International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 5 Issue 6 ǁ June. 2017 ǁ PP. 15-31

Preliminary Studies of the Litho-Structural Evolution of Areas Around Obudu Northeast, Sheet 291, Southeastern Nigeria

Ajadi Jimoh[1] and Yakubu Silas[2]
[1](*Department of Geology, Kwara State University, Malete, Nigeria)*
2(Department of Economic Geology, Nigeria Geological Survey Agency, Abuja)

ABSTRACT: *Rocks underlying the northeastern sector of Obudu area forms part of the Bamenda massif which is a westward extension of the Precambrian terrains of Cameroon into southeastern Nigeria. These rocks are frequently found in the basement complex of Nigeria and include the migmatitic gneiss as the early metamorphic tectonites constituting over 60% of the outcropping rocks in the study area. The basement rock of the study area comprised of the migmatite gneiss and biotite-hornblende garnetiferous gneiss as well as the porphyroblastic gneiss and granite gneiss which formed the basement intruded by the Older granites (Pan-African granitoids). The Older granites in this area include charnockite, porphyritic granite, medium grained granite, diorite and pegmatite/aplite with relatively undeformed veins of dolerite and quartz. The presence of garnet nodules in the biotite-hornblende gneiss indicates high grade tectono-thermal metamorphism of a possible sedimentary protolith. The shearing observed in some rock outcrops are indication that there have been a series of structural deformation alongside magmatism and metamorphism in the area.*

Keywords: *Garnetiferous, Granitoids, Massif, Porphyroblastic, Protholith, Tectonites*

I. INTRODUCTION

The Obudu NE area falls within the Bamenda massif which, as a result of rocks proximity and similarity, has been proved to be a westward extension of the Precambrian basement terrains of Cameroon into southeastern Nigeria [1]. The study area comprised of rocks which are similar to those frequently found in the basement complex of Nigeria and lies within 1:50,000 Obudu NE sheet 291 bounded by latitude 6º 45’ 00”N and 7º 00’ 00”N and longitude 9º 15’ 00”E and 9º 30’ 00”E. The area is dotted by high topographic features occurring as elevated hills such as the Usambe hills which rises 2,064m above the sea level to the southeastern part, Binda/Fada hill in the central part, Ushongo hill in the northwest and Gbonge, Aterse and Manyan Hills to the north and northeast respectively. These hills appear as conical, oval or as flat-topped ridges of altitudes ranging between 2,000m to 2,064m and are interspersed by peneplains and valleys of major rivers in the area, draining mainly from south to north. Over 95% of the area lies within Kwande LGA of Benue State.

II. REGIONAL GEOLOGICAL SETTING

The Nigerian Basement Complex lies within the reactivated Pan African ancient crystalline shield and it is bounded to the west and east by the West African and the Congo Cratons respectively, extending westward into the Dahomey (Benin Republic) and eastward into the Cameroon (Fig. 1). The Basement Complex which is exposed in the northwest, northeast, southeast and southwest of the country is known to have experienced a major tectono-thermal event about ~600±100Ma [2] which took place prior to the late Proterozoic to early Paleozoic. The basement complex of Nigeria consist of crystalline Precambrian rocks and it covers over half of the country comprising of three (3) broad litho-stratigraphic groups. These are the Migmatite-Gneiss complex, the Schist Belts and the Granitoids. Within the Migmatite-gneiss complex, there are metasedimentary rocks represented by medium-high grade calcareous rocks as well as pelitic and quartzitic rocks described as “ancient metasediments” [3]. The schist belts are low grade metasediments which forms narrow lithological units believed to be relics of a once widespread supracrustal cover [4] [5]. These rocks are infolded into the migmatite gneiss complex which were both intruded by syn-tectonic to late-tectonic Granitoids in the Pan African.

The geochemical behavior of trace elements has been used to identify the geodynamic disturbances in the mantle as being responsible for the tectonic activities in the Pan-African basement of Obudu Plateau [6]. The presence of hypersthene, plagioclase (An_{38}-An_{46}), hornblende and anti-perthitic intergrowths in the rocks of Ukwortung area of Obudu have been used to propose an uppermost amphibolite to granulite facies metamorphism for the rocks of the study area [7]. This high grade metamorphism was followed by retrograde metamorphism to amphibolite facies grade.

III. METHODOLOGY

Mapping of the study area was carried out on a scale of 1:50,000 to produce a geological map on a scale of 1:25,000. This was achieved by compass and road traversing to assess rock exposures for the purpose of taking field data and measurements which are promptly plotted on topographic maps and recorded in field notebook with annotated sketches and photographs of salient features and structures. Representative fresh samples of the various lithologies were collected for laboratory petrographic studies. Aerial photograph and aeromagnetic maps of the study area were acquired and studied while existing literatures on previous work done in the area were reviewed preparatory to fieldwork.

Figure 1: Sketched map of the Pan African mobile belt showing the study area.

IV. LITHOLOGICAL DESCRIPTION

This section highlights the different rock types, composition, mode of occurrence, distribution, field relationship and other features. Three major lithological groups were mapped in the study area (fig. 2). These include rocks of the migmatite-gneiss-quartzite unit, the Pan African Older Granites and the late intrusives. Two textural types of granites were mapped in the area, including the porphyritic granite and the medium grained granite. Using genetic data, the porphyritic granite was classified as belonging to the main phase while the medium grained granite corresponds to the late phase of the rock formation [8]. Generally the granitoids are crystalline, dense and massive rock types, with less than 30% biotite and hornblende, which makes them leucocratic.

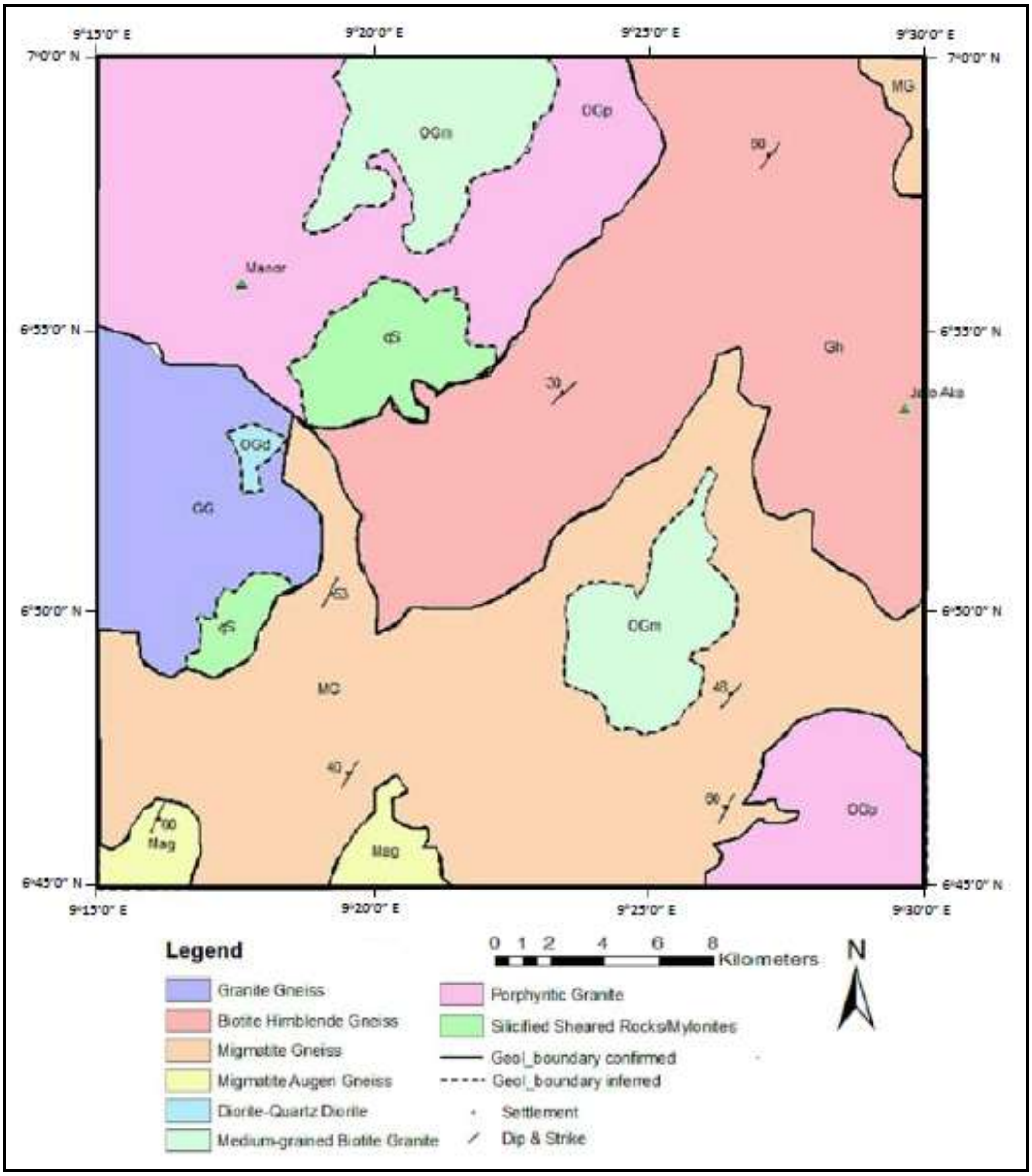

Figure 2: Geological map of Obudu N.E. sheet 291 showing lithological distribution in the study area.

4.1 Migmatite Gneiss (MG)

These rocks forms the most prominent outcrops in the study area, extending from the southwest through the central area to the northeast. The migmatites underlain more than half of the study area and in fact represent the country rock into which the other rock types have been emplaced. The main structural trends are NE-SW and NW-SE. Rocks mapped under this unit include the migmatite gneiss, biotite-hornblende garnetiferous gneiss, granite gneiss and porphyroblastic gneiss. The migmatitic gneiss is banded on millimetric to centimetric scale and comprised of the '*paleosome*' (older pre-existing part which could be schist, gneiss or amphibolites) and the '*neosome'* (younger part which often consists of the granitic rocks, aplites or pegmatites). The foliations in the rocks are defined by the parallel disposition of the '*leucosomes'* (felsic component) and '*mesosomes-melanosomes'* (mafic component) as observed near Mbadullah (06º49'43"N, 09º26'23"E). The preponderance of biotite in the rock also defines a strong foliation by its preferred orientation. Some of the characteristic features found within the outcrops include stromatic pinch and swell structures, as well as ptygmatic folds and multidirectional joints (fig. 3). Biotite gneiss is generally dark greyish colored, fine- to medium-grained in texture and exhibits foliation that is marked by alternating millimetric bands of the felsic and mafic minerals. The mafic bands are persistently thicker and contains nodules of almandine garnets in some outcrops (fig. 4).

The mineralogy of the biotite gneiss, from field observations, consists of feldspar (mostly labradorite to bytownite plagioclase), quartz, biotite and hornblende which form the paleosome. The small concordant bands of amphibolite constitute the melanosome, while the associated felsic rocks comprising of the pegmatite and vein quartz forms the neosome. Intrusives into the migmatites are made up of quartz, pegmatitic and aplite veins. Xenoliths of amphibolitic rocks are also common. Hornblende is anhedral to subhedral in shape and pleochroic from brownish green to dark dirty green colour under plane polarized light. Plagioclase constitutes 40% of the minerals in thin section with poikilitic biotite. Plagioclase crystals are tabular parallel to {010} and elongate parallel to C and A axis, showing Carlsbad twinning in some places and polysynthetic twinning in others. Orthoclase is 10% with micrographic texture and colorless in plain polarized light (figs. 5a & b).

Figure 3: Migmatite Gneiss showing bands (paleosome and neosome) 06º57’45”N, 09º25’56”E.near Mbadullah Village.

Figure 4: Garnetiferous biotite-hornblende gneiss.

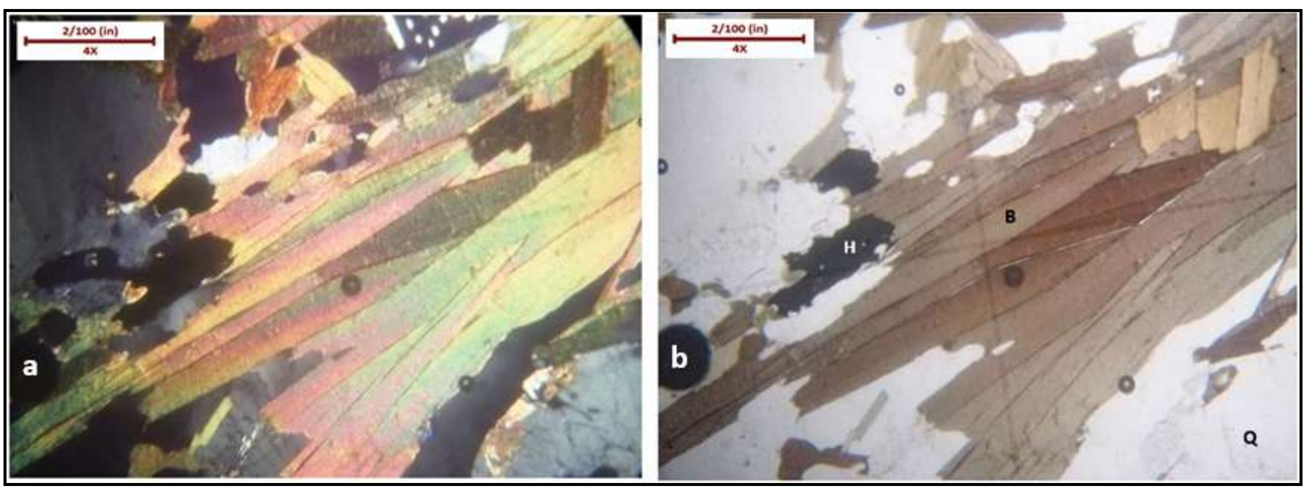

Figure 5: Photomicrograph of biotite gneiss showing the biotite cluster that define the foliation of the gneiss (a) under crossed polarized light (b) under plain polarized light. (H=hornblende, B=biotite, Q=quartz).

4.2 Augen Gneiss (Mag)

The rock is composed essentially of biotite, hornblende with minor amounts of quartz, plagioclase and garnet. The dominant felsic mineral is the plagioclase feldspar and microcline which, where present, constitutes the augen structure. The mineral foliation were observed to be rimming the porphyroblasts whose longer axis averagely measures 1.5cm while the shorter axis is up to 0.5cm. On some of the outcrops of this rock, the augen gneiss becomes migmatitic due to pervasive intrusions of felsic materials. The outcrop of this rock is prominent in the southwestern part of the sheet around Mbachor (06º46’11”N, 09º16’18”E) and Maav Sar (06º46’21”N, 09º20’08”E) where a discordant dolerite dyke intrudes into the rock (fig. 6).

4.3 Granite Gneiss (GG)

The granitic gneiss rock outcrops as hills around Abado and Hityom with well-developed foliation in which the quartzo-feldspathic materials commonly form impersistent leucocratic streaks a few millimeters thick, alternating with bands of the mafic constituents which forms the pervasive foliation observed on the outcrop. Generally, the rock is light to dark grey in colour with the foliation exhibiting sharp contacts with the intrusive pegmatite and quartzo-feldspatic veins (fig. 7). This rock constitutes one of the felsic components in the migmatitic gneiss which sometimes becomes thickened as mappable units and are identified as distinct granite gneiss outcrops. Thin section studies shows that tabular crystals of plagioclase constitute 15% of the modal composition with lamella twinning. Orthoclase is 20% and shows perthitic texture. Quartz is 55% and exhibits tectonic micro-cracks. Biotite, muscovite and accessory minerals constitute about 10% of the modal composition. Anhedral to subhedral grains of biotite shows a perfect cleavage in one direction and pleochroic from pale brown to greyish green (fig. 8).

Figure 6: An open joint at the contact between a dolerite dyke and porphyroblastic gneiss (06º42’24”N, 09º20’09”E).

Figure 7: Sharp contact between granite gneiss and a quartzo-feldspatic vein (06º52’43.3”N, 09º18’29.7”E).

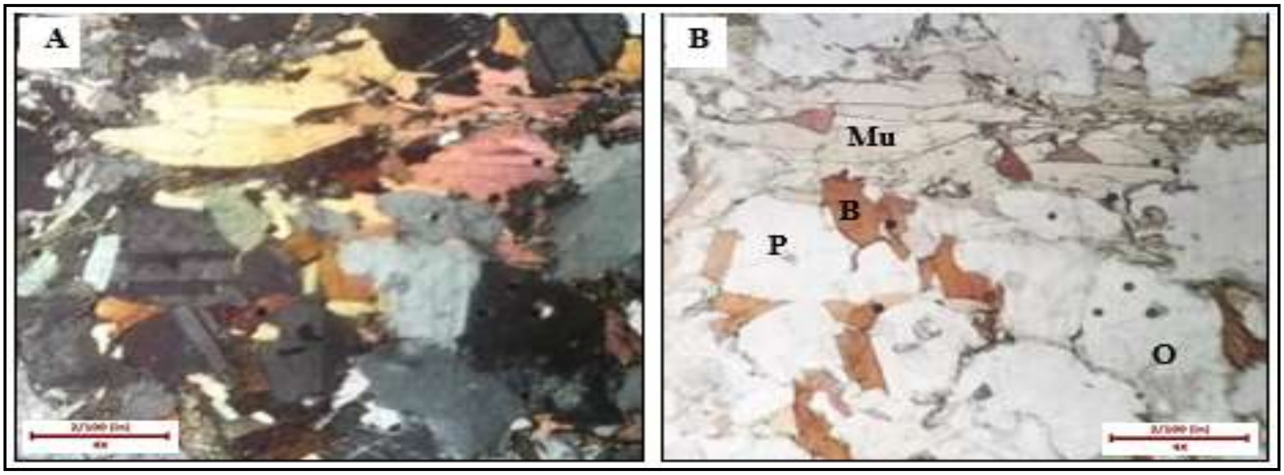

Figure 8: Photomicrograph of granite gneiss (a) under XPL (b) under PPL (B=biotite, Mu=muscovite, O=orthoclase, P=plagioclase).

4.4 Porphyritic Granite (OGp)

The rock occurs as distinct, large hills of batholitic dimension, forming prominent features in the study area. The rock fabric is characterized by the presence of subhedral to euhedral prismatic megacrysts of feldspar (mostly orthoclase and microcline) that measure up to 4cm long with crude alignment along their long axes (fig. 9). The feldspar megacrysts exhibit parallel twinning with the crystals symmetrically arranged. Under the thin section (fig. 10), large grains of microcline show the usual tartan pattern; colorless under plain polar, light grey in cross polar and constitutes about 10% of the modal composition. Tabular crystals of plagioclase (10%) shows polysynthetic twinning and is being altered to sericite. Orthoclase (20%) is colorless in PPL and grey in XPL showing Carlsbad twinning. Quartz (55%) is colorless and shows triple junction. Subhedral grains of muscovite (2%) are colorless in PPL with one directional cleavage pattern and bluish in XPL. Biotite (3%) is also subhedral with a moderate relief and shows pleochroism from brown-dark brown.

4.5 Medium Grained Granite (OGm)

The medium-grained granite is granular textured, massive and leucocratic to mesocratic in colour depending on the abundance of biotite. Hand specimen and thin section observations revealed that the rock is leuco-granite which is composed of quartz (50%), orthoclase (15%), plagioclase (25%), biotite (6%), muscovite (1%) and hornblende (3%). Figure 11 shows the photomicrograph of the minerals in the medium-grained granite in thin section. This rock is localized to the southeastern part of the study area around Mbadullah and Nye-tiev villages where it is called Uwi Wah hill. The medium grain granite is sandwiched between the porphyritic granites and gneisses, and sometimes occur as dykes within the host rock (fig. 9). The low colour index makes it appear light grey from a distance. The felsic minerals constituent is more abundant than biotite, the main mafic mineral. There seems to be a petrogenetic link between the granitic and charnockitic rocks in the study area in which the minor, usually bouldery and unmappable charnockite outcrops at the fringes of the granitic rocks. This is observed here as an admixture of the boulders of the medium-grained granite and charnockite at the base of Nji hill which is basically composed of granite.

4.6 Charnockite

In this area the charnockite occur as coarse-grained low-lying boulders composed of K-feldspar, microcline (up to 2cm thick), quartz, pyroxene, biotite and hornblende. Weathered parts of the charnockitic rock are brownish colored while the fresh surfaces show a greenish tinge. Generally the charnockitic rocks are hard, dense and massive (fig. 12) as was also reported for the charnockites around Ado-Ekiti-Akure areas [9]. In thin section (fig. 13), tabular and elongate crystals of plagioclase (25%) which shows polysynthetic twinning abound but are observed to be undergoing alteration to sericite. Orthopyroxene (10%) is weakly pleochroic from pale green to pink. Quartz shows triple junction and constitute about 48% of the modal composition. Biotite (5%) is pleochroic with a perfect cleavage in one direction. Orthoclase (7%) is colorless in plain polarized light with low relief. Sericite (3%) is seen as turbid pale grayish grains replacing some altered plagioclase. Opaque mineral is about 2%**.**

Figure 9: An outcrop of the medium-grained granite within the porphyritic granite. Note the crude alignment of the feldspar megacrysts in the porphyritic granite (06º59'32.9"N, 09º20'03.0"E).

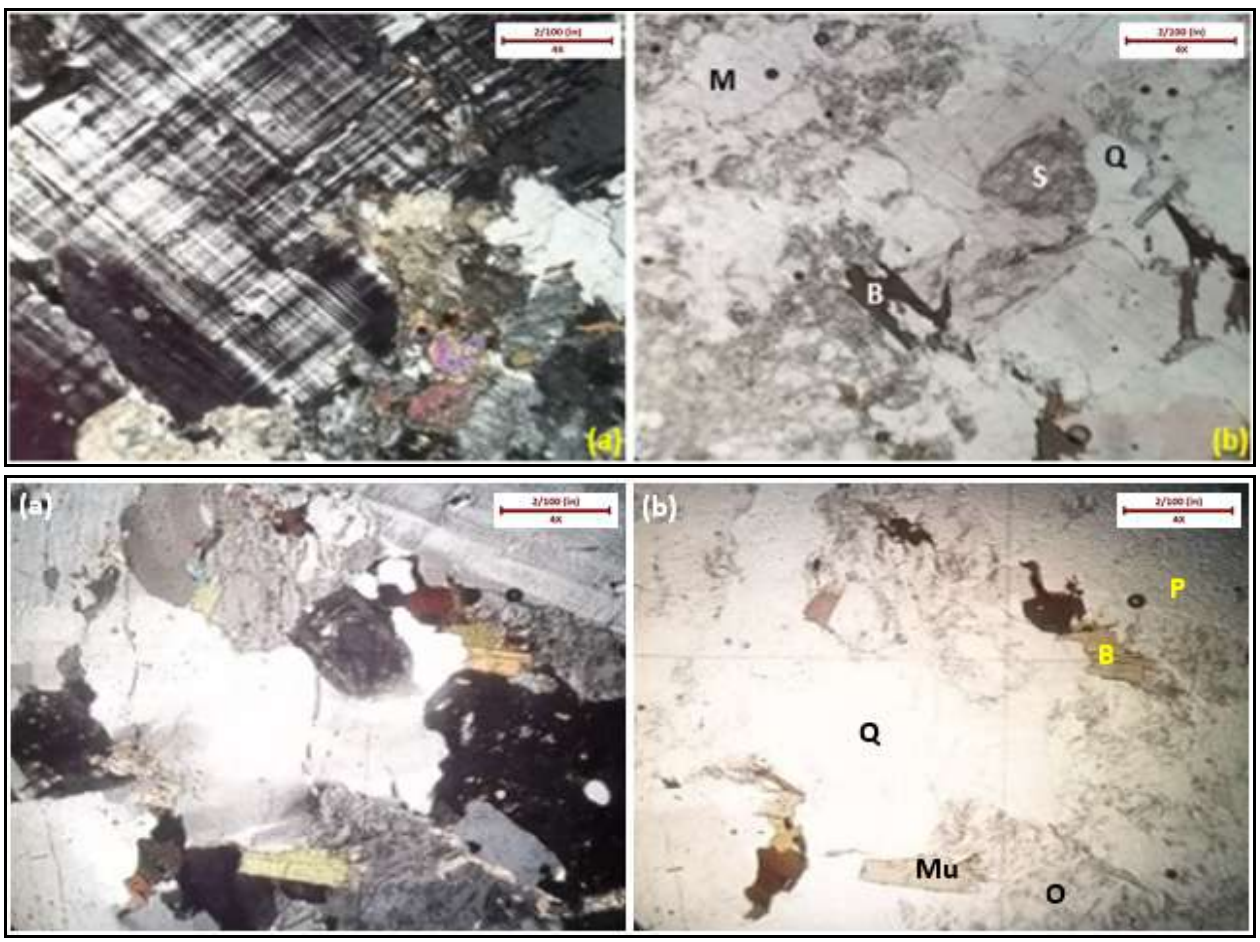

Figure 10: Photomicrograph of the porphyritic granite (OGp) (a) under cross polar and (b) under plain polar (B=biotite, M=microcline, Mu=muscovite, O=orthoclase, P=plagioclase, Q=quartz, S=sericite).

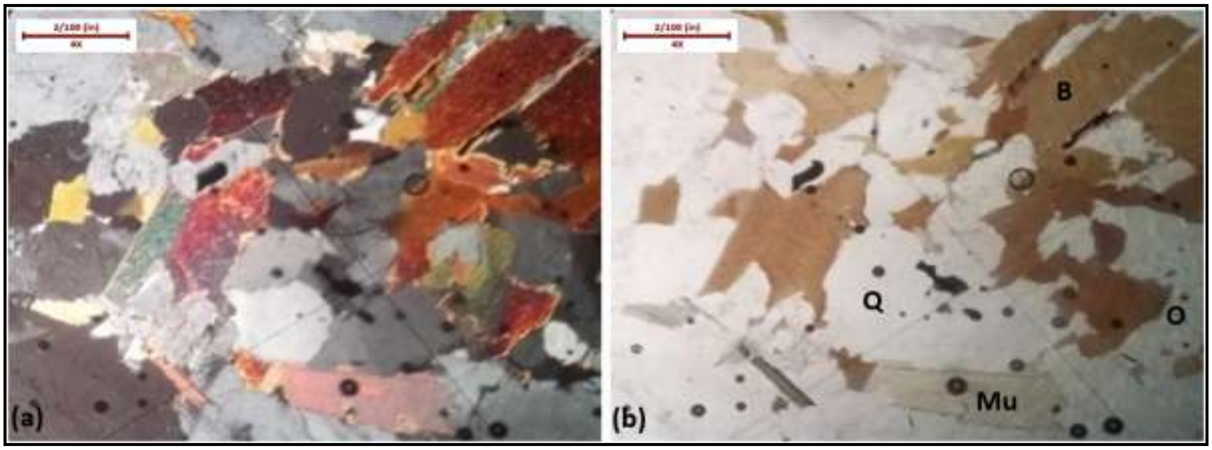

Figure 11: Photomicrograph of the medium-grained granite under (a) crossed polar (b) plain polarized light. (B=biotite, Mu=muscovite, O=orthoclase, Q=quartz).

Figure 12: An insitu boulder of a charnokitic rock at the foot of Nji Hill. (06º45'16.2"N, 09º29'19.5"E).

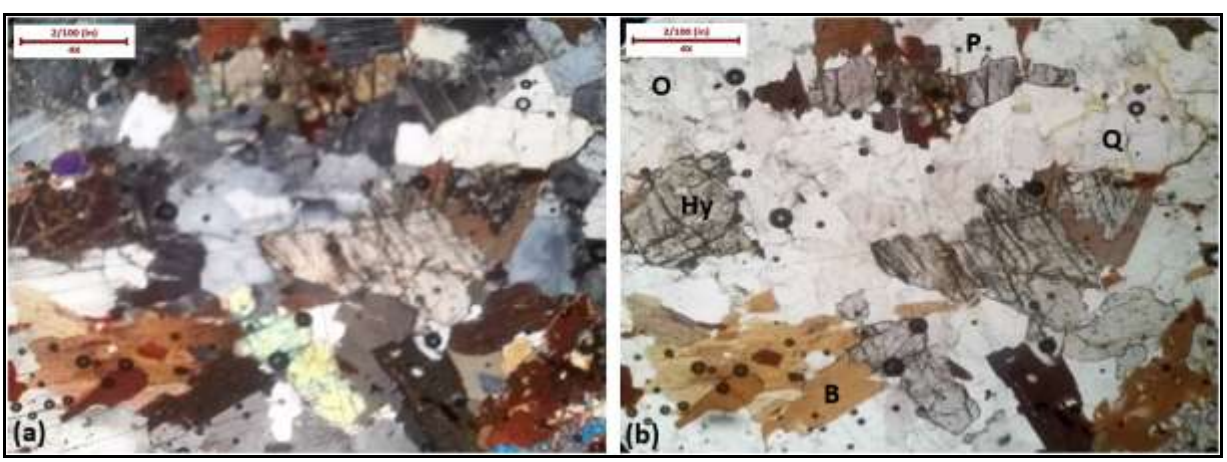

Figure 13: Photomicrograph of the charnockite under (a) crossed polar (b) plain polarized light. (B=biotite, Hy=hypersthene, O=orthoclase, P=plagioclase, Q=quartz).

4.7 Quartz Diorite (OGd)

The porphyritic quartz diorite rock outcrops as discrete low-lying exposures within the granitic gneiss host rock, showing sharp intrusive contacts. The quartz diorite is mesocratic to melanocratic textured and characterized by tabular megacrysts of plagioclase (fig. 14) (andesine) embedded within a groundmass composed of coarse-grained feldspar, quartz, biotite and hornblende. The rock shows a preferred alignment of the longer axis of the feldspar megacrysts, indicating flow foliation structure. In thin section, the rock is composed of quartz (10%), biotite (5%), hornblende (5%), minor pyroxene and plagioclase feldspar which is observed to be breaking down to orthoclase and sericite (fig. 15).

4.8 Dolerite

The doleritic rock in the study area occurs as small NNE-SSW trending lensoid bands intruding the older gneissic host rocks. Field observations shows that the dolerite is fine-grained equigranular, massive and sometimes displays a weak foliation. It outcrops both as insitu intrusive bodies exhibiting chilled margin at its contact with the host granitic rock (fig. 16), as boulders ranging in diameters from less than 0.3m to 0.95m and as discordant dykes (fig. 6). The mineralogy of the dolerite is variable due to varying amounts of biotite, hornblende and quartz.

Figure 14: An outcrop of porphyritic diorite showing tabular feldspar phenocrysts (06º55’57.7”N, 09º15’48.6”E).

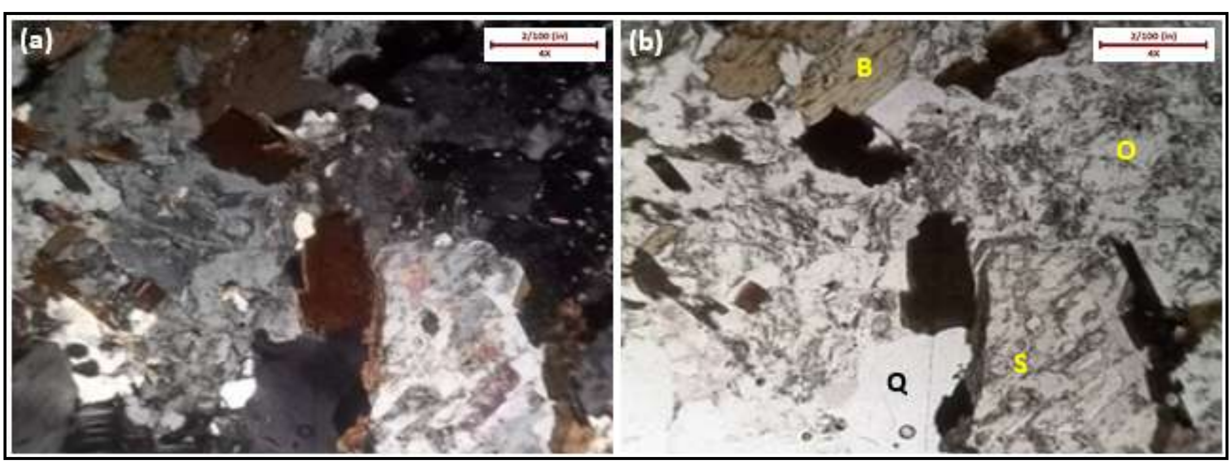

Figure 15: Photomicrograph of the porphyritic quartz diorite (a) in crossed polar (b) in plain polarized light. (B=biotite, O=orthoclase, Q=quartz, S=sericite).

Figure 16: Contact between diorite and granite gneiss showing quartzo-feldspatic veins, near Ahile village: (06º52'43.5"N, 09º18'29.7"E).

4.9 Amphibolite

The rock is fine to medium grained and dark green to greyish black colored with sparse porphyroblasts of hornblende. Field observations show that the amphibolite occurs as discrete xenolith (fig. 17a) and as thin concordant lenses, which form elongated bodies in the host rock trending 130° on the Tserga hill, where it is most found as in situ boulders (fig. 17b). At the contact with the host rocks, narrow discrete concordant amphibolite bands were observed to alternate with layers of gneiss/granites and are occasionally intruded by pegmatite in few of the outcrops.

4.10 Pegmatite and Aplite

Pegmatites and aplites form the late phase granite series, invading virtually all the rock units in various forms and shapes. The pegmatites often outcrops as minor concordant and discordant dykes (fig. 18) and veins on low relief or on ground level which when locally numerous may coalesce to form large pegmatite bodies. They range in size from veinlets of a few centimeters wide to large bodies of up to 1.5m wide. Hand specimen observations show that the mineral constituents in the pegmatite include coarse quartz, large euhedral pink feldspar, subhedral to anhedral plagioclase, flakes of muscovite and black tourmaline. The black variety of tourmaline (schorl) usually occurs as blebs where along with other mafic minerals forms a selvedge. The pegmatites and aplites that are associated with the gneisses and granites may be conformable but often cross cut or even oblique to the rock fabrics. Field observations suggest that the pegmatites are fracture-filling as they utilize weak zones such as joints, faults and tension cracks for their emplacement. The quartzo-feldspatic veins vary in sizes from a few millimeters to wide bodies up to 1.5m sometimes traceable for over 100m along strike and often exhibit sharp contacts with the host rocks. Aplitic dykes in the study area are mapped as sub-parallel to parallel concordant and discordant bodies with saccharoidal texture which often grades into the course texture of pegmatites with which they frequently associated.

Figure 17: (a) Xenoliths of amphibolite in porphyritic granite (b) Boulders of amphibolite at Tserga hill (06º49'49.1"N, 09º17'33.9"E).

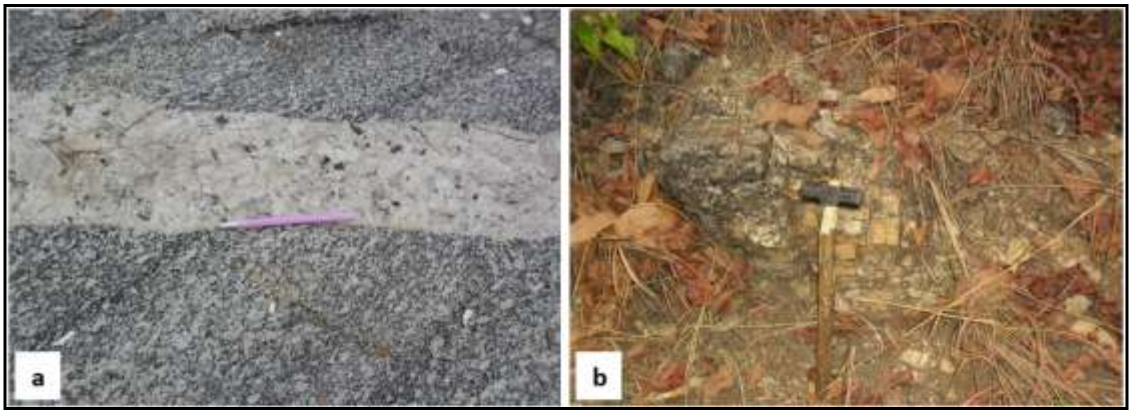

Figure 18: (a) A discordant dyke of pegmatite in porphyroblastic gneiss; (b) An outcrop of a decomposing pegmatite near Tserga village (06º49'49.1"N, 09º17'33.9"E).

4.9 Quartz Vein

Quartz vein is widely distributed in all the rocks types, with varying sizes from stringers of a few millimeters up to 5cm wide. On outcrops, the vein quartz appears as fracture-filling and this may account for the absence of open joints on most of the outcrops. Some of the veins are concordant with their host rock foliation (fig. 19) while others are discordant with sharp contacts. Most of the quartz observed in hand specimen are milky colored.

4.10 Mylonites/Sheared Rocks

This rock is exposed around Ugono village (06º54'16.6"N, 09º20'48.4"E) where fine grained quartzitic boulders with brownish bands are seen as in situ boulders at the foot of Tokude hill (fig. 20). Fresh faces of the cataclastic rock, which is a product of ductile shearing are white to pinkish in color. Quartz and feldspar are the prominent minerals observed in this rock.

Figure 19: Concordant quartz vein in biotite gneiss.

Figure 20: Mylonitic boulders at Tokude hill.

V. STRUCTURAL GEOLOGY

Field evidence revealed that the study area is affected by polyphase deformation which has imparted various structural imprints on the rocks. The two major categories of structural elements observed in the field are the ductile structures which include folds, foliation, shears, pinch and swell, as well as the brittle structures comprising joints and faults.

5.1 Ductile Deformation

The most conspicuous ductile structure in the area particularly on metamorphic outcrops is the foliation which includes gneissosity, cleavages and banding. Foliations in migmatites and gneisses are defined by the parallel alignment of platy, prismatic or tubular minerals such as mica, amphiboles and microcline megacrysts. The mafic bands that defines the foliation in migmatites are marked by flakes of mica and amphiboles as observed around Alogba. The gneisses show foliation whose bands are sometimes defined by alternating augens of feldspar and streaks of biotite. Slaty cleavages commonly found in the migmatites are pronounced in the mafic layers showing cleavage planes that are parallel to the compositional banding and hence defines the rock foliation (fig. 21).

Boudinage is a sausage-shaped pinch and swell body found in the gneisses and migmatites originating from the deformational stretching of the rigid ductile layers along bedding planes due to the shearing and gradual necking of the host rock fabrics (fig. 22). Subsequent brittle deformation leads to the formation of boudins from the pinch and swells. The gap between the boudins is often filled by recrystallized quartzo-feldspatic materials. The folds observed in the study area are minor with variable geometry ranging from symmetrical, simple to more complex asymmetrical folds which are common features in gneisses and migmatites (fig. 23). The axes of most tight isoclinal folds are parallel or sub-parallel to the rock foliation, indicating that the pervasive foliation on the migmatites and gneisses are axial planar to the axes of tight isoclinal folds. In areas that have suffered intense tectonism particularly on migmatitic gneiss outcrops, the simple axial planar cleavages are complexly folded into open or crenulated folds (fig. 24).

Figure 21: Slaty cleavage planes parallel to compositional banding in biotite gneiss (06º57'45"N, 09º25'56"E).

Figure 22: An outcrop showing pinch and swell near Akambo hill (06º47'35.5"N, 09º29'24.3"E).

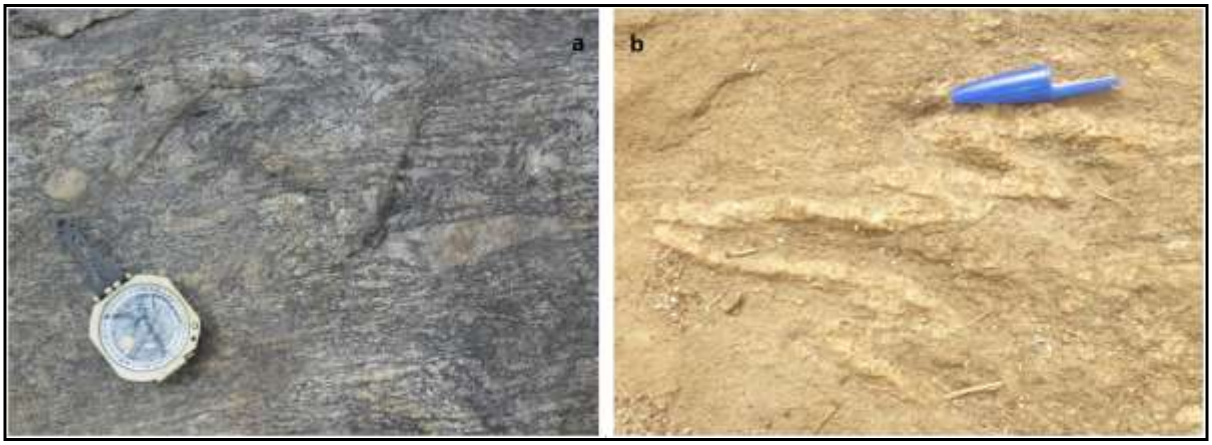

Figure 23: (a) Asymmetrical folds (06º59'09"N, 09º26'38"E); (b) A fold plunging 30^{o} with an azimuth of about 015^{o} (06º5'45"N, 09º25'56"E).

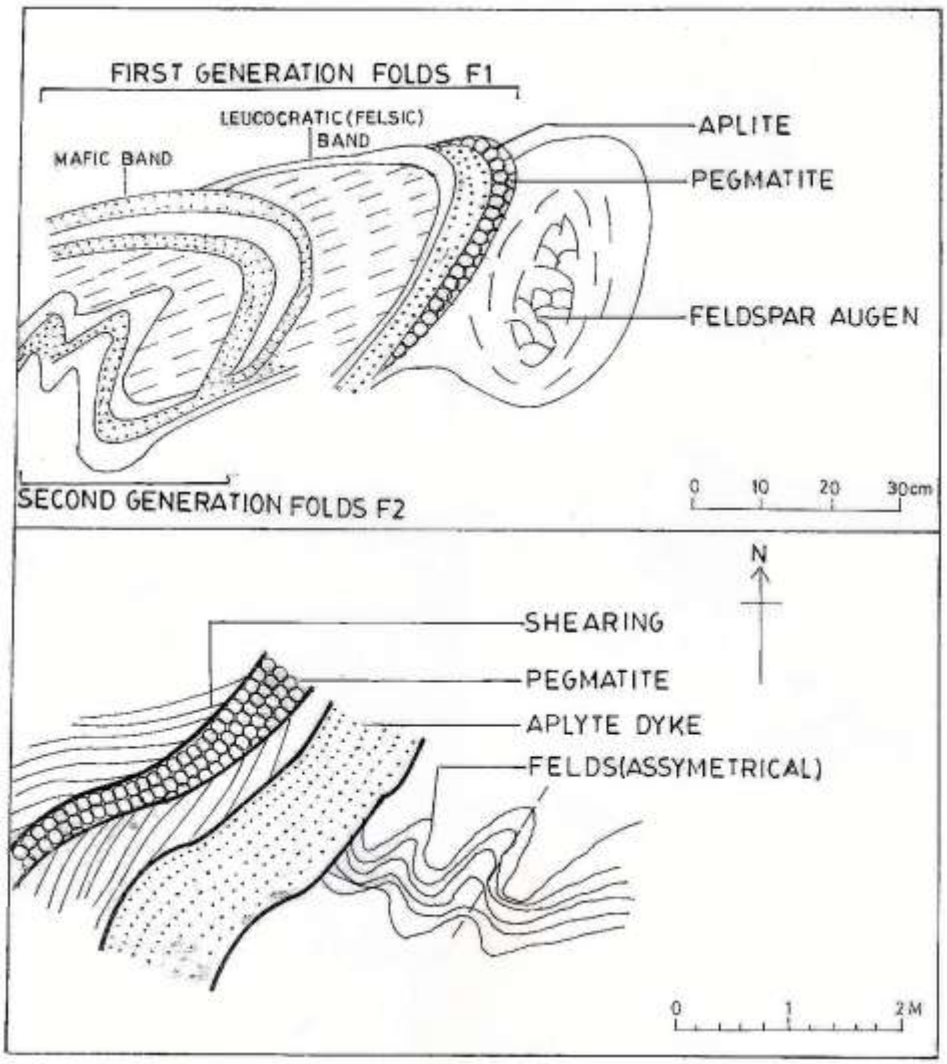

Figure 24: A sketched diagram of second generation folds showing re-folded tight isoclinal and crenulated folds.

5.2 Brittle Deformation

Fractures, faults and joints are the major discontinuities identified in the area. The fractures are of two kinds: open fractures and healed fractures. The open fractures are aligned in more than one direction in most of the rocks and form the youngest generation of fractures in the area (fig. 25). The healed fractures are those that have been filled up with late-stage magmatic fluids. They are usually seen as pegmatites/aplites and silicified veins (fig. 26). Mineralization of gemstone and metallic ores are known to occur along the zones. Joints is common in all rocks varying in attitude from vertical, horizontal to inclined and in geometry from strike, dip and diagonal joints. The joints crosscut each other and trend in all directions. Subsidiary joints sets in the rocks suggest that there are different episodes involved in the generation of these joints. The main joint direction in the study area is mainly in the northeast-southwest directions while few subsidiary joints trends in the northwest-southeast directions (fig. 27). Most of the faults observed are of the strike-slip type and reveal variable lateral displacements ranging from a few centimeters to approximately 1.2m which is commonly translational. Most of the faults planes have been in-filled by pegmatites, quartz veins and dykes, showing both dextral and sinistral displacements (fig. 28). The faults observed from aeromagnetic survey maps are marked in the field by zones of quartz rubbles and veins forming dykes or ridges along the trend of the faults.

Figure 25: Open exfoliation fractures in porphyritic granite (06º55’58”N, 09º15’49”E).

Figure 26: A fracture in migmatitic gneiss healed with quartzo-feldspatic materials (06º59’06”N, 09º26’38”E).

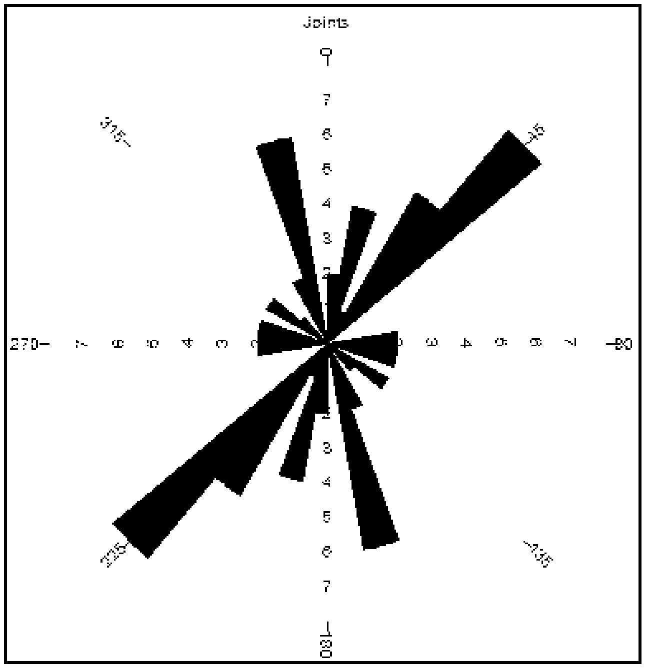

Figure 27: Rosette plot of joint sets in the study area.

Fig. 28: A Sinistral fault with a strike slip displacement of 35cm in the coarse- to medium-grained biotite granite (06º59’32.9”N, 09º20’03.0”E).

5.3 Structural Evolution/Geological History

Field relationships between the various lithologies mapped indicate that the biotite gneiss is the earliest metamorphic tectonites in the study area. The parallelism of the slaty cleavage foliation planes and the compositional banding in biotite gneiss as observed in figs. 4 & 21 as well as the presence of almandine garnet nodules confined to the mafic bands as observed near Mbadullah (06º49’43”N, 09º26’23”E) indicate a high grade gneiss of sedimentary precursor. The para-gneiss was deformed and partly intruded by Precambrian granitoids, thereby became migmatized in places to form the basement complex on which the older and younger metasediments were unconformably overlain and deformed. The migmatitic gneiss has suffered complex deformation which is reflected in the multi-directional trends of its foliation planes as indicated in fig. 29. Both the basement complex rocks and the overlying metasediments such as the amphibolite were subjected to thermotectonic deformation during the Pan-African orogeny which was accompanied by the emplacement of the Older granite suites, including the porphyritic diorite, porphyritic granite, charnockite, medium-grained biotite-hornblende granite, pegmatite, aplite and dolerite. Field evidences and data suggest at least more than two episodes of thermos-tectonic deformations has affected the study area. Foliation trends resulting from at least two phases of deformation were identified. A transposition of an earlier planar fabric S_1 into a later one S_2 was observed. The earliest deformation (D_1) produced the primary metamorphic fabrics (S_1) which trends NW-SE and was later deformed and folded by second filial deformation (D_2) to form the tight isoclinal folds (F_1) whose axial cleavages trend NE-SW and produced the S_2 foliation surfaces. The S_2 foliation, which is the pervasive planar fabrics in the study area, is parallel to the axial plane of F_1 folds. Evidence of refolding of the tight isoclinal folds by (D_3) that produced the F_2 folds can be observed near Mbadullah (06º49’43”N, 09º26’23”E). The third filial deformation episode (D_3) is probably responsible for several fractures, joints, shears and minor faults mapped in the area and may in fact account for some major fold and structural lineaments observed in the study area.

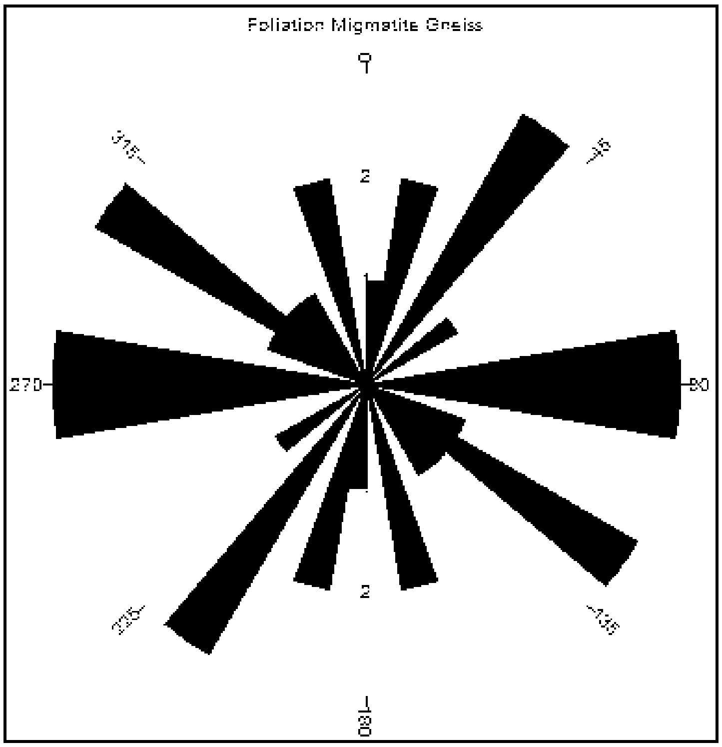

Figure 29: Rosette diagram of foliation trend in Migmatitic Gneiss

VI. CONCLUSION

The different types of Gneisses which make up more than half of the study area, show structural elements like foliation, lineament and folding depicting different episodes of deformation. Some of the structural grains mapped include stromatic in the migmatite gneiss, ophthalmic in the augen gneiss and nebulitic structures in the biotite gneiss. Field evidence suggests that the granitic rocks in the study area represent syn-tectonic to post tectonic intrusive rocks within the basement complex during the Pan African thermotectonic event (650+250ma). The presence and abundance of the pre-existing gneissic country rock as xenoliths in the granites indicates that the emplacement of the granitic plutons was by piecemeal stopping as also supported by previous workers [10]. The mineralogy of pegmatite, which includes quartz, feldspar, mica and tourmaline and their close association with aplites have led to a consensus by earlier workers that they represent granite residue. For example, the alternation of aplites and pegmatites was believed to correspond to alternation of periods of compression and relief.

ACKNOWLEDGMENT

The management of the Nigerian Geological Survey Agency is hereby acknowledged for all the supports offered towards the success of this work.

REFERENCES

[1] B. E. Ephraim, B. N. Ekwueme, and I. C. Adamu, Preliminary report on the geology of northeast Obudu, Bamenda Massif, southeastern Nigeria. International Journal of Natural and Applied Sciences, 1 (1), 2006, 84-89.

[2] N. K. Grant, Structural distinction between a sedimentary cover and an underlying basement in 600 m.y. old Pan-African domain of northwestern Nigeria, West Africa (Geol. Soc. Am. Bull. 89, 1978) 50-58.

[3] Oyawoye, M. O., The basement complex of Nigeria. In African Ecology Ibadan 1970 Eds. Dessavaugies and William Whiteman. Ecology Report, University of Ibadan, Nigeria, 1972, 67-99.

[4] Russ, W., The Geology of parts Niger, Zaria and Sokoto provinces, with special reference to the occurrence of gold. Bull Geol. Survey Nigeria. 27, 1957, 22-27.

[5] McCurry, P., Geology of Degree Sheet 21 Zaria, Nigeria. Overseas Geol. Min. Res. 44, 1973.

[6] Ukaegbu V. U. and Ekwueme B. N., Petrogenic Significance of Rare Earth Element behaviour in the basement rocks of southern Obudu Plateau, Bamenda Massif, southeastern Nigeria. Chinese Journal of Geochemistry. 34 (2), 2005, 132-135.

[7] Ukwang E. E, Ekwueme B. N. and Horsley J., Petrology of Granulite Facies Rocks in Ukwortung area of Obudu Plateau, southeastern Nigeria. Global Journal of Geological Sciences, 1 (2), 2003, 159-167.

[8] Jones, H. A. and Hockey, R.D., The geology of parts of Southwestern Nigeria: Nigeria Geol. Surv. Bull. 31, 1964, 87p.

[9] Olarewaju V. O., Petrology and geochemistry of the charnokitic and associated granitic rocks of Ado-Ekiti-Akure SW Nigeria. In Precambrian geology of Nigeria. A publication of geological survey of Nigeria, 1988.

[10] Mullan, H. S., Structural distinction between a metasedimentary cover and an under-lying basement in the 600 m.y. old Pan African domain of northwestern Nigeria, West Africa: discussion. Geol. Soc. Am. Bull. 90, 1979, 983-984.