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FIELD GEOLOGY AND PETROGRAPHY AROUND NABARDO-TORO ENVIRONS, NORTH EASTERN, NIGERIA

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ABSTRACT

Background: The mapping exercise within the study area on a scale of 1:25,000 was carried out to study the rocks, determine their distribution, composition, structures and assess the economic potential of the area. **Objectives:** The geology mapping aim to identify and understand the various geological structures present in the area to gain insights into the tectonic history and deformation processes that have shaped the area and to identify the minerals present in the rock, to understand the rock formation, composition and potential geologic processes involved. **Method:** Method of mapping involved road, footpath, rivers and stream traverses. Representative rock samples were collected for petrographic studies and geochemical analysis to establish the geology of the study area. **Result:** The study area which is part of Sheet 148, Toro SE is entirely typical of the Nigerian Basement Complex and is underlain by the following rock units: ***Migmatitic Gneiss, Granite gneiss, mica schist and porphyritic granite.*** The Migmatitic Gneiss constitutes the largest group of the rock units covering more than 45% of the mapped area and trending mainly NW/SE with few exceptions in an almost N/S to NE/SW direction. It is pertinent to know that almost E-W structures were also observed which forms relics of the older structure believed to have been affected by the eburnean (possibly) orogenic event. The granite gneiss shares boundary mainly with the migmatitic gneiss showing a weak foliation of light and dark materials. The mica schist is exposed at the western end, highly weathered with a general trend of NW/SE. The porphyritic granite intruded both the migmatite and granite gneiss occurring prominently as hilly and bouldery outcrops. However, flat lying – low lying was also observed in some other localities. With respect to field observation and petrographical study the lithologies encountered were grouped into nine (9) categories- homogeneous, inhomogeneous, stromatic, banded orthogneiss, nebulitic, apo granite, pegmatite, intermediate and schist.

Conclusion: Field evidence suggests that the study area has undergone an episode of metamorphism and deformations as depicted by the structural features like preferred orientation of the mineralogical and lithological units. It was also observed from the field measurements, that the main structural trend within the study area is from NNE/SSW.

Keywords: Nabardo, Geology, Petrography, Structures.

INTRODUCTION

The area of investigation is typical of the Precambrian to lower Paleozoic rocks of northern Nigeria with a type locality in Bauchi state. This region is underlained by migmatites, gneisses and meta-sediments of Precambrian age which have been intruded by a series of granitic rocks of late to lower palaeozoic age. The oldest rocks are represented by a series of older meta-sediments and gneisses believed to be of Birrimian age and older. These rocks have been variably metamorphosed and granitised through at least two tectonic–metamorphic cycles so that they have been largely converted to migmatites and granite–gneiss. Younger meta-sediments, believed to be upper Proterozoic in age, were deposited on this granitised basement and filled along with it during the pan–Africa orogeny. They are of low metamorphic grade and are now represented as synclinal trough.

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both the basement and the younger super crustal cover is a series of basic, intermediate and acid plutonic rocks known as the Older Granites. The youngest rocks in the area belong to a suit of volcanic rocks intruded into Older Granite bodies during Lower Palaeozoic epirogenic uplift following the Pan – African orogen (c.600 million years) as deduced from the radiometric data discussed by Rahaman (1988) and Dada (1999). However, Ogezi (1977) has , on the basis of Rb/Sr isochron age of 1050 $\pm$ 64 Ma obtained from the Maru phyllite, suggested the evolution of Kibaran event that predated the Pan African event in Nigeria. These palaeozoic and Precambrian rocks can be divided into four major groups; the basement complex (senso strict), younger meta-sediments, the older granite series and the younger volcanic rocks.

2. Geology of the study area

The study area is located on latitudes $10^0 9'00''$ N & 9^0 12'00" N and longitudes $9^0 23'00''$ E & $9^0 26'00''$ E (Fig.1). It covers an area of approximately 42.55km^2 with an average elevation of 900m above sea level (Fig.3). The study area which is part of Sheet 148, Toro SE is entirely typical of the Nigerian Basement Complex and is underlain by the following rock units (Fig.2); ***Migmatitic Gneiss, Granite gneiss, mica schist and porphyritic granite.***

2.1. Migmatite Gneiss

The Migmatite gneiss which is a member of the migmatite – gneiss complex constitutes the largest lithological unit mapped within the study area. It is a heterogeneous rock with different lithological components and occupies about half (45%) of the study area. They consist of felsic components which are pegmatitic, aplitic and granitic in composition and mafic components that are basic in composition. Texturally, they are medium to coarse grained and occurs as low-lying to gentle upland in most of the exposures. The migmatite gneiss is characterized by a variety of structures and textures. The well-foliated gneissic portion and the mafic component constitute the paleosome while the granitic and felsic component constitute the neosomes. The previous assume a general trend of NW/SE with few exceptions in NE/SW direction. It is pertinent to know also that almost E-W structures were also observed which forms relics of the older structure believed to have been affected by the eburnean (possibly) orogenic event. They are generally elongated along the strike of foliation for several meters. They are generally grey in colour and composed of feldspar, quartz and mafic minerals. Biotite and hornblende are the main mafic minerals and where their content is sufficiently abundant; the rock assumes a dark-grey colour. The foliation is marked by alternating bands of felsic and mafic materials ranging from millimetric to centimetric in widths. The felsic components comprise of quartzo-feldspathic materials, usually medium to coarse grained. They are layered with the mafic component band which is very dark, fine to medium grained and probably of amphibole/ biotite composition. The fine-grained granites were observed as intrusive bodies into the gneisses as part of the lithological components together with pegmatites (and quartzo-

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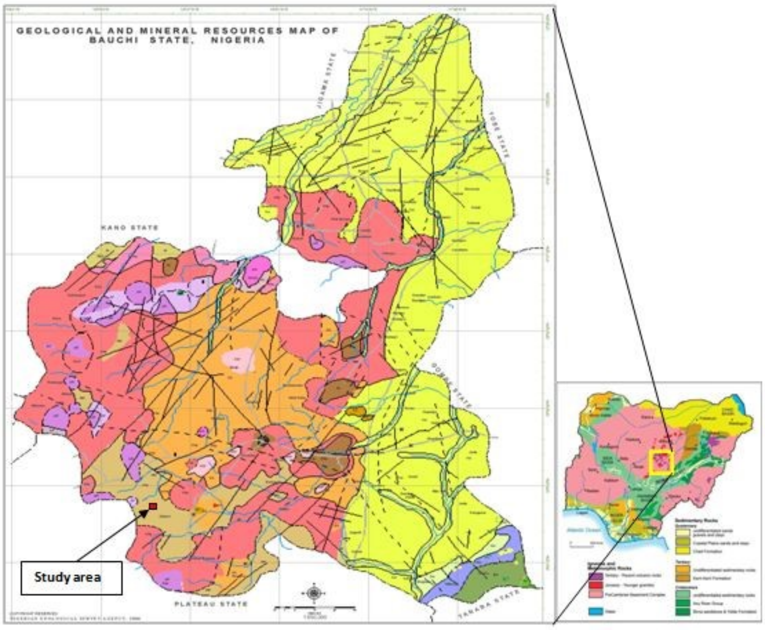

Fig.1. Geological map of Bauchi state showing the study area (source: NGSA)

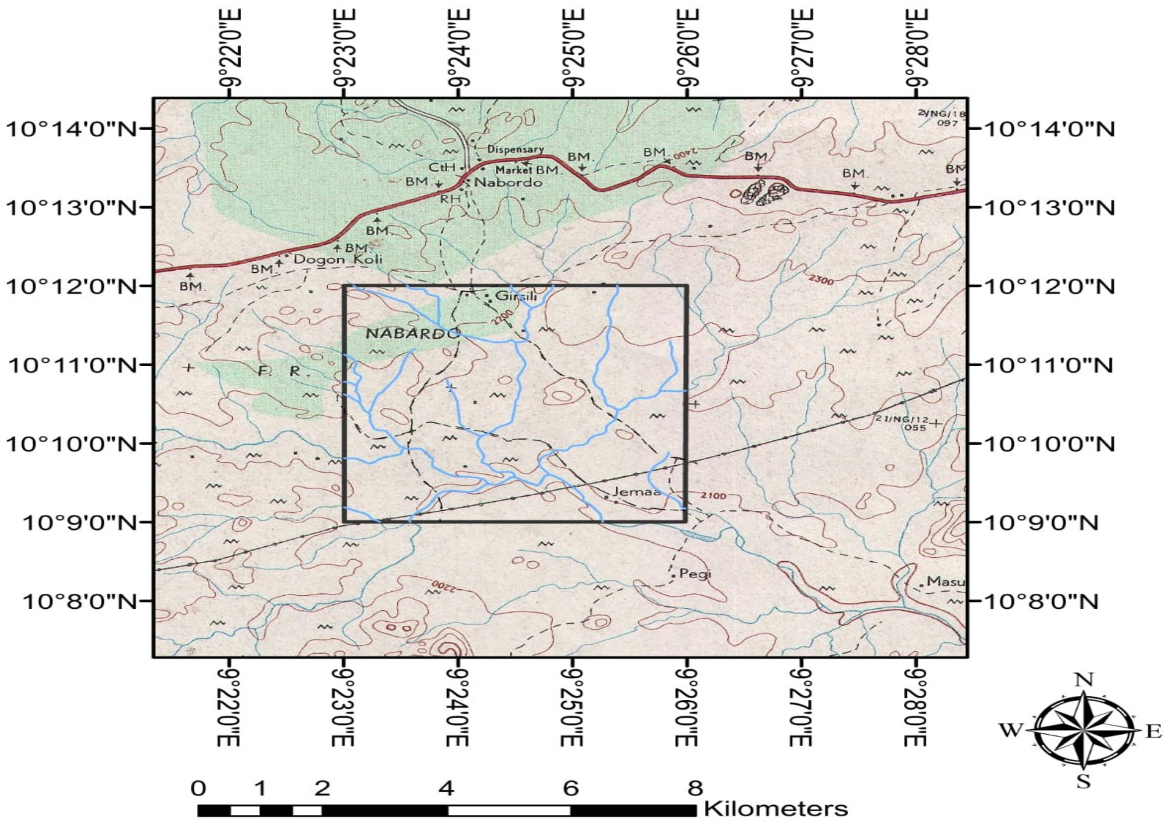

Fig 2. Location map of Nabardo and its environs drawn from ArcMap 10.3.

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which occur mainly as veins; some are large and extensive within some of the encountered outcrops as shown below (Fig. 4).

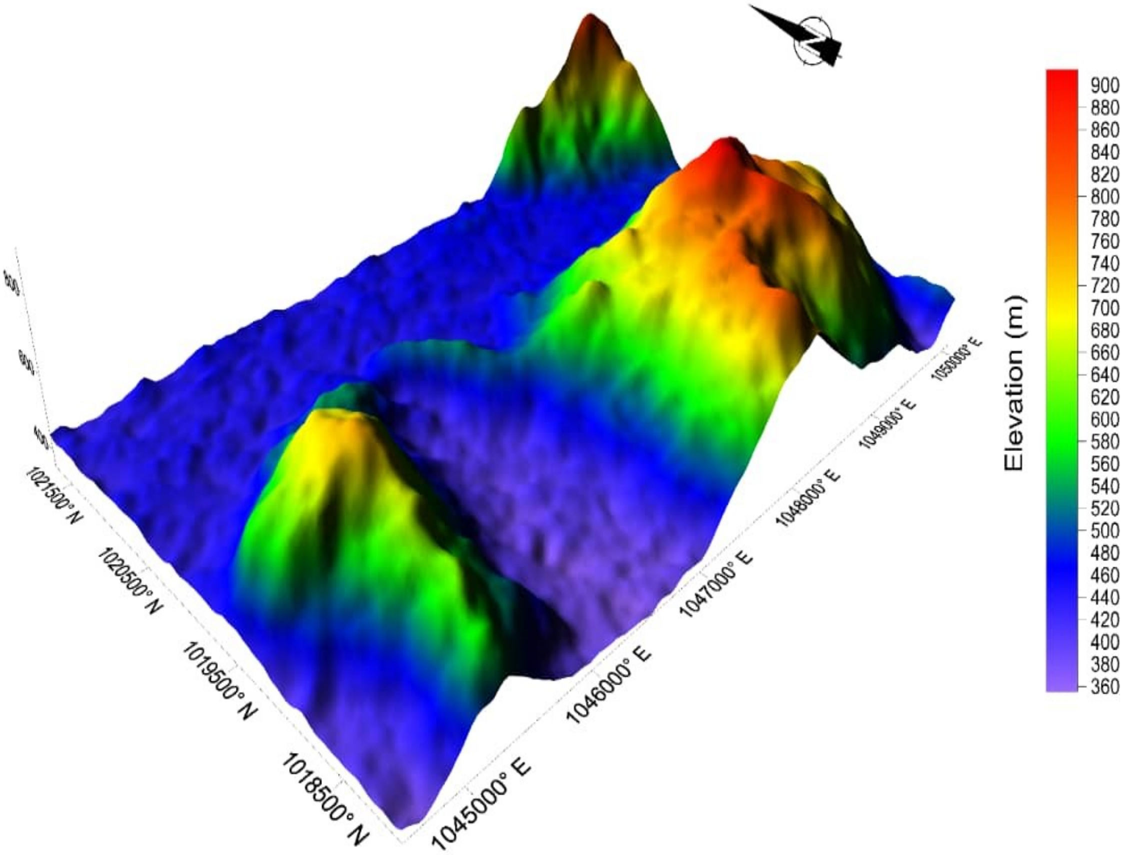

Fig 3. Digital Elevation model of the study area

Fig. 4: A low lying exposure of migmatite at N10^{0} 09′19.2″, E009^{0} 23′44.3″, 646m showing the gneissic and amphibolite portion as A and B respectively around Nabardo area.

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2.2. Granite Gneiss

This unit outcrops mainly at the north central and southeastern portion of the mapped area occupying about 40% of the landmass. It shares boundary mainly with the migmatite gneiss and porphyritic granite. It occurs as low-lying and gentle uplands of varying sizes. The rock is medium to coarse grained, light grey to pinkish in color due to abundance of orthoclase feldspar. The exposures show a weak foliation of light and dark materials. The foliation is marked by continuous mineralogical bandings on a millimetric to centimetric scale, measured on the field. The measurement from the field showed that light-colored bands varying in widths from about 0.5cm to 2.5cm and are rich in quartz and feldspars while the dark colored bands of about 0.4cm-1.8cm wide are rich in biotite and other ferromagnesian minerals. Some of the bands are wavy and discontinuous. The general trend (strike of foliation) is NW/SE. Mineralogically; the granite gneiss is composed of alkali feldspar, quartz, plagioclase, biotite and some other mafic minerals as shown in the figures below (Fig.5 and 6).

Fig.5: A low lying exposure of granite gneiss at N10^0 11′ 25.8″, E009^0 23′45.7″, 697m showing a weak foliation band of dark and light materials around Nabardo area.

Fig. 6: A bouldery exposure of weak thin bands and coarse nature of the granite gneiss at N10^0 10′ 39″, E009^0 24′ 42.2″ around Nabardo

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2.3. Mica Schist

About 5% of the study area is covered by mica schist outcropping mainly at the western flank of the mapped area. Most of the exposures occur as a low-lying, highly weathered rock some being exposed along the stream channel while others are seen with lots of quartz rubbles surrounding it. The mica schist generally trends in a **NW – SE** direction, dipping mostly westwards. The schist foliation is defined by its schistocity which is demonstrated by the parallel alignment of platy mineral grains. The texture is mostly fine grained but, in some cases, fine to medium. The minerals present which can be seen megascopically are muscovite, biotite and quartz. The color varies from light grey to dark grey as shown in Fig.7.

Fig.7: At location 5 showing a well foliated, weathered schist with a trend of 150^0 at $N10^0$ 10′ 27″, $E009^0$ 23′12.1″, 657m, Nabardo area.

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2.4. Porphyritic granite

This unit outcrops at the extreme northeastern axis of the study area (Fig 2) occurring prominently as hill and boulder outcrops, (Fig 8). However, flat lying – low lying was observed in some other localities. It is coarse to porphyritic texture and leucocratic/light in colour. They are fractured and well jointed. The rock composed mainly of whitish feldspar (plagioclase) phenocrysts, Quartz and Biotite forming the interlocking ground mass/matrix of the rock. The feldspar phenocrysts are randomly distributed (no preferred orientation) in most outcrops mapped and are densely populated or concentrated than the ground mass/matrix of the rock. The feldspar phenocrysts are mainly whitish type; the shapes vary from angular to oval-spherical, while the elongated ones are rectangular and are mostly common. The sizes obtained from the field varied, they range from 1.5cm–3cm by 5cm-8cm, and are randomly distributed. They constitute about 30- 40% by volume of most of the porphyritic granite outcrops.

Fig.8: A coarse porphyritic nature of the granite (top) and highly fractured, bouldery, gentle upland of same rock (below) at location N10^{0} 11′ 17.9″, E009^{0} 25′25.9″, 685m, around Nabardo

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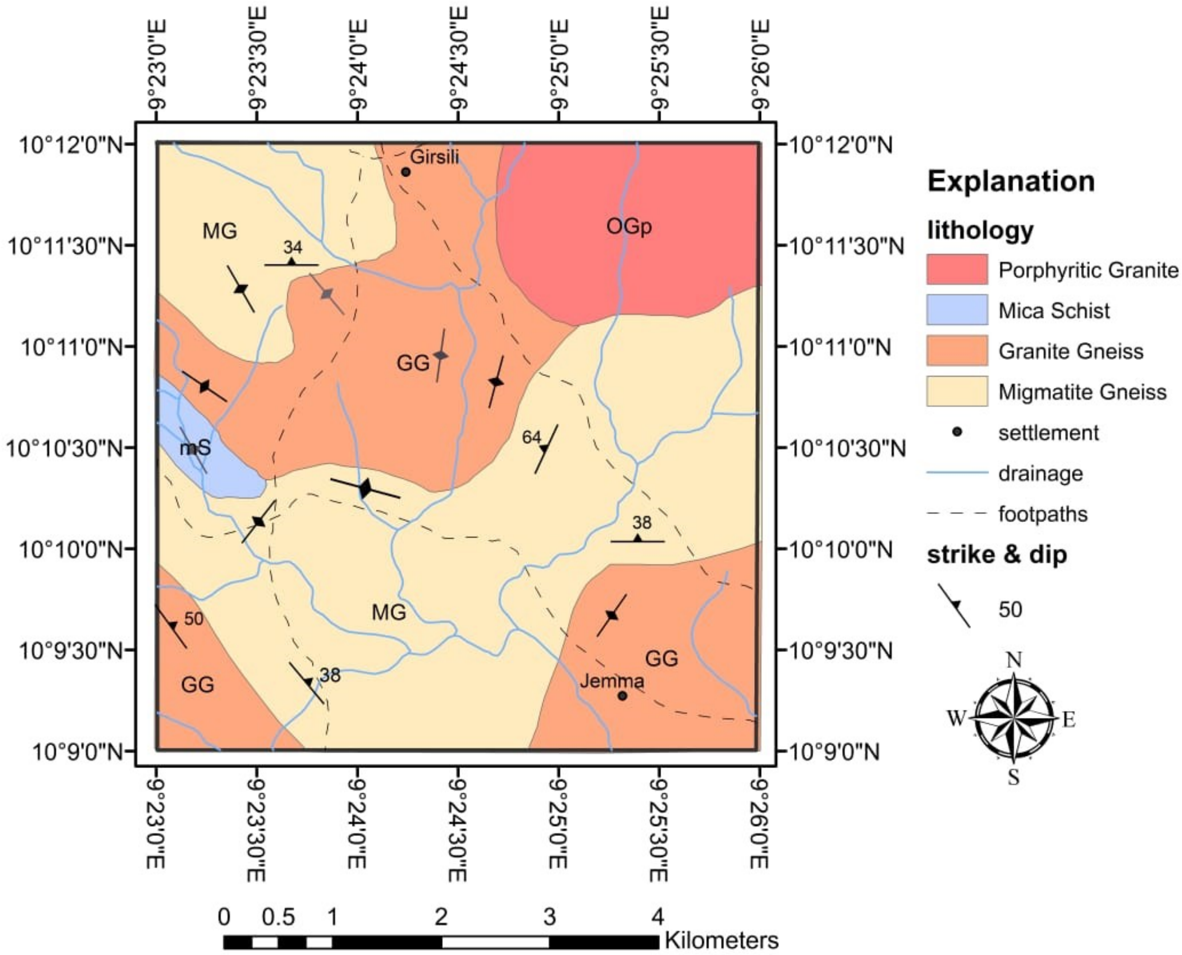

Fig. 9. Geological map of the study area

3. Structural Geology

In Nigeria, the major structural directions are oriented N-S, NE-SW, NW- SE, NNE-SSE and ENE - WSW, corresponding to the major structural trends in the Basement Complex and direction of alignment of the Younger Granite ring complexes (Rahaman et al, 1988; Turner 1989. Geological Structures are products of tectonic effect when rocks are subjected to different degrees of deformation coupled with intense heat and pressure. Within the study area, different types of structures were encountered which are displayed majorly on the migmatite gneiss, granite gneiss and the mica schist. The structures noticed on the field include *foliation, folds, faults and joints* which are discussed below;

3.1 Foliation

Foliations generally are repeated or penetrative planar feature in a rock which may be defined by its fabric. The main types of foliations encountered are gneissosity *(exhibited mostly in migmatite gneiss and granite gneiss)* and schistosity. Gneissosity is non-penetrative while schistosity is penetrative due to the abundance of mica content and deformation. The foliation in the migmatite gneiss have strong planar fabrics which arise because of deformation and recrystallization during metamorphism and is characterized by lithological banding as well

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well as mineralogical banding in which light colored band, rich in quartz and feldspar alternate with dark colored bands rich in biotite and ferromagnesian minerals. The foliation in the granite gneiss was observed to be weak as the minerals are gradually taking a preferred orientation (Fig. 10).

Fig.10: (a) showing gneissosity – penetrative, alternating bands of dark and light materials. (b) showing schistocity – penetrative foliation.

3.2. Shearing

A product of an intensive deformation resulting in the manifestation of steeply inclined, sub parallel planes with relative movement, probably in a semi plastic medium, conspicuously occur in the migmatite gneiss at location 1. The inter-fingering of the felsic constituents with the lithological bandings with marked incomplete resistant tendency, the effect which reorient the foliation planes, to form drag either sinistrally or dextrally, (Fig.11).

3.3. Joints

Joints, which are planar discontinuities along which there has been no apparent displacement, are associated with all the gneisses and the igneous intrusions mapped. They are of different generations; some are parallel, oblique and some cut across each other. Field observation and studies of

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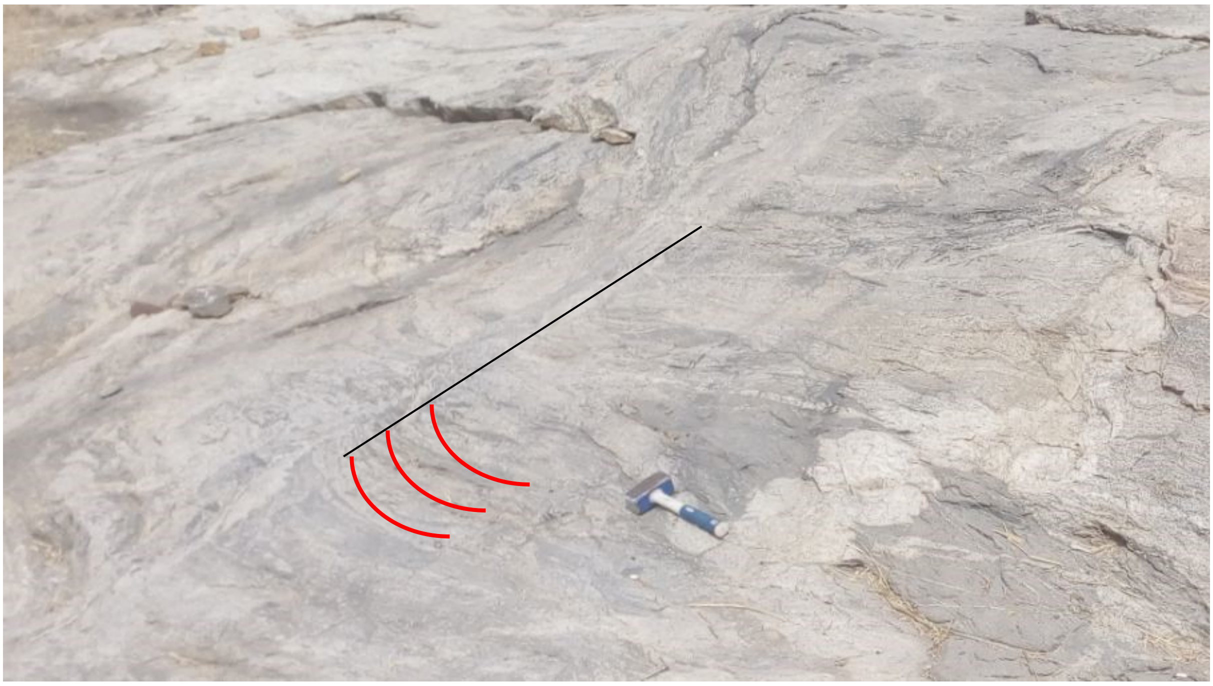

Fig. 11: Normal drag along the shear zone in migmatite gneiss at Nabardo

lineament map from the land sat Imagery of the project area shows that joints occurred almost in all directions and some cases they are partially or wholly healed by introduction of secondary minerals like quartz and pegmatite or by re-crystallization of original minerals.

In Nigeria, the major structural trends vary in N/S, NE/SW, NW/SE, NNE/SSW and ENE/ WSW direction which is typical in the basement complex (Fig. 12). The study area is not an exception as all directions were observed from field readings but one major peak which is gotten from all the rocks when combined suggests that the stress regime responsible for the joints in general is **NNE/ SSW** as seen in the rose plot (Figures 13).

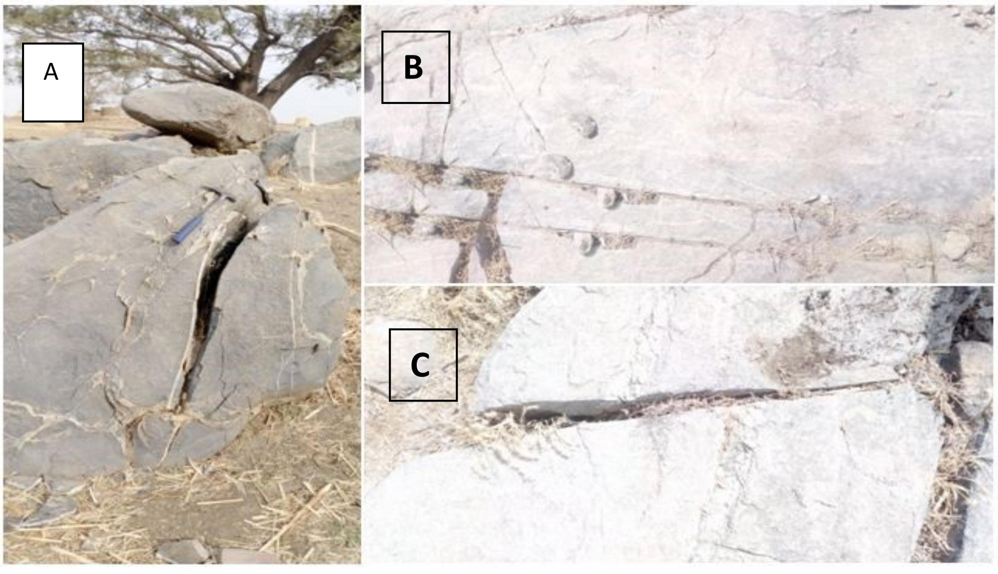

Fig.12: Joints encountered on different lithologies mapped within the study area: (A) (B) Parallel joints (C)

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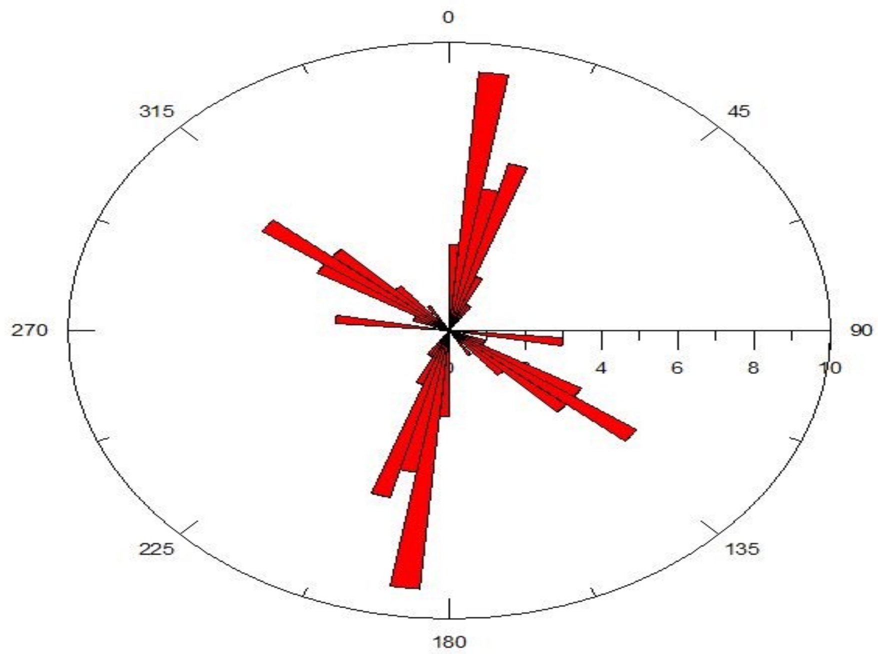

Fig.13 : Rose diagram of Joints in all the rock types within the study area showing a prominent trend of NNE-SSW orientation

4. Petrography

The thin section preparation and photomicrographs was carried out at University of Ilorin, Geological Laboratory at best laboratory practice. Thirty-three (33) rock samples were selected for thin section preparation and petrographic study out of Sixty-eight (68) samples obtained from the field. These thin sections which represent the lithological units in the study area were studied under the transmitted light microscope. Particular attention was given to descriptive features such as mineral composition, grain size and inclusions. With respect to field observation and petrographic study, the lithologies encountered were grouped into nine (9) categories- homogeneous, inhomogeneous, stromatic, banded orthogneiss, nebulitic, apo granite, pegmatite, intermediate and schist.

Homogeneous – the collection of these rock samples was classified due to an averagely equigranular texture of the samples when viewed in a hand specimen and as well under the microscope with very few exceptions. The sample is composed primarily of quartz, orthoclase feldspar, biotite, plagioclase feldspar and microcline. Quartz consists largely of anhedral crystals with internal fractures and suture boundaries, consequently exhibiting undulatory extinction. The crystal appears as inclusions in some of the feldspar and exhibit a moderate relief. The interference colors vary from white to grey and sometimes yellowish. Orthoclase feldspar was also observed under crossed nicols exhibiting its unique Carlsbad twinning which divides the crystal into two halves as seen in the photomicrograph with a moderate relief.

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It displays a light grey to greyish brown color as its interference colors. Biotite consists of elongated, subhedral to euhedral crystals that are arranged in preferred orientation (perfect cleavage). It is pleochroic and changes from light brown to dark brown and sometimes pale green on rotation of stage under plane polarized light. The plagioclase feldspar exhibited its unique characteristic of albite/ polysynthetic twinning. The microcline is identified by its cross-hatch twining exhibited under cross Nicols. The grains have straight edges and shows inclusions of quartz, (Plate I). Fig. 14 shows modal composition of Homogeneous Rock.

Inhomogeneous – the thin section study of these rocks shows much variability in the mineral grain size. The minerals observed include; *quartz, microcline, plagioclase and biotite.* Quartz constitutes the dominant mineral composition. It consists of large anhedral

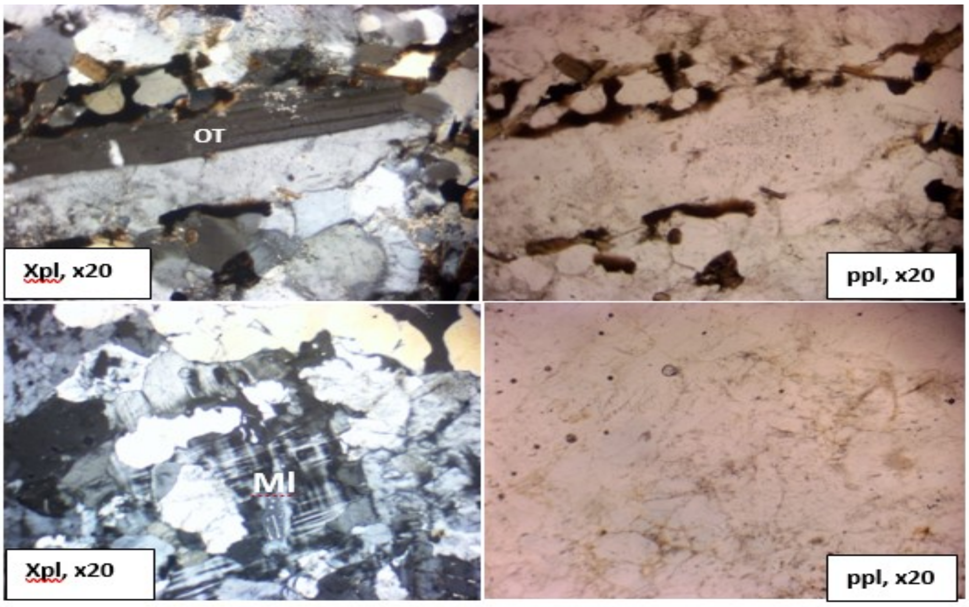

Plate I: Photomicrograph of Homogeneous. Q-quartz, PL-plagioclase, OT-orthoclase, MI-microcline, B-biotite, Op-opaque

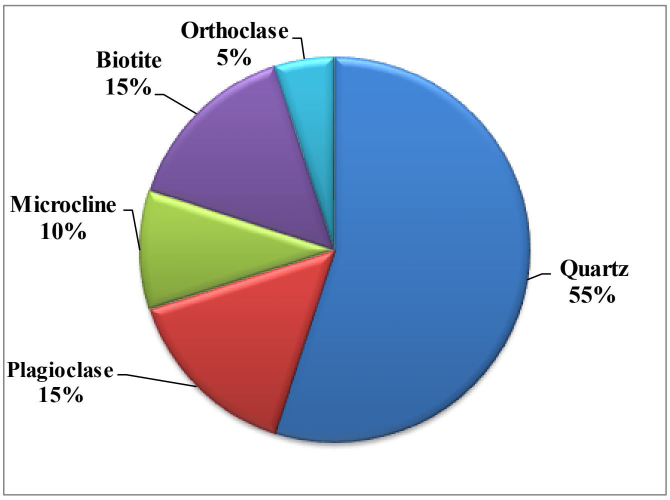

Fig 14: Modal composition of Homogeneous Rock

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crystals that are mainly internally sutured and are characterized by undulose extinction. It has a moderate relief and exhibit interference colors of white, grey and yellow. The plagioclase feldspar displays its unique characteristic of albite twinning. Has a moderate relief and shows some inclusions of quartz. Microcline was observed under cross nicol with its unique cross-hatch twinning. Has a low – moderate relief and shows inclusion of quartz grains. Biotite consists of elongated, subhedral to euhedral crystals that are arranged in preferred orientation (perfect cleavage). It is pleochroic and changes from brown to dark brown on rotation of stage under plane polarized light, (Plate II). Figure 15 shows its modal composition:

Apo Granite – the group of rocks that falls in this category has quartz grain as the most dominant mineral section while others include

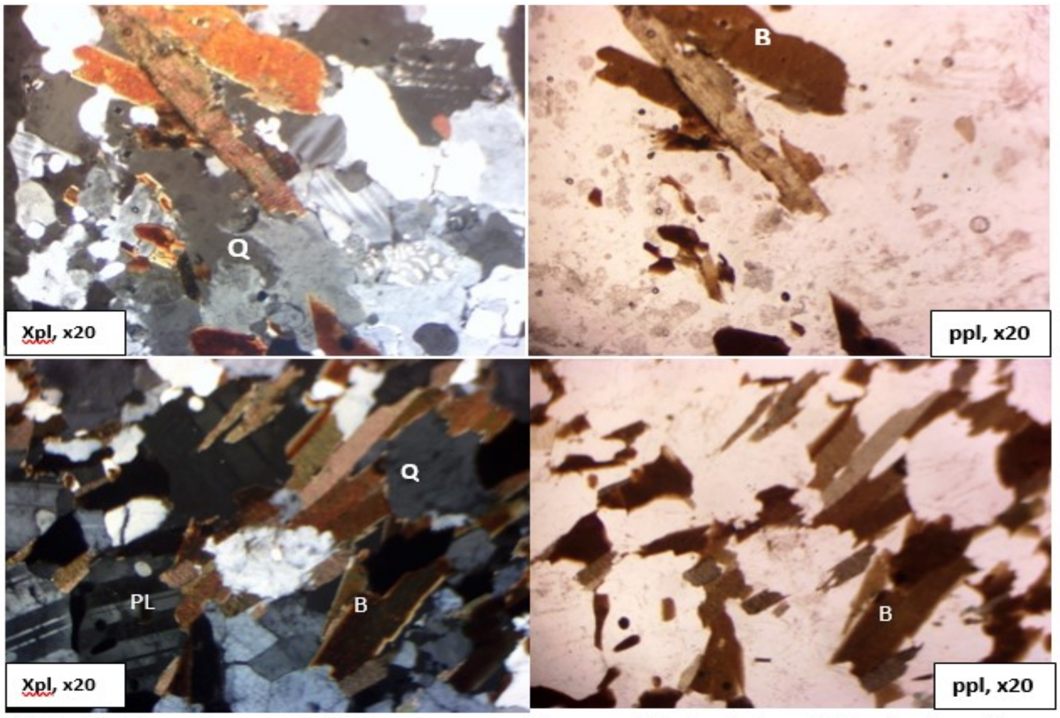

Plate II: Photomicrograph of Inhomogeneous. Q-quartz, PL-plagioclase, OT-orthoclase, B-biotite

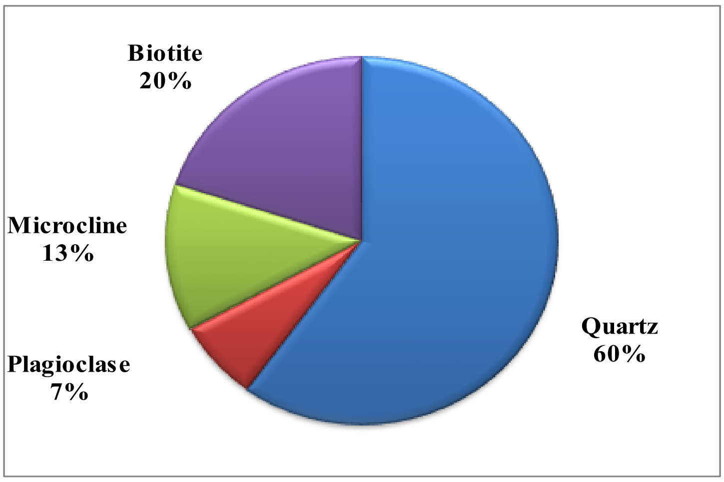

Fig 15: Modal composition of Inhomogeneous Rock

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plagioclase, biotite, microcline, muscovite and garnet. The quartz grain appears as large, anhedral crystal. Under plane polarized light, the section shows it to be colourless while under crossed nicol and it displays interference colors as it goes from whitish, black to light grey colour. The nature of the grain boundary is fairly polygonal to the preferred orientation of biotite. Has a low to medium relief. The plagioclase displays its unique polysynthetic twinning with a moderate relief. Microcline was observed under cross nicol with its unique cross-hatch twinning. Has a low – moderate relief and shows inclusion of quartz grains. The presence of muscovite was conspicuous with its perfect cleavage as observed under plane light with a moderate relief. It is colourless but shows interference colors of pink to yellow under crossed nicols. Similarly, biotite displays a perfect cleavage with many crystals as observed under plane light. It exhibits pleochroism as it changes from light brown to dark brown. The garnet present shows a subhedral-anhedral shape but with a unique corona texture. It has a high relief and when viewed under cross polars it is dark grey but under plane light it is pale brown, (Plate III), Fig. 16 shows the modal composition of Apo Granite.

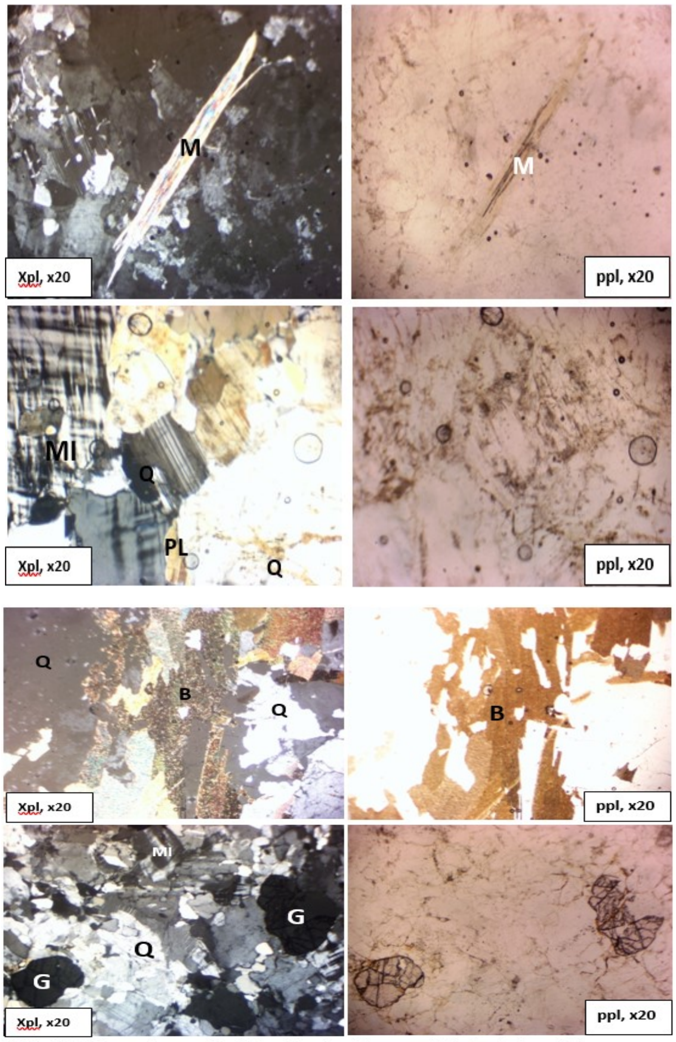

Plate III: Photomicrograph of Apo Granite. Q-quartz, PL-plagioclase, MI-microcline, B-biotite, G-garnet

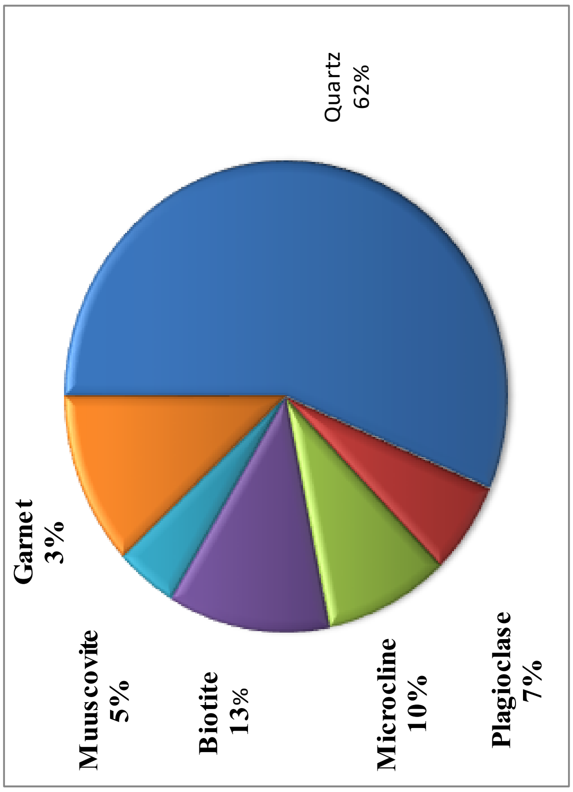

Fig 16: Modal composition of Apo Granite

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Banded Orthogneiss – Viewed under plane and crossed nicols, the following minerals were observed; *quartz, plagioclase, microcline, orthoclase and biotite*. The quartz grain appears as the most abundant and exhibits undulose extinction with a moderate relief. Under crossed nicol, it shows interference colors of white, light to dark grey and sometimes yellowish. The plagioclase feldspar was observed by its albite twinning forming a large crystal sandwiched by the quartz grains. The relief is moderate and shows some inclusions of quartz in some of the grains. The microcline uniquely exhibits its cross-hatch twinning and has moderate relief with quartz inclusions. Orthoclase feldspar exhibits Carlsbad twinning which divides the crystal into two halves with a moderately high relief. Biotite displays a perfect cleavage with a brownish color under plane light and its pleochroic as the color changes from light brown to dark brown, (Plate IV). Fig. 18 shows the modal composition.

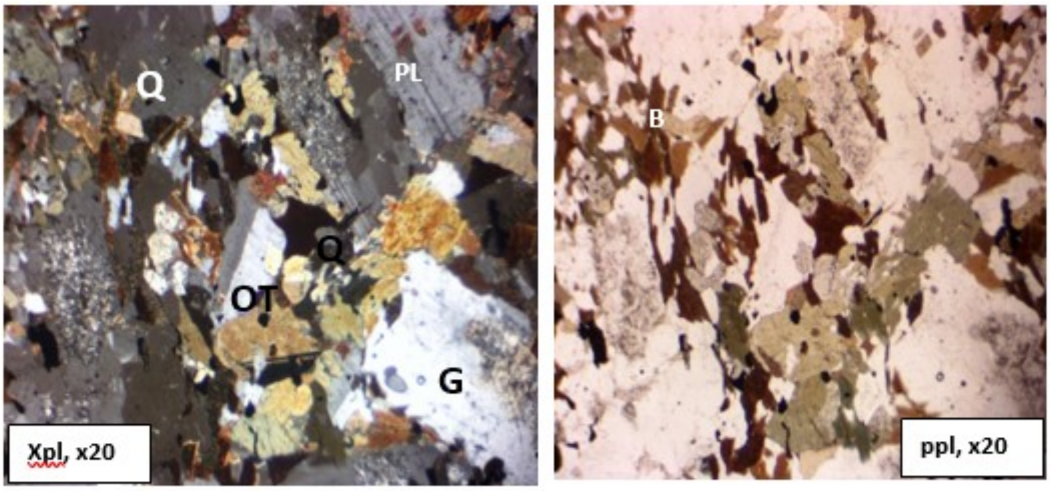

Plate IV: Photomicrograph of Banded Orthogneiss Q-quartz, PL-plagioclase, MI-microcline, B- biotite, OT-orthoclase

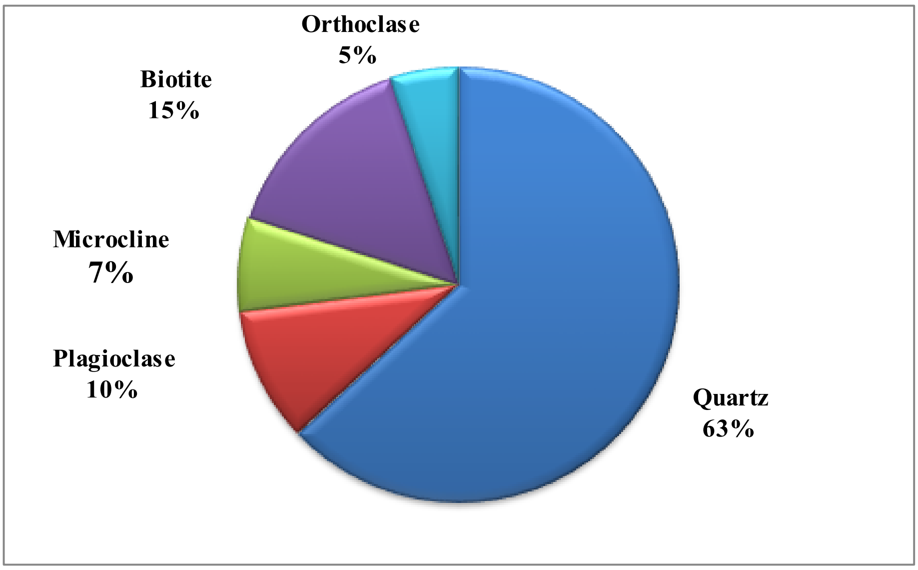

Fig 17: Modal Composition of Banded Orthogneiss

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Pegmatite – the grouping of the rocks classified as pegmatites shows the coarse-grained texture of the minerals when viewed under transmitted microscope with *quartz, plagioclase* and *microcline* as the main minerals observed. The quartz grain appears as big crystals with subhedral – anhedral in shape and exhibits interference colours of white, grey and yellow. The relief is moderate and shows no cleavage but goes into undulose extinction. The microcline was equally observed with a characteristic property of cross-hatch twinning and a low to moderate relief. Some of the quartz grains were seen as inclusions with the microcline feldspar. The plagioclase feldspars are few with a subhedral shape and were observed by its unique albite twinning. It is moderate in relief and shows no cleavage, (Plate V). Figure 18 shows modal composition

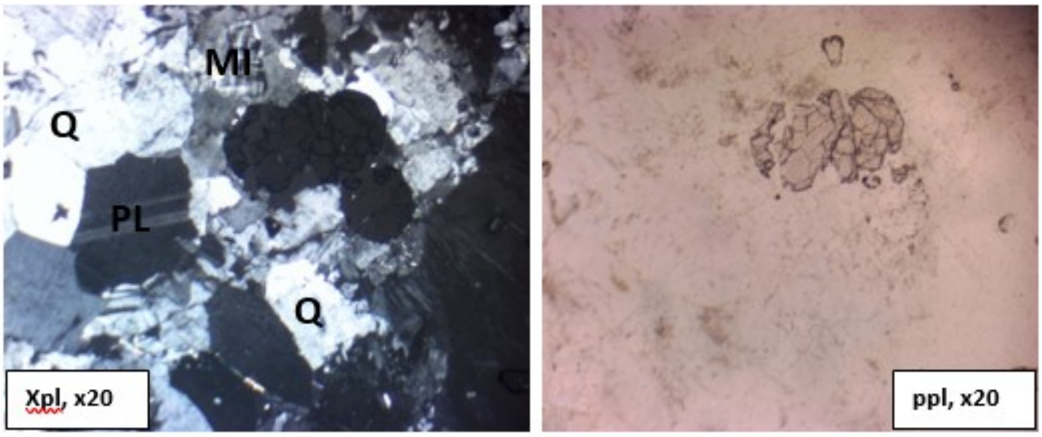

Plate V: Photomicrograph of Pegmatite. Q-quartz, PL-plagioclase, MI-microcline

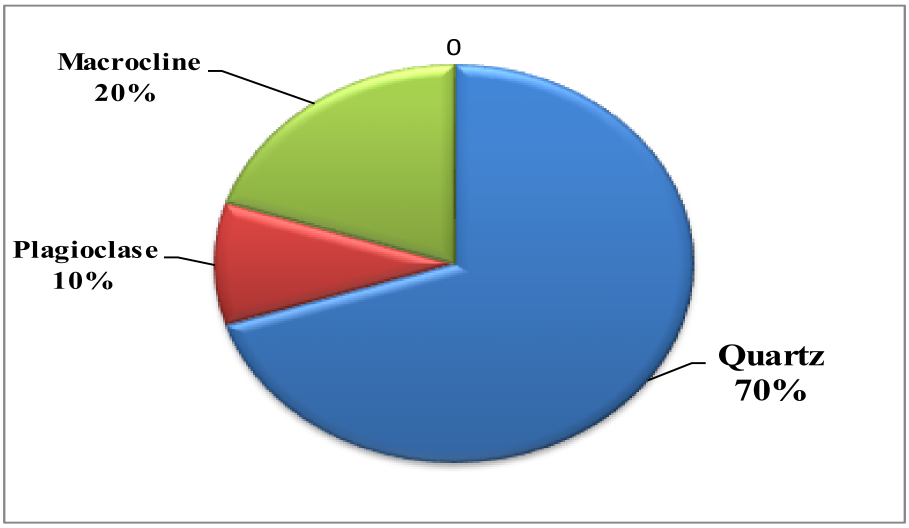

Fig.18: Modal Composition of Pegmatite

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Schist – this rock type was viewed both under plane and crossed nicol. The texture is generally fine – medium and main minerals observed include quartz, biotite and opaque minerals. The quartz appears as fine to medium grained crystal with a subhedral – anhedral shape and exhibits interference colors. The biotite grains are much observed with its brown colour seen under plane light though not much perfect cleavage seen but exhibits pleochroism as the color changes from light brown to dark brown. The opaque minerals appear as black grains but retain its black color both under plane light and crossed polars even when the stage is rotated, (Plate VI). Figure 19 shows modal composition.

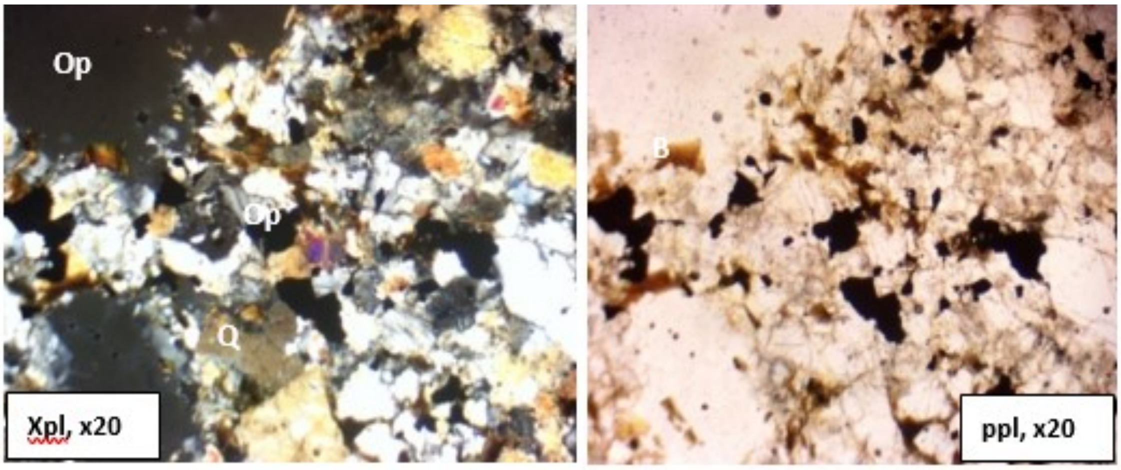

Plate VI: Photomicrograph of Schist , Q-quartz, B=Biotite, Op-opaque

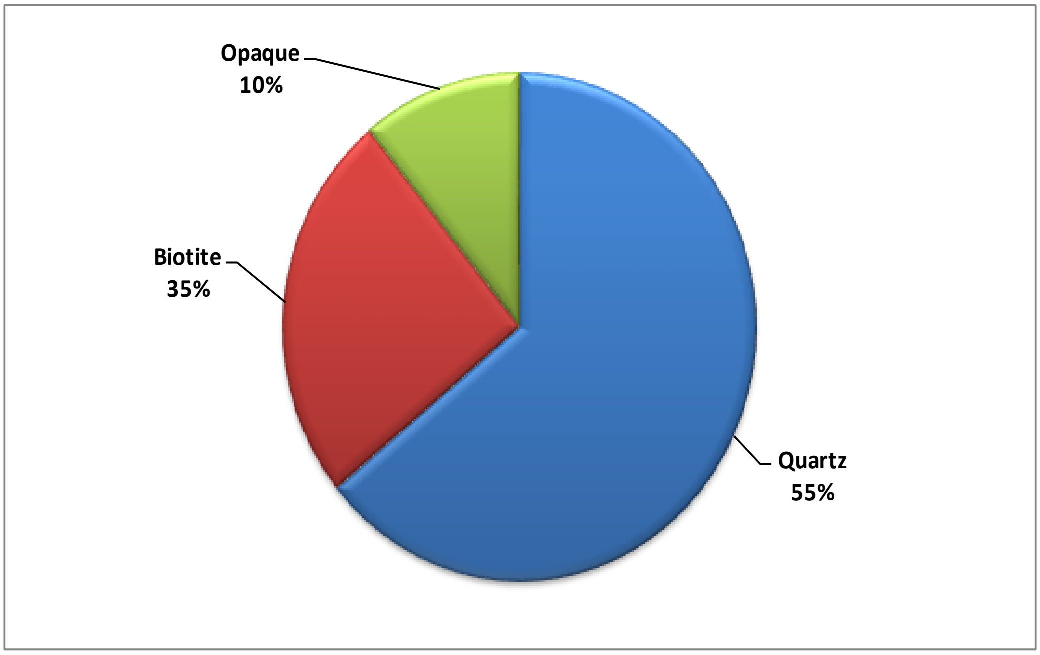

Fig. 19: Modal composition for Schist

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Intermediate – this rock type was classified as intermediate and viewed both under plane and crossed nicol. The texture is generally medium to coarse and the minerals present include quartz, plagioclase feldspar, biotite and some accessory minerals. Quartz consists largely of anhedral crystals with internal fractures and suture boundaries, consequently exhibiting undulatory extinction. The crystal appears as inclusions in some of the feldspar and exhibit a moderate relief. The interference colors vary from white to grey and sometimes yellowish. The plagioclase feldspar exhibits its unique albite/ polysynthetic twinning and having inclusions of quartz. It is low – moderate in relief and appears as anhedral-subhedral in shape. Biotite displays a perfect cleavage with a brownish color under plane light and its pleochroic as the color changes from light brown to dark brown. (Plate VII), Fig.20 The accessory mineral forms a minor proportion as zircons having a high relief.

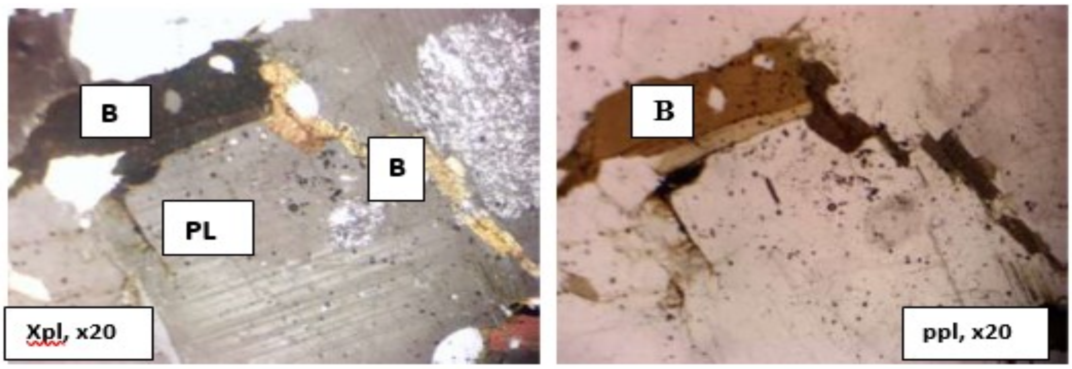

Plate VII: Photomicrograph of Intermediate. Q-quartz, PL-plagioclase, MI-microcline, B-biotite, G-garnet

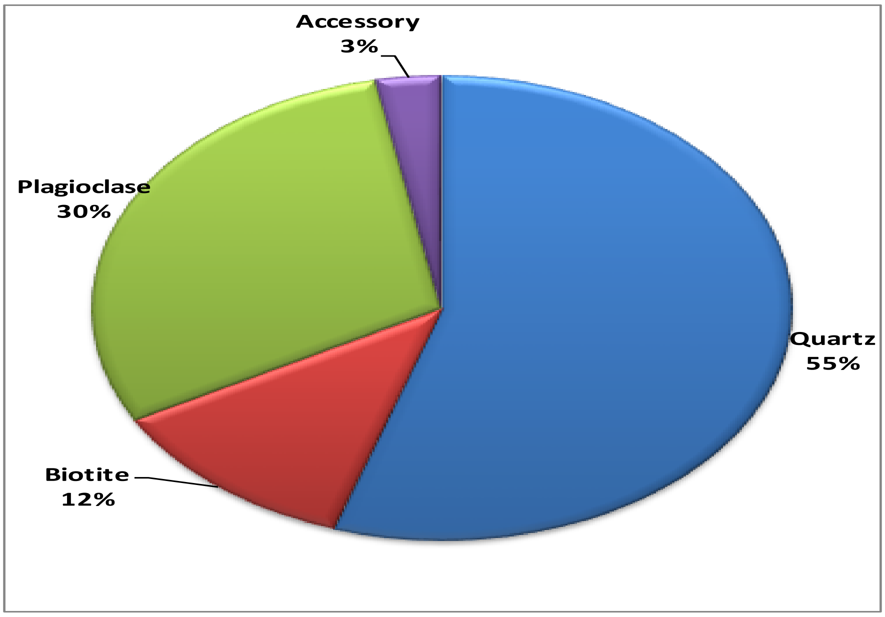

Fig. 20: Modal composition of Intermediate Rocks

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Nebulitic – the grouping of the rocks classified as Nebulitic shows the medium to coarse grained texture of the minerals when viewed under transmitted microscope with *quartz, plagioclase, microcline and biotite* as the dominant minerals while garnet was observed as the index and accessory mineral in the rock. The quartz crystal appears to be irregular in shape with a display of white, greyish and dark greyish coloration as the interference colors. It is moderate in relief and appears as inclusions in feldspars. The microcline displays a cross-hatch twinning with a moderate relief. The plagioclase feldspar displays its unique characteristic of albite twinning. Has a moderate relief and shows some inclusions of quartz. The biotite exhibits a perfect cleavage and shows a pleochroic effect as the color changes from light brown to dark brown on rotating the stage. The garnet crystal was also observed with a subhedral shape and having a moderately high relief, (Plate VIII). Figure 21 shows the modal composition.

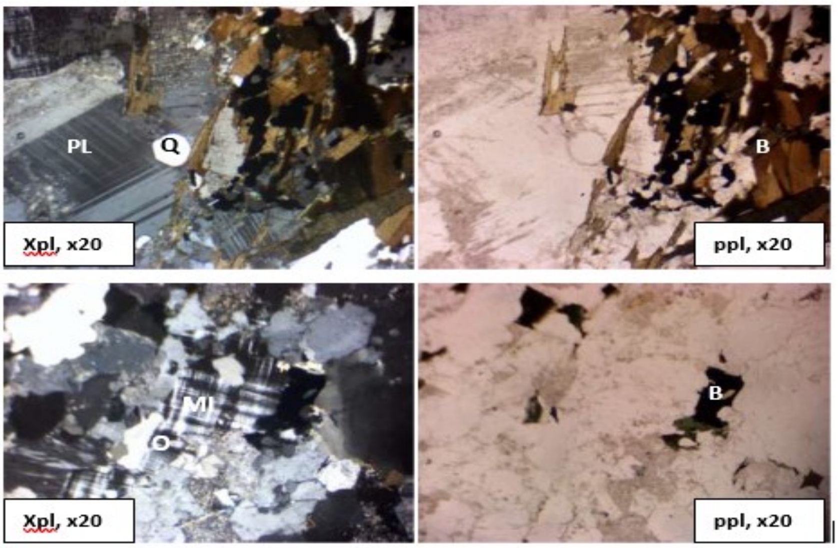

Plate VIII: Photomicrograph for Nebulitic. Q-quartz, PL-plagioclase, MI-microcline, B-biotite, G-garnet

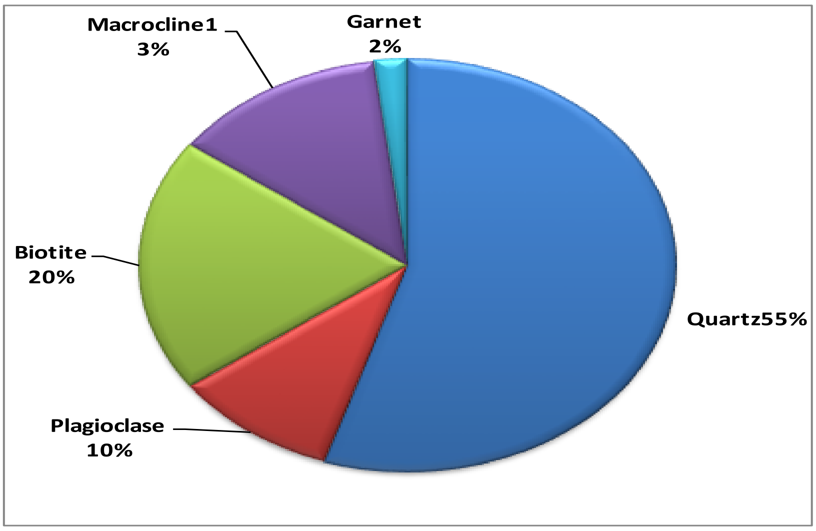

Fig. 21: Modal composition of Nebulitic

Stromatic – this group of rocks was viewed in both plane and crossed polarized light and appears to be generally medium to coarse grained in texture. Minerals observed include *quartz, biotite, muscovite, plagioclase, microcline, garnet and zircon*. The quartz mineral appears as large, anhedral crystal. Under plane polarized light, the section shows it to be colourless while under crossed nicol, it displays interference colors as it goes from white, dark grey to light grey colour. Has a low to medium relief. The plagioclase displays its unique polysynthetic twinning with a moderate relief. Microcline was observed under cross nicol with its unique cross-hatch twinning. Has a low – moderate

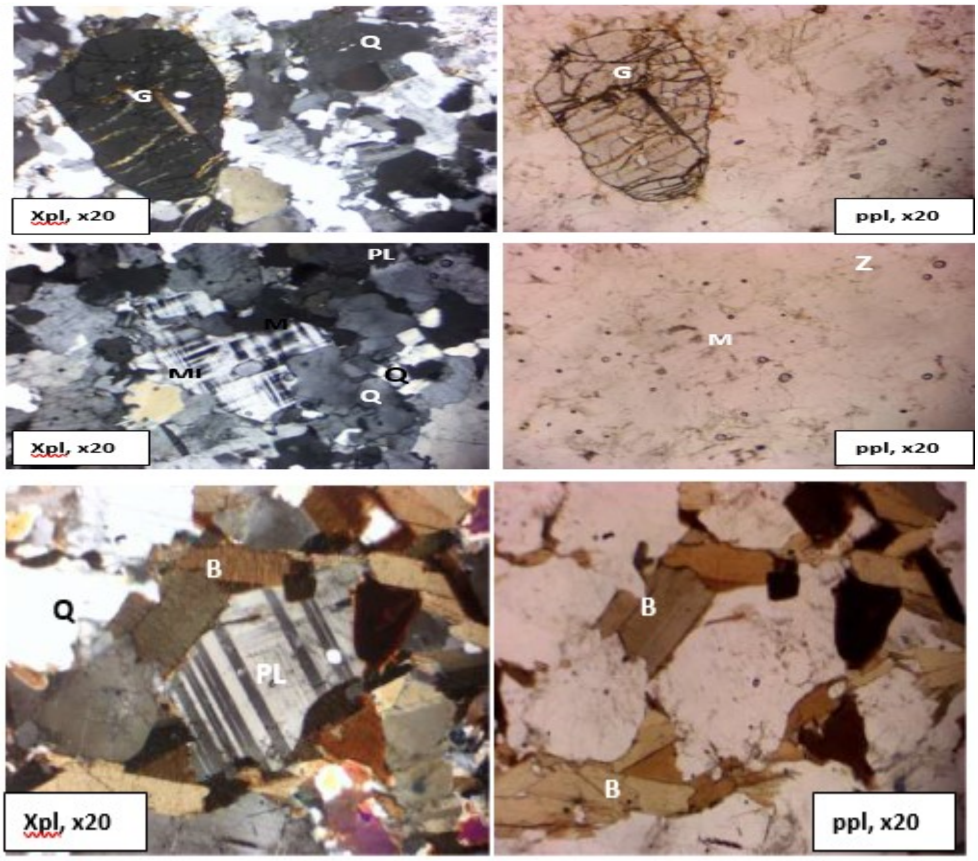

Plate IX: Photomicrograph of Stromatic . Q-quartz, PL-plagioclase, M-muscovite, B-biotite, Z-Zicron

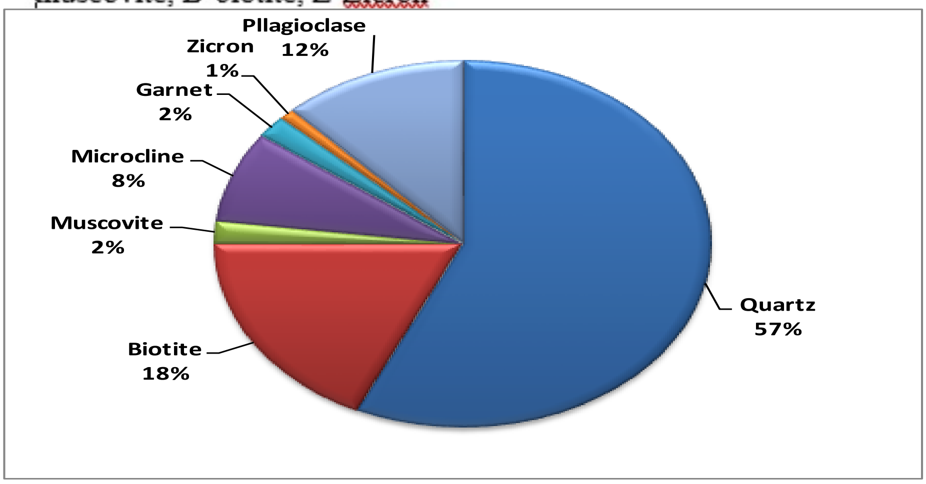

Fig. 22: Modal composition of Stromatic

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Conclusion

The geological mapping of the study area and petrographical study of the samples obtained was undertaken in order to understand the geological setting of the research area, to determine their distribution, composition, structures and assess its economic potentials. Based on the aforementioned, the geology of the mapped area is established. The migmatite gneiss complex is mainly represented by the migmatitic gneiss and granite gneiss being intruded by member of the Older Granite Suite precisely porphyritic granite. The schist belt is represented by the mica-schist which has undergone much weathering and lastly is the late intrusives represented by quartzo-feldspathic veins and quartz vein/ veinlets. From the field observation and petrographical study the lithologies encountered were grouped into nine (9) categories- homogeneous, inhomogeneous, stromatic, banded orthogneiss, nebulitic, apo granite, pegmatite, intermediate and schist. Field evidence suggests that the study area has undergone an episode of metamorphism and deformations as depicted by the structural features like preferred orientation of the mineralogical and lithologic units. At least two deformational episodes (D1and D2) which produced S1 and S2 planar fabrics. It was also observed from the field measurements, that the main structural trend within the study area is NNE/SSW.

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