Structural Geology

The noticeable structures encountered in the mapped area include; veins, lineations, joints and faults. Shear fractures observed are filled by late pegmatitic veins. The highland in Bumaji area are cliffs, which were

difficult to map, while the lowland has thick forest with tall trees. The faults in the study area were minor faults with small displacements.

Foliations and Lineations

Foliations which are common in the migmatites, gneisses and schists which occurs as simple mineralogical banding. The preferred orientation of the foliation is NW-SE trending which is indicating imprint of the Pan-African orogeny. Lineations in the rocks are displayed by the parallel alignment or preferred orientation of dark and light coloured minerals. The dark coloured minerals are the ferromagnesian minerals (hornblende and biotite) while the light coloured minerals are the quartzofeldspathic minerals (quartz and feldspar). Like the foliations, there are two generations of lineations, the first being more or less horizontal while the second is oblique (Figs. 7-8) while the rose diagram and dip value direction is shown on (Fig.9).

Both foliation and lineation probably developed as a result of tectonic activities led to the formation of the Benue Trough.

The Bumaji area attained a high grade regional metamorphism with contact and dynamic metamorphism in places. Relicts of lineation, faults, joints, as well as fractures were mapped in the area. The migmatites show granodioritic mineralogical composition while the granite gneisses are of granitic composition.



Figure 7: Field Photograph of migmatite showing mineral alignment along Bambariko road.

Fractures

Fractures are high as observed in the schists. This high density fractures may indicate surface stress relaxation effects during the un-roofing of the rocks. Variable dip angles and direction characterize the strike joints of the schists. Genesis of these structures may be attributed to visible expressions of residual stresses released after deformation.



Figure 8: Field Photograph of schist showing fractures and mineral lineation along at Akase river.

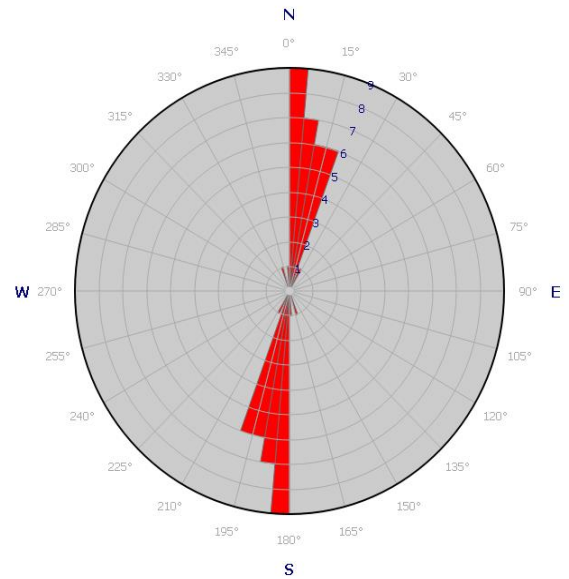


Figure 9a: Rose Diagram showing rock Fractures in N-S and NE-SW Direction at Akase river

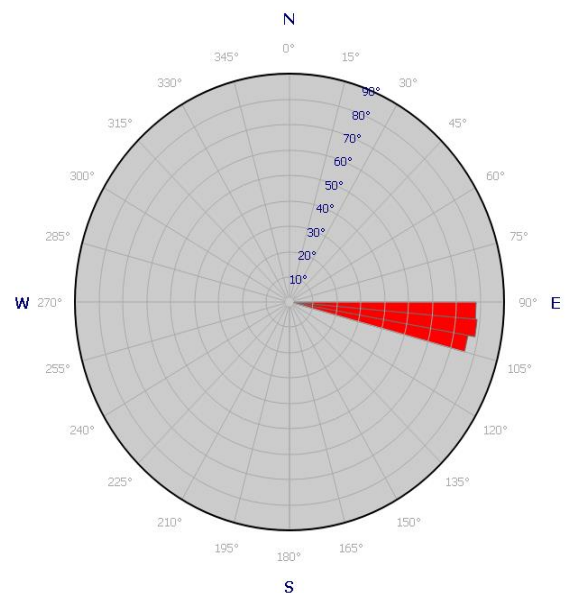


Figure 9b: Rose Diagram showing Dip in the East direction at Akase river

Table 1: Average Modal Composition of Bumaji basement rocks

Minerals	Pegmatite	Charnockite	Dolerite	Schist	Migmatite	Quartzite	Gneiss
Quartz	45	32	-	35	38	65	22
Biotite	6	3	17	6	18	5	10
Olivine	-	-	30	-	3	1	-
Muscovite	8	-	-	3	10	<1	7
Hornblende	10	15	16	5	<1	-	6
K-feldspar	15	20	10	25	15	3	30
Na-feldspar	9	-	-	-	-	-	-
Orthopyroxene	-	8	9	10	9	2	10
Plagioclase	-	10	5	13	-	-	12
Clinopyroxene	-	2	-	-	-	-	-
Ilmenite	-	-	8	-	-	-	-
Zircon	-	-	-	-	-	7	-
Rutile	-	-	-	-	-	5	-
Opaque minerals	6	10	4	3	6	12	3

DISCUSSION

Ekwueme (1994, 2003) observed that the nearby Obudu Plateau in Obalinku area compose of high grade rocks; schists, gneisses and migmatites. In the study area, the dominant intrusive rocks are charnockites, pegmatites and dolerites while the host rocks are migmatites, gneisses and schists. The gneisses, charnockites and pegmatites are dominated by quartz and feldspar, with subordinate biotite and pyroxene. The dolerites on the other hand are composed dominantly of olivine (30%), with no quartz in their norm, reflecting their mafic character.

Field relationship between the rocks of the studied area shows that the intrusive rocks are magmatic in origin. They are characterized by phenocrysts of minerals which are randomly oriented, the metamorphic rocks have fractures, planar and linear structures. These structures are signatures of polyphase deformation and residual stresses released after deformation of the metamorphic rocks. Charnockites intrusion occurs observed to have contact metamorphic aureole about 60cm in length. The dolerites however reveal spheroidal weathering and no contact metamorphic feature. The study area lacked abundant granite which appears to be the same with the central parts of Mukuru area reported by Egesi and Ukaegbu, (2013), and Ukaegbu, (2003) in the Obudu area. However, the area is similar to Boje-Ashuben axis Bansara area, in having charnockites with contact metamorphic aureole and random

oriented phenocrysts of minerals Egesi and Ukaegbu (2010). Lineations in the rocks are displayed by the parallel alignment or preferred orientation of dark and light coloured minerals. The dark coloured minerals are the ferromagnesian minerals (pyroxene, hornblende and biotite) while the light coloured minerals are the quartzo-feldsparitic minerals. Both foliation and lineation probably developed as a result of tectonic activities and magmatic differentiation.

CONCLUSION

The study area consists of migmatites, gneisses and schists that have been intruded by charnockites, dolerites and pegmatites. These rocks display distinctive mineralogical, textural and structural characteristics that lead to the basis of their nomenclatures. This area is compose of high grade schists. The type and nature of minerals the rocks contain together with the geometry reveal that the rocks have undergone more than one deformational event since the time of their formation.

The field and petrographic studies show that charnockite, dolerite, and pegmatite occur as igneous intrusives, while migmatite, biotite gneiss, and schist show presence of fractures and mineral lineations in the study area. The granite gneisses varies between medium to coarse grained while the dolerites show ophitic texture. The area comprising of two major rivers – Akase and Etikpe. The Etikpe river trend in the NE-SW direction and the Akase river trend in N-S to NE-SW direction, which shows they are

structurally controlled. The rivers are in their youthful stages showing high gradients, steep-sided valleys, irregular courses, waterfalls and few tributaries.

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