Geological Characteristics and Petrographic Analysis of Rocks of Ado-Awaiye and its Environs, Southwestern Nigeria.

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Abstract

Ado-Awaiye and its environs is part of Iseyin Local Government Area of Oyo State and falls within the basement complex of southwestern Nigeria. The research work was focused on the geological mapping of the area, and study of the different rock units in order to determine the structural elements and mineral resources of the area. Information such as strike, dip etc acquired in the field were used to establish field relations and geological boundaries. This ultimately aided in the working out of the origin and evolution of the different rock units and the deduction of the geological history of the area.

Field traversing and rock sample collections were carried out and thin sections of the different rock types were prepared and mounted on glass slides for microscopic observation.

Migmatite-gneiss and Hornblende granite-gneiss were the two major outcrops encountered with some associated minor rock units such as amphibolite and pegmatite. The petrographic investigations of the rock units revealed the following minerals: biotite mica, muscovite mica, k-feldspar, Plagioclase feldspar, quartz, hornblende, microcline etc. The rocks are characterized by structures such as ptygmatic folds, joints, fault, foliation, mineral lineation, veins, sink holes and exfoliation domes and also bears the imprints of Pan African orogeny. The area is devoid of economic minerals (barren pegmatite i.e no gemstones) and is fairly suitable for quarry activities.

Keywords: Ado-Awaye; Ptygmatic fold; Foliations; Petrographic observation; Pan African Orogeny.

1.0 Introduction

The Study area Ado-Awaiye and its environs is part of Iseyin Local Government Area of Oyo State and falls within Latitudes 07^{O}48'00''N and 07^{O}54'00''N and on the Longitudes

$003^0 18^' 00^{''}$E and $003^0 30^' 00^{''}$E with an approximate area of about 220sq Km. It falls within the Basement complex of Southwestern Nigeria which are characterized by rocks of mainly Precambrian age. Several authors had written on the general geology of this region with no specific account on the geology of this studied area and hence the justification for the present detailed work aimed at reviewing the past work in order to shed more light on recent geological occurrences as they unfold over time in the area.

An interesting tourist center, Ado-Awaiye suspended lake (a lake suspended within migmatite-gneiss) has an elevation of about 420m above sea level (figure 1). The drainage pattern is mainly dendritic and a few trellis pattern with the stream flowing almost south. There is no major river within the catchment. The environment is characterized by thick forest and evergreen bushes, it is within the humid tropics, with a mean annual rainfall of 1237 mm (Akintola, 1986). Most of the precipitation is received during the wet season and all the streams are perennial.

Figure 1: Ado-Awaiye suspended Lake located within the village

1.1 Basement complex of southwestern Nigeria

The generalized geology of Nigeria and the Basement complex of south-western Nigeria is shown in figure 2.

Field evidences and radiometric dating have shown that the Nigerian basement complex bears the imprints of the major orogenies in the earth history dating back to 3000 Ma (Table 1) and it undergone its most pervasive deformation and remobilization during the Pan African (< 600 Ma) (Odeyemi, 1981).

The basement complex is believed to be polycyclic (where rocks are found in the same environment with different age and mode of occurrence) and has responded totally to tectonic episodes with differing relics from Achaean to Late Proterozoic (Pan African).

Rahaman, 1976, carried out the review of basement geology of southwestern Nigeria and the result shows that there are five major rock groups which have been recognized. These include:

- Migmatite-Gneiss Complex which comprises of biotite-hornblende gneiss, quartzite and quartz schist and lenses of calc-silicate rocks. Rahaman, 1988, also described this Complex as the most widespread rock unit in the basement complex of Nigeria and further stated that it is a heterogeneous assemblage including migmatites, orthogneisses, paragneisses and a series of basic and ultrabasic metamorphosed rocks. Petrographic evidence indicates that the Pan African reworking has led to recrystallization of many of its constituent minerals by partial melting, with most displaying medium to upper amphibolite facies metamorphism.
- Slightly migmatized paraschists and metaigneous rocks, which consist of pelitic schist, quartzite talcose rock, metaconglomerate and calc-silicate rocks. They usually defined belts and some of the belts host metamorphosed chemical sediments [marbles and banded iron formation (BIF)] while mafic to ultramafic rocks in form of amphibolites and ultramafites occur in others. Minor felsic to intermediate metavolcanics and greywackes has also been described.

  The belts are among the best-studied groups of rocks in Nigeria (Truswell and Cope, 1963), because of the associated mineralization of gold, banded iron formation (BIF), marble, manganese, talc, anthophyllitic asbestos etc.
- Charnockitic rocks
- Older Granite, which comprises of rocks varying in composition from granodiorite to granite and potassic syenite.

  Falconer, (1911) introduced the term “Older Granites” who on the basis of morphology and texture distinguished the Pan-African granitoids from the Carboniferous-Cretaceous high level anorogenic volcanic, hypabyssal, peralkaline, “Younger Granites” of the Jos Plateau Region. The granitoids include biotite and biotite-muscovite granites, syenites, charnockites, diorites, monzonites, serpentinites, anorthosites etc. In many places, the coarse-grained biotite-hornblende granites have concordant foliation with the host schists.

- Unmetamorphosed dolerite dykes believed to be the youngest.

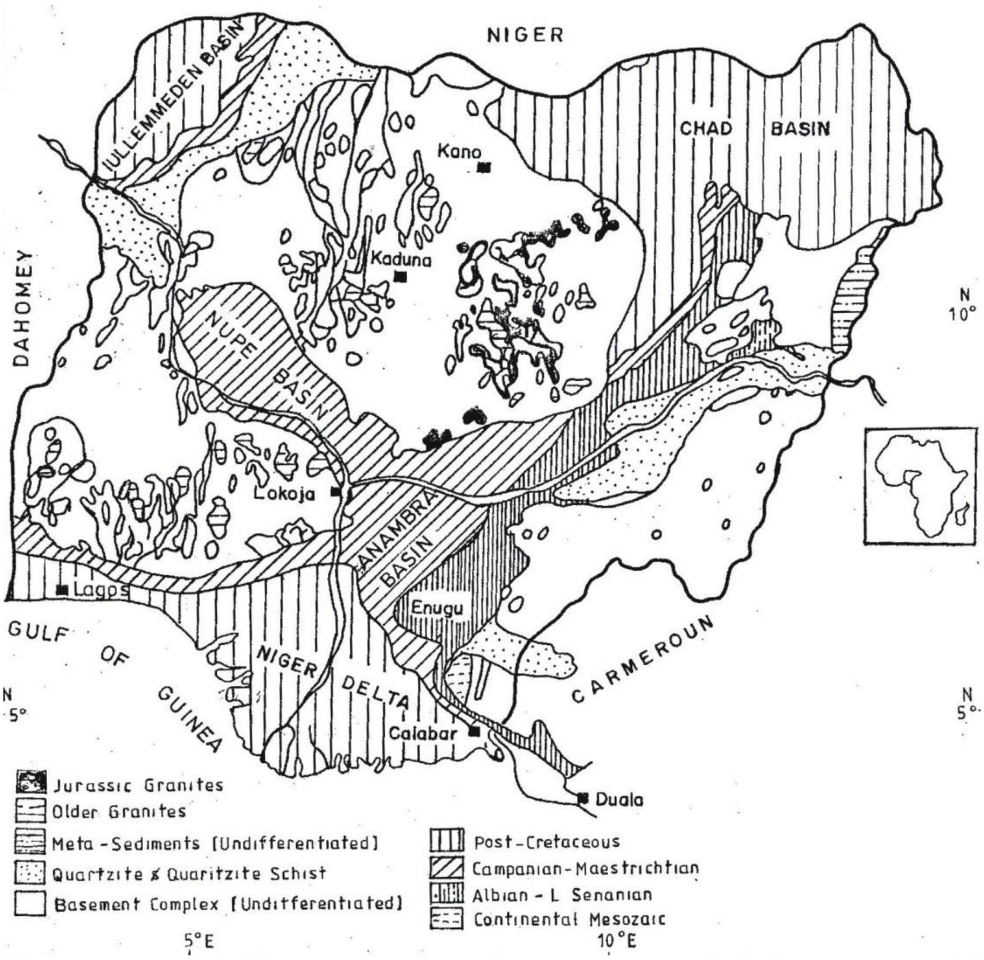

Figure 2: Generalised geological map of Nigeria (After Elueze, 1982)

Table 1: Generalized chronology for the basement rocks of Nigeria (modified after McCurry, 1976)

Age (Ma)	Period (or epoch)	Activity	Remarks
540±40	Late Pan-African	Uplift, cooling, faulting, high level magmatic activity	Gold Mineralisation rare-metal Pegmatites
650,580	Pan African	Granitic intrusion, pegmatites and aplite development	Older Granite Magmatism
650-850	(Main Phase)	Orogenesis: deformation, metamorphism, migmatisation and reactivation of pre-existing rocks	
800-1000	Katangan	Geosynclinal deposition, intrusion of hypersthenes-bearing rocks	Katangan metasediments
1900+250	Eburnean	Granite intrusion Orogenesis: folding, metamorphism and reactivation of pre-existing rocks	Eburnean granites
2500	Birimian	Geosynclinal deposition	Birimian metasediments
2800+200?	Liberian Cycle?	Possible formation of banded gneiss complex near Ibadan	
>2800	Dahomeyan	Crystalline basement	

2.0 Materials and Methods

The field work exercise was accomplished with the use of several field materials such as topographic map, Global Positioning System (GPS), compass clinometer, geological hammer, field notebook, sample bag, marker, field board, pen, crayon, tape rule, cutlass, and tracing paper. The topographic map used was on a scale of 1: 25000 but reduced by eight (8) to scale of 1:200000 during digitization in order to be contained on a page.

The mapping was carried out scientifically through traversing along foot paths, tarred roads and mostly cutting through the bushes to an outcrop (figure 3). This helped to determine the geological boundary from the systematic measurement of strike and dip value. Laboratory work includes thin section preparation and observations under a petrological microscope for mineral identifications and microstructures study.

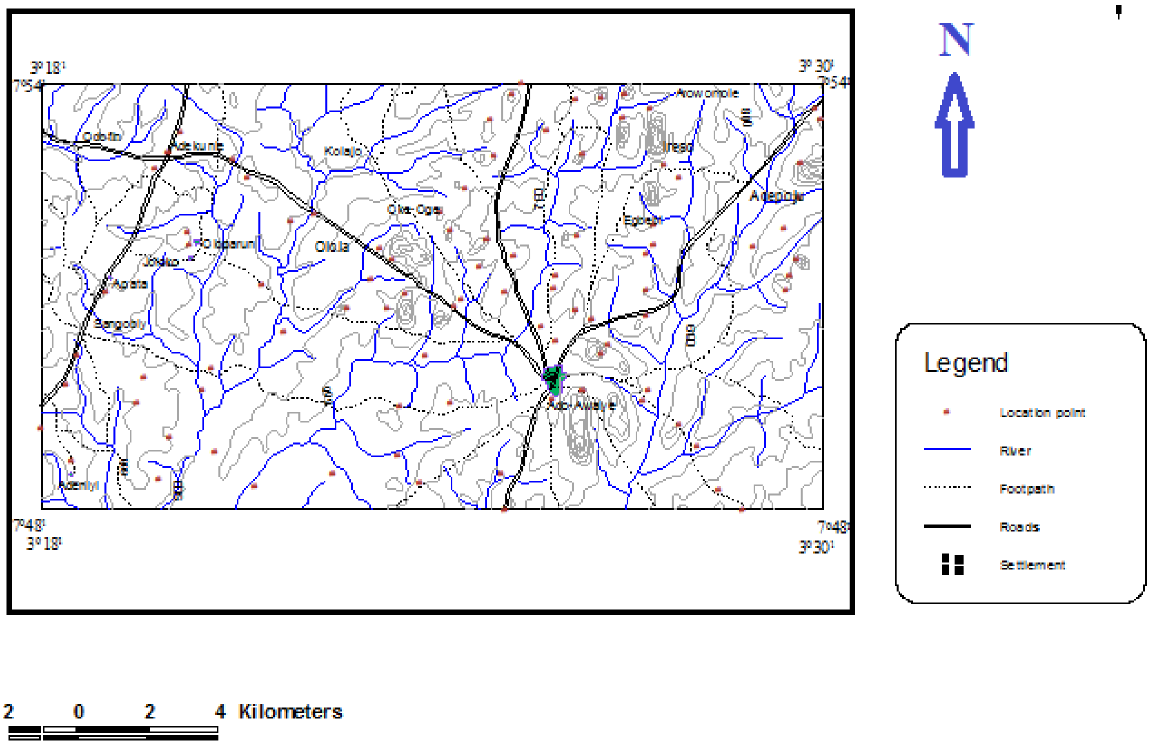

Figure 3: Outcrop Location Map of Ado-Awaiye and its Environs Part of Igangan, Sheet 240, Southwestern, Nigeria.

3.0 Results and Discussions

3.1 Field observations

Relevant information was obtained through mapping exercise. The area is characterized by mainly migmatite-gneiss and hornblende granite-gneiss with some minor rock types such as pegmatite and amphibolite which define vein of small extent. The migmatite-gneiss occupies the eastern part of the area characterized by hilly and rugged terrain while the hornblende granite-gneiss defined minor undulations. Most of the outcrops occur in form of dome with associated screes while others occur as elongated and massive rock unit. Therefore they stand out as high ground above the adjacent low land. There are network of streams (figure 3) and these exploit the weaker zones and unconsolidated / poorly consolidated materials.

3.2 Observed Lithology and Field Relationship

The mapped area, a metamorphic terrain characterized by defined and clear orientation consists of two main rock types of slightly contrasting characteristics. They include migmatite-gneiss and hornblende granite-gneiss with some minor rock occurrences of amphibolite schist, pegmatitic intrusions, and quartzofeldspathic veins which occur mostly as near linear intrusions. Some of the rocks exhibit jointing and show strong mineral lineation and foliation. The megascopic minerals observed on these outcrops include feldspar, quartz and biotite.

From the field relation, the migmatite-gneiss appears to be the oldest rock unit.

3.2.1 Migmatite-Gneiss

About 60% of the outcrops in the study area is migmatite – gneiss; a mixed rock containing igneous and metamorphic portions. This is a metamorphic rock of highest grade. It outcrops from the center to the eastern part of the map especially in Ado-Awaiye, Oha, Adepoju, etc. Some of these migmatite-gneiss outcrops are nearly low–lying and very extensive. Quite a number of them occur as conical hills, dome and ridge-like structures. An example is the Ado-Awaiye hill which has an elevation of 423m, the Ireso hill and Adepoju hill. The outcrops are fractured and weathered at some locations. The rock is affected by exfoliation process resulting in screes or talus at the base of the outcrops. Several pegmatitic intrusions, quartz veins, fractures and faults characterized the migmatite-gneiss. Foliation, lineation and migmatitic structures which include folds of various kinds were also observed on the outcrop (figure 4). The folds occur as normal fold, tight fold and ptygmatic fold i.e the initial parallel bands appear to be contorted due to compressive stress that existed during its formation.

The general orientation of the rocks is NE-SW with moderate dip. The minerals are separated into light and dark bands. i.e. gneissosity. The rock consists of palaeosome which is the unaltered parent rock in metamorphic stage and the neosome which is the newly formed rock portion. The lighter bands which are the leucosome consist of feldspars and quartz while the darker bands which are the melanosome contain biotite mica, muscovite mica and hornblende. The micaceous minerals produce a lustrous shiny surface on the hand specimen observation. The rock is light-coloured, medium to coarse grain and hard but tends to split along the plane of foliation.

3.2.2 Hornblende-Granite Gneiss

This is a crystalline metamorphic rock in which the rock is unusually rich in hornblende. It occupies about 40% of the mapped area outcropping on the western part of the area. They trend from nearly North-South to North-East / South-West. The outcrop is found around villages of Joloko, Onigbongbo, Adekunle, Sanija, Oke-Oge etc. It shows some jointing and faulting with few being healed (filled) with the newer material (figure 5). They are also characterized by sink holes probably resulting from differential chemical weathering. The rock outcrop as low lying in most places but as a ridge and dome in few places. It is light in colour except where it is dominated by mafic alternations.

Figure 4: Migmatite – Gneiss with characteristic different folds

Figure 5: Hornblende Granite-Gneiss characterized by faulted mafic and felsic bands.

3.2.3 Amphibolite

It occurs as a dyke-like structure within the migmatite-gneiss and granite-gneiss. It has a medium grain size because of the effect of metamorphism. It appears to be schistose. It is weathered at some places. It also appears as either continuous vein parallel to the regional trend of the rock or it shows discordant relationship with the host rock. It is predominantly characterized by mafic or dark coloured mineral (figure 6).

3.2.4 Pegmatite

It is a very coarse grain rock with large crystal of feldspar and quartz with some micas (figure 7). It is a light-coloured rock because of the dominance of felsic materials and it is hosted by banded gneiss. It crystallizes from residual melt during the later stage of crystallization. This pegmatite lacks economic minerals and hence it is barren.

Figure 6: Amphibolite rock hosted by medium grain gneiss.

Figure 7: Pegmatite hosted by Gneissic rock.

3.3 Petrographic observation and analysis of the rock samples

Petrographic analysis on thin sections prepared from different rock samples observed under polarizing petrographic microscope revealed their mineral constituents. Identification of minerals was done using their diagnostics optical characteristics under plane polarized and cross polar media. This analysis allowed the modal composition to be determined and aided in the proper naming of the rock. The modal compositions of the rocks from which the slides were prepared are shown with the following photomicrographs.

3.3.1 Migmatite – Gneiss

Thin section observation revealed that the rock is composed of orthoclase, plagioclase, quartz, hornblende and biotite. Accessory minerals are also present (figure 8). Plagioclase constitutes about 40% and is colourless with quartz inclusion. It is euhedral in outline and characterized by cleavage. Some also occur as subhedral crystal. Quartz is about 20% and is colourless, clear and some show conchoidal fracture. Some also show undulose extinction which is a sign of straining. It shows no pleochroism and alteration. Orthoclase is about 15% and has cloudy and colourless colour in plane polarized light (PPL) and show Carlsbad twinning in cross polarized light (CPL). Biotite is about 15% . Some are brown to green with strong pleochroism and pleochroic haloes. It is also characterized by cleavage and moderate relief. Hornblende (about 10%) is green in colour and it is characterized by cleavage intersection of approximately $56^0/124^0$. Opaque mineral constitutes about 5% and it is black in both Plane Polarised Light and Cross Polarised Light.

3.3.2 Hornblende Granite Gneiss

Thin section study indicates the presence of the following minerals. Quartz is about 30%, orthoclase is about 15%, hornblende is about 15%, biotite is about 5%, plagioclase is about 35%, and opaque mineral (probably iron oxide) constitute 10%. Quartz is colorless to yellow with conchoidal fracture and no sign of alteration. It also has low relief and shows no pleochroism. Few of the crystal show undulose extinction. Orthoclase is colourless and cloudy with some pethitic structure. It undergoes extinction and show Carlsbad twining. It has a moderate relief. Most of the crystal is euhedral to subhedral with define cleavage. Biotite is greenish to brown with strong pleochroism, pleochroic haloes and cleavage. It is characterized by jagged edges. Hornblende is characterized by cleavage intersection. It is light yellow to green and interference colour of second order. Opaque mineral is dark in both plane and cross polarized light (figure 9).

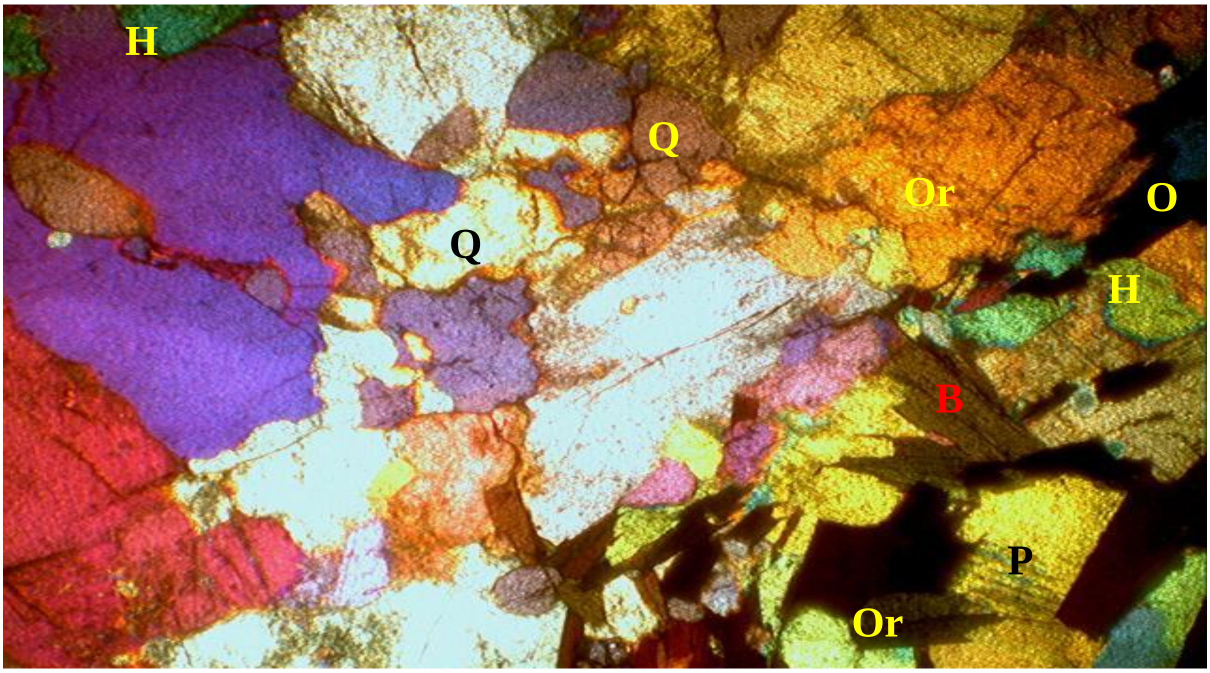

Figure 8: Photomicrograph of thin section of Migmatite-Gneiss (Cross Polarized Light)

H = Hornblende, **B** = Biotite, **P** = Plagioclase, **Or** = Orthoclase, **Q** = Quartz, **O** = Opaque Mineral

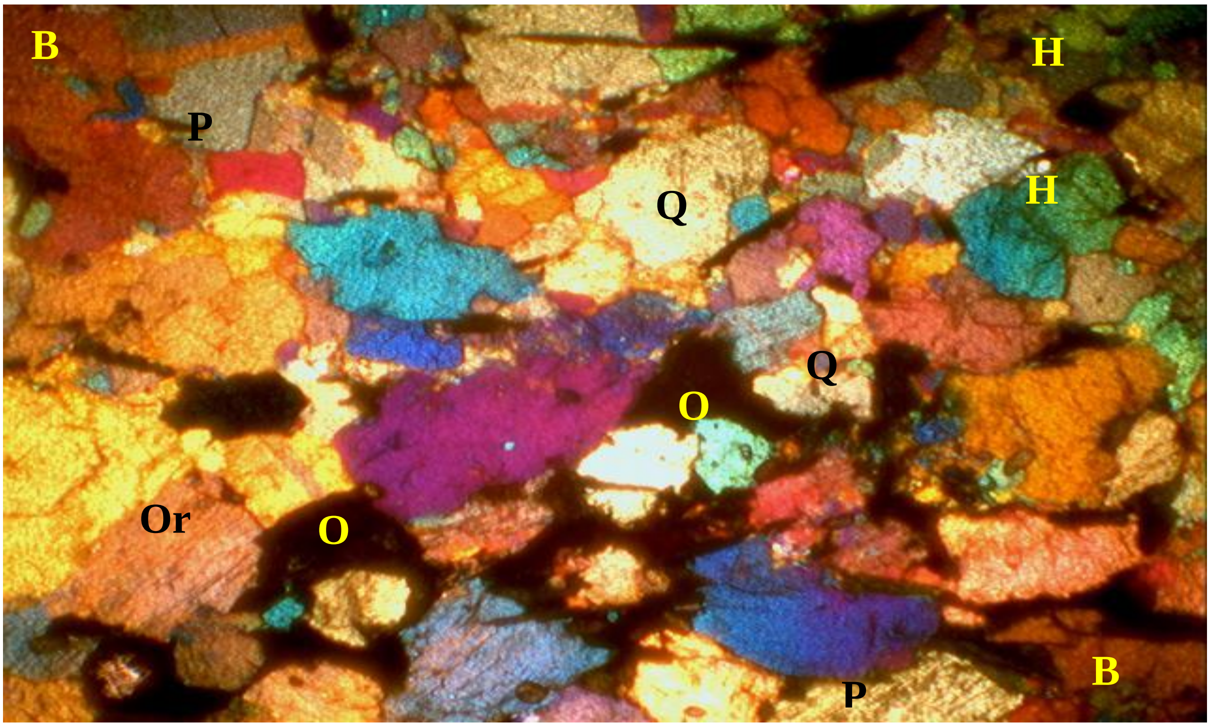

Figure 9: Photomicrograph of thin section of Hornblende Granite-Gneiss (Cross Polarized Light)

H = Hornblende, **B** = Biotite, **P** = Plagioclase, **Or** = Orthoclase, **Q** = Quartz, **O** = Opaque Minerals

3.3.3 Amphibolite

From the thin section observation, the rock is dominantly composed of hornblende (about 35%), plagioclase (albite about 20%) and quartz (about 20%). Other minerals include biotite (about 18%), augite (about 3%), and opaque mineral is about 4%. Hornblende is greenish-brown to brown. It is characterized by cleavage plane intersecting at nearly $56^0/124^0$. It shows strong pleochroism and interference colour of second order. Plagioclase is colourless to light grey and lacks pleochroism but characterized by albite (polysynthetic) and periclase twining. Quartz is colourless to light yellow and shows no cleavage. Biotite occurs as an elongated crystal and in form of lath. Augite is green and has cleavage intersection of nearly perpendicular to one another (figure 10).

3.3.4 Pegmatite

It is composed of orthoclase (about 25%), quartz (about 20%), Plagioclase (about 30%), biotite mica (about 10%), hornblende (about 10%) and opaque mineral (about 5%). Orthoclase is colourless and cloudy with no pleochroism. It shows cleavage, extinction and Carlsbad twinning. Plagioclase is also colourless but characterized by albite twinning and cleavage. Quartz is colourless with no cleavage and alteration along the fractured plane. It has low refractive index and hence low relief. Biotite is characterized by pleochroic haloes and jagged edge. It is mostly brown but some are also green in colour. Hornblende is green with cleavage intersection of 56^0/124^0 (figure 11). Opaque mineral is black in both plane and cross polarized light.

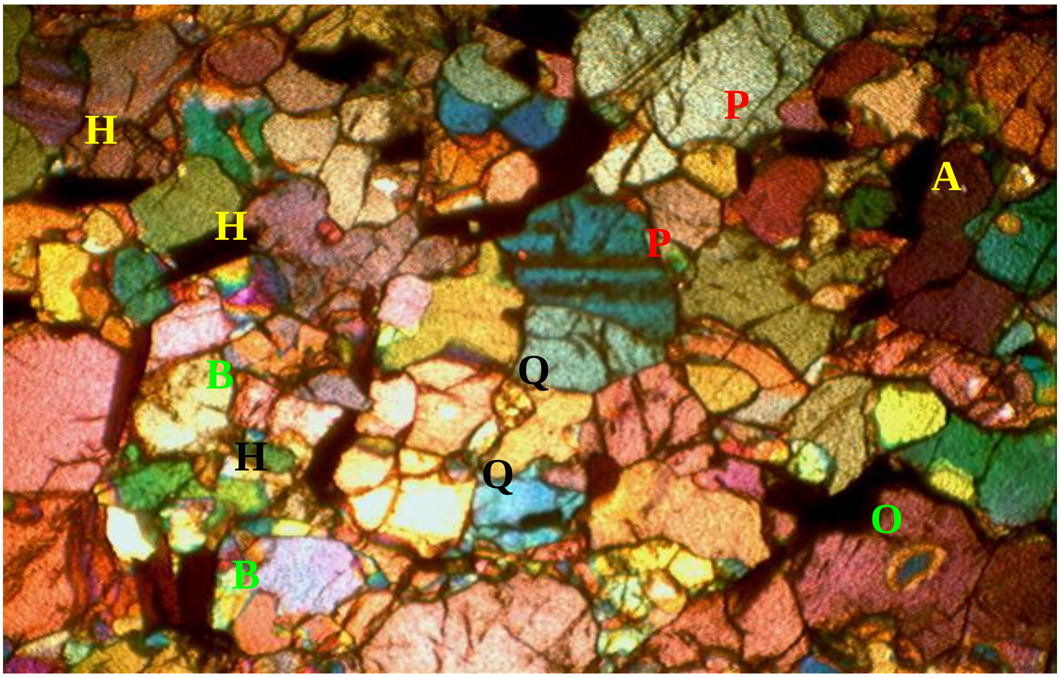

Figure 10: Photomicrograph of thin section of Amphibolite (Cross Polarized Light)

H = Hornblende, **B** = Biotite, **P** = Plagioclase, **Or** = Orthoclase, **Q** = Quartz, A = Augite, **O** = Opaque Minerals.

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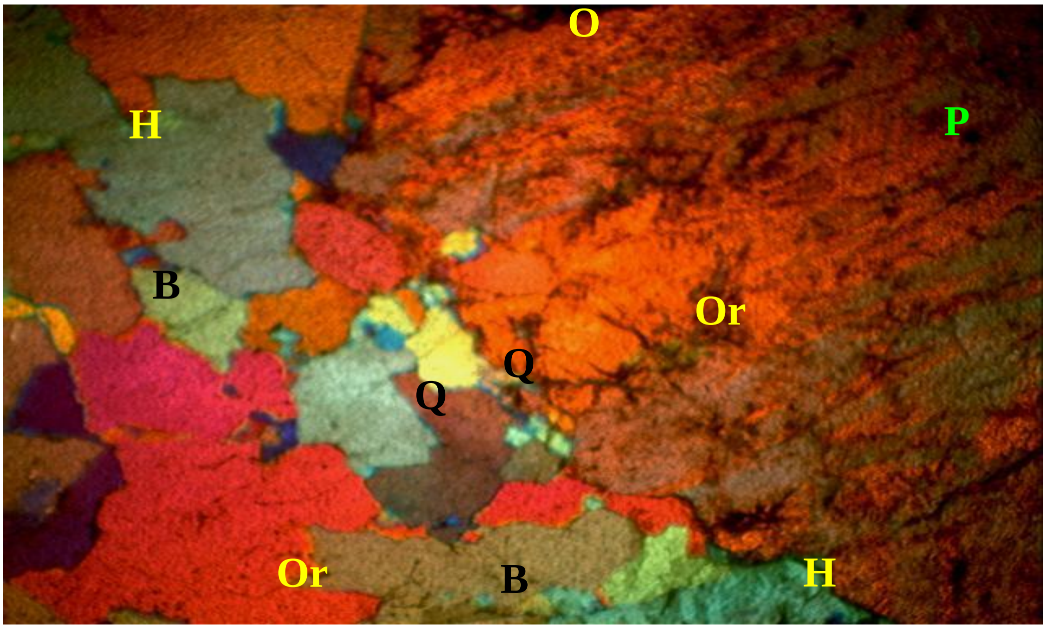

Figure 11: Photomicrograph of thin section of Pegmatite (Cross Polarized Light)

H = Hornblende, **B** = Biotite, **P** = Plagioclase, **Or** = Orthoclase, **Q** = Quartz, **O** = Opaque Minerals

3.4 Structural Features and its Interpretation

Structures are the principal sources of information on the nature of the deformational episodes as it affects the earth. Structural geology relates structures to some chronology that is, the sequence in which structural features developed. It also reveals the processes that produced the observed structures, the temperature-pressure condition operating at the time of the deformation and the stress distribution at the time of formation. The movements that affect solid rocks result from forces within the earth causing folds, joints, faults and lineation. Geological structures are strains resulting from the application of stress. The deformation produced is a manifestation of the type of stress, nature of the rock as well as the environment. The following structures were observed and these provided an information about the geological history of the area.

3.4.1 Folds

These are bend-like structures resulting from compressional forces acting from opposite sides of a rock. It usually leads to shortening of initially straight parallel layers and finally become contorted following plastic / ductile deformation. Several fold types were observed on the outcrops particularly the migmatites. The folds were commonly observed on the top of the outcrops. They represent plastic deformation. Perhaps folding took place when the rock was buried at depth where high confining pressures favoured plastic strain. The fold types observed includes simple folds, ptygmatic folds, tight folds, and open folds. Many of the quartz veins observed have been intensely folded and were suspected to be of different ages. Ptygmatic fold (figure 12) differs from others because it has uniform thickness at both crest, limb and trough while the other types of fold has different thickness.

3.4.2 Faults

Some of the rocks have been heavily fractured and displacement of the outcrop has been indicated by the discontinuity in the lithology on the opposite side of the fault plane (figure 13). A few localized fault were seen on the outcrop at some locations. It is a sinistral strike-slip fault with the fault plane filled with felsic material. It strikes at an angle of 120^0. Other micro faults strikes at various angle.

Figure 12: Migmatite-Gneiss characterized by faulted ptygmatic fold

Figure 13: Sinistral strike-slip fault with quartz vein as the fault plane.

3.4.3 Joint

This is an opening or crack within the rock with no appreciable displacement. This was found in most of the outcrop. In some outcrop it was healed to form vein while in some it was an open joint. No relative displacement between the adjacent block. Several parallel joints were observed in all the outcrops. The migmatite-gneiss exhibits different degrees of jointing. The joints show concordant to discordant relationship to the regional strike of the outcrop. They are oriented in different directions. The following strike readings were obtained for joints in outcrops of the mapped area. From the Rose diagram, the dominant joint direction is almost NE – SW (figure 14). This is the direction of failure mainly resulting from the Pan – African event.

Table 2: Readings of joint orientation from the outcrops

AZIMUTHAL RANGE (^{0})	FREQUENCY	PERCENTAGE FREQUENCY (%)
0 -30	16	14.4
31 – 60	22	19.8
61 – 90	30	27.0
91 – 120	21	18.9
121 – 150	16	14.4
151 – 180	6	5.4
TOTAL	111	100.0

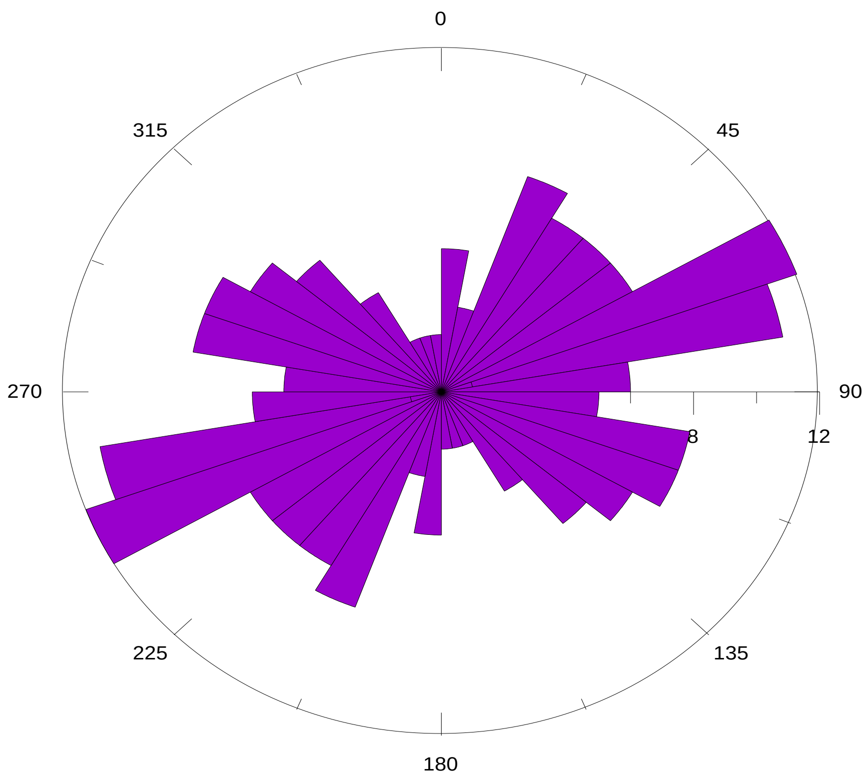

Figure 14: Rose diagram for strike of joints on outcrop.

3.4.4 Lineation

Several linear structures occur repeatedly on the outcrops. Minerals with similar physical and chemical properties are aligned in the same directions i.e parallel orientation of linear and elongate features. The mineral lineation (Table 3) mainly characterized both migmatite-gneiss and granite-gneiss. They are mostly N – S to NE – SW but in some outcrop they are NW – SE to E – W. This reveals the resultant orientation impacted by combine effect of Pan-

Africa and Eburnean orogeny. The Rose plot reveals the dominant direction of mineral lineation. It is oriented in a NNE – SSW (figure 15) which is an imprint of Pan – African orogeny on the basement rock being the recent orogenic episode that affected Nigerian basement rock.

Table 3: Strike readings of the mineral lineations

AZIMUTHAL RANGE(^{0})	FREQUENCY	PERCENTAGE FREQUENCY (%)
0 – 30	16	51.6
31 – 60	5	16.1
61 – 90	3	9.7
91 – 120	1	3.3
121 – 150	2	6.7
151 – 180	4	13.3
TOTAL	31	100.0

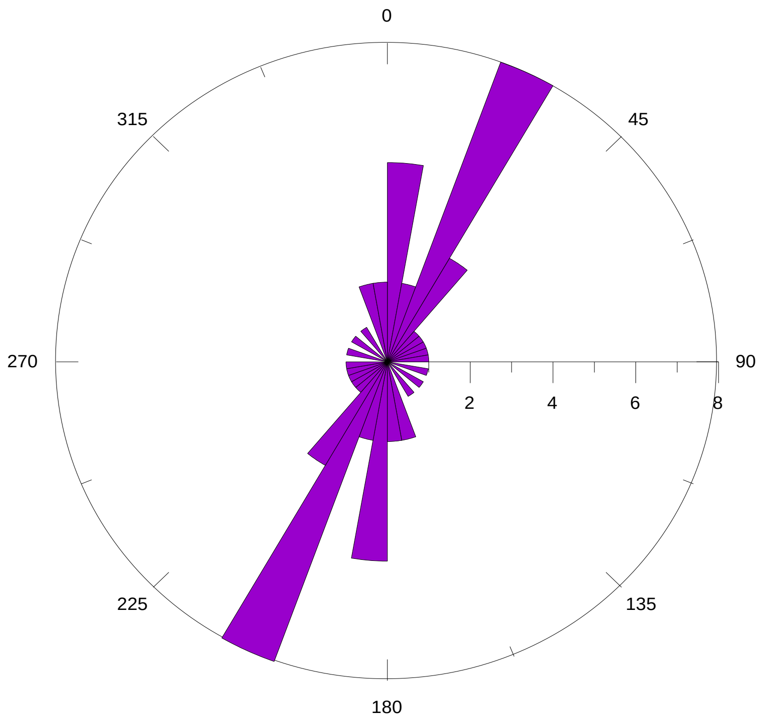

Figure 15: Rose Diagram for Orientation of Mineral Lineation.

3.4.5 Foliation

This is the most typical characteristic of metamorphic rocks and it is a planer structure. It results primarily from the parallel to sub-parallel alignment of inequant mineral grains such as micas or amphiboles. These alignments of minerals are induced by the directional stress that characterizes the formation of many metamorphic rocks. All the strike readings (Table 4) were taken with respect to mineral alignment of the rock and its foliation plane. The plot of rose diagram shows the general orientation of the outcrops (NE – SW) especially migmatite. This is confirming the works of other workers that most of the rock in the basement complex trends in the NE-SW direction. From the Rose Diagram, the material are aligned or foliated dominantly in both NNE – SSW and NNW – SSE (figure 16).

Table 4: Strike readings of foliation trend of the outcrop

AZIMUTHAL RANGE(^{0})	FREQUENCY	PERCENTAGE FREQUENCY (%)
0 -30	4	40.0
31 – 60	1	10.0
61 – 90	0	0.0
91 – 120	0	0.0
121 – 150	1	10.0
151 – 180	4	40.0
TOTAL	10	100.0

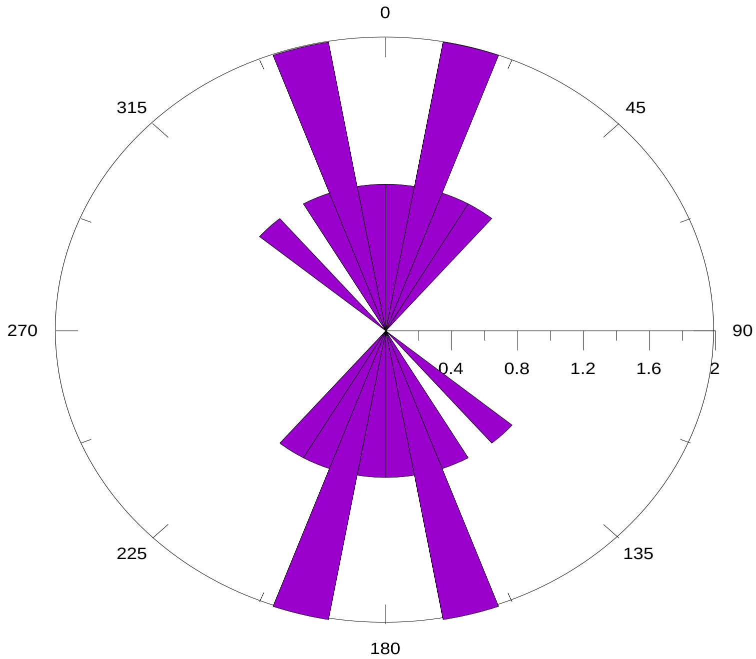

Figure 16: Rose diagram for strikes of foliation orientation.

From the structural analysis, lineation, foliation, joints, fault and the rock outcrop e t c have orientation aligned in the direction associated with many of these major tectonic episodes indicating that the rocks had undergone polyphase metamorphism and series of deformation processes.

3.5 Geological Relation of the area

The mapped area is made up of two major rock unit; the migmatite-gneiss and the hornblende granite-gneiss including amphibolite and pegmatite as shown in the figure 17 below. Both amphibolite and pegmatite were not mappable and hence do not appear on the geological map.

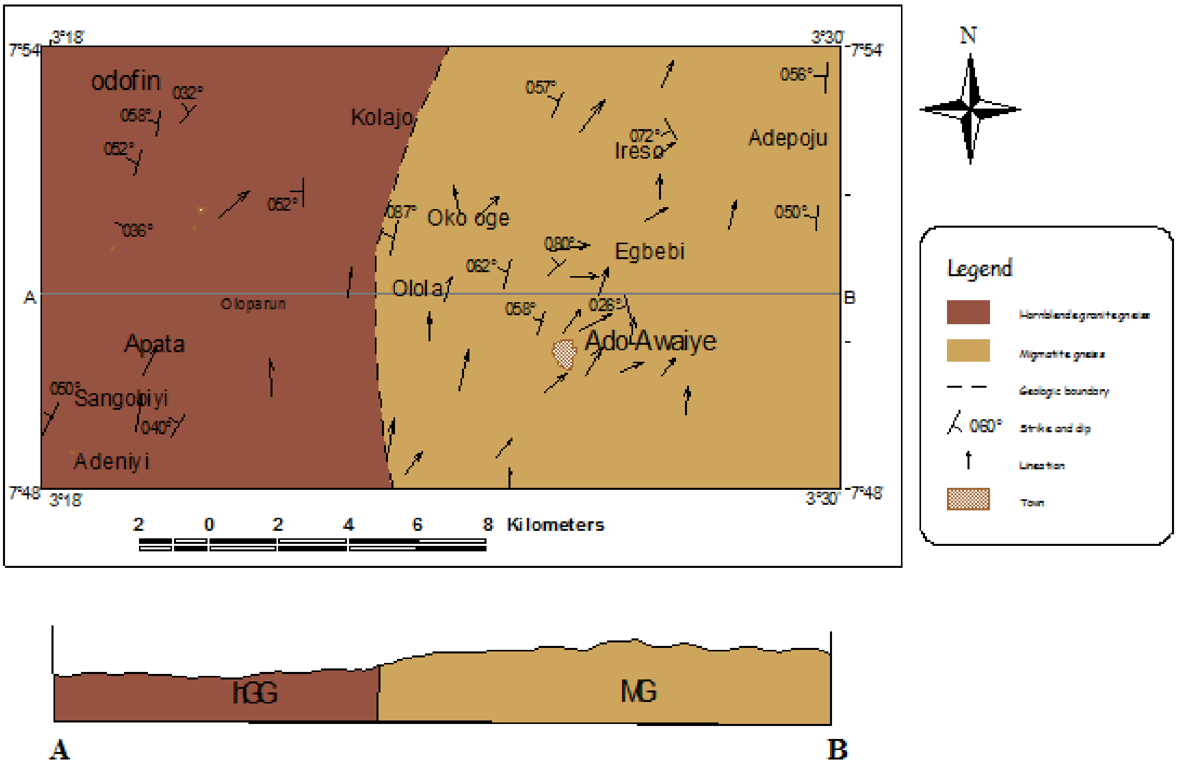

Figure 17: Geological map and cross-section of Ado-Awaiye and its environs, Part of Igangan Sheet 240, Southwestern Nigeria.

3.5.1 Lithological and Chronological Relationship

From the strikes, dip and dip direction of all the rock units, the geologic map and profile was drawn and this indicates that the migmatite-gneiss is the oldest rock unit in the mapped area while pegmatite hosted by the gneiss is the youngest. Migmatite-gneiss is a composite rock consisting both metamorphic and igneous units. It is believed to be formed under the granulite facie condition when there is partial melting. At the beginning of melting that is during anatexis the light coloured minerals melt away. This corresponds to the granitic component (the newly formed portion) of the migmatite. The remaining material is devoid of granitic component (degranitization) and rich in granodiorite composition (granodioritization) and this correspond to the older parent material in metamorphic stage.

3.6 Economic Geology

This is a very important aspect of the geological mapping because it deals with the exploration of natural resources of the area. Although the mapped area is not well mineralized but it contains abundant geological materials such as alluvial deposit, laterite and hard rocks such as migmatite-gneiss and granite-gneiss. The rocks have domestic and engineering uses. Alluvial sand can be used for building and construction purposes. Laterite is an iron-rich residual deposit which is resistant to moisture and hence it is mostly used for engineering purposes such as road and dam construction. Hard rocks are good construction materials because of their tensile strength. They can be crushed into different sizes such as gravel and powder for construction purposes. Migmatite and gneiss are charaterised by migmatitic and gneissic structures and when cut into dimension stones and polished produces a fascinating appearance and can be used as wall tiles. The pegmatite encountered is somehow barren but it is dominated by feldspars. This can be exploited and used for ceramics.

4.0 Conclusion

The study area lies within the basement complex of southwestern Nigeria. Rocks encountered include migmatite-gneiss and granite-gneiss and some intrusions of pegmatite and amphibolite. The mineralogical compositions of the rocks include: biotite mica, muscovite mica, k-feldspar, Plagioclase feldspar, quartz, hornblende, microcline etc. The rocks are characterized by structures such as folds, joints, fault, foliation, mineral lineation, veins, sink holes and exfoliation domes. The pegmatite encounter is barren and the study area is said to be fairly good for quarry activities.

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