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# Petrology and Petrochemistry of Basement Rocks in Ila Orangun Area, Southwestern Nigeria

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**Abstract:** *From field studies, six (6) lithological units were identified to be common around the study area which includes quartzites, granites, granite gneiss, porphyritic granites, amphibolite and pegmatites. The results of petrographical analyses show the mineral assemblages of the various rock types in the area which include quartzites as containing quartz, biotite, muscovite and myrmekite. Granite gneiss contains quartz, biotite, orthoclase, myrmekite, microcline, nepheline, hornblende and plagioclase. Pegmatite contains quartz, myrmekite, plagioclase, hornblende, microcline and muscovites. Porphyritic granites were observed to contain quartz, biotite, microcline, orthoclase and tourmaline. Granite contains quartz, biotite, hornblende, plagioclase and orthoclase while Amphibolite schist contains quartz, biotite, hornblende and muscovites. For the purpose of this study twenty (20) pulverized rock samples were taken to the laboratory for geochemical analysis with their results used in the classification as well as suggest the geochemical attributes of the rocks. Geochemical results obtained and interpreted using various geochemical plots or discrimination plots all classified the rocks in the area as belonging to both the peralkaline metaluminous and peraluminous types. Results for the major oxides ratios produced for $Na_2O/K_2O$, $Al_2O_3/Na_2O + CaO + K_2O$ and $Na_2O + CaO + K_2O/Al_2O_3$ show the excess of alumina, $Al_2O_3$ over the alkaline $Na_2O + CaO + K_2O$ thus suggesting peraluminous rocks. While the excess of the alkali over the alumina suggests the peralkaline metaluminous rock type. The results of correlation coefficient show a perfect strong positive correlation which shows that they are of same geogenic sources while negative correlation coefficient values indicate a perfect weak negative correlation suggesting that they are of heterogeneous geogenic sources. The result of the factor analysis show the elemental association of the trace elements and heavy metals represented as variables in the statistical analysis. Hence, establishing the elemental association of Component 1 as consisting of Ag-As-Ba-Cd-Co, Component 2 as Cr-Cu-Ni, Component 3 as Pb-Rb, Component 4 as Zn-Fe-V and Component 5 as U-Mn. Component 1 suggest the possibilities of sulphide and gold mineralization. Component 2 suggesting pathfinder elements while Components 3, 4 and 5 suggest weathered or dispersed elements. Hence, the occurrence of heavy metallic minerals in the rocks will serve huge economic significance with focus on the pegmatites in the area.*

**KEYWORDS:** Petrography, Ila Orangun, Petrochemistry, Pegmatites, Peraluminous

## INTRODUCTION

Accurate and reliable geoscience information in form of geological data from geological studies have been found to be very important for the purpose of mineral resources exploration, development and production across the globe. In a country like Nigeria especially in the basement complex which cuts across the various regions of the country is well noted for large and enormous occurrence of rocks. Two distinct provinces can be recognized in the Nigerian Basement Complex, namely: the western province, approximately west of longitude 80ºE, characterized by narrow, sediment-dominated, N-S trending belts. The eastern province which is composed mainly of migmatite-gneiss complex intruded by larger volumes of Pan-African granites and by the Mesozoic ring complexes (Younger Granites) of central Nigeria (Ajibade *et. al.*, 1987). The prospect thus leading to mineral resource development in recent times has played an important role for sustainable economic development with rapt attention given to the Ilesha schist belt because of the enormous economic potentials for which it is noted for. However, with the continuously growing availability of geoscience data acquired from field study, there is an increasing demand to interpret and analyze such multivariate data sets in a spatially consistent and integrated manner. For geochemical analysis the consideration for whole rock sample analysis is however a reliable and useful laboratory method that can provide important information concerning the concentration and range of major and trace elements present in the rocks, their primary dispersion in rocks and the mineralogical relationships. The aim of this research is to investigate the petrography, composition and possibility of mineralization in rocks mapped in the study area using geochemical and geostatistical study approach.

### The Study Area: Accessibility, Topography, Drainage and Climate

The study area is located within the Ilesha schist belt on a merged map sheet of Ilorin SE (Sheet No. 223) and Ilesha NE (Sheet No. 243). It is located between latitudes7$^{o}$54' and 8$^{o}$ 001'N and longitudes 4$^{o}$53' and 5$^{o}$00'E covering a total estimated area of about 143.745km$^2$. It is geographically located within Osun state in the southwestern part of Nigeria (Figure 1). It is the gateway to both Ekiti and Kwara States and share boundaries with Ora Igbomina and Oke Ila to the North East; Agbamu, Arandun, Omuo-Aran to the North; Oyan to the west; Otan-Ayegbaju to the southwest and Okemesi in Ekiti State to the east. Ila Orangun township is accessible through major roads from Ora Igbomina junction, Otan-Ayegbaju, Ikirun and Ajaba. The various camps and settlements within the area are accessible through footpaths, minor road networks and motorable tracks which are all interconnected (Figure 2).

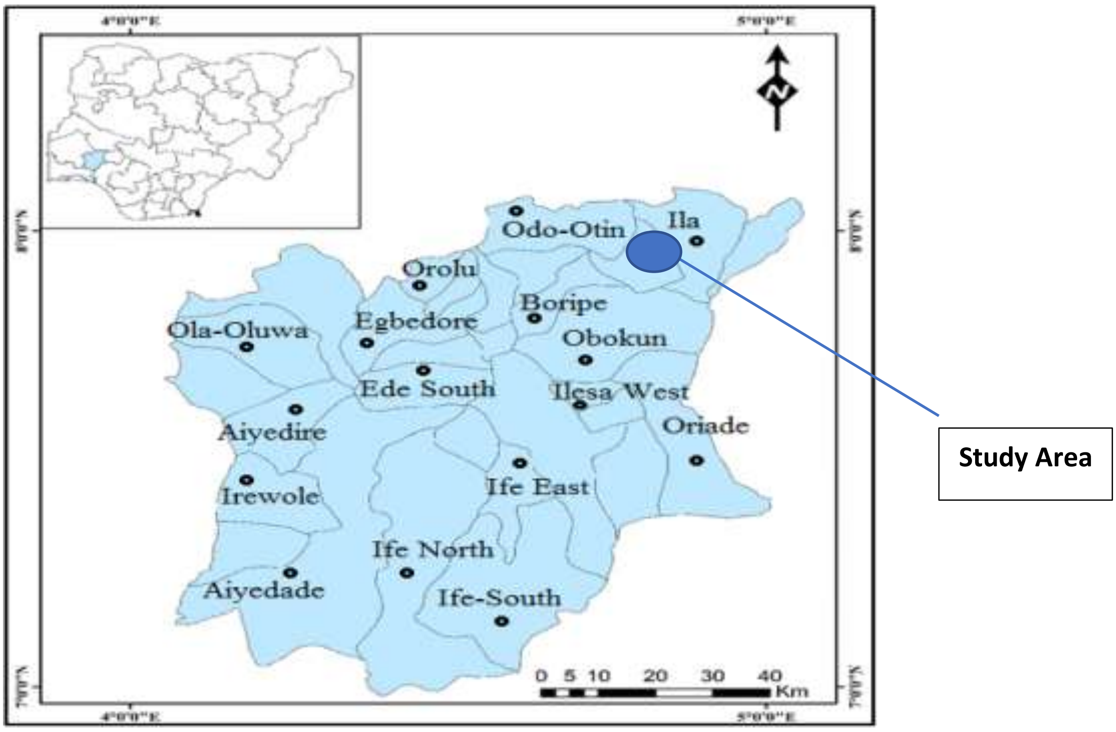


**Figure 1: Map of Osun State showing the study area (Inset: Map of Nigeria)**

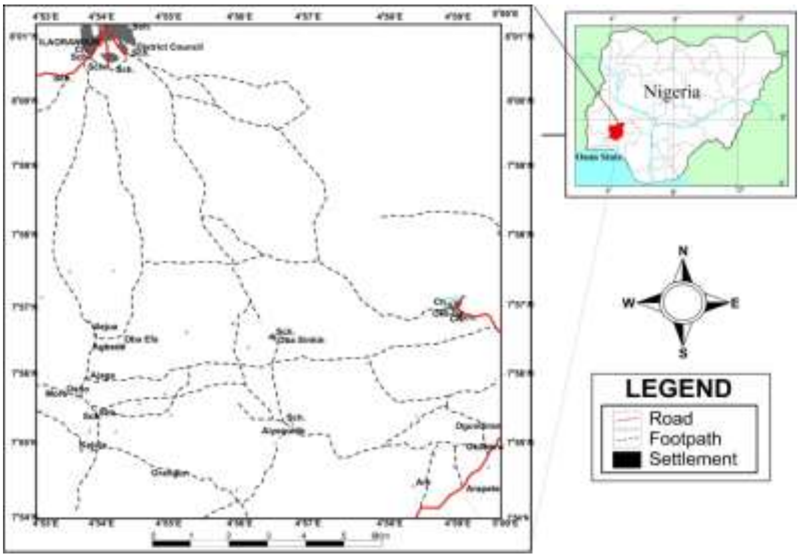


**Figure 2: Interconnectivity and accessibility map of the study area (Inset: Map of Nigeria)**

The topography being the general relief and landform that is peculiar to the study area depicts a rugged terrain characterized by high ranging hills with very high elevations. Hence the study area is an expression of both undulating hills which are almost flat in certain areas and plains dotted with different outcrops in several parts. Most of the outcrops in the study area are well exposed, existing in-situ as low lying and very tall massive hills forming ridges and high mountain ranges. These massive hills were observed to dominate the entire eastern (north - eastern and south – eastern) parts of the area which was observed to be the most difficult terrain because of the rugged nature (Figure 3). Rocks forming long range of massive ridges in the eastern parts were observed to be dominant around Aiyegunle, Obasinkin, Obebe, Obalumo and Oke Ila which are relatively higher with heights ranging between 450m - 650m above sea level. The western parts of the area exhibit scanty outcrops as the rock exposures are generally lowlying and has no hills forming ridges. On this western section lies settlements like Ilejua, Agbede, Ajaba, Moro Osho, Oba Efa, Balogun Orangun and Edemosi which were seen to be plains with few rock exposures but having more of grazing ground.

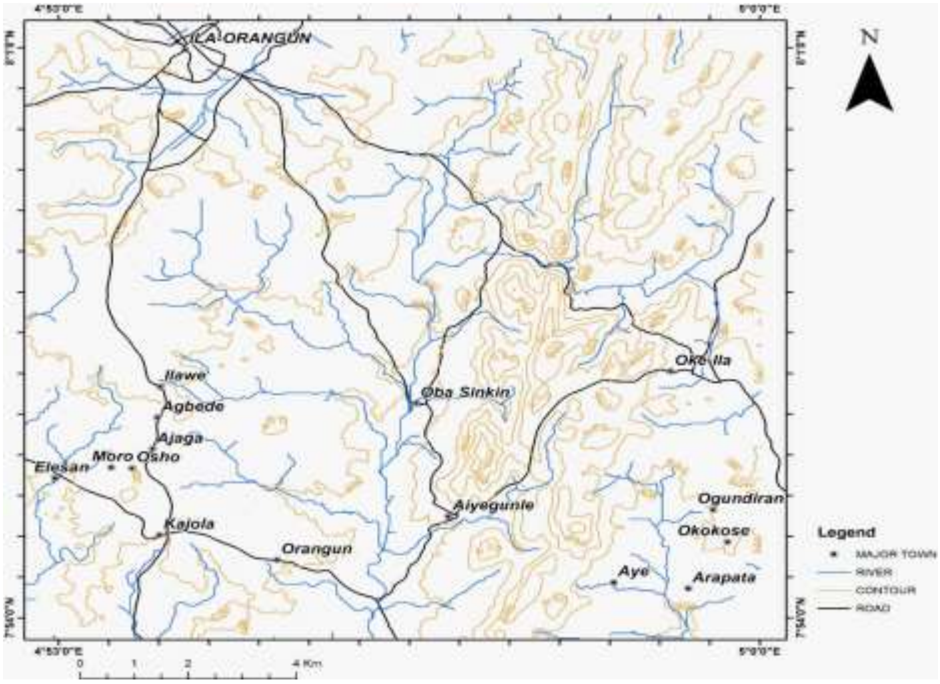


**Figure 3: Digitized topographical map sheet of the study area on a scale of 1:50,000 (Federal Surveys Nigeria 1966, Sheet No. 223 & 243 merged)**

The major river in the study area is River Oyi with its various tributaries flowing around the various villages, hamlets and farm settlements spotted within the area. Various sections of River Oyi are seen traversing Ila Orangun and its environs as river channels bearing lowlying outcrops. The river was observed to be flowing mostly in the NE-SW directions with the river course being moderately wide and taking its tributaries from the Ayikinugba water falls. Its width is estimated to being almost 15meters during the raining season and an estimated depth of about 5meters during this season. While during the dry season, its width is estimated to being about 5 meters and a very shallow depth of about 1 to 2 meters when the river value is at its

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lowest during severe dry season. However, River Oyi is observed to flow throughout the year irrespective of season. The drainage pattern in the south-eastern part of the area where topography is dominated by series of ridges is the trellis type which suggests that the drainage here is structurally controlled whereas, the drainage pattern in other parts of the study area is dendritic, due to homogeneity of the rocks. (Figure 4).

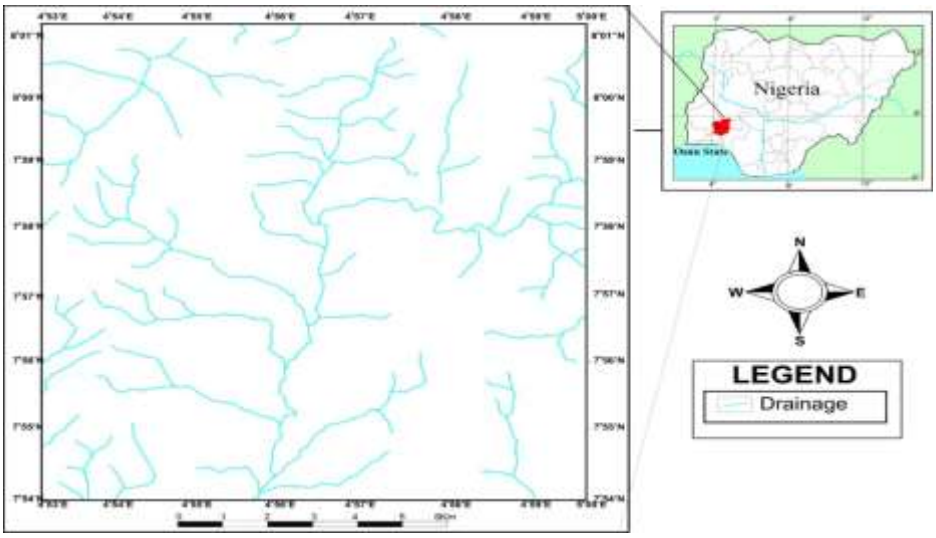


**Figure 4: Drainage map of the study area**

Ila Orangun falls within the tropical rain forest and has a humid tropical climate characterized by distinct wet and dry seasons. The wet season extends mostly between March and October while the dry season lasts between November and February. This area has an average temperature of about 29$^{o}$C (Figure 5)**.** The vegetation is generally depicted by moist deciduous forest. Due to the relatively high rainfall experienced annually the vegetation is thicker and more luxuriant. The forests are made up of different species of trees typical of the semi deciduous forest. The western part of the study area is characterized by savannah tree vegetation such as the bamboo and other wet species of trees are also found along the banks of streams and rivers. The vegetation in some parts are mainly shrubs which are used as grazing area for herbivores.

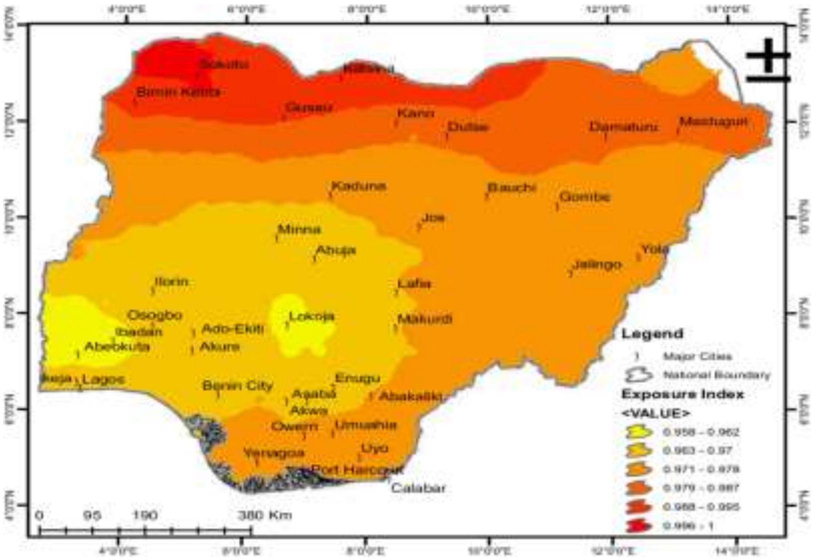


**Figure 5: Map of Nigeria showing climate distribution (Source: NIMET, 2022)**

## Regional Geologic Settings

The study area lies within the basement complex and within the southwest basement complex of Nigeria, four major petro-lithological units (Dada, 2006; Obaje, 2009) are distinguishable namely the Migmatite-Gneiss-Quartzite Complex (Achaean to Early Proterozoic age), the Schist belts (Upper Proterozoic age), the Pan African granitoids (Pan African age) and undeformed acid and basis dykes. The Basement complex in South-western, Nigeria is composed of Migmatite - Gneiss Complex (MGC) that is characterized by grey foliated biotite, acid/biotite hornblende, quartz - feldspathic gneiss of tonalitic to granodioritic composition (Rahaman, 1988); Mafic to ultramafic component which outcrops as discontinuous boudinage lenses or concordant sheet of amphibolites with minor amount of biotite-rich ultramafic and felsic component, a varied group comprised of pegmatite, aplite**,** quartz-oligoclase veins, fine-grained granite gneiss, and porphyritic granite. The study area being part of the Ilesha Schist belt, the Nigerian schist belts are exposed predominantly west of longitude 8° within a North-South trending (Figure 7). The lithology of schist belts generally consists of pelitic and semi-pelitic schist, phyllites, quartzites, polymict meta-conglomerate, iron formation, marbles, calcsilicate rocks and subordinate igneous rocks. These rock types occur in varying proportions in different schist belts across Nigeria (Rahaman, 1976; King and De Swardt, 1949; Elueze, 1981; Odeyemi, 1988; Adekoya, 1996). The quartzites are prominent as ridges and their texture varies from massive quartzites to quartz schist. They are highly fractured and as a result can support denser vegetation (Rahaman and Malomo, 1983). Prominent minerals are quartz, muscovite, tourmaline, sillimanite, biotite, staurolite, garnet, epidote and clinopyroxene. Basic schists are extensively developed in Ife-Ilesha and Effon Psammite Formation.

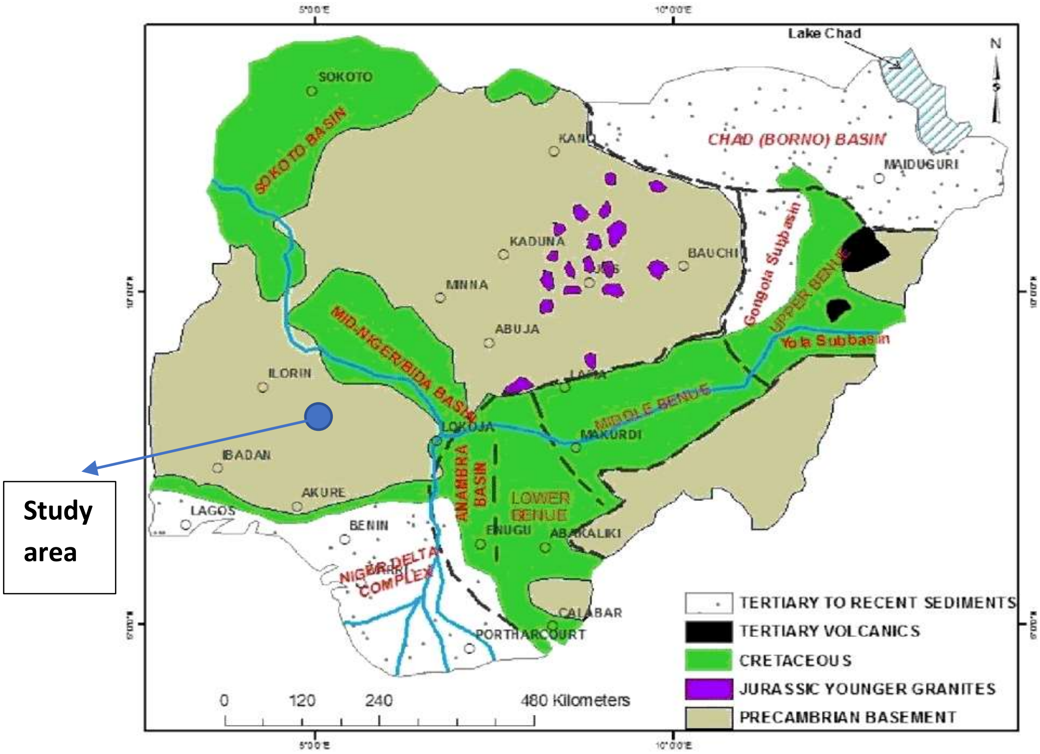


**Figure 6: Generalized Geological Map of Nigeria (Obaje, 2009)**

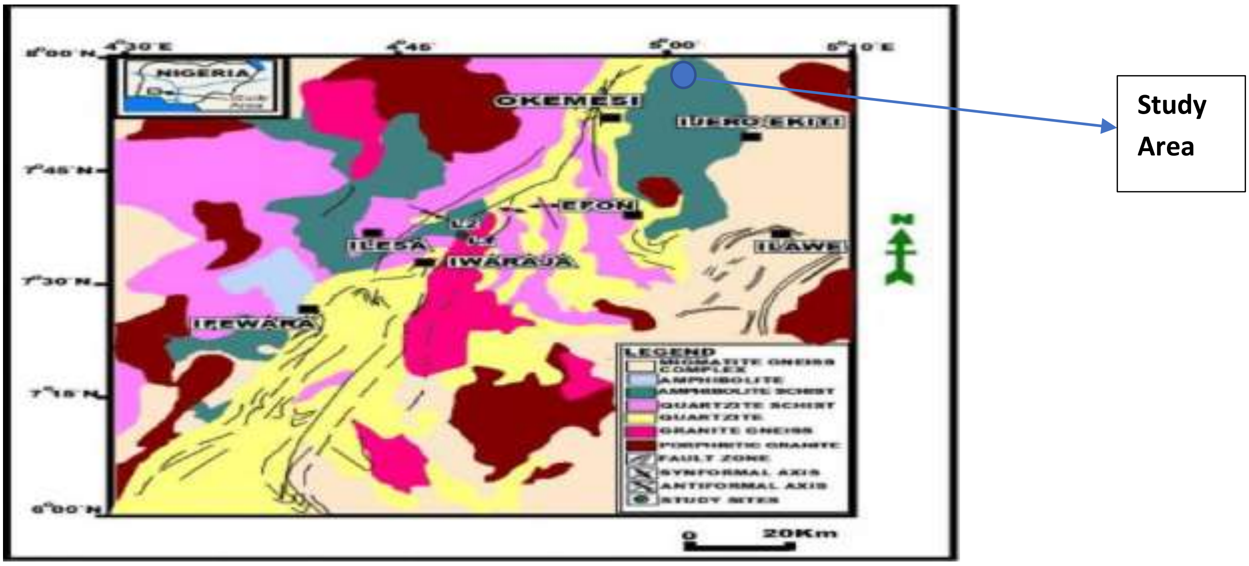


**Figure 7: Geological Map of Ilesha Schist Belt Showing the Study Area (Modified After Odeyemi,1993)**

## Local Geologic Settings

Six (6) lithological units were identified in the study area which includes quartzites, granites, granite gneiss, porphyritic granites, amphibolite schists and pegmatites. The most common

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rock in the area is the quartzite which was observed to be widely distributed within the area but forming hills and ridges of high elevations in the eastern part. Quartzites, both massive and schistose were observed around Aiyegunle, Obasinkin, Obalumo and Obebe while quartzites spotted around Aba Agbonore and Aba Jagi was seen to be very massive, extensive enough and covering a natural space of about 3km. Hence, forming a very difficult terrain with an elevation of about ±650 meters above mean sea level. The quartzites were seen to also extend to parts of Oke-Ila as you ascend uphill from Oyi Aiyegunle to Ayikinugba all within Ifedayo Local Government area. The heavy presence of these quartzite ridges forming clusters of varying heights around Obasinkin, Aba Aromodana, Aba Jagi, Aba Agbonore, Aba Obalumo and Oke Ila all in the northeastern section of the study area according to the researcher can be described as forming the '**Ila Orangun Massive Quartzite Group'.** The pegmatites spotted in Obasinkin were suspected to be intrusives which are younger than the quartzites found within the locality. The western part of the study area was seen to be characterized with scanty low-lying outcrops mainly granite gneiss, amphibolite schists, low lying quartzites, lateritic concretions common within Ila Orangun township indicating highly weathered rocks for which mineral attributes and structural features have been severely eroded. Generally, the rocks in the study area are mostly of the granitic and metamorphic origins. Thus, on the basis of its' regional geology belong to the Precambrian basement rocks of southwestern Nigeria, which itself is part of the basement rocks of Nigeria (Figures 8 and 9).

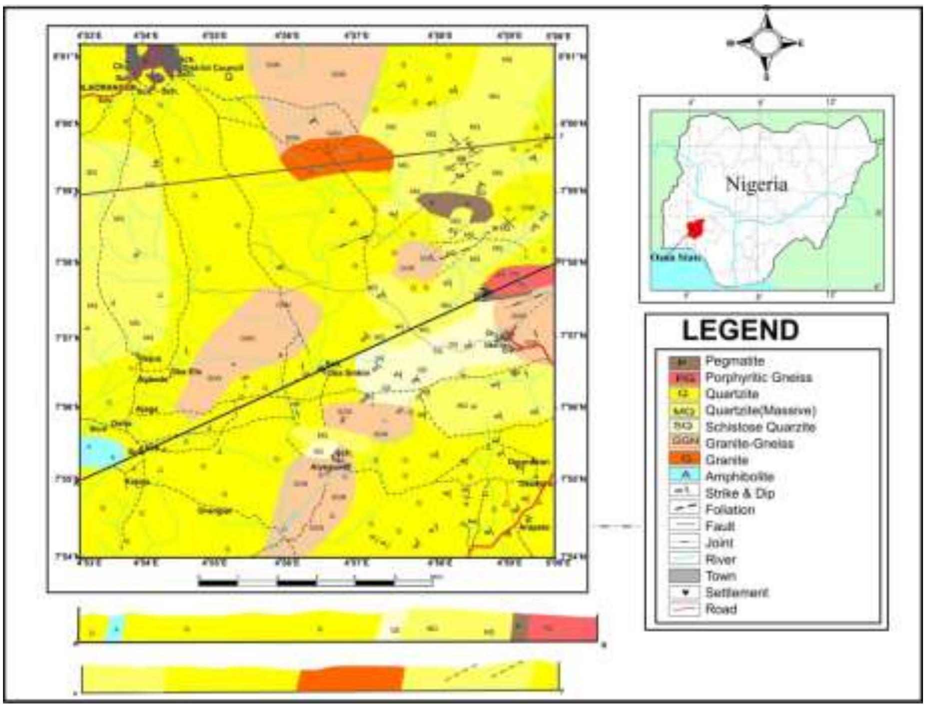



**Figure 8: Geological Map of the study area with cross sections**

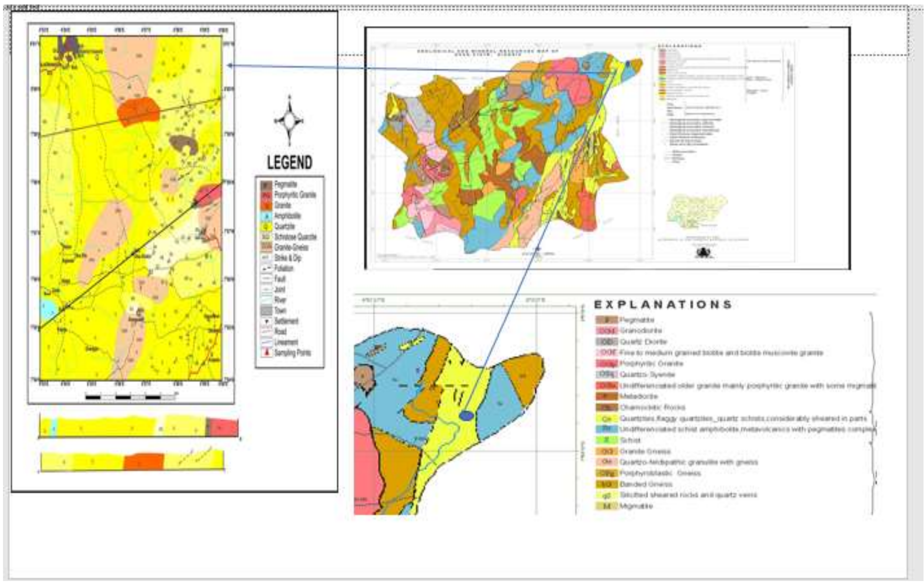



**Figure 9: Modified Geological Map of the study area (After NGSA, 2006)**

## MATERIALS AND METHODS

Materials used for this research have been utilized to meet the needs of both field and laboratory studies which are essential aspects of this work. The field research materials include those used by the researcher on the field for the purpose of systematic field work, mapping and sampling exercise carried out around the study area (Figure 10). These materials include topographical map sheets with sheet number 223 (Ilorin SE) and sheet number 243 (Ilesha NE) on a scale of 1:50,000, geological hammer(sledge), Global Positioning System (GPS), compass clinometer, cutlass, digital camera, sample bags, field boot, hand lens, tracing paper, measuring tapes, ruler, protractor, pencil field notebook, marker, paper tape and motorbike for the purpose of easy mobility around the study area. Laboratory research materials put to use for the purpose of geochemical analyses include the pulverized rock samples, pulverizing machine, Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Microwaves PerkinElmer (Titan MPS) model, white Teflon PFA plastic tubes, consumables identified as reagents which include Lithium metaborate ($LiBO_2$), Lithium tetraborate ($Li_2B_4O_7$), Nitric acid ($HNO_3$) and Hydrochloric acid (HCl), transparent sample bags, transparent plastic containers, fume cupboard among others which were all readily available for use in a standard laboratory with state-of-art facilities. For the geochemical analysis the digestion method involved both partial and total digestions. The total digestion employed Hydrochloric acid (HCl), Nitric acid ($HNO_3$), Hydrofluoric acid (HF) and Perchloric acid ($HCl0_4$) for major oxides. These digestion methods were chosen to provide a more aggressive dissolution of refractive minerals than a standard mixed acid method (Watts and Johnson, 2012). The partial digestion for trace elements using Lithium metaborate ($LiBO_2$) fusion and combination of acids such as Hydrochloric acid (HCl), Nitric acid ($HNO_3$) and Perchloric acid ($HCl0_4$) for digestion without Hydrofluoric acid (HF). After the samples have been digested, then the mixtures in the 50ml calibrated plastic tube is diluted so as to reduce the concentration of the acid as well as make the solution look more lighter and clearer to enhance the lowest limit of detection (blank view) of all the major and trace elements under the ICP-MS. All laboratory analyses were carried out in the Department of Geology (Jabalan Geologi) and the Department of Chemistry (Jabalan Kimia) of the University of Malaya, Malaysia where the author was on six months laboratory benchwork and internship training programme.

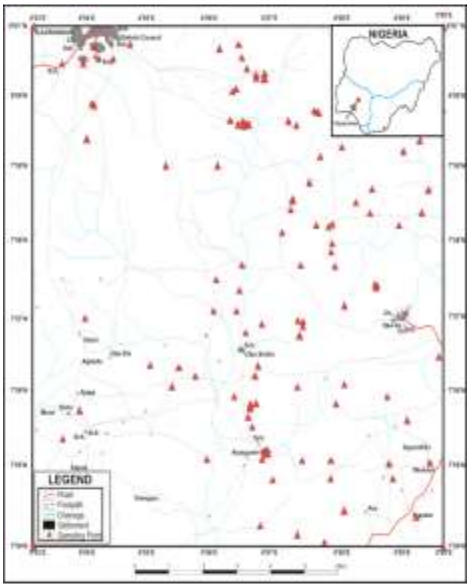



**Figure 10: Study area showing the sampling points (Inset: Inset: Map of Nigeria)**

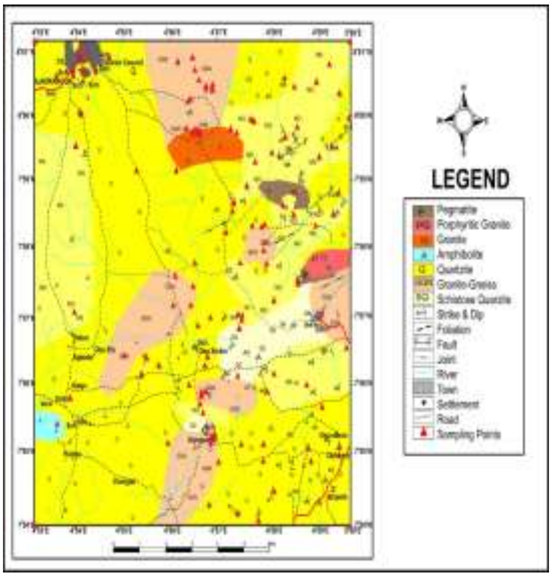



**Figure 11: Study area showing the sampling points superimposed on the geological map (Inset: Map of Nigeria)**

## RESULTS AND DISCUSSION

### Field Geology

From the field work report, about two hundred (200) rock exposures describing and representing various rock lithologies within the study area were sighted, studied and mapped with about one hundred and sixty (160) of them sampled. Areas within the study area that falls within the eastern section and are also visible on the field map was observed to be characterized and predominantly seen to display massive quartzite ridges with an elevation of about ±650meters high above mean sea level. Outcrops around this part of the area were spotted in-situ in small camps which include Agbonore, Jagi, Oke Ila, Ayetoro, Aromodana, Ogini, Ilupeju, Obasinkin, Ayegunle, Oyi Adunni, Obanle, Obajisun and Ajebandele while outcrops on the western section were spotted around. Moro Osho, Ajaba, Alagbede, Kajola, Ejigbo, Balogun orangun, Ejenwa, Oke Aloyin, Gaa ojonla, Onifare and Onigbon. However, the outcome of the field mapping exercise conducted around the study area being a comprehensive, detailed and systematic exercise show six (6) lithological units representing the rock types common in the area with their descriptions presented as follows.

**1 Quartzites**

Quartzites either lowlying or massive are observed to be the most common and dominant type of rock mapped within the entire parts of the study area. The quartzites in this area are mostly lowlying while a few are massive as they were observed forming ridges. Cases of the occurrence of quartzites was spotted on the western section of the study area around Oke Aloyin in Ila Orangun. The coordinate of this outcrop falls within latitude 7° 49' 13.9''N and longitude 4° 55' 15.4'' E. The outcrop was found to be lowlying, unweathered and well preserved in-situ. Pinkish colouration indicating the possibility of oxidation predicting the presence of plagioclase and felspar as possible minerals present. Around Gaa-Ojonla road in Ila Orangun was a road cut displaying massive quartzites underlain by a weak layer of clay minerals. Quartz veins were observed to be conspicuous, mappable and seen to be running concordantly to the direction of planar surfaces. The outcrop as a road cut was seen arranged in layers or beddings and found extending from one end to the other covering about 30meters from tape measurement on both sides of the road. Some sections of the quartz veins also run discordantly to the direction of bedding. Existing quartz veins were seen to be ferrugenized ($Fe^{3+}$) as a result of oxidation from chemical weathering. Length of concordant quartz veins estimated at about 1410cm. Massive quartzite schist was spotted as the dominant rock type in areas around Obasinkin as they seen to form several well-arranged hills of complex ridges. The outcrops are massive quartzite schist, good exposures and are best described as the Obasinkin massive quartzite ridges. The outcrops are fresh, well preserved and unweathered. The rocks are foliated and highly foliated in some cases, have shallow and deep-seated fractures which are of short lengths and are believed to have been formed due to the rock's response to much internal or external stress. In front of Baptist Church Aiyegunle is the in-situ presence of a massive quartzite spotted within coordinate of latitude 7° 55' 19.4''N and longitude 4° 56' 59.2'' E. The outcrop was observed to have their planar surfaces dip in varying directions, they are massive and found scattered around the location. Some of the quartzite were also found to be pink in colour which could indicate the presence of felspathic minerals in the rocks. Areas around the Ayikinugba waterfall was dominated by the presence of massive quartzite and typically extending from the junction from Oke-Ila town as the hill is being ascended and descended through a 245 steps corridor which were constructed to be easily accessible to tourists and field workers. The height of the hill is estimated to about 680meters tall above mean sea level. Along Obasinkin-Aiyegunle road is a massive quartzite whose in-situ occurrence was observed to be scattered around the location where found. Quartzites found at this spot were whitish, some looking smoky some pinkish as a result of iron stain due to oxidation from chemical reaction. The rock samples have planar surfaces which allows strike and dip values to be conveniently read

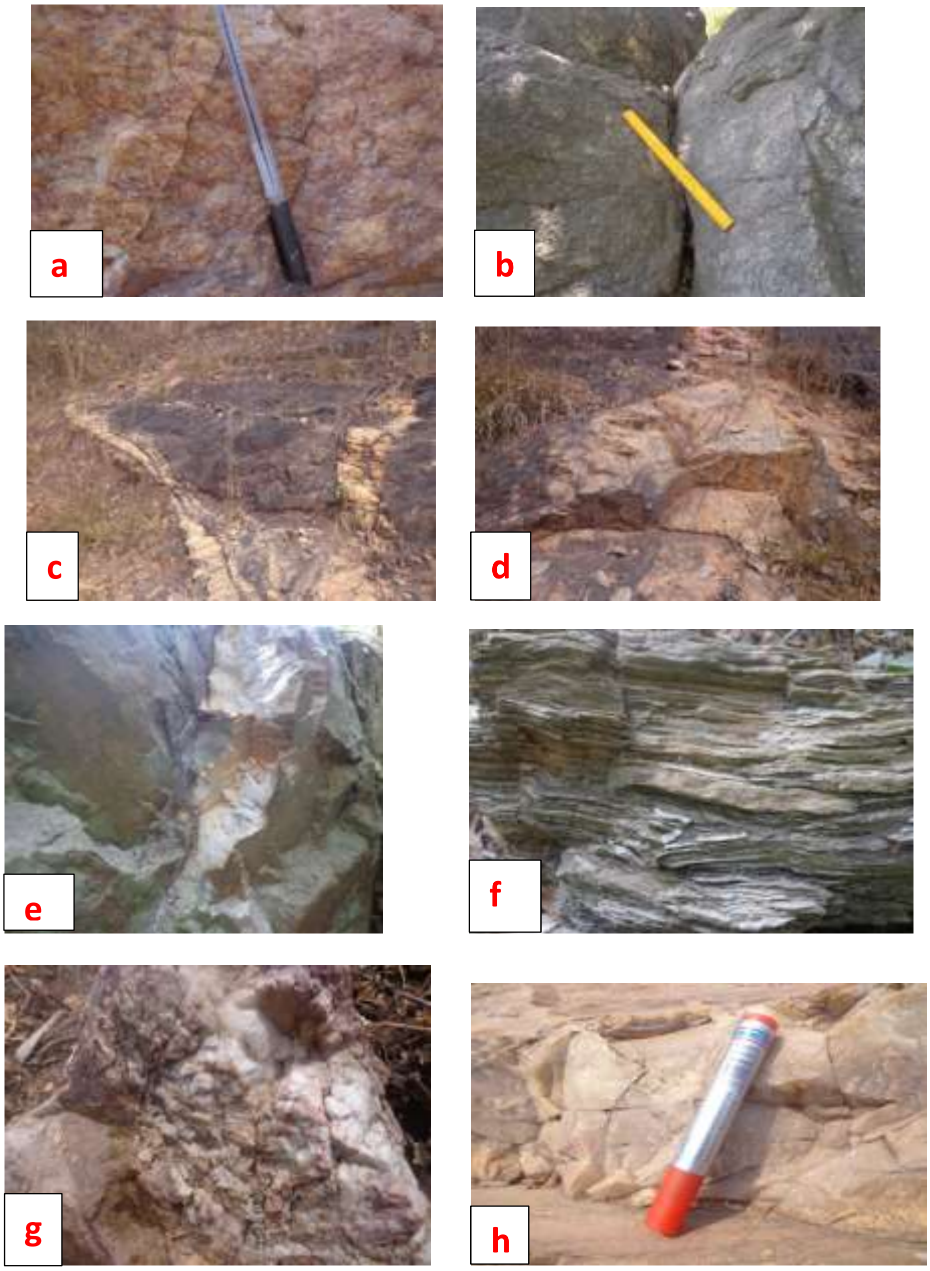



Plate 1:(a) to (h) Showing the various types of quartzites mapped around sections of the study area to include Oke Aloyin, Gaa-Ojonla, Aba Agbonore and Aiyegunle all in Ila Orangun.

**2. Granites, Granite Gneiss and Porphyritic Granites (Identified as different lithologies)**

On the other side of the road behind Aba Alagbede along Ajaba - Ila Orangun Road is the occurrence of a granite rock which was found to be massive with some lowlying resemblance of same rock type appearing at the foot of the hill. Imminent structures observed are fractures and lineations with planar surfaces. Close to Baba Eko behind the college is the granite gneiss which was found in Obasinkin. The rock was found to exhibit dark patches which is largely the presence of biotite. A massive exposure of porphyritic granites, observed to be very extensive and spotted a few meters off the Gaa-Ojonla expressway. This rock contains smaller bubbles of phenocrysts describing it as porphyritic granite. The crystals were seen to be coarse grained and conspicuous as observed by the field worker. Structures clearly observed include quartz veins, solution holes with the quartz veins observed in-situ to exhibit the smoky appearance. spotted along Aiyegunle-Oke Ila footpath is granite gneiss mapped within a coordinate of latitude 7° 55' 45.7"N and longitude 4° 57' 39.8" E. Similarly, under the bridge along Oke-Ila main town and leading to the Ila-Orangun and Ora Igbomina major road, granite gneiss was found to be lowlying under the bridge and occupying the river bed of River Oyi (a major river in the study area) which is a slow flowing stream. The rock is fine grained with dark patches of mineral dots which is biotite. They were observed to be foliated showing foliations and lineations within the internal fabrics of the rock. In Oke-Ede area of Oke Ila is also a lowlying outcrop of granite gneiss with a dark grey colour appearance. Typically, medium to fine grained texture and foliated. At a coordinate of latitude 7° 57' 10.9"N and longitude 4° 59' 28.0" E another granite gneiss was mapped found to be lowlying, dark grey and found to be medium to fine grained but exhibit traces of shining flints of minerals glittering on the outcrop which is possibly assumed to be mica. Traces of quartz vein was seen on the granite gneiss running concordantly in the direction of mineral alignment.

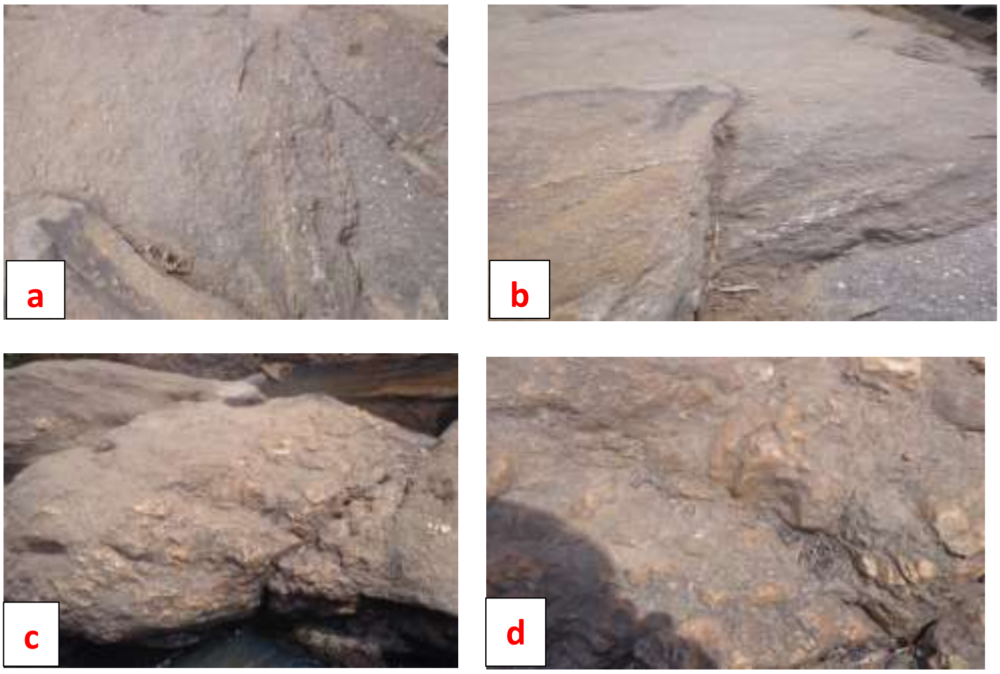



Plate 2: (a) – (d) Showing granite gneiss, porphyritic granite mapped in parts of the study area around Oke Ede, along Ominla stream in Oke Ila.

**3 Pegmatites**

Areas around Aba Aromodana the researcher spotted areas around a massive outcrop which play host to massive quartzite ridges which are a continuous ridge forming long walls of similar rock type and almost same elevation above mean sea level. The massive quartzites were seen to host a strange and different rock type identified to be pegmatites. The pegmatite however exists as intrusives, younger to the host rock and exist within quartz veins which occurrence was also conspicuous on the older massive quartzite. Similar lithological occurrence of massive and schistose quartzites playing host to pegmatites were clearly spotted within latitudes 7° 58' 40.5"N and longitude 4° 58' 10.3"E, latitudes 7° 58' 33.0"N and longitude 4° 58' 09.4"E, latitudes 7° 58' 33.0"N and longitude 4° 58' 10.5"E and latitudes 8° 00' 00.0"N and longitude 5° 00' 00"E all falling within the northeastern section of the study area. Typical cases of quartzites hosting a large chunk or sizeable quantity of a different type of rock were mapped as they were seen as a conglomerate of minerals which are most likely to serve huge economic benefit. At a coordinate within latitude 7° 58' 33.0"N and longitude 4° 58' 10.5"E is a massive quartzite which contains pegmatite. The rock is highly mineralized as the pegmatites was a clear evident of serious mineralization process that is best confirmed geochemical analysis in the laboratory for mineral ore potential or prospect of these spots visited. Localities around Aba Ogini and Ilupeju were noted to be the settlements or camps having quartzites with the pegmatite intrusions within latitude 7° 58' 56.4"N and longitude 4° 59' 26.2"E and latitude 8° 00' 10.1"N and longitude 4° 59' 35.0"E with their average elevations being about 800m above mean sea level.

Plate 3: Pegmatite intrusions hosted within massive quartzite ridge in Aba Aromodana. The intrusion was seen to be younger, held as large chunk of strange rock mineral within smoky, milky and white quartzites as observed in-situ.

**4. AMPHIBOLITE SCHIST**

Spotted in-situ at the back of Baptist Elementary School in Ajaba community is Amphibolite Greenschist. This rock type exhibits a kind of greenish colour which also penetrates the internal fabric of the rock. The outcrop was found to be lowlying and suspected to be an intrusion and younger as it occurs in the form of a vein within the area noted to be surrounded by the dominance of quartzites and few cases of granites. In its in-situ occurrence, it was found to be dipping in same direction as those of the surrounding rock types, hence concordant to the older rocks. Structures clearly observed include solution holes, foliations and lineations. Some parts of the outcrop appear weathered due to severe weathering as they exhibit some facial weakness.

Plate 4: Amphibolite schist around Ajaba

**PETROGRAPHY: Petrographical Studies**

For the purpose of petrographical studies, forty (40) good, fresh and quality rock samples were randomly selected from the numerous rock samples collected from the field. However, for the purpose of publication six (6) representative samples of each of the lithologies that make up the rock types common within the study area are thus presented.

**1. Sample 1: Quartzite**

Slide 1 was prepared from quartzite and closely examined under both plane and cross polarized lights of the electron microscope. All coloured minerals show a needle - like shape and appearing in different directions or preferred orientations along the cleavage line. Twining observed in cases of two-coloured minerals formed side by side with mutual growth. From petrographical studies the mineral count shows quartz (71.59%), muscovite (24.26%) and biotite (2.36%) while other accessory minerals constitute less than 2% of the total possible mineral composition. The dark, grey, white and colourless crystal faces suggest the presence of quartz which are also found in metamorphic rocks. Under the thin section exhibits refractive index of 1.54 -1.55, cleavage not clearly defined as they are seen to be characterized with fractures having random orientations of cracks. It possesses low birefringence, low relief, hence habit is low.

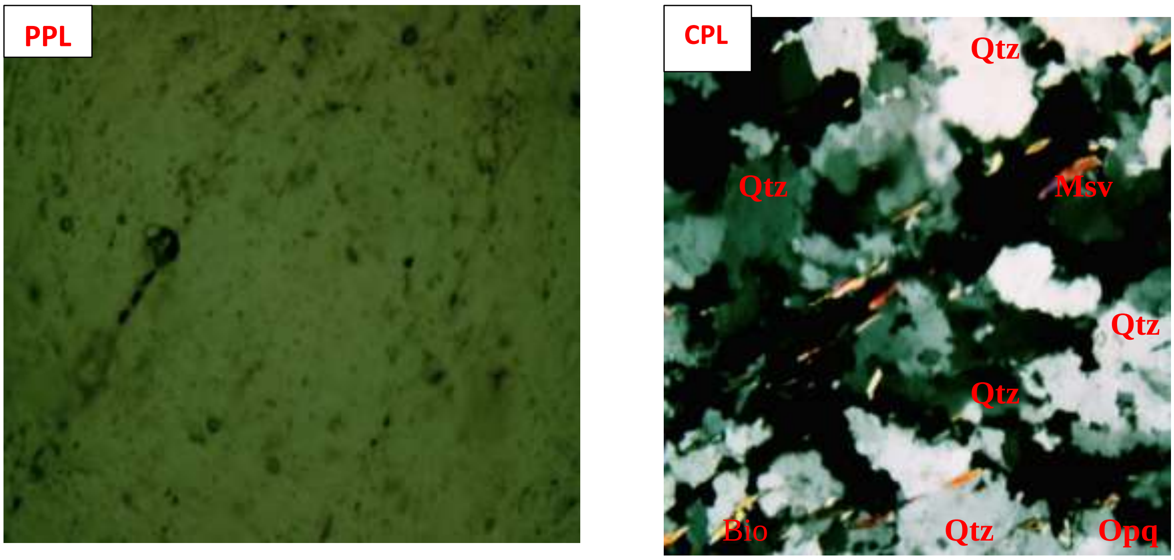
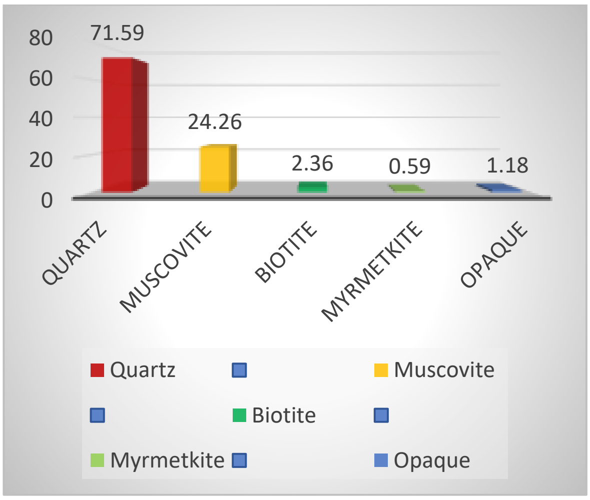



Plate 5: Photomicrograph of quartzite under PPL and CPL showing its mineral assemblages. Magnification × 10

| MODAL ANALYSIS<br>Slide 1 (Quartzite) Aiyegunle | |
|---|---|
| **Minerals** | **Composition (%)** |
| Quartz | 71.59% |
| Muscovite | 24.26 |
| Biotite | 2.36 |
| Myrmekite | 0.59 |
| Opaque | 1.18 |
| **Total** | **99.98** |



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**2. Sample 2: Granite Gneiss**

Slide 2 was prepared from granite gneiss. Thick dark brown coloured mineral was seen to be overprinted on the crystal faces as they are formed as an emplacement between crystal boundaries causing some of the crystal faces to have been affected or deformed in the process. This thick brown mineral emplacement suggesting biotite are emplaced in preferred directions and orientations. Mineral count under the cross nicol shows biotite (32.97%), quartz (56.91%), microcline (3.19%) and other accessory minerals account for about 7% of the entire mineral assemblage which include orthoclase, plagioclase, nepheline, myrmekite and hornblende all making up the rock components as observed under thin section

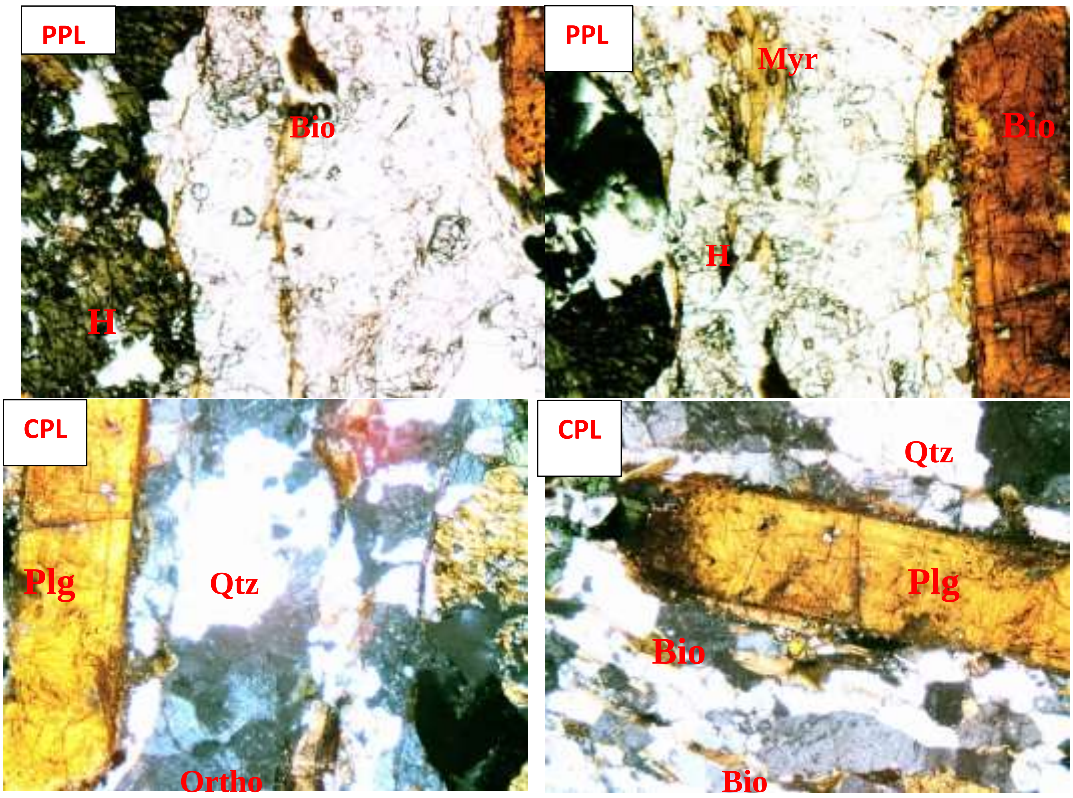


Plate 6: Photomicrograph of granite gneiss under PPL and CPL showing its mineral assemblages. Magnification × 10

**3 Sample 3: Pegmatite**

Sample 3 was prepared from pegmatite and investigated for petrographical study under the plane and cross polarized light. Mineral count under the cross nicol accounts for quartz (29.54%) and microcline (54.54%) while muscovite and other accessory minerals constitute about 15.90% of the entire mineral assemblage that make up the rock under thin section. The dark, grey, white and colourless crystal faces suggest the presence of quartz. Green coloured

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mineral suggests the present of chlorite, yellow suggests epidote, staurolite and rutile, and pink suggests andalusite while the possibility of pink muscovite may suggest the possibility of chemical reaction due to the presence of manganese. The yellow suggests the presence of epidote, staurolite and rutile. The colourless suggests the presence of muscovite, microcline and possibly other colourless minerals like olivine and sillimanite. The blue colour may suggest the presence of fluorite.

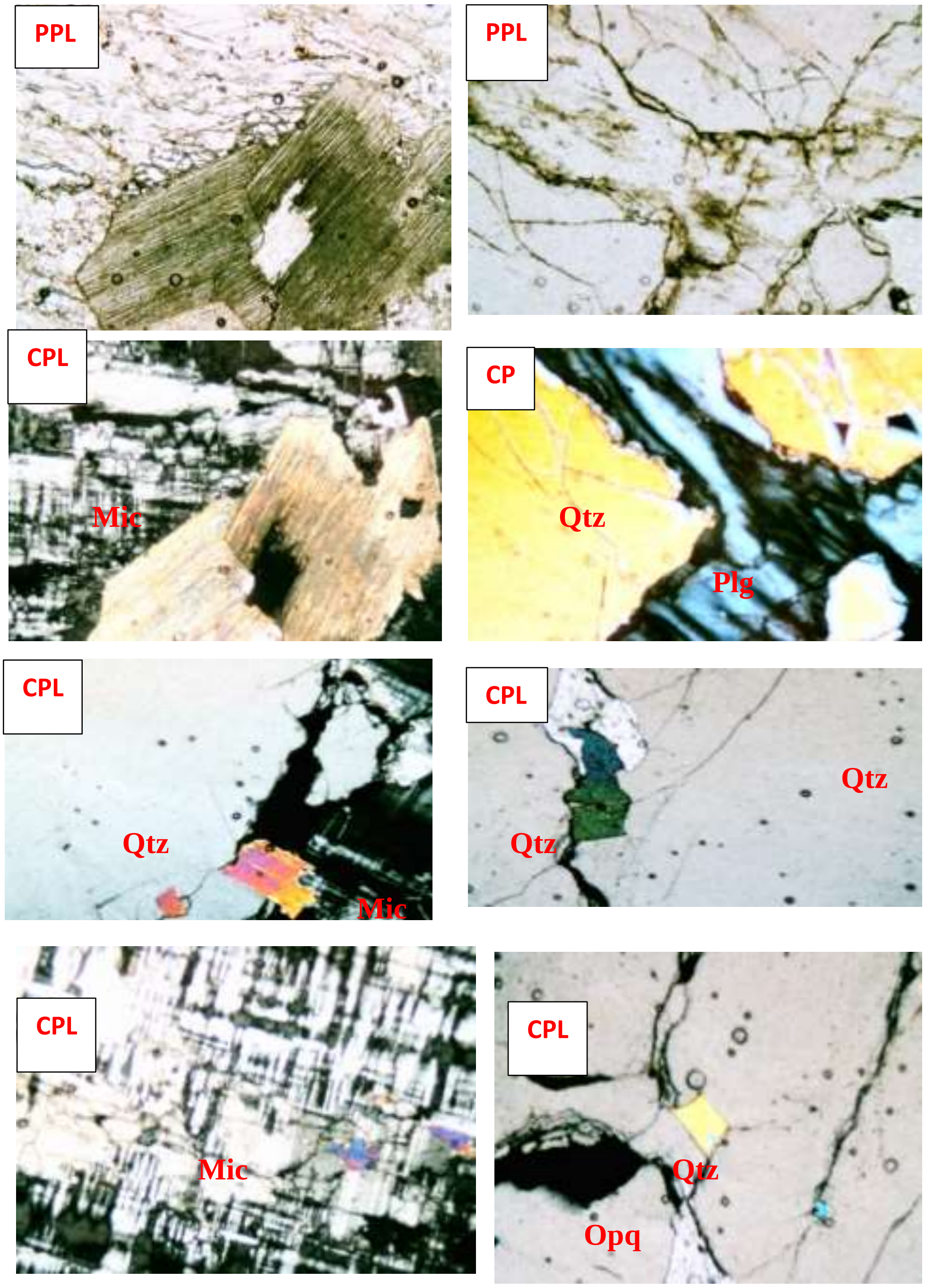
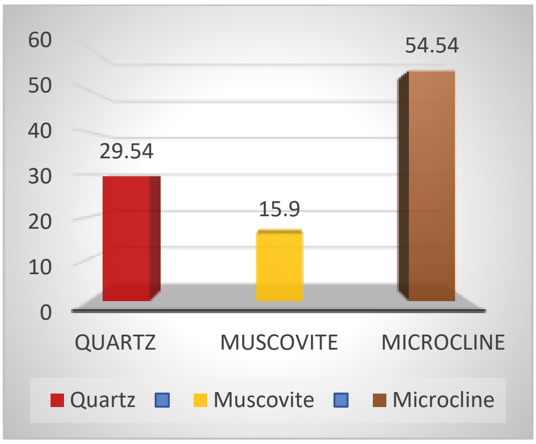


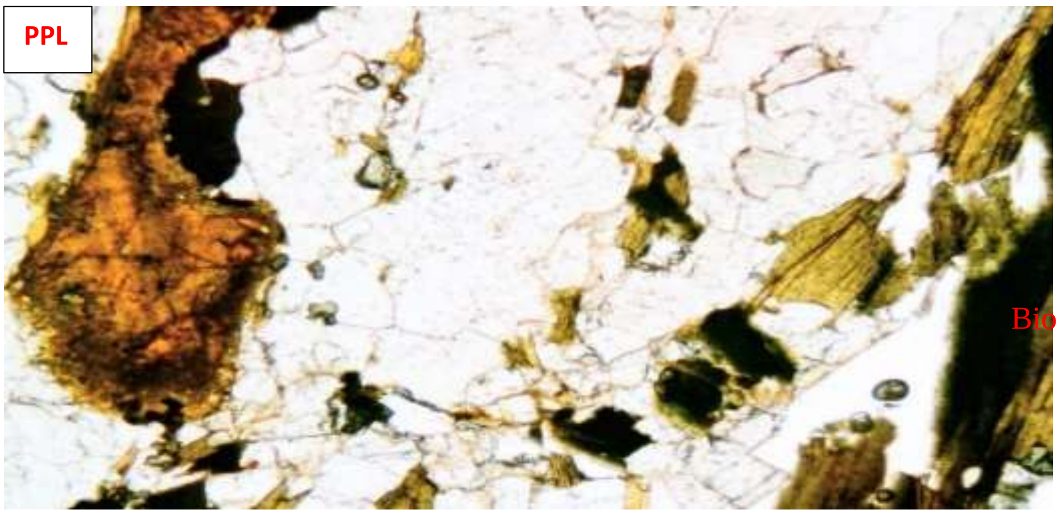
Plate 7: Photomicrograph of pegmatite under PPL and CPL showing its mineral assemblages. Magnification × 10

| MODAL ANALYSIS<br>Slide 3 (Pegmatite) Obasinkin | |
|---|---|
| **Minerals** | **Composition (%)** |
| Microcline | 54.54 |
| Muscovite | 15.90 |
| Quartz | 29.54 |
| **Total** | **99.98** |




## 4. Sample 4: Porphyritic Granite

Sample 4 was prepared from porphyritic granite which when viewed under the plane polarized light display light to dark brown coloured features which were clearly distinct and identified under the light. Mineral count under the cross nicol accounts for biotite (15.65%), quartz (73.04%) and microcline (4.34%) while accessory minerals which include orthoclase, tourmaline and opaque minerals constitute about 7% of the entire mineral assemblage that make up the rock under thin section. The colourless suggests the presence of muscovite, microcline and possibly other colourless minerals like olivine and sillimanite. The blue colour may suggest the presence of fluorite. The pink suggests andalusite while the possibility of pink muscovite may suggest the possibility of chemical reaction due to the presence of manganese. The opaque minerals neither transmit nor reflect lights which may suggest an ore mineral.



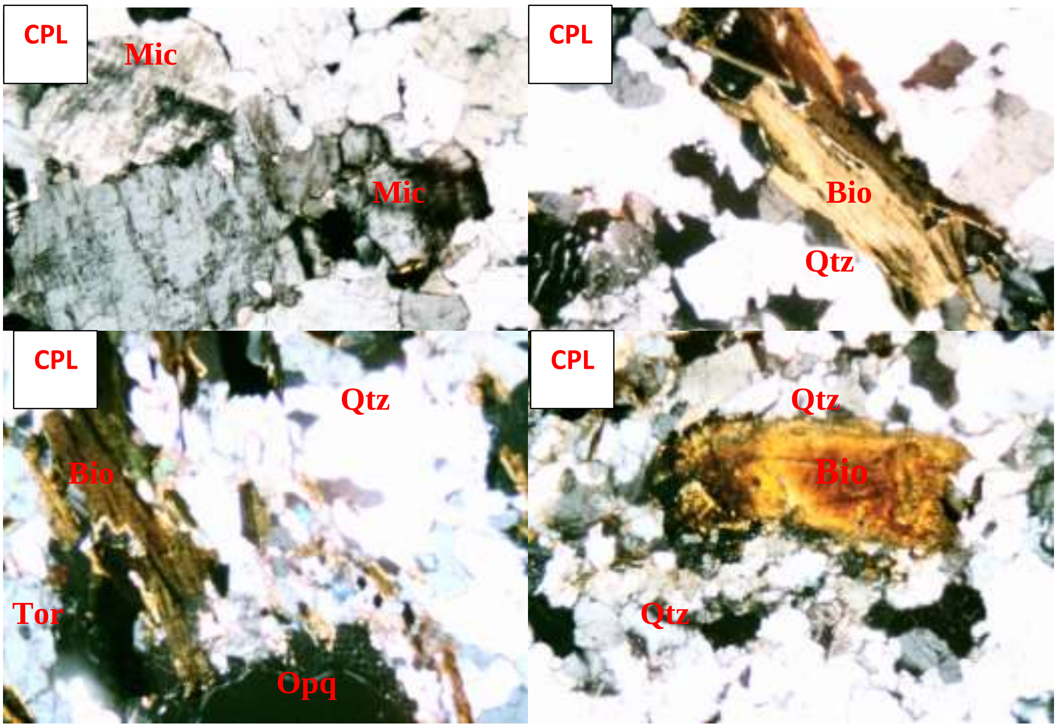
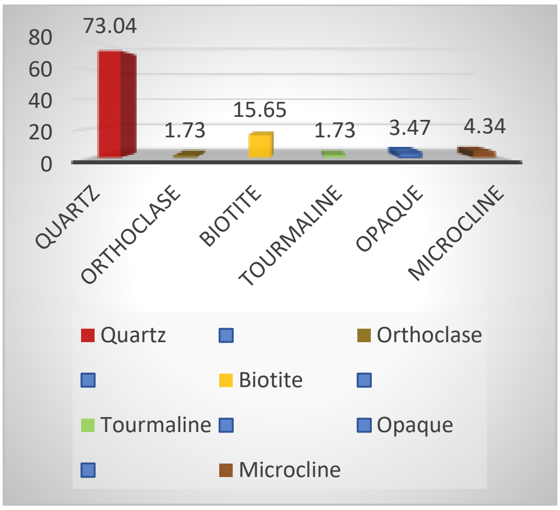



Plate 8: Photomicrograph of porphyritic granite under PPL and CPL showing its mineral assemblages. Magnification × 10

| MODAL ANALYSIS<br>Slide 4 (Porphyritic Granite) Oke Ila | |
|---|---|
| **Minerals** | **Composition (%)** |
| Microcline | 4.34 |
| Orthoclase | 1.73 |
| Biotite | 15.65 |
| Tourmaline | 1.73 |
| Opaque | 3.47 |
| Quartz | 73.04 |
| **Total** | **99.96** |




## 5. Sample 5: Granite

Sample 5 was prepared from granite which when examined under the plane polarized light, brown-coloured features suspected to be minerals with some attributes of opaque minerals were spotted. The various minerals formed were seen to be emplaced between intercrystal boundaries as a result of metamorphic process. Mineral count under the cross nicol accounts for biotite (15.88%), quartz (63.55%), orthoclase (7.47%), hornblende (5.60%) and plagioclase

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(3.73%) while other accessory minerals including opaque minerals accounts for 3% of the total mineral assemblage that make up the rock composition under thin section.

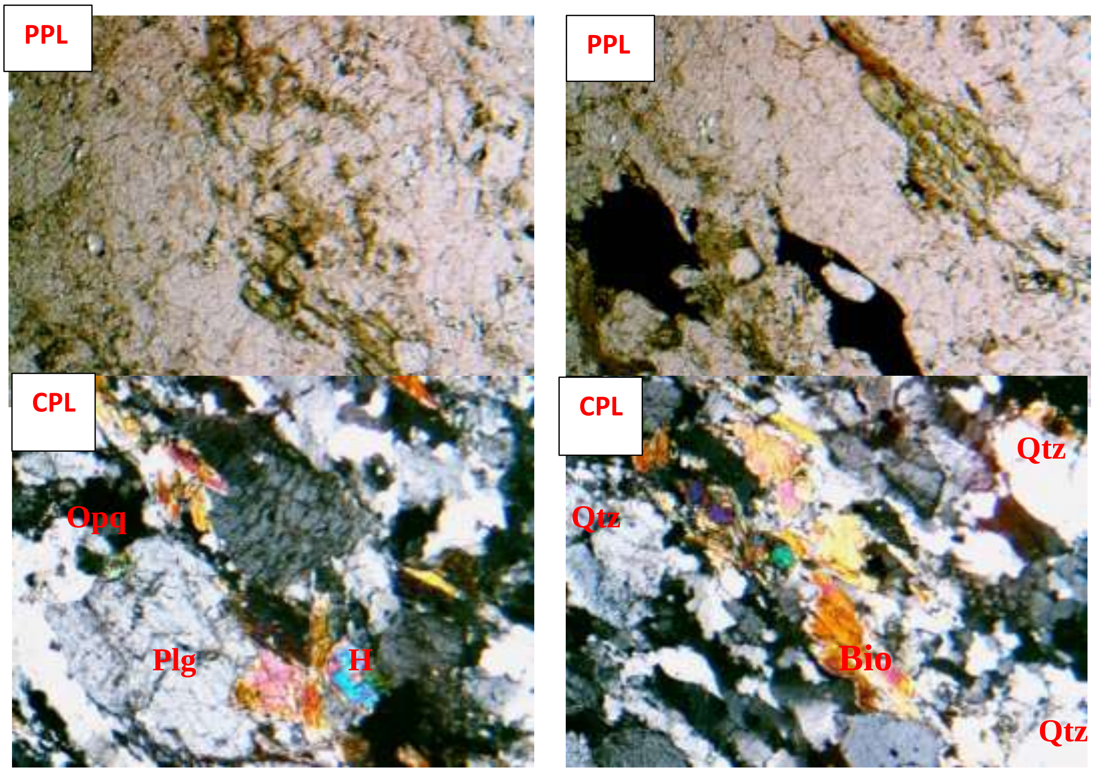
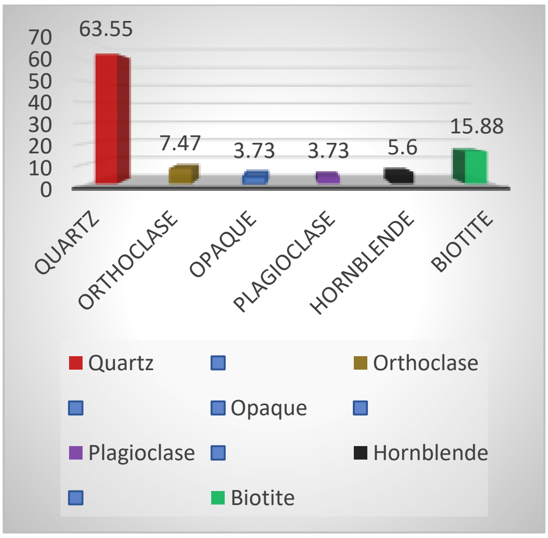



Plate 9: Photomicrograph of granite under PPL and CPL showing its mineral assemblages. Magnification × 10

| **MODAL ANALYSIS<br>Slide 5 (Granite) Aba Oyi Aduni** | |
|---|---|
| **Minerals** | **Composition (%)** |
| Biotite | 15.88 |
| Orthoclase | 7.47 |
| Opaque | 3.73 |
| Plagioclase | 3.73 |
| Hornblende | 5.60 |
| Quartz | 63.55 |
| **Total** | **99.96** |



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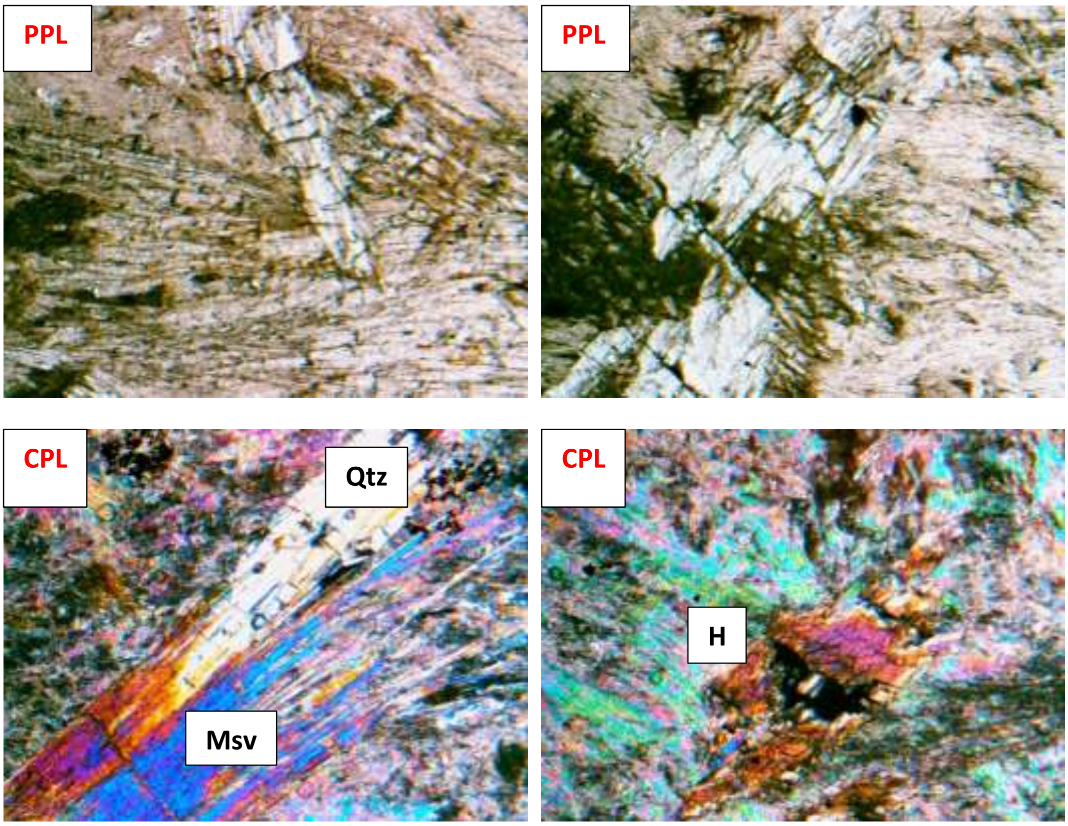
**6. Sample 6: Amphibolite Greenschists**

Sample 6 was prepared from amphibolite greenschist which when examined under the plane polarized light display traceable light brown-coloured features observed to be clumsy and cloudy under the plane light. Mineral count under the cross nicol accounts for biotite (21.31%), quartz (22.95%) and muscovite (50.81%) while other accessory minerals including hornblende accounts for about 5% of the total mineral assemblage that make up the rock composition under thin section. The bluish green suggests the presence of actinolite which is Fe rich. Actinolite is noted to exhibit moderate birefringence, moderate relief and up to the II Order. This mineral is very common in low grade metamorphic rocks. They are known to be characterized by elongated crystals, weak colours. However, the rock under thin section can be described to be highly mineralized as it was also spotted to be dominant with green-coloured minerals confirming it as a greenschist amphibole.



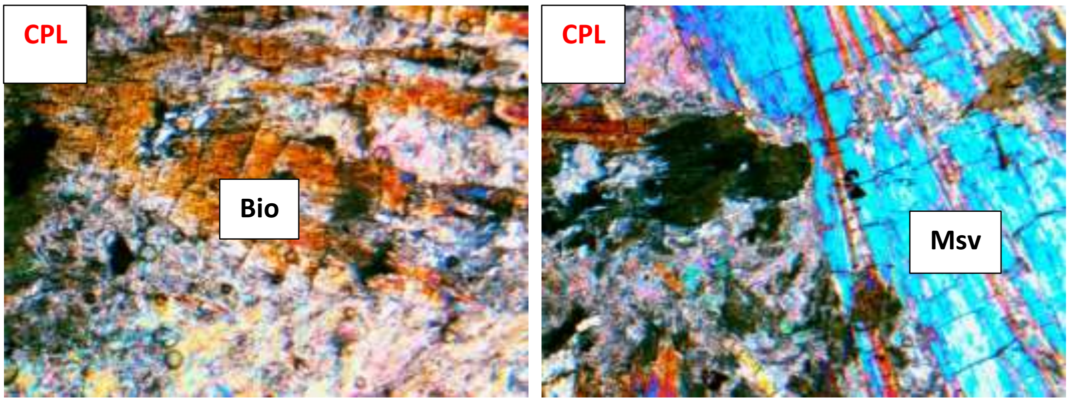
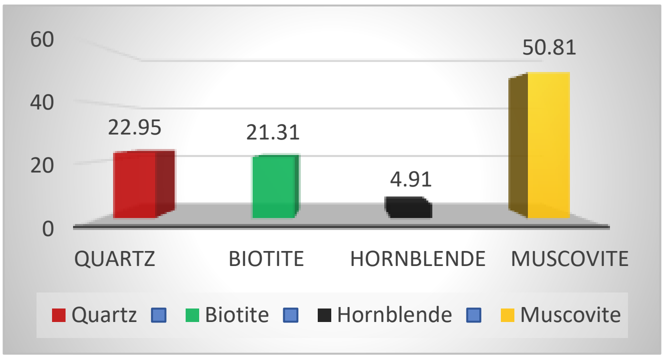



Plate 10: Photomicrograph of amphibolite greenschist under PPL and CPL showing its mineral assemblages. Magnification × 10

| **MODAL ANALYSIS<br>Slide 6 (Amphibolite) Ajaba** | |
|---|---|
| **Minerals** | **Composition (%)** |
| Muscovite | 50.81 |
| Biotite | 21.31 |
| Hornblende | 4.91 |
| Quartz | 22.95 |
| **Total** | **99.98** |




**GEOCHEMISTRY: Geochemical Studies**

**Table 1: Selected rock samples from the study area for Geochemical Analysis**

| Sample ID | Location | Latitude | Longitude | Rock Type | Texture | Structure | Mineralogy |
|---|---|---|---|---|---|---|---|
| S1 | Ayegunle | 7°55'19.4" | 04°56'59.2" | Quartzite | Medium to fine grained | Planar surface, fracture and lineation. | Quartz, Biotite, Plagioclase, Feldspar |
| S2 | Ayegunle | 7°55'20.4" | 04°56'59.5" | Quartzite | Medium to fine grained | Planar surface, fracture and lineation. | Quartz, Biotite, Plagioclase, Feldspar |
| S3 | Obasinkin | 7°57'02.0" | 04°57'35.8" | Quartzite | Medium to fine grained | Foliation, fracture, fluid inclusion | Quartz, Feldspar, Biotite |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S4 | Ayegunle | 7°55'15.8" | 04°56'59.2" | Quartzite | Medium to fine grained | Planar surface, Fracture, lineation | Quartz, Feldspar, Biotite, Plagioclase. |
| S5 | Ila Town | 8°00'02.0" | 04°52'40.5" | Quartzite(smoky) | Medium to fine grained | Planar surface, Quartz vein, Planar bedding, lineation. | Quartz, Feldspar, Plagioclase and accessory minerals. |
| S6 | Aba BabaEko | 8°00'26.7" | 04°56'38.6" | Granite Gneiss | Medium to fine grained | Planar surfaces, fracture, foliation. | Biotite, Quartz, Feldspar and accessory minerals. |
| S7 | Aba Kajola | 8°00'21.8" | 04°56'47.8" | Granite Gneiss | Medium to fine grained | Lineation, Planar surfaces, | Quartz, Biotite, Feldspar. |
| S8 | Oke Ila | 7°56'26.7" | 04°57'50.0" | Quartzite | Medium to fine grained | Foliation, Planar bedding | Quartz, Biotite, Feldspar. |
| S9 | Aba Paanu | 7°59'41.9" | 04°56'39.1" | Granite Gneiss | Medium to fine grained | Lineation, Planar Surfaces. | Quartz, Biotite, Feldspar. |
| S10 | Ila Orangun | 8°01'33.3" | 04°53'57.9" | Quartzite (Smoky) | Medium to fine grained | Cracks, fractures, solution holes | Quartz, Biotite, Feldspar, mica, muscovite. |
| S11 | Obasinkin | 8°01'33.3" | 04°53'57.9" | Quartzite | Medium to fine grained | Lineation, Foliation, Planar surfaces, Fractures. | Quartz, Biotite, Feldspar, Plagioclase |
| S12 | Aba Alagemo | 7°58'39.4" | 04°57'24.7" | Quartzite | Medium to fine grained | Fracturing, Planar surface. | Quartz, Feldspar, Biotite. |
| S13 | Obasinkin | 7°56'38.2" | 04°56'47.5" | Pegmatite | Medium to coarse grained | Quartz vein, Solution holes, | Quartz, Feldspar, Biotite, Muscovite. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S14 | Obasinkin | 7°57'36.4" | 04°56'07.1" | Granite Gneiss | Medium to fine grained | Lineation, Fracture. | Quartz, Biotite, Feldspar. |
| S15 | Aba Alagemo | 7°58'05.3" | 04°58'05.6" | Granite Gneiss | Medium to fine grained | Foliation, Planar bedding | Quartz, Feldspar, Biotite. |
| S16 | Obasinkin | 7°56'39.4" | 04°56'48.5" | Pegmatite | Medium to coarse grained | Quartz vein, Solution holes, | Quartz, Feldspar, Biotite, Muscovite. |
| S17 | Obasinkin | 7°56'40.0" | 04°56'50.0" | Pegmatite | Medium to coarse grained | Quartz vein, Solution holes, | Quartz, Feldspar, Biotite, Muscovite. |
| S18 | Aba Oyi | 7°58'20.8" | 04°58'06.2" | Granite Gneiss | Medium to fine grained | Planar surface, Lineation. | Biotite, Quartz, Feldspar, |
| S19 | Aba Paanu | 7°59'41.2" | 04°56'40.6" | Granite Gneiss | Medium to fine grained | Planar surface, Lineation. | Quartz, Biotite, Feldspar. |
| S20 | Oke Ila | 7°57'47.9" | 04°59'33.5" | Porphyritic Granite | Medium to coarse grained | Lineation, Planar surface, Joint. | Quartz, Biotite, Feldspar. |

Results of geochemical analyses are presented in a manner that they show the concentration of each major element in (wt) % and trace elements in parts per million (ppm) for each of the rocks. Geochemical data acquired was found useful in the discussion and interpretation of major oxides and trace elements geochemistry as well as producing relevant geochemical and statistical plots which are well discussed and presented below (Table 2):

**Table 2: Major Elements Composition Analysed in Rock Samples (%)**

| Sample ID | Location | Rock Type | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | $Cr_2O_3$ | MnO | $Fe_2O_3$ | $Na_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | Ayegunle | Quartzite | 0.00017 | 2.79 | 73.5 | 0.14 | 0.169 | 0.031 | 0.00017 | 0.00014 | 0.022 | 23.22 | 0.08 | 0.05 |
| S2 | Ayegunle | Quartzite | 0.00017 | 2.98 | 71 | 0.17 | 0.46 | 0.029 | 0.00017 | 0.031 | 0.056 | 24.8 | 0.12 | 0.36 |
| S3 | Obasinkin | Quartzite | 0.00016 | 2.85 | 72 | 0.058 | 0.194 | 0.036 | 0.00016 | 0.00015 | 0.059 | 24.4 | 0.09 | 0.4 |
| S4 | Ayegunle | Quartzite | 0.00016 | 1.34 | 79.2 | 0.14 | 0.09 | 0.024 | 0.00016 | 0.031 | 0.39 | 18.3 | 0.13 | 3.8 |
| S5 | Ila | Quartzite | 0.00016 | 1.52 | 82.5 | 0.19 | 0.16 | 0.018 | 0.00016 | 0.0016 | 0.025 | 15.3 | 0.11 | 0.2 |
| S6 | Aba Baba Eko | Granite Gneiss | 0.00016 | 3.5 | 77 | 0.24 | 3.19 | 0.17 | 0.00016 | 0.0016 | 0.018 | 16 | 0.049 | 0.00001 |
| S7 | Aba Baba Eko | Granite Gneiss | 0.00016 | 0.32 | 71 | 0.22 | 3.87 | 0.23 | 0.084 | 0.0045 | 0.086 | 24.3 | 0.12 | 0.00001 |
| S8 | Oke Ila | Quartzite | 0.00016 | 3.06 | 78 | 0.11 | 0.29 | 0.0096 | 0.00016 | 0.022 | 0.00013 | 18.9 | 0.03 | 0.00001 |
| S9 | Aba Paanu | Granite Gneiss | 0.00016 | 6.69 | 72 | 0.17 | 4.35 | 0.11 | 0.00016 | 0.00014 | 0.00012 | 16 | 0.84 | 0.00001 |
| S10 | Ila | Quartzite | 0.00017 | 1.14 | 84 | 0.19 | 0.013 | 0.0074 | 0.00016 | 0.016 | 0.05 | 21.1 | 0.09 | 0.00001 |

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**Table 2: Cont……. (ppm)**

| Sample ID | Location | Rock Type | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | $Cr_2O_3$ | MnO | $Fe_2O_3$ | $Na_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S11 | Obasinkin | Quartzite | 0.06 | 1.83 | 83 | 0.35 | 0.066 | 0.0001 | 0.0001 | 0.00014 | 0.00012 | 14.1 | 0.11 | 0.5 |
| S12 | Aba Alagemo | Quartzite | 0.00016 | 2.18 | 81 | 0.18 | 0.13 | 0.014 | 0.00016 | 0.0014 | 0.0037 | 16.2 | 0.11 | 0.2 |
| S13 | Obasinkin | Pegmatite | 0.00016 | 5.62 | 83 | 0.16 | 2.04 | 0.1 | 0.00016 | 0.00014 | 0.00012 | 9.27 | 0.05 | 0.0001 |
| S14 | Obasinkin | Granite Gneiss | 0.00016 | 4.53 | 76 | 0.13 | 4.15 | 0.00016 | 0.00016 | 0.00014 | 0.05 | 14.8 | 0.12 | 0.3 |
| S15 | Aba Alagemo | Granite Gneiss | 0.00016 | 5.52 | 69 | 0.25 | 3.79 | 0.28 | 0.14 | 0.00014 | 0.12 | 20.4 | 0.097 | 0.41 |
| S16 | Obasinkin | Pegmatite | 0.00016 | 4.24 | 81 | 0.21 | 0.64 | 0.091 | 0.00016 | 0.00014 | 0.00012 | 13.9 | 0.004 | 0.00001 |
| S17 | Obasinkin | Pegmatite | 0.00016 | 4.25 | 79 | 0.25 | 6.49 | 0.068 | 0.00016 | 0.00014 | 0.00012 | 10.1 | 0.05 | 0.00001 |
| S18 | Aba Oyi Aduni | Granite Gneiss | 0.00016 | 6.18 | 67 | 0.14 | 3.39 | 0.32 | 0.09 | 0.00014 | 0.14 | 22.3 | 0.11 | 0.4 |
| S19 | Aba Paanu | Granite Gneiss | 0.00016 | 2.11 | 83 | 0.12 | 0.15 | 0.014 | 0.00016 | 0.012 | 0.00012 | 14.6 | 0.266 | 0.00001 |
| S20 | Oke Ila | Porphyritic Granite | 0.00016 | 5.48 | 68 | 0.15 | 3.73 | 0.29 | 0.00016 | 0.0014 | 0.15 | 21.8 | 0.013 | 0.4 |

**Major Oxides Geochemistry**

From the results presented in the table 2 above the major oxides determined include MgO, $Al_2O_3$, $SiO_2$, $P_2O_5$, $K_2O$, CaO, $TiO_2$, $Cr_2O_3$, MnO, $Fe_2O_3$ and $Na_2O$. Loss of Ignition values (LOI) have values less than 1 except in sample 4 being quartzite from Ayegunle which recorded LOI value of 3.8. These oxides were observed to occur in various amounts of concentrations in each of the pulverized rocks with values determined in percentage weight(w%). From the data, the compositional range of the various oxides show MgO (0.00016 – 6.66 wt%), $Al_2O_3$ (0.32 - 6.69 wt%), $SiO_2$ (40 – 92 wt%), $P_2O_5$ (0.058 - 0.35 wt%), $K_2O$ (0.00012 - 6.49 wt%), CaO (0.00016 - 26.24 wt%), $TiO_2$ (0.00016 - 0.3 wt%), $Cr_2O_3$ (0.00014 - 0.21 wt%), MnO (0.00012 - 0.39 wt%), $Fe_2O_3$ (4.99 - 32.0 wt%) and $Na_2O$ (0.004 - 1.62 wt%). It was observed that $SiO_2$, $Fe_2O_3$ and $Al_2O_3$ show high concentrations while other major oxides were observed to occur in moderate and very low concentrations. The result justifies the geochemical properties of quartzites which have been described to commonly contain in excess of 95% $SiO_2$ (Wedepohl, 1978). On the other hands the high concentration of $Fe_2O_3$ implied that rocks within the study area are ferrugenized as they contain iron -rich minerals. The high concentration of $Al_2O_3$ may be linked to the effect of high-pressure melting of low to moderate degrees of Iherzolites which is capable of generally producing melts with high $Al_2O_3$ and low $Cr_2O_3$ which best describes the major oxides geochemistry of these rocks.

**Major Oxides Ratio**

Major oxides ratio was considered for key geochemical data results obtained in each of the pulverized rock samples. These include oxide ratio for alumina and the alkali as they are very vital in the proper classification of the rocks. The alumina oxide includes $Al_2O_3$ while the alkali oxide includes $Na_2O$, CaO and $K_2O$. Hence the ratio of these major oxides was determined using $Na_2O/K_2O$, $Al_2O_3/Na_2O+CaO+K_2O$ and $Na_2O+CaO+K_2O/Al_2O_3$ while the excess of $Al_2O_3$ over $Na_2O+CaO+K_2O$ was also determined in ascertaining the exact ratio in which the oxides occur per sample. The table below show the major oxide ratios as determined for the various samples with values in wt% (Table 3).

Table 3: Major Elements Analysed in Rock Samples (wt%)

| SAMPLE ID | Rock Type | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | $Cr_2O_3$ | MnO | $Fe_2O_3$ | $Na_2O$ | SUM | $Na_2O/K_2O$ | $Al_2O_3/Na_2O+CaO+K_2O$ | Excess of $Al_2O_3$ over $Na_2O+CaO+K_2O$ | $Na_2O+CaO+K_2O/Al_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 Ayegunle | Quartzite | 0.00017 | 2.79 | 73.5 | 0.14 | 0.169 | 0.031 | 0.00017 | 0.00014 | 0.022 | 23.22 | 0.08 | 99.9 | 0.47 | 9.9 | 2.51 | 0.1 |
| S2 Ayegunle | Quartzite | 0.00017 | 2.98 | 71 | 0.17 | 0.46 | 0.029 | 0.00017 | 0.031 | 0.056 | 24.8 | 0.12 | 99.6 | 0.26 | 4.89 | 2.37 | 0.2 |
| S3 Obasinkin | Quartzite | 0.00016 | 2.85 | 72 | 0.058 | 0.194 | 0.036 | 0.00016 | 0.00015 | 0.059 | 24.4 | 0.09 | 99.6 | 0.46 | 8.9 | 2.53 | 0.1 |
| S4 Aiyegunle | Quartzite | 0.00016 | 1.34 | 79.2 | 0.14 | 0.09 | 0.024 | 0.00016 | 0.031 | 0.39 | 18.3 | 0.13 | 99.6 | 1.4 | 5.58 | 1.1 | 0.18 |
| S5 Ila Orangun | Quartzite | 0.00016 | 1.52 | 82.5 | 0.19 | 0.16 | 0.018 | 0.00016 | 0.0016 | 0.025 | 15.3 | 0.11 | 99.8 | 0.69 | 5.24 | 1.23 | 0.19 |
| S6 Aba Baba Eko | Granite Gneiss | 0.00016 | 3.5 | 77 | 0.24 | 3.19 | 0.17 | 0.00016 | 0.0016 | 0.018 | 16 | 0.049 | 100.1 | 0.015 | 1.02 | 0.09 | 0.97 |
| S7 Aba Kajola | Granite Gneiss | 0.00016 | 0.32 | 71 | 0.22 | 3.87 | 0.23 | 0.084 | 0.0045 | 0.086 | 24.3 | 0.12 | 100.2 | 0.03 | 0.08 | -3.9 | 13.2 |
| S8 Oke Ila | Quartzite | 0.00016 | 3.06 | 78 | 0.11 | 0.29 | 0.0096 | 0.00016 | 0.022 | 0.00013 | 18.9 | 0.03 | 100.4 | 0.1 | 9.27 | 2.73 | 0.11 |
| S9 Aba Paanu | Granite Gneiss | 0.00016 | 6.69 | 72 | 0.17 | 4.35 | 0.11 | 0.00016 | 0.00014 | 0.00012 | 16 | 0.84 | 100.1 | 0.19 | 1.26 | 1.39 | 0.79 |
| S10 Ila Orangun | Quartzite | 0.00017 | 1.14 | 77 | 0.19 | 0.013 | 0.0074 | 0.00016 | 0.016 | 0.05 | 21.1 | 0.09 | 99.6 | 6.92 | 10.4 | 1.03 | 0.09 |

From Table 3 above, considering the $Na_2O/K_2O$ ratio for the rock samples result show that the ratio of sodium oxide to potassium oxide ($Na_2O/K_2O$) is generally low for most of the analysed rock samples. Results show that the only values above 5wt% for $Na_2O/K_2O$ ratio was only recorded in samples 10(6.92wt%), 23(5.79wt%) and 40(9.3wt%). The alumina ($Al_2O_3$) and the summation of the alkali ratio ($Na_2O+CaO+K_2O$) expressed mathematically as $Al_2O_3/Na_2O+CaO+K_2O$ show greater values of $Al_2O_3$ in most cases as observed in some rock samples. Where the $Al_2O_3$ exceeds the alkali in the ratio it implies that the rocks are peraluminous and metaluminous where the alkali exceeds the alumina. However low values of MgO, CaO as well as low ratio of $Na_2O/K_2O$ is a clear indication that the study area is fertile and peraluminous (Cerny, et al; 1981 and Longstaff, 1982). To further justify the geochemical attributes and characters of the rocks as to either peraluminous or metaluminous some geochemical classification plots were produced to include the FeOt/(FeOt+MgO) versus $SiO_2$, A/NK versus ASI, Molar $Na_2O$ -$Al_2O_3$- $K_2O$, A/CNK-A/NK (Shand, 1943) and AFM ( Irvine and Baragar, 1971) plots among others (Figures 16,17 and 18).

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| SAMPLE ID | Rock Type | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | $Cr_2O_3$ | MnO | $Fe_2O_3$ | $Na_2O$ | SUM | $Na_2O/K_2O$ | $Al_2O_3/Na_2O+CaO+K_2O$ | Excess of $Al_2O_3$ over $Na_2O+CaO+K_2O$ | $Na_2O+CaO+K_2O/Al_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S11 Obasinkin** | Quartzite | 0.06 | 1.83 | 83 | 0.35 | 0.066 | 0.0001 | 0.0001 | 0.00014 | 0.00012 | 14.1 | 0.11 | 99.5 | 1.67 | 10.1 | 1.65 | 0.09 |
| **S12 Aba Alagemo** | Quartzite | 0.00016 | 2.18 | 81 | 0.18 | 0.13 | 0.014 | 0.00016 | 0.0014 | 0.0037 | 16.2 | 0.11 | 99.8 | 0.85 | 8.72 | 1.93 | 0.11 |
| **S13 Obasinkin** | Pegmatite | 0.00016 | 5.62 | 83 | 0.16 | 2.04 | 0.1 | 0.00016 | 0.00014 | 0.00012 | 9.27 | 0.05 | 100.2 | 0.025 | 2.57 | 3.43 | 0.39 |
| **S14 Obasinkin** | Granite Gneiss | 0.00016 | 4.53 | 76 | 0.13 | 4.15 | 0.00016 | 0.00016 | 0.00014 | 0.05 | 14.8 | 0.12 | 99.7 | 0.029 | 1.06 | 0.26 | 0.94 |
| **S15 Aba Alagemo** | Granite Gneiss | 0.00016 | 5.52 | 69 | 0.25 | 3.79 | 0.28 | 0.14 | 0.00014 | 0.12 | 20.4 | 0.097 | 99.5 | 0.026 | 1.35 | 1.35 | 0.76 |
| **S16 Obasinkin** | Pegmatite | 0.00016 | 4.24 | 81 | 0.21 | 0.64 | 0.091 | 0.00016 | 0.00014 | 0.00012 | 13.9 | 0.004 | 100 | 0.006 | 5.77 | 3.5 | 0.17 |
| **S17 Obasinkin** | Pegmatite | 0.00016 | 4.25 | 79 | 0.25 | 6.49 | 0.068 | 0.00016 | 0.00014 | 0.00012 | 10.1 | 0.05 | 100.2 | 0.008 | 0.64 | -2.36 | 1.56 |
| **S18 Aba oyiaduni** | Granite Gneiss | 0.00016 | 6.18 | 67 | 0.14 | 3.39 | 0.32 | 0.09 | 0.00014 | 0.14 | 22.3 | 0.11 | 99.6 | 0.032 | 1.62 | 2.36 | 0.62 |
| **S19 Aba Paanu** | Granite Gneiss | 0.00016 | 2.11 | 83 | 0.12 | 0.15 | 0.014 | 0.00016 | 0.012 | 0.00012 | 14.6 | 0.266 | 100.2 | 0.56 | 4.91 | 1.68 | 0.2 |
| **S20 Oke Ila** | Porphyritic Granite | 0.00016 | 5.48 | 68 | 0.15 | 3.73 | 0.29 | 0.00016 | 0.0014 | 0.15 | 21.8 | 0.013 | 99.6 | 0.003 | 1.36 | 1.45 | 0.74 |

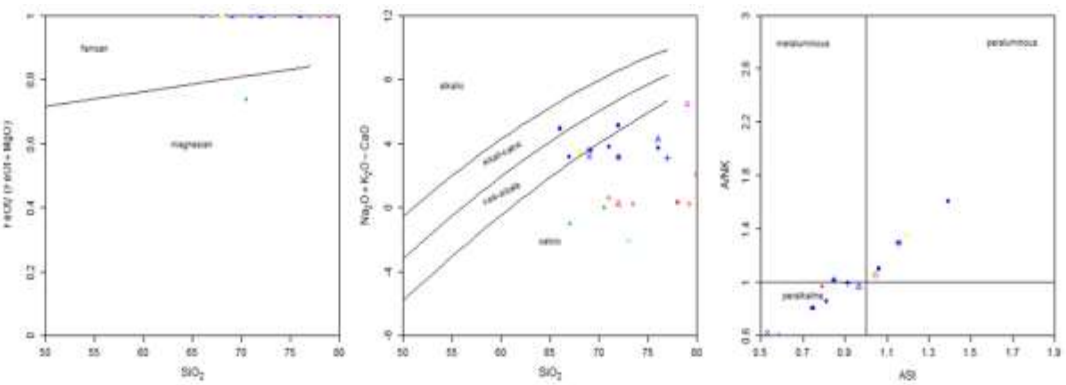


**Figure 12: Granite tectonic classification plot (Frost et al., 2001)**

The plot of FeOt/(FeOt+MgO) versus $SiO_2$ shows a clearly defined discrimination between rocks classified geochemically as being Ferroan and Magnesian considering the iron and magnesium oxides values (Figure 12). Ferroan (Fe-enriched) granites are closely associated with conditions of limited availability of $H_2O$ and low oxygen fugacity during partial melting of their source rocks (Frost et al., 2001) as well as the crystallization of anhydrous silicates. However, from the plot it is clearly noted that a few of the rocks falls within the magnesian group which appear below the line. Prominent lithology within the area which falls in this category are the amphibolite greenschist while falling into section above the line are the ferroan group as most of the rock types identified within the study area falls within the ferroan group.

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The A/NK versus ASI plot confirms that the rocks fall within both the peralkaline metaluminous and peraluminous sections of the plot. Hence, further establish a combination of both metaluminous and peraluminous characters of the rocks. Chappell and White (1974) in their geochemical classification of granitic rocks recognized two major types of granitoids which are identified as the I-type metaluminous formed from a mafic metaigneous source and the S-type peraluminous formed from the melting of metasedimentary rocks. Rock types such as granite gneiss in Aba Oyi, Aba Paanu as well as quartzites in Aba Paanu, Aba Alagemo, Aba Agbonore and porphyritic granites in Oke Ila exhibit the peraluminous character while granite gneisses from Aba Baba Eko, Aba Oyi Aduni and quartzites from Aba Moro Osho and pegmatites from Aba Agbonore exhibit metaluminous characters.The Molar $Na_2O$-$Al_2O_3$- $K_2O$ plot (Figure 13) further prove the excess of $Al_2O_3$ over the alkali $Na_2O$ and $K_2O$ in this case while few rocks recorded low $Al_2O_3$ hence having deficiency in the $Al_2O_3$ contents which defines the metaluminous or peralkaline metaluminous geochemical character. Very few were seen to be identified as ultrapotassic (high potassium) and perpotassic (low potassium) contents.

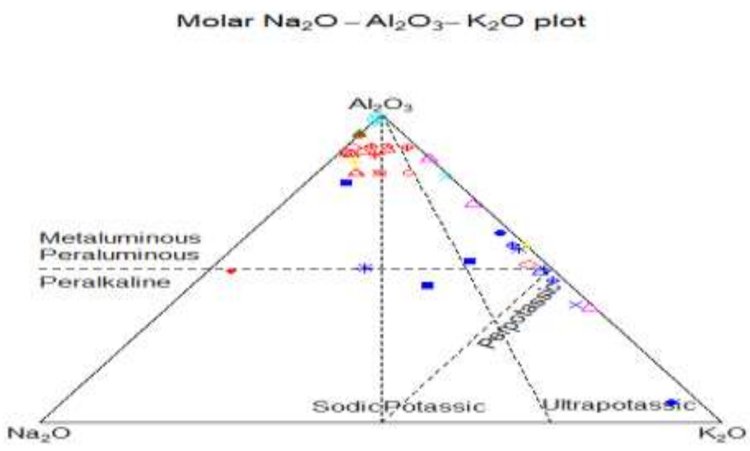


**Figure 13: Molar $Na_2O$ -$Al_2O_3$- $K_2O$ Classification Plot** (Source: Hastie et al,2007 GCDKit)

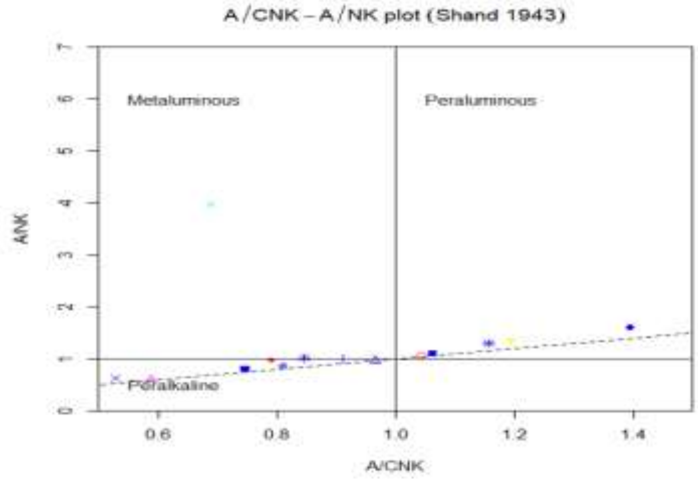


**Figure 14: A/CNK-A/NK Classification Plot (Shand, 1943)**

A/CNK-A/NK classification plot (Shand, 1943) was also considered for the geochemical classification of rock types in the study area (Figure 14). From the plot the rocks exhibit peraluminous and peralkaline metaluminous characters as they are seen to be found falling within the boundaries of both geochemical attributes. However, the plot shows predominantly a peraluminous character in the rocks as most of the rock types have excess of $Al_2O_3$ than the alkaline. The AFM classification plot( Irvine and Baragar, 1971) which was produced to be able to discriminate between Calc-alkaline series and the tholeiitic series fields for rocks in the study area. The AFM plot by nomenclature depits the relationship between the Alkali ($Na_2O$+$K_2O$), Iron oxide($Fe_2O_3$) and Magnessian oxide (MgO) using a traingular plot. However from the plot, the parabolic line or curve at the centre of the triangle clearly distinguish between the tholeiitic field and the calc-alkaline field. The distribution on the plots show that the magma from which the rocks were formed are from the oceanic crust of the tholeitic environments(Figure 15).

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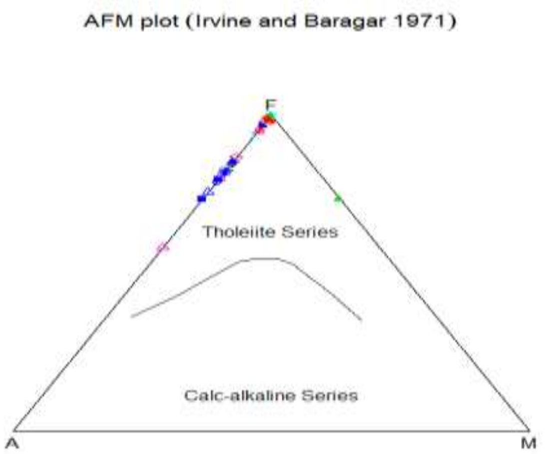


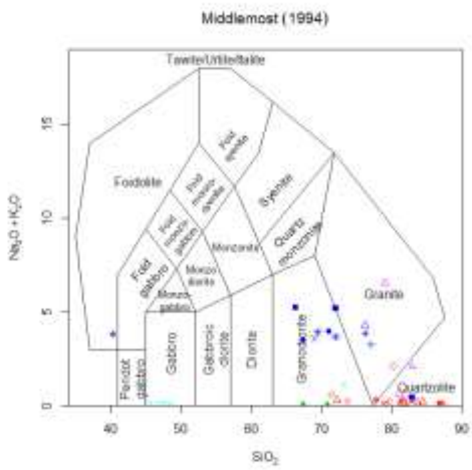


**Figure 15: AFM plot( Irvine and Baragar, 1971)** **Figure 16: Middlemost (1994) plot**

Harker variation diagrams were plotted to show the relationship between $SiO_2$ and other major oxides such as $Al_2O_3$, CaO, $Cr_2O_3$, $Fe_2O_3$, $K_2O$, MgO, MnO, $Na_2O$, $P_2O_5$ and $TiO_2$. as obtained from geochemical analysis of the samples. The use of the Harker diagram clearly shows that the magma that produce the rocks are from different sources (Figure 17).

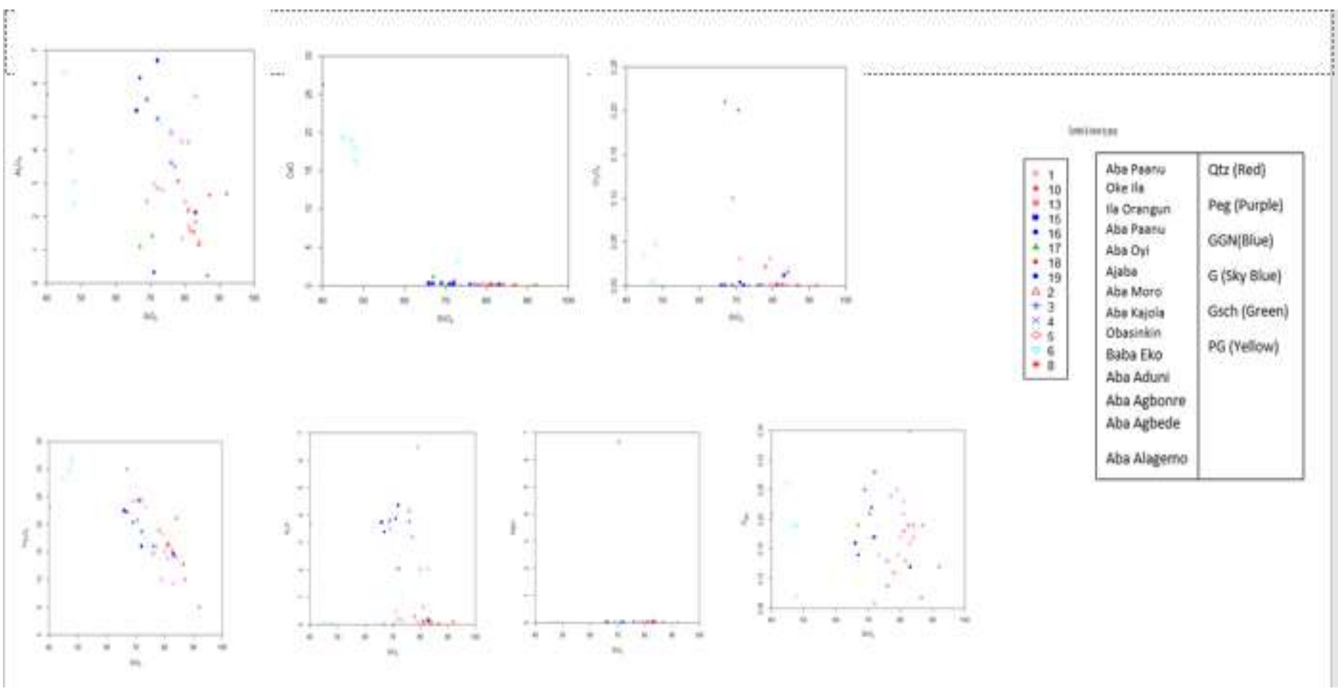


**Figure 17: Harker variation diagrams showing $SiO_2$ versus other major Oxides**

## Trace Elements Geochemistry

Table 4: Trace Elements Analysed in Rock Samples (ppm)

| Sample | Rock Type | Ag | As | B | Ba | Be | Cd | Co | Cr | Cu | Hg | Mo | Ni | P | Pb | Rb | Nb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 Aiyegunle | Quartzite | 0.076 | 0.06 | 0.05 | 0.02 | 0.06 | 0.07 | 0.014 | 0.14 | 0.102 | 0.46 | 1.16 | 0.092 | 3 | 0.03 | 0.07 | 0.0083 |
| S2 Aiyegunle | Quartzite | 0.074 | 0.04 | 0.03 | 0.032 | 0.04 | 0.05 | 0.112 | 0.016 | 0.162 | 0.55 | 1.28 | 0.08 | 2.86 | 0.06 | 0.062 | 0.00014 |
| S3 Obasinkin | Quartzite | 0.077 | 0.077 | 0.14 | 0.031 | 0.071 | 0.084 | 0.113 | 0.012 | 0.106 | 0.46 | 1.138 | 0.094 | 2.66 | 0.027 | 0.067 | 0.00014 |
| S4 Aiyegunle | Quartzite | 0.077 | 0.06 | 0.04 | 0.026 | 0.062 | 0.04 | 0.06 | 0.085 | 0.104 | 0.38 | 1.16 | 0.08 | 2 | 0.82 | 0.08 | 0.00014 |
| S5 Ila-Orangun | Quartzite | 0.078 | 0.09 | 0.038 | 0.05 | 0.053 | 0.02 | 0.18 | 0.062 | 0.103 | 0.65 | 1.17 | 0.06 | 2.82 | 0.74 | 0.065 | 0.00014 |
| S6 Aba Baba-Eko | Granite Gneiss | 0.078 | 0.059 | 0.049 | 0.06 | 0.072 | 0.085 | 0.116 | 0.083 | 0.117 | 0.253 | 0.859 | 0.112 | 3.938 | 0.041 | 0.019 | 0.1 |
| S7 Aba Kajola | Granite Gneiss | 0.072 | 0.06 | 0.046 | 0.04 | 0.06 | 0.06 | 0.116 | 0.053 | 0.116 | 0.42 | 0.92 | 0.116 | 3.94 | 0.08 | 0.025 | 0.066 |
| S8 Oke Ila | Quartzite | 0.062 | 0.09 | 0.048 | 0.03 | 0.05 | 0.04 | 0.118 | 0.06 | 0.118 | 0.78 | 1.16 | 0.96 | 2.76 | 0.04 | 0.07 | 0.035 |
| S9 Aba Paanu | Granite Gneiss | 0.078 | 0.06 | 0.046 | 0.04 | 0.04 | 0.09 | 0.116 | 0.07 | 0.25 | 0.65 | 0.82 | 0.116 | 3.62 | 0.06 | 0.08 | 0.0017 |
| S10 Ila Orangun | Quartzite | 0.065 | 0.08 | 0.038 | 0.07 | 0.06 | 0.06 | 0.114 | 0.76 | 0.116 | 0.66 | 1.18 | 0.94 | 2.65 | 0.07 | 0.04 | 0.0014 |
| S11 Obasinkin | Quartzite | 0.08 | 0.06 | 0.017 | 0.06 | 0.07 | 0.08 | 0.117 | 0.08 | 0.182 | 0.82 | 2 | 1.2 | 3 | 0.25 | 0.82 | 0.00014 |
| S12 Aba Alagemo | Quartzite | 0.082 | 0.04 | 0.02 | 0.06 | 0.04 | 0.07 | 0.113 | 0.06 | 0.35 | 0.89 | 0.45 | 1.18 | 2.65 | 0.267 | 0.07 | 0.009 |
| S13 Obasinkin | Pegmatite | 0.07 | 0.08 | 0.025 | 0.08 | 0.08 | 0.08 | 0.115 | 0.09 | 0.115 | 0.46 | 0.706 | 0.06 | 1.96 | 0.03 | 0.092 | 0.023 |
| S14 Obasinkin | Granite Gneiss | 0.074 | 0.04 | 0.023 | 0.04 | 0.06 | 0.05 | 0.115 | 0.06 | 0.28 | 0.35 | 0.65 | 0.18 | 2.62 | 0.04 | 0.018 | 0.036 |
| S15 Aba Alagemo | Granite Gneiss | 0.072 | 0.03 | 0.024 | 0.03 | 0.04 | 0.07 | 0.118 | 0.08 | 0.115 | 0.42 | 0.86 | 0.09 | 1.86 | 0.06 | 0.024 | 0.13 |
| S16 Obasinkin | Pegmatite | 0.078 | 0.021 | 0.13 | 0.023 | 0.073 | 0.088 | 0.116 | 0.063 | 0.19 | 0.222 | 0.709 | 0.107 | 1.888 | 0.038 | 0.063 | 0.00014 |
| S17 Obasinkin | Pegmatite | 0.076 | 0.08 | 0.014 | 0.04 | 0.06 | 0.082 | 0.117 | 0.076 | 0.119 | 0.04 | 0.85 | 0.182 | 2.06 | 0.08 | 0.066 | 0.00014 |
| S18 Abaoyi Adunni | Granite Gneiss | 0.56 | 0.07 | 0.012 | 0.06 | 0.07 | 0.083 | 0.18 | 0.072 | 0.116 | 0.66 | 0.65 | 0.09 | 1.82 | 0.041 | 0.12 | 0.045 |
| S19 Aba Paanu | Granite Gneiss | 0.08 | 0.08 | 0.014 | 0.07 | 0.04 | 0.04 | 0.11 | 0.072 | 0.115 | 0.69 | 0.92 | 0.06 | 3.62 | 0.08 | 0.018 | 0.00014 |
| S20 Oke Ila | Porphyritic Granite | 0.078 | 0.018 | 0.018 | 0.069 | 0.072 | 0.082 | 0.115 | 0.077 | 0.116 | 0.206 | 0.631 | 0.107 | 4.119 | -0.035 | 0.013 | 0.076 |

| Sample | Rock Type | W | Au | Sn | Sb | U | Zn | V | Ti | Tl | Ga | Cs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S1** Aiyegunle | Quartzite | 0.21 | 0.0011 | 4.5 | 3.79 | 0.065 | 0.36 | 0.08 | 2.4 | 0.062 | 0.06 | 0.6 |
| **S2** Aiyegunle | Quartzite | 0.00013 | 0.0004 | 3.82 | 3.72 | 0.07 | 0.38 | 0.05 | 3.55 | 0.045 | 0.08 | 0.08 |
| **S3** Obasinkin | Quartzite | 0.034 | 0.001 | 3.62 | 3.64 | 0.045 | 0.34 | 0.06 | 2.285 | 0.032 | 0.079 | 0.047 |
| **S4** Aiyegunle | Quartzite | 0.041 | 0.0001 | 4.74 | 4.67 | 0.5 | 0.42 | 0.06 | 2.46 | 0.065 | 0.92 | 0.05 |
| **S5** Ila-Orangun | Quartzite | 0.00013 | 0.0001 | 5.94 | 5.42 | 0.06 | 0.55 | 0.02 | 3.08 | 0.07 | 0.08 | 0.04 |
| **S6** Aba Baba-Eko | Granite Gneiss | 0.11 | 0.0001 | 3.24 | 2.91 | 0.045 | 0.419 | 0.099 | 15.15 | 0.03 | 0.07 | 0.048 |
| **S7** Aba Kajola | Granite Gneiss | 0.20 | 0.0001 | 3.48 | 3.47 | 0.06 | 0.06 | 0.02 | 13 | 0.06 | 0.08 | 0.09 |
| **S8** Oke Ila | Quartzite | 0.00012 | 0.0001 | 4.49 | 4.15 | 0.07 | 0.02 | 0.06 | 2.65 | 0.09 | 0.07 | 0.08 |
| **S9** Aba Paanu | Granite Gneiss | 0.00013 | 0.0001 | 4.21 | 3.84 | 0.046 | 0.08 | 0.26 | 10.06 | 0.04 | 0.09 | 0.06 |
| **S10** Ila-Orangun | Quartzite | 0.00013 | 0.0001 | 5.11 | 4.59 | 0.06 | 0.15 | 0.34 | 3.42 | 0.06 | 0.86 | 0.09 |
| **S11** Obasinkin | Quartzite | 0.00013 | 0.0001 | 5.82 | 5.19 | 0.082 | 0.52 | 0.08 | 2.66 | 0.09 | 0.77 | 0.08 |
| **S12** Aba Alagemo | Quartzite | 0.00013 | 0.0001 | 4.98 | 4.84 | 0.03 | 0.46 | 0.08 | 2.42 | 0.06 | 0.65 | 0.06 |
| **S13** Obasinkin | Pegmatite | 0.24 | 0.0001 | 5.55 | 5.09 | 0.05 | 0.39 | 0.066 | 0.62 | -0.06 | 0.08 | 0.62 |
| **S14** Obasinkin | Granite Gneiss | 0.00013 | 0.0001 | 4.93 | 4.05 | 0.06 | 0.52 | 0.03 | 12.15 | 0.09 | 0.07 | 0.1 |
| **S15** Aba Alagemo | Granite Gneiss | 0.061 | 0.0001 | 3.82 | 3.59 | 0.06 | 0.46 | 0.07 | 10.6 | 0.06 | 0.06 | 0.63 |
| **S16** Obasinkin | Pegmatite | 0.15 | 0.0001 | 4.54 | 4.27 | 0.042 | 0.384 | 0.097 | 0.655 | 0.029 | 0.086 | 0.051 |
| **S17** Obasinkin | Pegmatite | 0.11 | 0.0001 | 4.88 | 4.27 | 0.08 | 0.42 | 0.08 | 0.72 | 0.04 | 0.08 | 0.53 |
| **S18** Abaoyi Adunni | Granite Gneiss | 0.16 | 0.0001 | 3.23 | 3.06 | 0.16 | 0.82 | 0.2 | 12.5 | 0.06 | 0.06 | 0.04 |
| **S19** Aba Paanu | Granite Gneiss | 0.19 | 0.0001 | 4.71 | 4.39 | 0.02 | 0.84 | 0.35 | 10.6 | 0.082 | 0.06 | 0.05 |
| **S20** Oke Ila | Porphyritic Granite | 0.00013 | 0.00014 | 3.43 | 3.49 | 0.043 | 0.415 | 0.099 | 17.72 | 0.029 | 0.07 | 0.049 |

Trace elements detected from available standards using certified reference materials (CRM) with the ICP-MS machine include Ag, As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, Rb, Nb, W, Au, Sn, Sb, U, Zn, V, Ti, Tl, Ga and Cs. Thus, making a total of 27 trace elements determined with their concentration values in parts per million(ppm). From the range of values obtained for the trace and rare earth elements combined together, it is observed that the values are very low. In most cases, values were seen to be less than 1.0 except for Hg, Mo having values to be approximately 1.0 and P, Sn, Sb and Ti where values are greater than 1.0. The

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compatible elements such as Ni (0.056-1.18) and Cr (0.012-0.47) have very low concentrations. Titanium recorded higher concentrations than vanadium in all the rock samples as the least value for titanium concentration is 0.59 ppm observed in Amphibolite Greenschist. The highest value in concentration for titanium is 17.72 ppm which was observed in porphyritic granites. The concentration of titanium and vanadium are justified by literatures which have established that they are both common in many igneous and metamorphic rocks and sediments and their concentrations detected because of their resistance to weathering while most Titanium bearing minerals are biotites and amphiboles (Scheinost et al.,2022).

**X-Ray Fluorescence Results for Rock Samples Analysed**

Results obtained for the concentrations of these elements in each lithologic type mapped within the study area are presented with their graphical presentations shown in spikes and signatures as the heights of the various spikes or signatures represents the exact content and concentration of each of the elements per sample. The lengths of the various spikes or signatures suggests high, moderate or low concentrations as they fall within detectable limits (Figures 18-23).

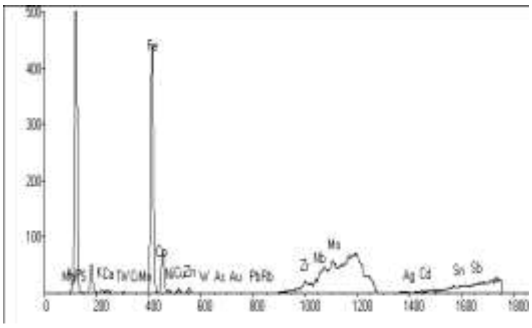

Figure 18: XRF results showing concentration of Elements in Quartzite

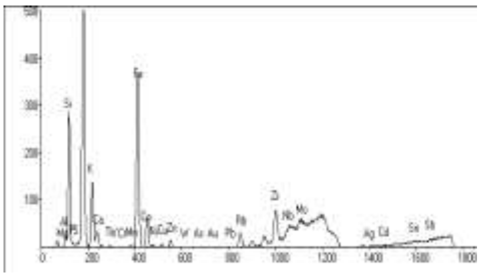

Figure 19: XRF results showing concentrations of elements in Granite Gneiss

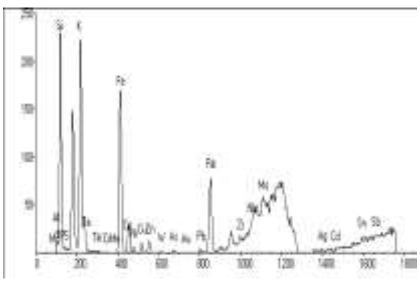

Figure 20: XRF results showing concentrations of elements in Pegmatite

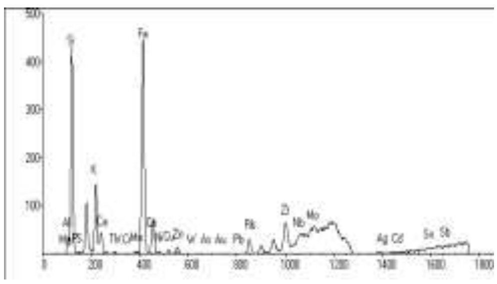

Figure 21: XRF results showing concentrations of elements in Pegmatite

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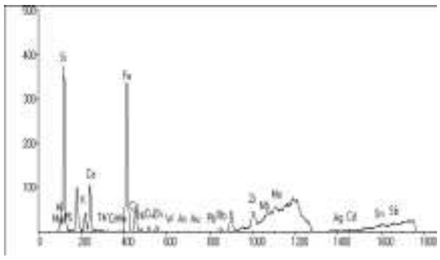

Figure 22: XRF results showing concentrations of elements in Granite

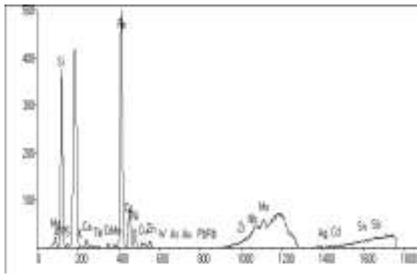

Figure 23: XRF results showing concentrations of elements in Amphibolite

**Statistical Analyses**

Correlation of these variables which are trace elements adopts the Pearson Correlation Coefficient method (Table 5). A total of seventeen (17) variables were considered for correlation which include trace elements such as Ag, As, Ba, Cd, Co, Cr, Cu, Ni, Pb, Rb, U, Zn, Fe, Ti, V, Sr and Mn analysed in the pulverised rock samples. From the correlation table, the results of correlation coefficient between Ag and As using Pearson Correlation Coefficient is 0.164 while the significant value for correlation between the pair is 0.311. For Ag and Ba, Pearson Correlation shows 0.116 and significant values for correlation of the pair of variables is 0.475. For Ag and Cd Pearson correlation value of 0.192 and significant values for correlation for the pair is 0.235. For Co and Cd Pearson correlation values is 0.283 and significant values for correlation(2-talled) is 0.077. However, other results show Cu and Cr (0.162,0.319), Ba and Ag (0.116,0.475), Cd and As (-0.018, 0.913), Co and Ba (0.157,0.333), Cr and Cd (-0.020,0.901), Cu and Co (0.290,0.069), Ni and Cr (0.389,0.013), Cd and Ag (0.192,0.235), Co and As (0.134,0.409), Cr and Ba (-0.263,0.101), Cu and Cd (0.461, 0.003), Ni and Co (-0.023,0.887) while Pb and Cr (-0.058, 0.722). Considering Fe and Ag show correlation values of -.291, Fe and As (.146), Fe and Ba (.182), Fe and Cd (-.064), Fe and Co (-.112), Fe and Cr (-.420), Fe and Cu (-.093), Fe and Ni (-.290), Mn and Ag (.194), Mn and As (.110), Mn and Ba (.219) while Mn and Cd (.103). Generally, from the results obtained paired variables representing heavy metals such as As and Ag, Ba and As, Cd and Ba, Co and Cd, Cu and Cr, Ba and Ag, Co and Ba, Cu and Co, Ni and Cr, Cd and Ag, Co and As, Cu and Cd all show strong positive correlation values while Cd and As, Cr and Cd, Cr and Ba, Ni and Co, Pb and Cr show negative correlation values. Summarily from the values presented on the table, correlation coefficient values of heavy metals showing positive suggest a strong positively correlated pair while those showing negative values suggest a strong negatively correlated pair. This geologically implied that strong positive correlated pair of variables or heavy metals were obtained from same geogenic sources while negatively correlated pair of heavy metal were sourced from different or heterogenous sources putting into consideration that correlation is significant at the 0.01 and 0.05 level(2-talled).

**Table 5: Pearson correlation matrix for log-transformed geochemical data of rock samples from the study area**

Correlation Matrix

| | | Ag | As | Ba | Cd | Co | Cr | Cu | Ni | Pb | Rb | U | Zn | Fe | Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correlation | Ag | 1.000 | | | | | | | | | | | | | |
| | As | .164 | 1.000 | | | | | | | | | | | | |
| | Ba | .116 | .098 | 1.000 | | | | | | | | | | | |
| | Cd | .192 | -.018 | .001 | 1.000 | | | | | | | | | | |
| | Co | .293 | .134 | .157 | .283 | 1.000 | | | | | | | | | |
| | Cr | .172 | .023 | -.283 | -.020 | .074 | 1.000 | | | | | | | | |
| | Cu | .392 | .248 | .072 | .461 | .290 | .162 | 1.000 | | | | | | | |
| | Ni | .196 | .089 | .142 | -.019 | -.023 | .389 | -.010 | 1.000 | | | | | | |
| | Pb | .097 | .028 | .029 | .201 | .292 | -.058 | .145 | -.085 | 1.000 | | | | | |
| | Rb | .188 | .006 | .213 | .154 | .178 | -.074 | .266 | .537 | .023 | 1.000 | | | | |
| | U | .246 | .070 | -.094 | .102 | .171 | .011 | .196 | -.003 | -.440 | .150 | 1.000 | | | |
| | Zn | .245 | -.022 | .351 | -.031 | .231 | -.262 | .127 | -.142 | -.012 | .162 | .057 | 1.000 | | |
| | Fe | -.291 | .146 | .182 | -.064 | -.112 | -.420 | -.093 | -.292 | .106 | -.147 | -.116 | .202 | 1.000 | |
| | Ti | .164 | -.331 | .307 | .049 | .165 | -.190 | .072 | -.245 | .383 | .090 | -.153 | .109 | -.051 | 1.000 |
| | V | .404 | .226 | .277 | .025 | .531 | .293 | .349 | .321 | .340 | .258 | .080 | .067 | -.214 | .158 |
| | Sr | .282 | .069 | .169 | .170 | .259 | -.233 | .224 | .283 | .124 | .528 | .221 | .260 | -.163 | -.045 |
| | Mn | .194 | .110 | .219 | .103 | .396 | -.169 | .331 | -.150 | .507 | .060 | -.020 | -.020 | .118 | .632 |

The result of the factor analysis show the elemental association of the trace elements and heavy metals represented as variables in the statistical analysis. Hence, establishing the elemental association of **Component 1** as consisting of Ag-As-Ba-Cd-Co, **Component 2** as Cr-Cu-Ni, **Component 3** as Pb-Rb, **Component 4** as Zn-Fe-V and **Component 5** as U-Mn (Tables 6 and 7).

**Component 1: Ag, As, Ba, Cd, Co:** This component accounts for 21.416% of the data variability of the model. Factor 1 indicates lithological and environmental control. However, the strong positive correlation between Ag, As, Ba, Cd and Co is evident from the results obtained in the R-mode varimax rotated matrix for log-transformed geochemical data of rock samples in the study area (Table 4.55). This elemental association has been identified as a pathfinder element for the mineralization of gold. Silver (Ag) are associated with lead, antimony, arsenic in sulphide deposits (H.E. Hawke *et.al* (1962). The primary mineral for silver extraction is argentite ($Ag_2S$), it can also occur in other forms such as native silver (Ag), galena and argentite. Cobalt (Co) are associated with siderophile, to a lesser degree of chalcophile. Moreso, associated with Fe, As, Sb, Cu, Ni, Ag and U in sulphide deposits. Arsenic (As) are associated with chalcophile; Au, Ag, Cu and Co in sulphide deposits. Barium (Ba) are associated with lithophile, K in felsic igneous rocks. Barite serves as the primary mineral for barium extraction. It is useful as pathfinder element for Pb, Zn and Ag deposits.

**Component 2: Cr, Cu, Ni:** This component accounts for 14.606% of the data variability of the model. The elemental association between Cr, Cu and Ni on R-mode varimax rotated matrix for log-transformed geochemical data of rock samples in the study area suggest sulphide mineralization. Nickel (Ni) are associated with siderophile, to a lesser degree of chalcophile.

Chromium (Cr) are associated with lithophile; Ni, Mg in ultramafic rocks. Chromite is the primary rock mineral in the extraction of Chromium.

**Component 3: Pb, Rb:** Component 3 accounts for 10.769% of the data variability of the model. The association is a lithological factor. The sources of the elements in this factor may possibly be from the felsic rocks in the study area. The sources of Pb in this factor may possible be from feldspar and biotite in gneiss, granites and pegmatites which are rock types identified in the study area. Pb occurs in K-feldspar and in mica. Pb has been observed to accumulate in pegmatite where it occurs in amazonite feldspar.

**Component 4: Zn, Fe, V:** Component 4 accounts for 8.964% of the data variability of the model. There is a strong positive correlation between these elements as obtained on the R-mode varimax rotated matrix for log-transformed geochemical data of rock samples in the study area. This elemental association is a pointer to the possibility of gold and tin mineralization in the area. The positive correlation between Zn, Fe and V indicate the scavenging activity of the hydrous Fe-oxides on these elements, hence establishing an Fe scavenging factor. Zinc (Zn) are commonly associated with Chalcophile such as Cu, Pb, Ag, Au, Sb, As, Se in base-metal and precious metal deposits; ferromagnesian minerals. Sphalerite is the primary ore mineral for zinc extraction. Vanadium (V) are associated with lithophile; Fe, Ti in magnetite; Pb, Zn in some sulphide deposits. They are useful as a pathfinder element for V-rich sulphide deposits.

**Component 5: U, Mn:** Component 5 accounts for 7.953% of the data variability of the model. No doubt that this association depicts a factor that indicate both lithological and environmental controls. The presence of Mn in this association suggests the scavenging action of Mn- oxide on uranium and also capable of causing false anomaly because of its potential to absorb or co-precipitate a large amount of uranium. Manganese (Mn) are associated with lithophile; Fe and Mg in silicates. Uranium (U) are associated with lithophile; Co and Ag in some sulphide deposits. Uraninite is the primary mineral for uranium extraction.

**Table 6: R-mode varimax rotated matrix for log-transformed geochemical data of rock samples in the study area**

| | 1 | 2 | 3 | 4 | 5 | Communality |
|---|---|---|---|---|---|---|
| Ag | .609 | | | | | .468 |
| As | .208 | | | | | |
| Ba | .377 | | | | | .793 |
| Cd | .365 | | | | | .541 |
| Co | .662 | | | | | |
| Cr | | .594 | | | | .407 |
| Cu | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ni | | .110 | | | | .499 |
| Pb | | .648 | -.431 | | | .723 |
| Rb | | | | | | |
| U | | | .374 | | -.250 | .604 |
| Zn | | | | .046 | | .827 |
| Fe | | | | | | |
| Ti | | | | .153 | | .649 |
| V | | | | | | .655 |
| Sr | | | | -.159 | | |
| Mn | | | | | | .590 |
| | | | | | .071 | |
| **Eigen Value** | 3.641 | | | | | .492 |
| **% VAR** | | | 1.831 | | 1.352 | .677 |
| | | 2.483 | | 1.524 | | |
| | 21.416 | | | | | |
| **% CVAR** | | | | | | .797 |
| | | | 10.769 | | 7.953 | |
| | | 14.606 | | 8.964 | | |
| | 21.416 | | | | | .771 |
| | | | 46.791 | | 63.708 | |
| | | 36.022 | | 55.755 | | .591 |
| | | | | | | .749 |

**Table 7: Result of total variance explained from extraction sums of squared loadings for geochemical data**

**Total Variance Explained**

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.641 | 21.416 | 21.416 | 3.641 | 21.416 | 21.416 | 2.567 | 15.100 | 15.100 |
| 2 | 2.483 | 14.606 | 36.022 | 2.483 | 14.606 | 36.022 | 2.410 | 14.177 | 29.277 |
| 3 | 1.831 | 10.769 | 46.791 | 1.831 | 10.769 | 46.791 | 2.346 | 13.800 | 43.077 |
| 4 | 1.524 | 8.964 | 55.755 | 1.524 | 8.964 | 55.755 | 2.078 | 12.223 | 55.301 |
| 5 | 1.352 | 7.953 | 63.708 | 1.352 | 7.953 | 63.708 | 1.429 | 8.407 | 63.708 |
| 6 | 1.162 | 6.835 | 70.543 | | | | | | |
| 7 | .949 | 5.582 | 76.125 | | | | | | |
| 8 | .851 | 5.004 | 81.129 | | | | | | |
| 9 | .723 | 4.253 | 85.382 | | | | | | |
| 10 | .597 | 3.514 | 88.896 | | | | | | |
| 11 | .506 | 2.974 | 91.870 | | | | | | |
| 12 | .464 | 2.732 | 94.602 | | | | | | |
| 13 | .262 | 1.540 | 96.141 | | | | | | |
| 14 | .241 | 1.417 | 97.558 | | | | | | |
| 15 | .182 | 1.069 | 98.627 | | | | | | |
| 16 | .166 | .975 | 99.602 | | | | | | |
| 17 | .068 | .398 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

## CONCLUSION AND RECOMMENDATION

It can therefore be concluded that the geological mapping conducted on the study area was effective as it provided an update on the rock types, occurrence and their distributions. The outcome of the ground truthing confirmed the major rock types as quartzites, granites, granite gneiss, porphyritic granites, pegmatites and amphibolite greenschists. However, the most dominant rock type being quartzites of both massive and schistose types. The results of petrographical analyses show the mineral assemblages of the various rock types in the area which include quartzites as containing quartz, biotite, muscovite and myrmekite. Granite gneiss contains quartz, biotite, orthoclase, myrmekite, microcline, nepheline, hornblende and plagioclase. Pegmatite contains quartz, myrmekite, plagioclase, hornblende, microcline and muscovites. Porphyritic granites were observed to contain quartz, biotite, microcline, orthoclase and tourmaline. Granite contains quartz, biotite, hornblende, plagioclase and orthoclase while Amphibolite schist contains quartz, biotite, hornblende and muscovites. The pegmatites from thin section probe involving petrographical studies were found to be highly mineralized. Component 1 suggest the possibilities of sulphide and gold mineralization. Component 2 suggesting pathfinder elements while Components 3,4 and 5 suggest weathered or dispersed elements. The occurrence of heavy metallic minerals in rocks in the area will serve huge economic significance. It is therefore recommended that further studies should be specifically carried out with focus on the pegmatites within the study area which will unravel mineralization potential of the pegmatite in Ila Orangun, southwestern Nigeria.

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