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MINERALOGICAL CHARACTERIZATION OF THE GOLD-BEARING ROCKS AROUND OKEMESI-IJERO AREA, SOUTHWESTERN NIGERIA

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ABSTRACT

The mineralogical characterization of the gold bearing rocks around Okemesi-Ijero, South Western Nigeria was carried out using Petrographic and X-ray diffraction (XRD) studies to determine the mineralogical phase of the gold showings. Various researchers have worked in the studied area most especially Ayodele *et al*., (2017), who carried out geochemical analysis (XRF) on the bedrocks, indicating showings of gold mineralization in Okemesi (Ajindo) with concentration values of 10-0.05ppm. This prompted the investigation for confirmation of gold mineralization on the bedrocks of Okemesi area (Ajindo). The method of investigation included systematic geologic mapping of the various lithologies, sampling of the various lithologic units at a density of one sample per 100sqkm, followed by petrographic studies using light transmitting Petrological Microscope and mineralogical characterization of the various rocks using X-ray diffraction techniques (XRD). Twenty-six (26) rock samples were collected from the studied area, and were prepared for thin section using the standard procedures. However, seven (7) out of the samples majorly schistose and massive quartzites were selected and prepared for XRD analysis. The results of the petrographic studies revealed the dominance of the following minerals from four major rock types (schistose and massive quartzites, granites and pegmatites) such that quartz has the highest percentage (62.29%), followed by the feldspars such as microcline (18.59%), plagioclase (6.89%), Orthoclase (0.82%), muscovite (15.71%), biotite (14.85%), opaque (3.47%), hornblende (1.12%), and mymakite (0.36%).The X-ray diffractograms confirmed the presence of gold (Petrovskaite) in the Ajindo schistose quartzites. The schistose quartzites exhibited poor foliation which prevented the flow of auriferous hydrothermal fluid into the host rock. Further studies can be carried out by using Micro X-ray Spectral Analysis to determine the concentration of the gold (petrovskaite) present in the host rock.

Keywords: ***Okemesi, Lithologies, XRD, Photomicrographs, Minerals***

Introduction

Gold production in Nigeria is believed to have started in 1913 and got to its peak from 1933-1943 (MMSD, 2010). Gold in the schist belt of Nigeria occur as alluvial and elluvial deposits. Only 5-10% of Nigeria's 12,000kg of reported gold production has come from vein deposits, while the greater part has been from modern alluvial derived from basement rocks. Four gold fields, encompassing the main producing area, can be defined in the western province of basement; Ilesha-Egbe, Minna Birnin-Gwari, Sokoto and Yelwa (Woakes and Bafor; 1984). All are generally associated with the schist belts although gold-quartz veins also occur in gneisses (e.g. Malele, Diko and Iperindo).The Iperindo mineralization comprises a series of auriferous quartz-carbonate veins localized by a subsidiary fault within biotite gneiss and mica schist, presently defined by sub-parallel old workings extending overall for about 9m in a NNE direction. Gold occurs with pyrite, pyrrhotite and minor chalcopyrite, galena, sphalerite, magnetite and ilmenite. (Manu *et al*., 2004; Hilson, 2006). Adjacent to the gold-bearing veins, the host granite-gneiss has been hydrothermally altered to a sericite-chlorite epidote assemblage (also with hematite and pyrite).Gold quartz veins are generally conformable with the N-S to NNE-SSW structural grain of basement rocks. The schist belts of Nigeria are widely celebrated as hosts to many mineral deposits. For instance, the Ife-Ilesha schist belt is known for its gold mineralization which is structurally controlled by Ifewara fault system and its subsidiary fractures Oyinloye and Steed, (1996). The Proterozoic Ilesha schist belt of southwestern Nigeria has been mapped in various degrees of details by workers, such as, Deswardt (1953), Hubbard (1966, 1975), Elueze, (1986), Klemm *et al.*, (1984), Kehinde-Phillips, (1991) and Ayodele *et al.*, (2017). This was largely due to the discovery of gold in the Ilesha area in 1940 and also some gold showings in southern extension of Ilesha schist belt, as the Ilesha amphibolite complex was suspected to be the source of the alluvial gold. Chaowen Huang and Shugen, (2017) also carried out research on prospecting potential of gold deposits in Dongchuan Area, Yunnan, China which it was determined that the core of the anticline complex and its nearby fault zone are the major ore hosting structures and that gold deposit prospecting should be conducted around the N–S compressive shear zone. Thair Al-Ani *et al.,* (2008), carried out research on mineralogy and geochemistry of till and eathered bedrock of some gold occurrence in the central Lapland and Pirkanmaa, Finland in which the study revealed that 600 Au grains were recovered from 16 samples studied. Geochemical study proves that the studied till targets consist of high contents of Au, Cu, As and Zn particularly in a fine till size fraction (<0.06 mm), when compared to the average level of Au in the Finland. Especially the distribution of Au is highly anomalous in the fine fraction but also in coarser fraction of till in some samples, such as in the Petäjäselkä target, where the highest Au content (130 ppb) was in the middle till fraction (0.5-2.0mm). Adeleke *et al.,* (2014) carried out mineralogical and geochemical characterization of gold-bearing quartz veins and soils in parts of maru schist belt Area, north western Nigeria with the aim of examining the field characteristics, mineralogical and geochemical composition of gold bearing quartz veins and soils to establish prospectively prediction models that indicate ranking of areas with potential gold mineralization. Geologic mapping of the area revealed that the area is made up of different lithology's such as undifferentiated schists, gneisses and migmatites with pegmatite's, schists and epidiorite complex, quartzite and quartz schist.The study area is an extensive psammitic units with minor meta-pelites which constitute the eastern segment. They occur as quartzites and quartz schist. The Ilesha schist belt is associated with migmatitic gneisses and are cut by variety of granitic rock bodies, (Olusegun and Gerg, 1995; Rahaman, 1976). Research on Auriferous showings in the bedrocks and stream sediments of Okemesi-Ijero Area, South western Nigeria was carried out by Ayodele *et al.*, 2017, concluded that there were gold showings in the schistose quartzites of Okemesi area. The identification and interpretation of gold in stream sediments has been the major work carried out so far. However, the mineralogical study of the gold bearing rocks is still lacking in the studied area and none

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of the bedrocks has been studied to know the mineralogical phase of the gold. Therefore, the focus of this research is aimed at determining the mineralogical phase of the rock bearing the gold showings in the study area.

Location and Accessibility of the Study Area

The study area lies within latitudes 7◦ 45'N and 8◦ 00'N and longitudes 4◦ 52'E and 5◦ 08'E. It covers part of the topographic map sheet No. 243 (Ilesha N.E. 1:50,000) and sheet No. 244 (Ado N.W. 1: 50,000). The study areas extend to parts of Ekiti and Osun States, southwestern Nigeria with a total surface area of $821.4km^2$ (Figure. 1). It is generally accessible through network of all seasonal roads and tracks which links it with other parts of the country.

Geologic setting and local geology of the study area

The major rock associations of Ilesha area form part of the Proterozoic schist belts of Nigeria, which are predominantly developed in the western half of the country. In terms of structural features, lithology and mineralization, the schist belts of Nigeria show considerable similarities to the Achaean Green Stone Belts. However, the latter usually contain much larger proportions of mafic and ultramafic bodies and assemblages of lower metamorphic grade (Olusegun, *et al.*, 1995; Ajayi, 1981, Rahaman, 1976). Rocks in the Ilesa schist belt area are structurally divided into two main segments of contrasting lithologies by two major fracture zones often called the Iwaraja faults (Figure 2) in the eastern part and the Ifewara faults in the western part (Folami, 1992, Elueze, 1986). The western part of the fault comprises mostly amphibolites, amphibole schist, meta-ultramafites, and meta-pelites. Extensive psammitic units with minor meta-pelite constitute the eastern segment. These are found as quartzites and quartz schists. All these assemblages are associated with migmatitic gneisses and are cut by a variety of granitic rock bodies, (Olusegun, *et al.*, 1995, Rahaman, 1976). However, the field descriptions of the different rocks mapped in the study area are discussed below.

Banded gneisses

This lithology covers the southwestern part of the study area around Okokoro, Aba Francis and Aba-Ori-Apata near Ikoro Ekiti. Texturally, they are medium to coarse grained with alternating bands of light and dark colored portions of about 3cm thickness with complete gradation between them. They occur as low lying outcrops which have

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been intruded by pegmatite in the south eastern corner of the area. The rock consists of alternating felsic and mafic minerals and structures like banding, micro folds and fractures were noticed on the outcrop. They have whitish grey tones. The samples mapped around Okemesi and Ipoti are medium to coarse grained and are foliated and display compositional banding of the mafic and felsic minerals. The rock strikes at 33◦N and dips at 60◦W. These tend to form good topographical features which rise up to about 400 meters above the surrounding terrains forming ridges

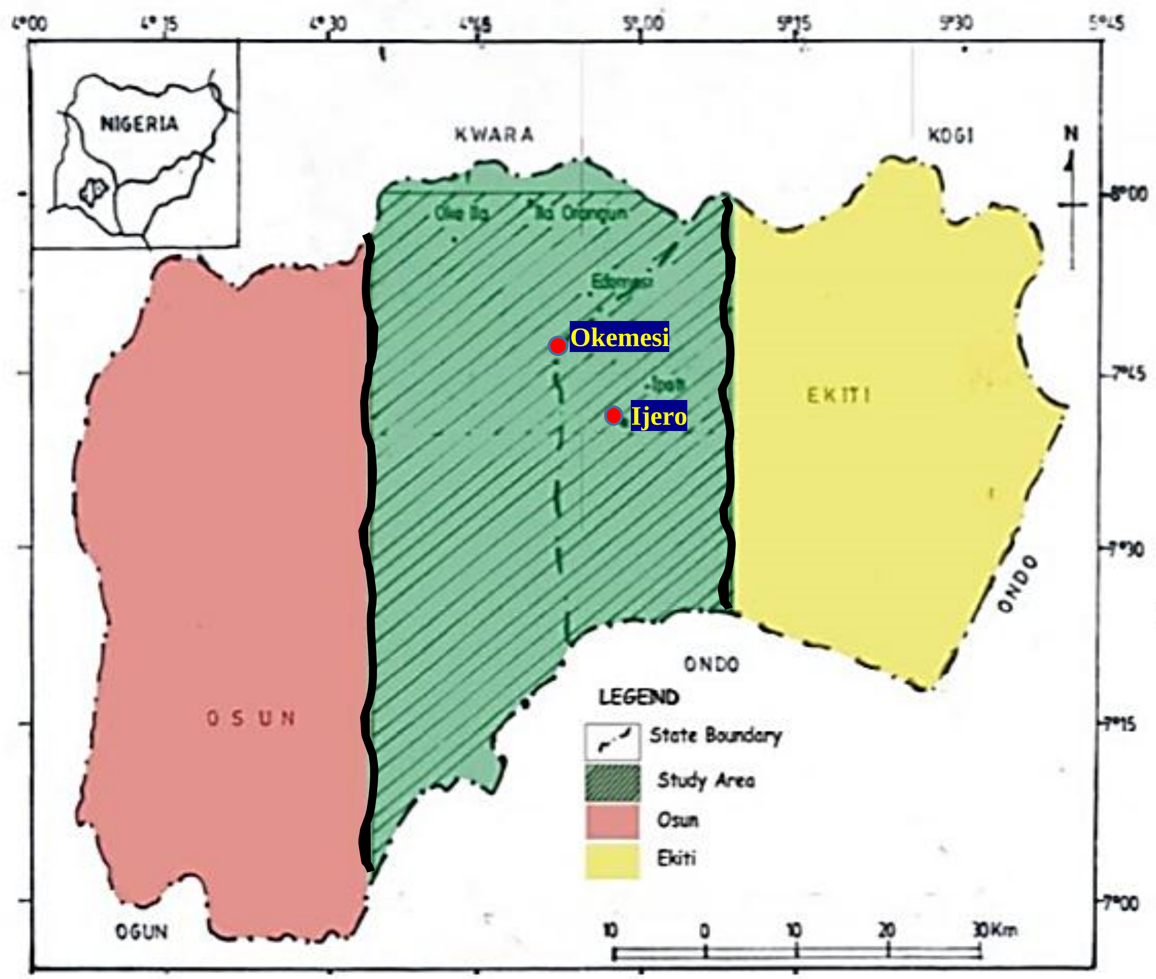

Figure 1: Location map of the study area (inset: Map of Nigeria showing Osun and Ekiti States

Quartzites

This outcrop covers the northern part around Oke-Ila, Ilupeju areas to central, western (Ayegunle), extending to the southwestern and southern parts of Okemesi (Ajindo) of the study area. Around the study area, the varieties of quartzite encountered are massive, milky, smoky, sugary, ferruginous and schistose quartzites. However, schistose, ferruginous and smoky varieties are the commonest in Okemesi area. The massive quartzites are not foliated but hard and are compact, the schistose quartzite's are foliated and exhibit alternations of felsic mineral such as quartz and mafic mineral such as biotite with planar fabric. The milky ones have milky appearance by inspection and developed slickenside surfaces with specks of muscovite. The smoky ones are formed by different oxidation states of iron in the crystal lattices of the rock or due to impregnations of some transition elements during the rock formation. The sugary ones have granular textures and are friable when struck with hammer. The ferruginous types are rich in iron. They are very common in Okemesi and Itawure. The quartzites have varying textures from equigranular, medium grained to coarse grained. The varieties of quartzites are closely related that, often, it is impossible to indicate them as separate units on the map. The quartzites consist of mainly quartz which is usually more than 70% with minor amounts of interlocking grains of biotite and orthoclase. Structurally, the quartzites are jointed, with some having joint sets around Ayikunnugba (Oke-Ila) area, while others are foliated. Dips ranging between 40◦W-66◦ W were measured around Ajindo areas. In some areas for instance, they have very high dips ranging from 66◦ E to almost horizontal at Okemesi, most especially along the limbs and fold closure. The quartzites in the area have orange-yellow colour due to mineral impurities. Quartz vein is the dominant structural feature on the rocks in this locality.

Biotite-gneiss

This is a foliated, medium to coarse-grained, dark to almost black colored rock composed chiefly of biotite and little quartz. It occupies the north central area and extends towards the north western part of the study area. A band of biotite gneiss concordantly lies within the quartzites around Ajindo area. The rock has been severely weathered and covered with sand thereby making field observation difficult to carry out.

Granite-gneiss

The granite gneisses are common in Okemesi. They exhibit mineralogical banding of felsic and mafic minerals. The texture is medium to coarse grained.

Biotite-schist

The biotite schists encountered in the study area occurs around Arapate, Erigbe and Soso area of Ekiti State as a lenticular body within the quartzite's and migmatite gneiss, and it is exposed due to stream activity as low lying outcrop. It has undergone various levels of deformation. Structurally, foliation is present. Other structural features on the rock include micro folds and joints which control the stream flow. Field observations showed that this rock dips at 48◦ W to the surrounding rocks. The rock is medium grained and it is dark grey in color. The rock also occurs in Ikoro and Ijero area as a schistose rock with grayish color, and with black patches of biotite, it exhibits fine grained texture. It covers nearly two-thirds of Ijero area with pegmatite intrusions along Ijero-Ikoro road. It is also found in Arapate/Soso area with structures such as foliations and micofolds. It contains quartz and biotite.

Quartz-Biotite Schists

This group of rock occurs in lowland areas between quartzite and banded gneiss around Oko-Esinkin area (eastern part of Okemesi) where it has been exposed by stream channel and road cut. The rock has been highly deformed with the adjacent migmatite-gneiss-quartzite complex, the foliations on the outcrop is defined by biotite streaks. The rock has medium to coarse grained texture. Structures found on the outcrop are fractures, and the rock is grey to dark in color.

Pegmatites

This lithological unit ranges from a few meters in length and is located in the southeastern part of Okemesi where it intrudes the banded gneiss around Aba Francis and Ikoro area as an isolated hill. Texturally, it is extremely coarse-grained with quartz, feldspar and muscovite as distinguished mineral component. Quartz vein, joints and veinlets are the structures observed on the outcrop. Based on field observation, the pegmatite is the complex type with distinct textural and mineralogical variations with an impure white coloration. It is the youngest rock in Ikoro area, unlike the Okemesi pegmatite which is the simple type due to uniform variation of its constituent minerals. Pegmatite intrusions also occur towards the south-western part very close to the center of Ijero town, which is also complex. It extended to the quarry site in Ijero along Ijero- Ipoti road. The pegmatite in Ijero area is zoned, consisting of massive quartz at the core, and followed by mica schists with smoky quartz impregnated with tourmaline and purplish quartzite. In Ara and Epe area of Ijero, the pegmatite's here intruded into the biotite schist and migmatite gneiss that occupies the central part of the area, covering about three-quarter of the total land mass. The pegmatites in this area are very coarse grained igneous type with phenocrysts over 250mm in length, usually of granitic composition. The pegmatite in Ipoti and Odo Owa areas are associated with cassiterite-tantalite mineralization (Fadipe, 1988). They are found associated with migmatite gneiss and amphibolite with very coarse grained texture. The pegmatites in Ijero occur as a low but large elongate hill of average height of about 50m above sea level. Some of the pegmatites in Ijero have been and are still being worked on most especially at Ijero and other villages such as Ikoro, Odo-Owa, Saloro and Oke Asa.

Calc-gneiss

This is a typical gneissic rock with abundance of calcium. It exhibits a characteristic black color with white fragments of quartz. The texture of the rock is mostly fine grained. Joints are the major structures discovered on the outcrop, and are common in most parts of Ikoro. Part of the lithological unit is exposed at Odo agba (Ikoro) where the stream takes it course. They are medium to coarse grained. It is also common in Ijero where it is composed chiefly of calcite and quartz. It occurs mainly as nodules and discontinuous streaks up to four inches in thickness. It is also made up of a mosaic of twinned grains of calcite enclosing isolated rounded crystals or composite spots of silicate minerals.

Granites

Varieties of granites based on mineral composition, texture and grain sizes are very prominent in the south eastern part of the study area most especially in Ofale, Osun/ Epe, Iroko, and Idao parts of the study area and form well defined boundaries with the quartzite's. Their textures range from fine, medium to coarse grained. They occur as hilly, low lying, flat and extensive outcrops in most area with sparse vegetation's. Structures common on the outcrops include quartz vein, veinlets, pegmatite dykes which trend north-south, exfoliation, folds of different styles, xenoliths etc. A typical granitic rock must have > 60% of quartz to be termed an acid igneous rock. However, the granites occur as pockets of rocks within the biotite gneiss in Ikoro and Ijero area. They have color variations ranging from specks of whitish, grayish to ash color and patches of dark color indicating ferromagnesian minerals.

Mica schists

The mica schists extend across most part of Ipoti, Odo Owa and Ijero, but occur prominently around Ipoti and Ijero. They are highly susceptible to weathering and erosion thereby reducing the quantity of fresh samples. In these areas, quartz-muscovite and quartz-muscovite-biotite schist are exposed in many places and have been highly pegmatized. The quartz biotite schist found in the area could be due to boron metasomatic traceable to tourmaline at Odo Owa where they are relatively well exposed.

Migmatite-gneiss complex

This is presumably the oldest group of rocks and the widest spread of all the lithology's, occupying 30% of the total surface area of Ijero and its surroundings. Its concordant lithostratigraphic relationship with the juxtaposed quartzite at Ayegunle gives credence to its probable metasedimentary origin. It is a mixed rock with a characteristic nature of a typical metamorphic rock which has taken an igneous character through partial melting. The migmatite has a mineralogical composition of quartz, orthoclase feldspar, hornblende and mica. It is not widely distributed in Ara Epe area unlike the pegmatite's, but occupies the northern part. It is characterized mostly by alternating light and dark bands of minerals. In Ipoti, Odo Owa area, the rock has been weathered in-situ to give rise to high quality clays of economic importance, whereas, it occurred as a fresh low-lying outcrop in Ijero. This is typical of the samples picked from Epe. Migmatites in Epe are characterized by ptygmatic folds and are believed to exhibit ductile deformation of the gneissic banding. Structures like folds and micro faults were also seen on the outcrop. The strike value of the rock is 34◦N and dip is 32◦W.

Charnockites

The charnockites occur as an intrusive body north of Odo Owa within the massive quartzite's and the gneisses as a coarse grained variety of charnockites which are foliated. They vary in texture and range from banded types to fine and medium grained. Though, the coarse grained varieties are common around Ipoti and Odo-owa Area. They also occur as discrete and individual bodies within the migmatite-gneiss-quartzite complex. Structures seen on the rock are solution holes, quartz veins. The various rock units mapped in the course of field work were compiled to produce a geologic and cross-section map of the study area (Figure 3).

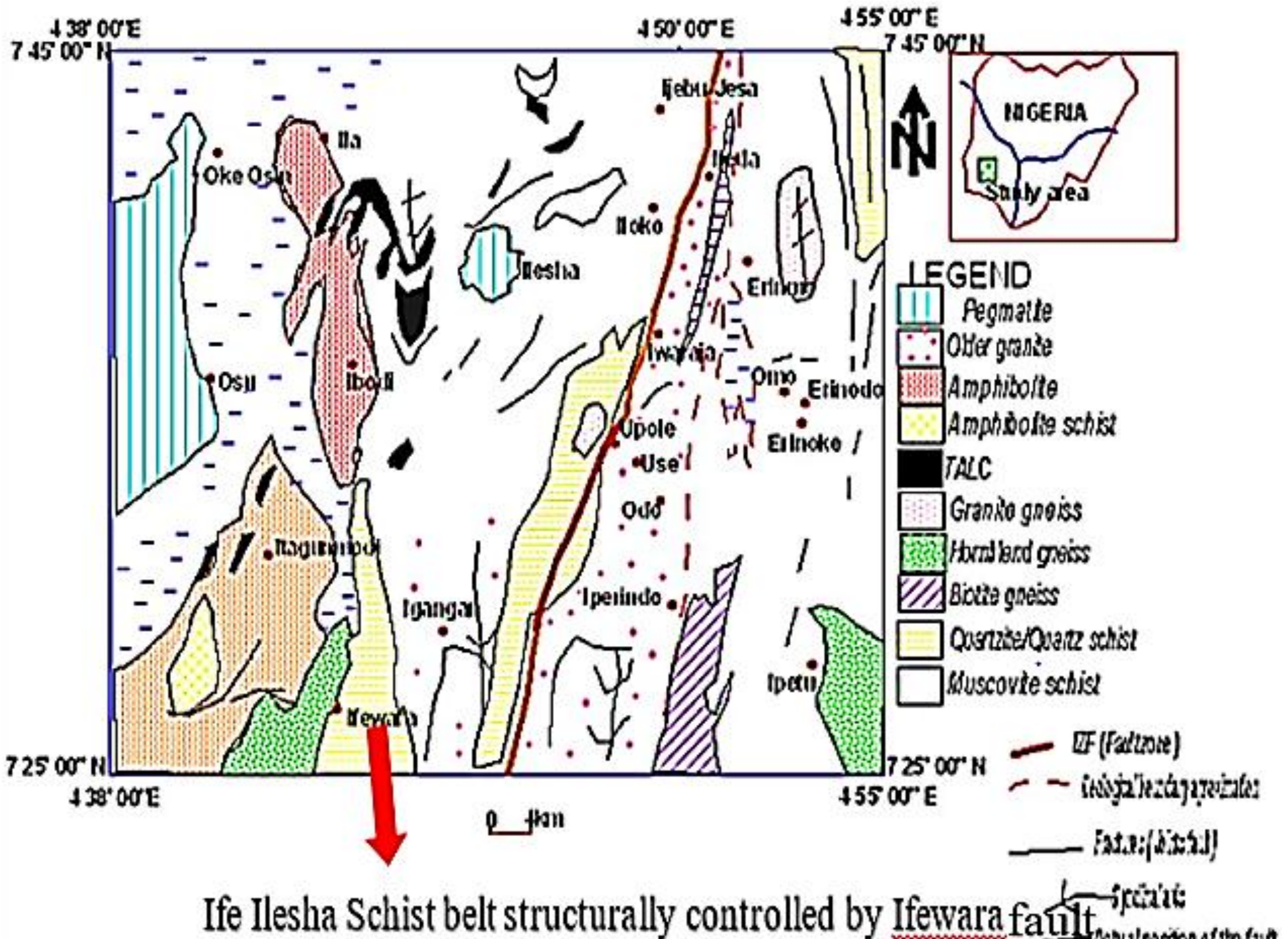

Figure 2: Geological Map of Ilesha Schist Belt Area (Fatoba and Tijani, 2015)

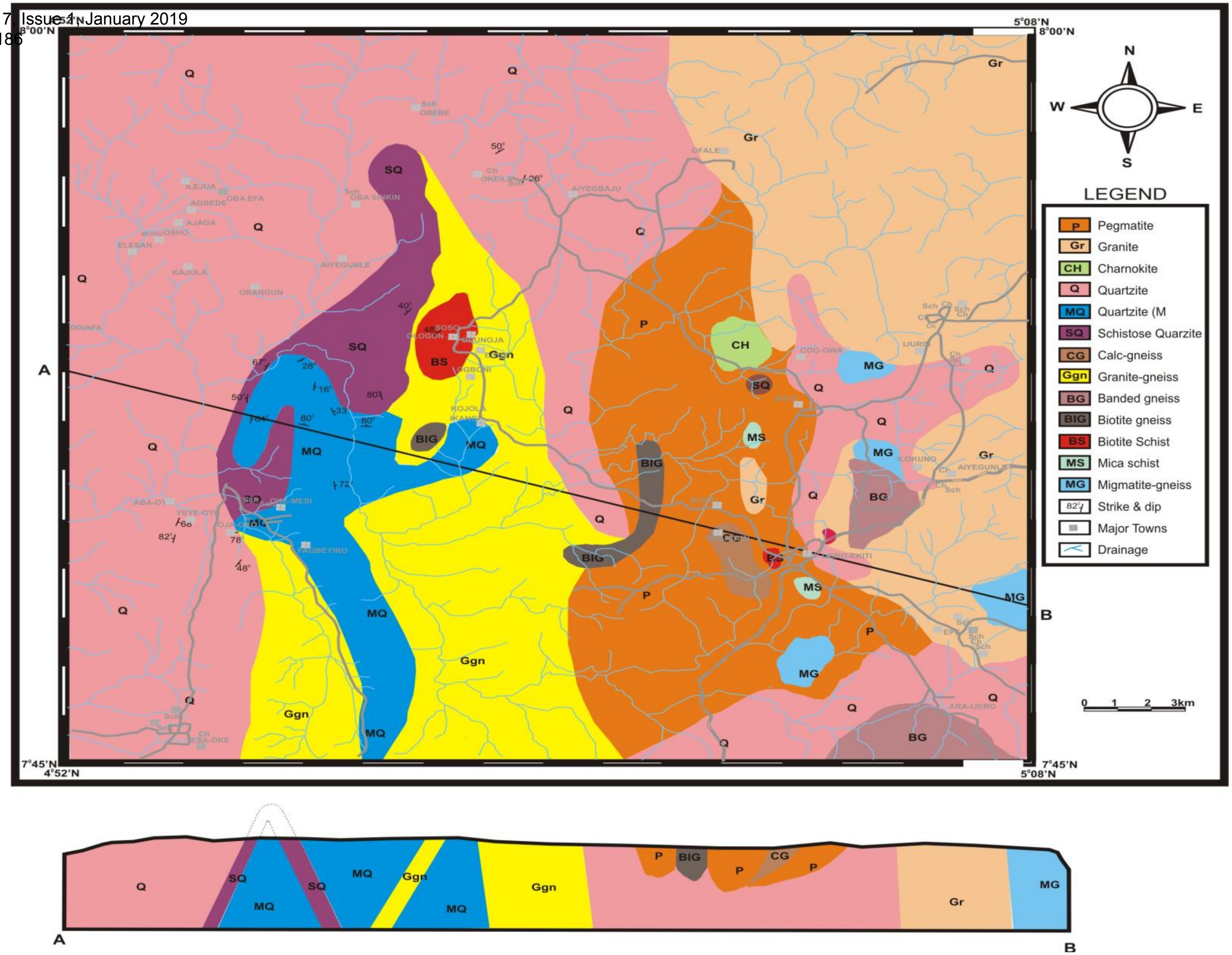

Figure 3: Geologic and cross-section map of the study area (Ayodele, 2015)

Method of Study

Field examination of the various rock samples were carried at various locations using systematic sampling method and at a sampling density of one sampler per 100sq km with the aid of the global positioning system (GPS). This was followed by sample collection at different locations which were carefully labeled to avoid mix up. Twenty-six (26) rock samples were brought to the Petrology Laboratory of the Applied Geology Department, The Federal University of Technology, Akure and prepared for thin-section studies using the standard procedures of thin section preparations. Modal analysis of minerals identified in the slide were carried out using the Polarizing microscope.

For XRD analysis, seven of the rock samples (mainly schistose quartzites) were carefully selected and re-labelled, and were sent to National Geosciences Research Laboratory (NGRL), Kaduna. The rock samples were grinded to a fine talc-like powder by Rock Labs hardened steel "masher" The procedures include; crushing the samples, sieving and transferred to a labeled glass bottle, soaking the samples in 3% H_2O_2 for at least 24 hours in a beaker to digest organic matter, digestion in ~250ml of Na-hexametaphosphate solution (concentration of 4 g/1000 mL) and added to the digested samples in the beaker. The beakers were inserted into an ultrasonic bath for several minutes to promote disaggregation and deflocculation. This step (and additional soaking) was repeated until visual inspection indicated complete disaggregation.Washing consisted of two passes through a centrifuge (8200 revolutions per minute [rpm] for 25 min; ~6000g) with resuspension in distilled water after each pass. After transferring the suspended sediment to a 60-mL plastic bottle, each sample were re-suspended by vigorous shaking and a 2-min application of a sonic cell probe, the small size like clay-size particles (<2 µm equivalent settling diameter) were then separated by centrifugation (1000 rpm for 2.4 min; ~320g). Oriented aggregates were prepared using the filter-peel method and 0.45-µm membranes (Moore and Reynolds, 1989), the small size aggregates were saturated with ethylene glycol vapor for at least 24 hours prior to XRD analysis, using a closed vapor chamber heated to 60°C in an oven. Finally, the samples were analyzed as soon as the glycol was uniformly absorbed on the sample mount. The samples were later scanned in XRD machine in which the result was converted to UXD (Users experience design) file.

Results and Discussion.

Sampling location of the rocks

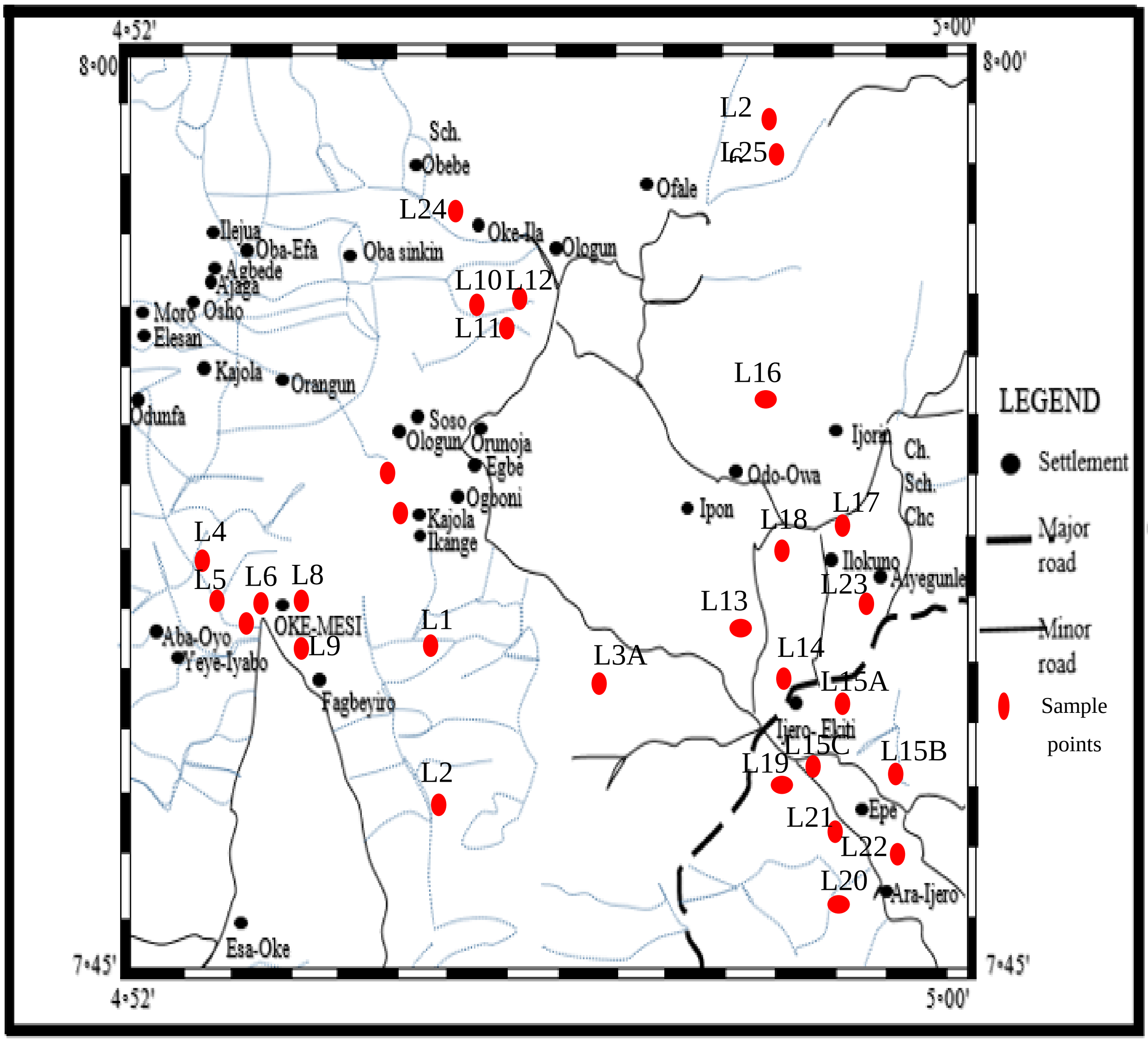

Figure 4: Map of the Study Area with Sampling Location modified by Akanmu, (2018)

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Table 1: Field description of the study area

S/N	LOCTION	LONGITUDE	LATITUDE	ROCK TYPE	LITHOLOGY	STRUCTURES
1	IDO ILE 1	7◦ 47.625'	4◦ 57.667'	METAMORPHIC	QUARTZITE	FRACTURE
2	IDO ILE 2	7◦ 50.524'	4◦46.436'	METAMORPHIC	QUARTZITE	FRACTURE, JOINTS
3	ITAWURE 1A,1B,1C	7◦43.736'	4◦57.330'	METAMORPHIC	QUARTZITE	FRACTURE, JOINTS.
4	OKEMESI 1	7◦50.117'	4◦54.921'	METAMORPHIC	SCHISTOSE QUARTZITE	FRACTURE, JOINTS, FOLDS,PEGM ATITIC INTRUSION
5	OKEMESI 2	7◦50.315'	4◦54.816'	METAMORPHIC	SCHISTOSE QUARTZITE	FRACTURES
6	OKEMESI3	7◦49.854'	4◦54.985'	METAMORPHIC	SHISTOSE QUARTZITE	FRACTURES
7	OKEMESI 4	7◦50.340'	4◦54.828'	METAMORPHIC	SHISTOSE QUARTZITE	PEGMATITIC VEIN, FRACTURE & FOLDS
8	OKEMESI 5	7◦50,349'	4◦54,832'	METAMORPHIC	SCHISTOSE QUARTZITE	FOLDS
9	OKEMESI 6	7◦50.398'	4◦54.812'	METAMORPHIC	SCHISTOSE QUARTZITE	FOLDS
10	AJINDO 1A	7◦52.354'	4◦57.496'	METAMORPHIC	SHISTOSE QUARTZITE	FOLDS
11	AJINDO 1B	7◦52.381'	4◦57.535'	METAMORPHIC	SCHISTOSE QUARTZITE	FOLDS
12	AJINDO 1C	7◦52.381'	4◦57.535'	METAMORPHIC	SHISTOSE QUARTZITE	FOLDS
13	IKORO 1	7◦50.850'	5◦02.059'	METAMORPHIC	MIGMATITIC QUARTZITE	FRACTURE, PEGMATITIC

						VEIN
14	IJERO 1	7◦49.721'	5◦03.514'	IGNEOUS	PEGMATITIC	FRACTURE
15	IJERO 2A, 2B, 2C	7◦49.481'	5◦04.204'	IGNEOUS	PEGMATITIC	FRACTURE
16	ILORO 1	7◦53.989'	5◦06.353'	METAMORPHIC	MIGMATITE GNEISS	FOLD, PEGMATITIC INTRUSIONS, FRACTURE
17	OKE ORO 1	7◦49.692'	5◦05.591'	METAMORPHIC	QUARTZO-GRANITIC	PEGMATITIC INTRUSIONS, PEGMATITIC VEINS
18	OKE ORO 2	7◦49.791'	5◦05.275'	METAMORPHIC	GRANITE	FRACTURE, PEGMATITIC INTRUSIONS
19	IJERO 3	7◦49.440'	5◦04.907'	METAMORPHIC	MIGMATITE	DYKE, PEGMATITIC INTRUSIONS
20	ARA IJERO 1	7◦47.638'	5◦05.486'	METAMORPHIC	MIGMATITE GNEISS	DYKE, PEGMATITIC INTRUSIONS, QUARTZ VEINS, FRACTURES.
21	EPE 1	7◦46.700'	5◦07.267'	IGNEOUS	PEGMATITE	PEGMATITIC INTRUSIONS.
22	EPE 2	7◦46.822'	5◦07.271'	METAMORPHIC	GRANITE	PEGMATITIC VEINS
23	AYEGUNLE	7◦50.456'	5◦06.248'	METAMORPHIC	QUARTZITE	FRACTURE
24	OKE ILA	7◦57.193'	4◦59.459'	METAMORPHIC	PORPHYRITIC/MIGMATITE GNEISS	CONTACT BETWEEN PORPHYRITIC & MIGMATITE

						GNIESS
25	OSUN EKITI 1	7◦58.313'	5◦05.306'	METAMORPHIC	MIGMATITE GNEISS	FRACTURES, PEGMATITIC INTRUSIONS, QUARTZ VEIN
26	OSUN EKITI 2	7◦58.251'	5◦05.338'	METAMORPHIC	MIGMATITE GNEISS	QUARTZ VEIN, PEGMATITIC INTRUSIONS, CONTACT BETWEEN PEGMATITE AND MIGMATITE GNEISS

The field description of the study sites are presented in Table 1 above. Twenty-six locations were mapped within the study area and the various attributes of the rocks mapped have been presented. The rocks are crystalline in nature (igneous and metamorphic) with distinguishing petrological characters. Also, the sampling locations of the rocks are presented in Figure 4.

Interpretation of the thin sections

The petrographic examinations of the thin sections revealed the various mineral distribution in the rocks such as quartz, biotite, hornblende, mymakite, muscovite and feldspar (orthoclase, plagioclase and microcline). Quartz and feldspar alone constituted up to 78% of the thin sections. Quartz is the most abundant and dominant mineral in all the slides and this indicated that the rocks are products of acidic magma crystallization. Microcline is second to quartz in abundance.

Petrographic description of some minerals in the slides

Quartz

Quartz in all the thin sections account for about 30% of the total mineral present as viewed under crossed nicol. It partially greyish to white colour, and has wavy extinction. Its crystal can be described as subhedral and sometimes euhedral crystals with well-developed crystal faces. The extinction angle is symmetrical with respect to crystal angle and it has tight refraction than orthoclase and microcline

Biotite

Generally, in all the slides viewed under Research Petrological Microscope, the percentage of biotite is about 20% of the total mineral present in the thin sections. It is dark brown in colour, highly pleochroic (changing from dark brown to light brown in colour). It is subhedral, having cleavage in one direction and of high relief. The longer axes of the biotites are aligned in a preferred orientation direction which shows foliation trend of the rock under plane polarized light. They are usually overprinted or super imposed on the muscovite minerals with yellowish brown to black colour when viewed under polarized light. Biotite has some inclusions of some accessory minerals like apatite, zircon, rutile and magnetite.

Muscovite

When muscovite is observed under Petrological microscope between crossed nicols, the interference colours are pure. However, second and third order tints of green and red crystals of muscovite were seen. They belong to the white mica which are grouped as felsic minerals. The muscovite crystals are porphyroblastic in nature, while the extinction angles of the crystals are parallel to the cleavage direction.

Plagioclase Feldspar

Plagioclase feldspars account for about 48% of the total mineral present and is partially greyish and light grey in colour and exhibits albite twining with an extinction angle of about 160◦. They are generally distinguished from the other feldspars by higher refraction, the plagioclase crystals are strongly pleochroic

Hornblende

Hornblende constitutes one of the essential minerals found in granites. It is a mineral very difficult to distinguish from biotite unless the stage is rotated. Hornblende will remain unchanged from its brownish colour whereas, biotite exhibits variation in colour (pleochroic). Hornblende has a small extinction angle usually between 120- 250. The crystals of the minerals are usually overprinted on muscovite flakes thus; the subhedral crystal of hornblende has some elongated prism with two good cleavages

Orthoclase and Microcline Feldspar

Orthoclase feldspar occurs slightly in all the thin sections. The distinguishing factor from other feldspars is its carlsbard twinning, while microcline feldspar is also common in all the thin sections and exhibit perthite (cross-hatch) twinning under crossed nicol. It has greyish colour. Microcline also occurs as coarse grains with average composition decreasing from Ara to Ijero

Opaque

It is a mineral which cannot be seen under transmitted light microscope. The best microscope to use to identify the opaque mineral is the reflected light (Ore microscope). In the thin section prepared under the plane polarized light, it appeared black.

Mymakite

The mymerkite seen under thin section, appears as an intergrowth between the plagioclase feldspar and quartz. Myrmekite also occurs after the rock crystallizes by replacement of the plagioclase during metasomatism or hydrothermal alteration. These quartz-plagioclase intergrowths are associated with and commonly in contact with potassium feldspar. Myrmekite is formed under metasomatic conditions, usually in conjunction with tectonic deformations.

Petrography of Migmatite-gneiss Rocks

Table 2 showed the modal values of minerals in Migmatite Gneiss and Figure 8 presents the histogram of distribution of the different minerals such as biotite (22.06%), quartz (52.51%), plagioclase feldspar (6.12%), orthoclase (2.92%), microcline (9.76%), muscovite (4.54%) and mymakite. The photomicrographs are shown in Figures 5, 6 & 7 respectively.

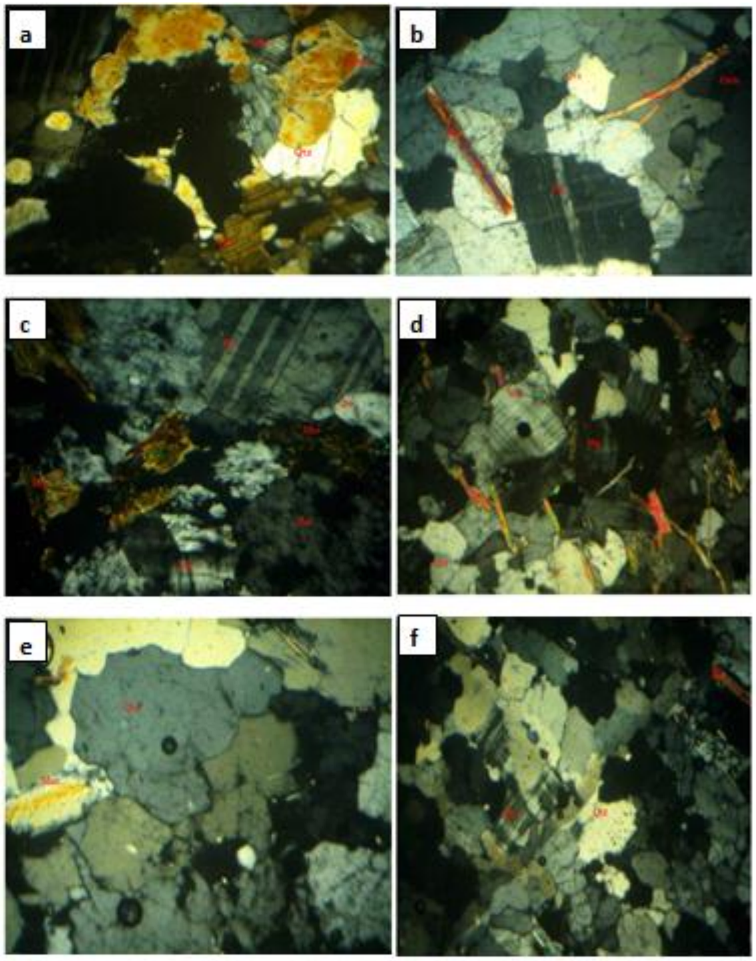
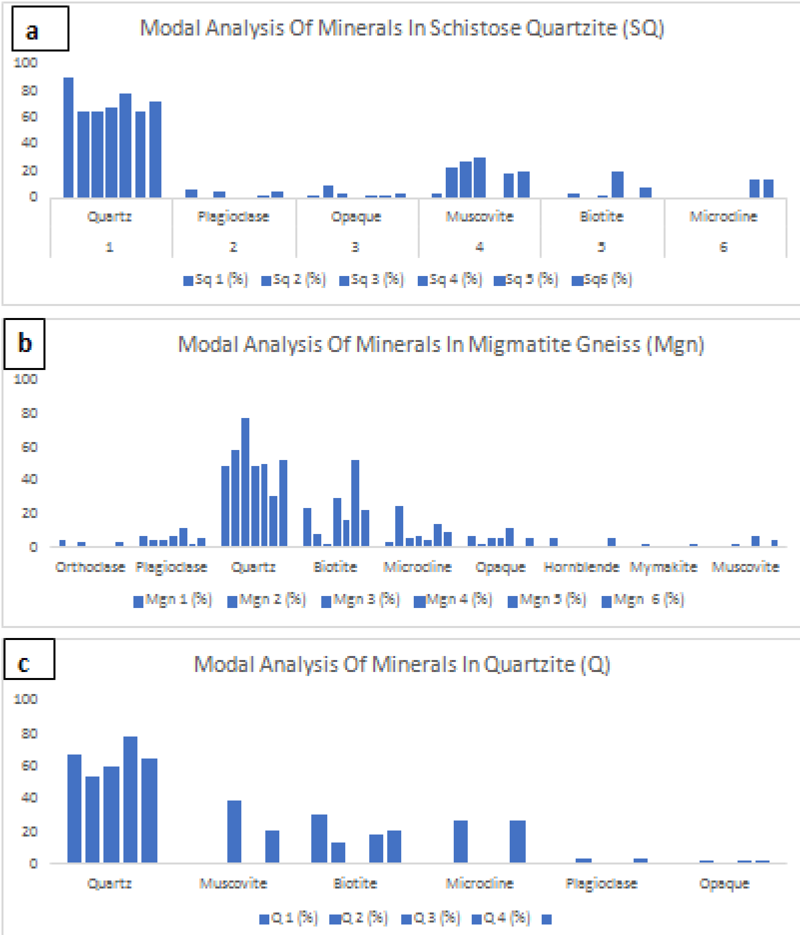


Figure : **(a)** Photomicrograph of Migmatite Gneiss showing Quartz (Qtz), Biotite (Bio), Plagioclase (Plg) and Mymakite (Mym) under ×-Nicols (×100) (Location N7◦ 53.989' E5◦ 06.353' **(b)** Photomicrograph of Migmatite Gneiss showing Quartz (Qtz), Biotite (Bio), Plagioclase (Plg) and Muscovite (Mus) under ×-Nicols (×100) (Location N7◦ 49.440' E5◦ 05.907') **(c)** Photomicrograph of Migmatite Gneiss showing Quartz (Qtz), Biotite (Bio), Plagioclase (Plg) and Muscovite (Mus), Microcline (Mic) and Hornblende under ×-Nicols (×100).(Location N7◦ 50.850' E5◦ 02.059') **(d)** Photomicrograph of Quartzite showing twinning according to Albite law in plagioclase (Plg), Biotite (Bio), Microcline (Mic), Quartz (Qtz) under ×-Nicols (×100).(Location N7◦ 50.117' E4◦ 54.921') **(e)** Photomicrograph of Quartzite showing Quartz (Qtz) and Muscovite (Mus) under ×-Nicols (×100).(Location N7◦ 43.736' E4◦ 57.330') **(f)** Photomicrograph of Schistose Quartzite Showing Quartz (Qtz), Biotite (Bio), and Microcline (Mic) under ×-Nicols (×100).(Location N7◦ 50.349' E4◦ 54.832')

Table 2: Modal Analysis of Minerals in Migmatite gneiss (%)

S/N	Minerals Present	Mgn 1	Mgn 2	Mgn 3	Mgn 4	Mgn 5	Mgn 6	Average
1	Orthoclase	4.22	-	3.50	1.04	0	0	2.92
2	Plagioclase	7.04	4.54	4.38	7.29	11.29	2.22	6.12
3	Quartz	49.29	59.09	77.19	48.95	50	30.55	52.51
4	Biotite	23.94	8.18	1.75	30.20	16.12	52.22	22.06
5	Microcline	2.81	24.54	5.26	7.29	4.83	13.88	9.76
6	Opaque	7.04	1.81	5.26	5.20	11.29	1.11	5.28
7	Hornblende	5.63	0	0	0	0	0	5.63
8	Mymakite	0	1.81	0	0	0	0	1.81
9	Muscovite	0	0	2.63	0	6.45	0	4.54


a
Modal Analysis Of Minerals In Schistose Quartzite (SQ)
100
80
60
40
20
0
Quartz
1
Plagioclase
2
Opaque
3
Muscovite
4
Biotite
5
Microcline
6
Sq 1 (%)
Sq 2 (%)
Sq 3 (%)
Sq 4 (%)
Sq 5 (%)
Sq6 (%)
b
Modal Analysis Of Minerals In Migmatite Gneiss (Mgn)
100
80
60
40
20
0
Orthoclase
Plagioclase
Quartz
Biotite
Microcline
Opaque
Hornblende
Mymekite
Muscovite
Mgn 1 (%)
Mgn 2 (%)
Mgn 3 (%)
Mgn 4 (%)
Mgn 5 (%)
Mgn 6 (%)
c
Modal Analysis Of Minerals In Quartzite (Q)
100
80
60
40
20
0
Quartz
Muscovite
Biotite
Microcline
Plagioclase
Opaque
Q 1 (%)
Q 2 (%)
Q 3 (%)
Q 4 (%)

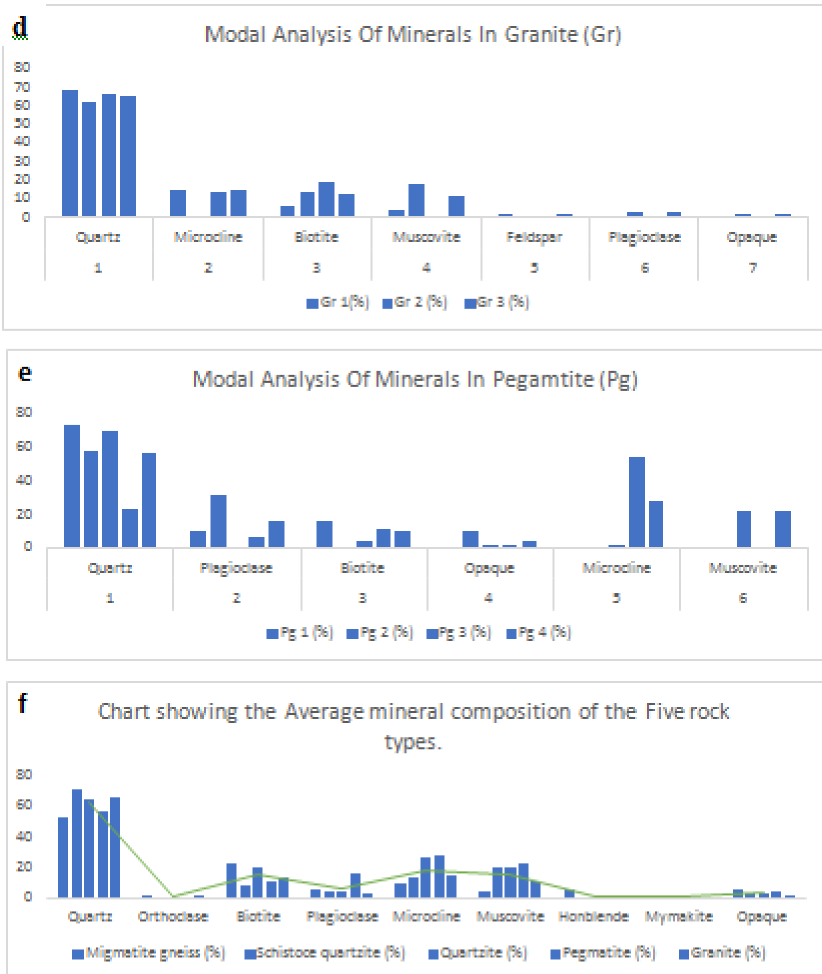


Figure: **(a)** Chart showing (%) Composition of Minerals in Schistose Quartzites; **(b)** Chart showing (%) composition of Minerals in Migmatite Gneiss; **(c)** Chart showing (%) Composition of Minerals in Quartzite; **(d)** Chart showing (%) Composition of Minerals in Granites; **(e)** Chart Showing (%) Concentration of Minerals in Pegmatites; **(f)** Chart showing the Average mineral composition of the four rock types.

Petrography of Massive Quartzite

Petrographic analysis under transmitted polarizing microscope revealed the presence of quartzite as subhedral to anhedral quartz crystals, plagioclase with its characteristic polysynthetic twinning visible in the crystals according to Albite law, biotite, microcline, muscovite and opaque minerals are also present. Results of the modal analysis presented in Table 3 reveal the mineral composition as quartz (65.34%), plagioclase (1.02%), biotite (15.51%), microcline (6.55%) and muscovite (10.27%). The Graphical expression of the constituent minerals of the rock is presented in Figure 11 and the photomicrographs are displayed in Figures 8, 9 & 10.

Table 3: Modal Analysis of Minerals in Massive Quartzite (%)

S/N	Minerals present	MQ 1 (%)	MQ 2 (%)	MQ 3 (%)	MQ 4 (%)	Average (%)
1	Quartz	67.89	54.09	60.46	78.94	65.34
2	Muscovite	1.57	0	39.53	0	20.55
3	Biotite	30.52	13.11	0	18.42	20.68
4	Microcline	0	26.22	0	0	26.22
5	Plagioclase	0	4.09	0	0	4.09
6	Opaque	0	2.45	0	2.63	2.54

MQ= Massive Quartzite

LOCATION 1 (Ido-Ile Massive quartzite)

The quartzite in this location is whitish to brownish, with fine to medium grain size (Figure 12). The mineral composition consists of high amount of quartz (78.94%) and little amount of Muscovite (39.53%). The structures present are joints and fractures.

Location 2 (Itawure massive quartzite)

This location is dominated by massive quartzites with varying colors ranging from reddish brown, brownish, milky to brownish with yellow specks and grey colorations (Figure 13). The texture also varies from medium to coarse grained and fine to medium grained size. The mineral composition of the samples in this location is quartz. The structures mapped are basically fractures and Joints. The quartzites are also jointed and they display several joint sets. Some of the samples in this location have smoky appearance which could be an entrapment of some gases within the crystal lattice of the quartzite. The outcrop dips towards east direction

Petrography of Schistose quartzite

Table 4 indicate the modal values of minerals in schistose quartzite and Figure 18 presents the histogram as biotite (8.16%), quartz (71.59%), plagioclase feldspar (4.37%), muscovite

(20.08%), microcline (13.97%) and opaque minerals (3.49%). The photomicrographs are displayed in Figures 14&15 and the photographs of structures mapped on the lithology (Figures 16&17).

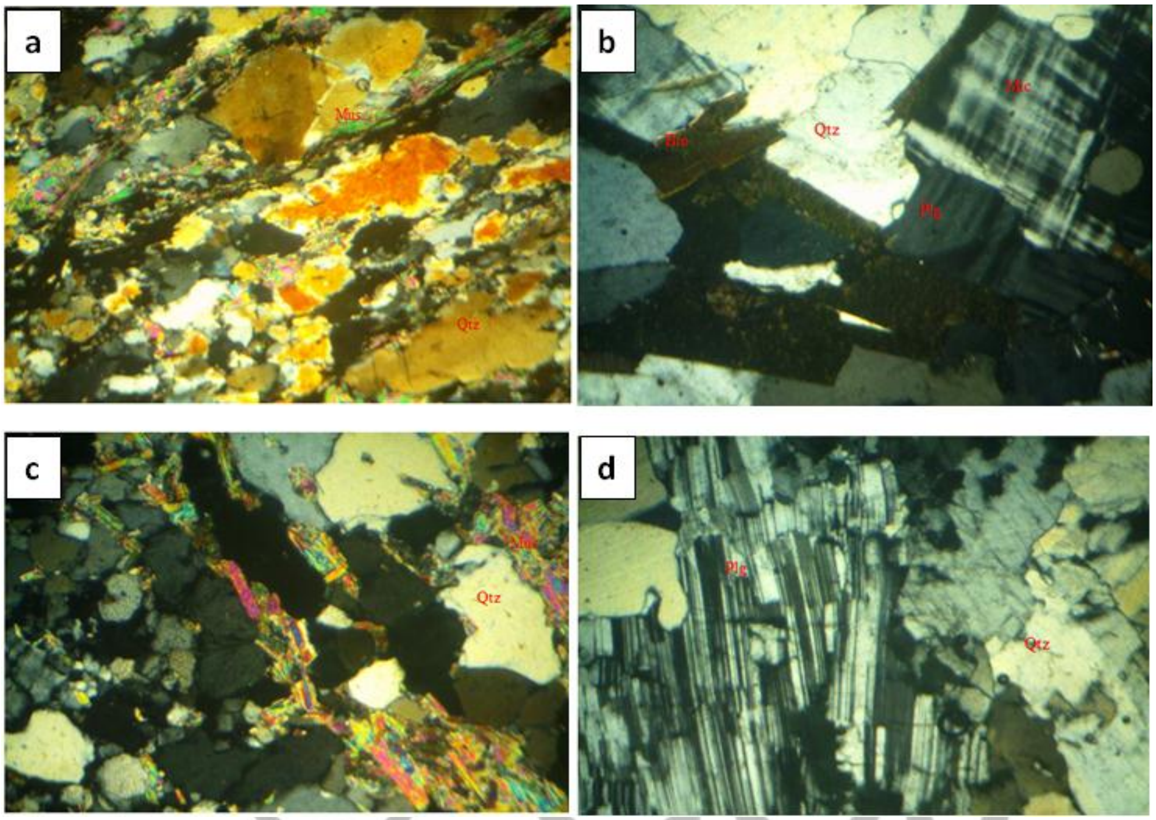


Figure : **(a)** Photomicrograph of Schistose Quartzite Showing Quartz (Qtz) and Muscovite (Mus) under ×-Nicols (×100).(Location 7◦ 52.354' E4◦ 57.496') **(b)** Photomicrograph of Granite showing Quartz (Qtz), Microcline (Mic), Plagioclse (Plg), Biotite (bio) under ×-Nicols (×100).(Location N7◦ 49.692' E5◦ 05.591' **(c)** Photomicrograph of Pegmatite showing Quartz (Qtz), Muscovite (Mus), under ×-Nicols (×100) (Location N7◦ 46.700' E5◦ 07.267') **(d)** Photomicrograph of Pegmatite showing Quartz (Qtz) and Plagioclase (Pl) under ×-Nicols (×100) (Location N7◦ 49.81' E5◦ 04.204')

Location 4 (OKEMESI Schistose Quartzite)

Okemesi schistose quartzite have grayish color with fine to medium grain size (Figures16). The mineral composition are quartz, plagioclase, biotite and microcline. Various structures are displayed on the outcrop such as folds, joints, veins, simple pegmatite intrusions (Figure 17).

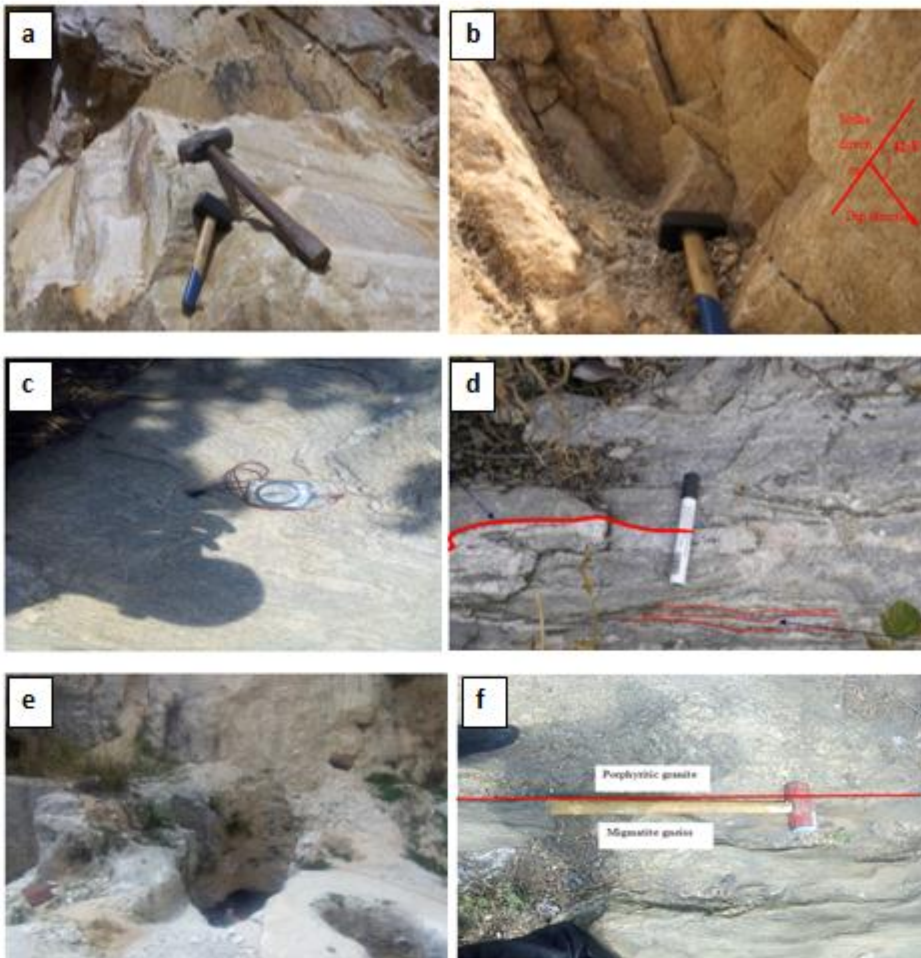


Figure: (a) Photograph of Ido Ile fine-grained massive Quartzite. (Location N07◦47.625 E004◦57.667) (b) Photograph of Itawure Quartzite displaying fractures. (Location N 07◦43.736 E004◦57.33) (c) Photograph displaying ptygmatic folds on Okemesi Schistose quartzite. (Location N07◦50.117 E004◦54.921); (d) Photograph displaying Foliations and Veins on Okemesi Schistose Quartzite.(Location N07◦50.117 E004◦54.921); (e) Photograph of Ijero Mining Site of pegmatites displaying one of the distinguished minerals (Muscovite). (Location N7◦49.81' E5◦04.204'); (f) Photograph of Osun-Ekiti outcrop displaying Contact between porphyritic granite and migmatite Gneiss. (Location N7◦58.313' E5◦05.306').

Table 4: Modal Analysis of Minerals in Schistose quartzite (%)

S/N	Minerals Present	Sq 1	Sq 2	Sq 3	Sq4	Sq 5	Sq6	Average
1	Quartz	89.78	65.06	64.5	67.02	78.5	64.70	71.59
2	Plagioclase	5.91	0	5	0	0	2.20	4.37
3	Opaque	1.61	8.90	3.5	0	2	1.47	3.49
4	Muscovite	2.68	22.6	27	30.52	0	17.64	20.08
5	Biotite	0	3.42	0	1.57	19.5	0	8.16
6	Microcline	0	0	0	0	0	13.97	13.97

Sq= Schistose quartzite

Petrography of Granite

Table 5 indicated the modal values of minerals in Granite. The photomicrographs are shown in Figure 19 while the histogram of mineral distribution in the rock is presented in Figure 20 as biotite (12.91%), quartz (65.60%), plagioclase feldspar (3.26%), muscovite (11.25%), microcline (14.55%) and opaque minerals (1.51%).

Petrography of Pegmatite

Table 6 indicate the modal values of minerals in Pegmatites. The photomicrographs are presented in Figures 21 & 22. Figure 23 gives the histogram as biotite (7.86%), quartz (56.45%), plagioclase feldspar (12.47%), muscovite (14.23%), and opaque minerals (3.41%). Table 7 presents the average modal composition of the four rock types and Figure 26 also showed the charts of their average modal composition respectively. The photograph Ijero pegmatite mining site and contact between migmatite-gneiss are shown in Figures 24&25 respectively. The charts of percentage modal compositions of all the rocks studied are presented in Figures 27-49.

Table 5: Modal Analysis of Minerals in Granite (%)

S/N	Minerals present	Gr 1	Gr 2	Gr 3	Average (%)
1	Quartz	68.5	61.95	66.37	65.60
2	Microcline	15.32	0	13.79	14.55
3	Biotite	5.64	14.13	18.96	12.91
4	Muscovite	4.03	18.47	0	11.25
5	Feldspar	1.81	0	0	1.81
6	Plagioclase	0	3.26	0	3.26
7	Opaque	0	2.17	0.86	1.51

Gr= Granite

Table 6: Modal Analysis of Minerals in Pegmatite (%)

S/N	Minerals present	Pg 1	Pg 2	Pg 3	Pg 4	Average (%)
1	Quartz	73.68	58.06	70.27	23.80	56.45
2	Plagioclase	10.52	32.25	0	7.14	16.63
3	Biotite	15.78	0	3.78	11.90	10.48
4	Opaque	0	9.67	1.62	2.38	4.55
5	Microcline	0	0	2.16	54.76	28.46
6	Muscovite	0	0	22.16	0	22.16

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Pg=Pegmatite

Table 7: Average modal analysis of the four (4) rock types (%)

S/N	Minerals	Rock types					
		Migmatite gneiss	Schistose quartzite	Massive quartzite	Granite	Pegmatite	Average
1	Quartz	52.51	71.59	65.34	65.60	56.45	62.29
2	Orthoclase	2.29	0	0	1.81	0	0.82
3	Biotite	22.06	8.16	20.68	12.91	10.48	14.85
4	Plagioclase	6.12	4.37	4.09	3.26	16.63	6.89
5	Microcline	9.76	13.97	26.22	14.55	28.46	18.59
6	Muscovite	4.54	20.08	20.55	11.25	22.16	15.71
7	Honblende	5.63	0	0	0	0	1.12
8	Myrmekite	1.81	0	0	0	0	0.36
9	Opaque	5.28	3.49	2.54	1.51	4.55	3.47

Chart of Slides Showing the Percentage Concentration of Each Minerals in Each Locations

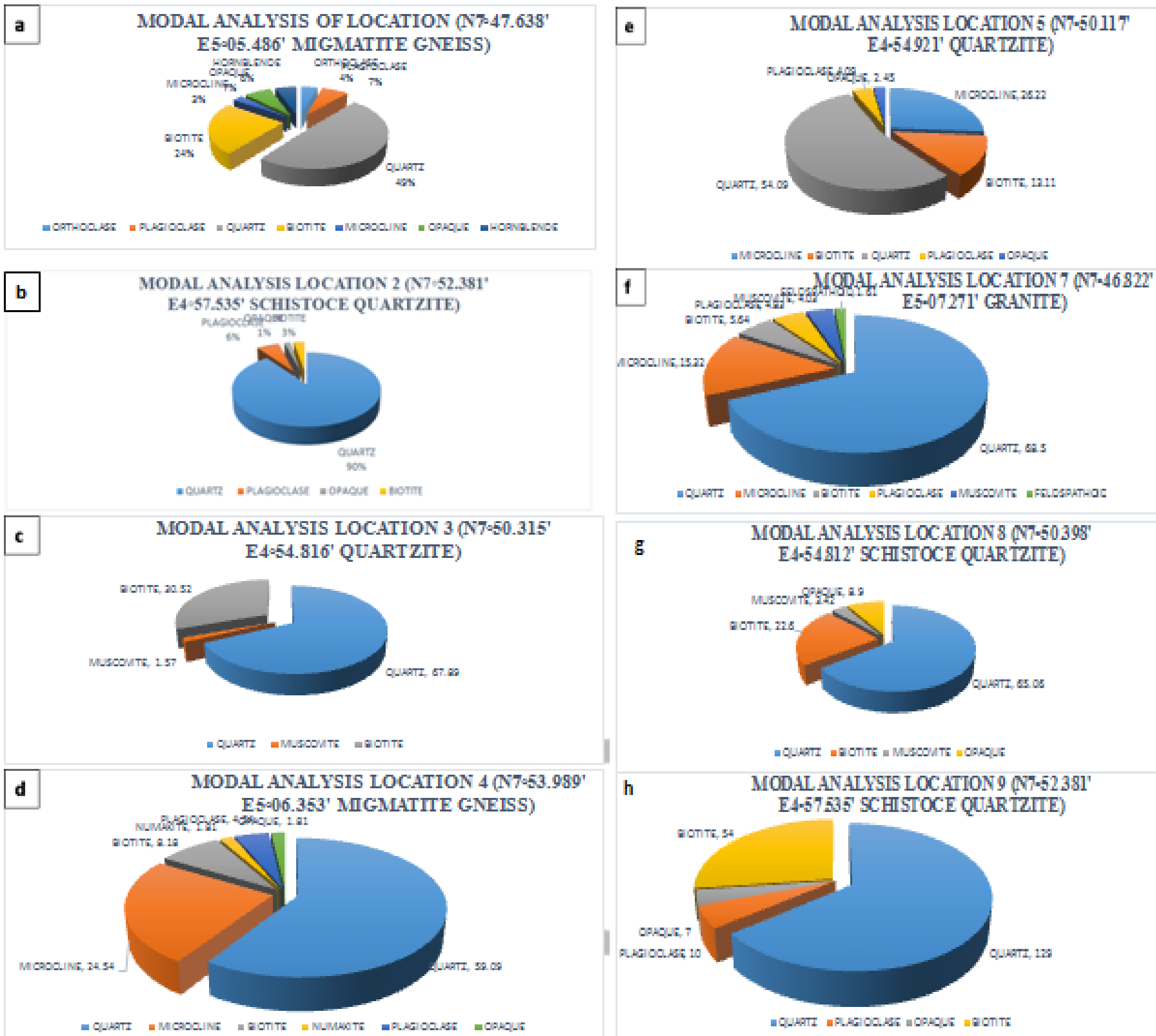

Figure : (a) Modal Analysis of Minerals in Migmatite-Gneiss (N7◦47.638' E5◦05.486'); **(b)** Modal Analysis of Minerals in schistose quartzite (N7◦52.381'e4◦57.535'; **(c)** Modal Analysis of Minerals in Quartzite (N7◦50.315' E4◦54.816'); **(d)** Modal Analysis of Minerals in Migmatite-Gneiss (N7◦53.989' E5◦06.353'); **(e)** Modal Analysis of Minerals in Quartzite (N7◦50.117' E4◦54.921'); **(f)** Modal Analysis of Minerals in Granite (N7◦46.822' E5◦07.271'); **(g)** Modal Analysis of Minerals in schistose quartzite (N7◦50.398' E4◦54.812'); **(h)** Modal Analysis of Minerals in schistose quartzite (N7◦52.381 E4◦57.535').

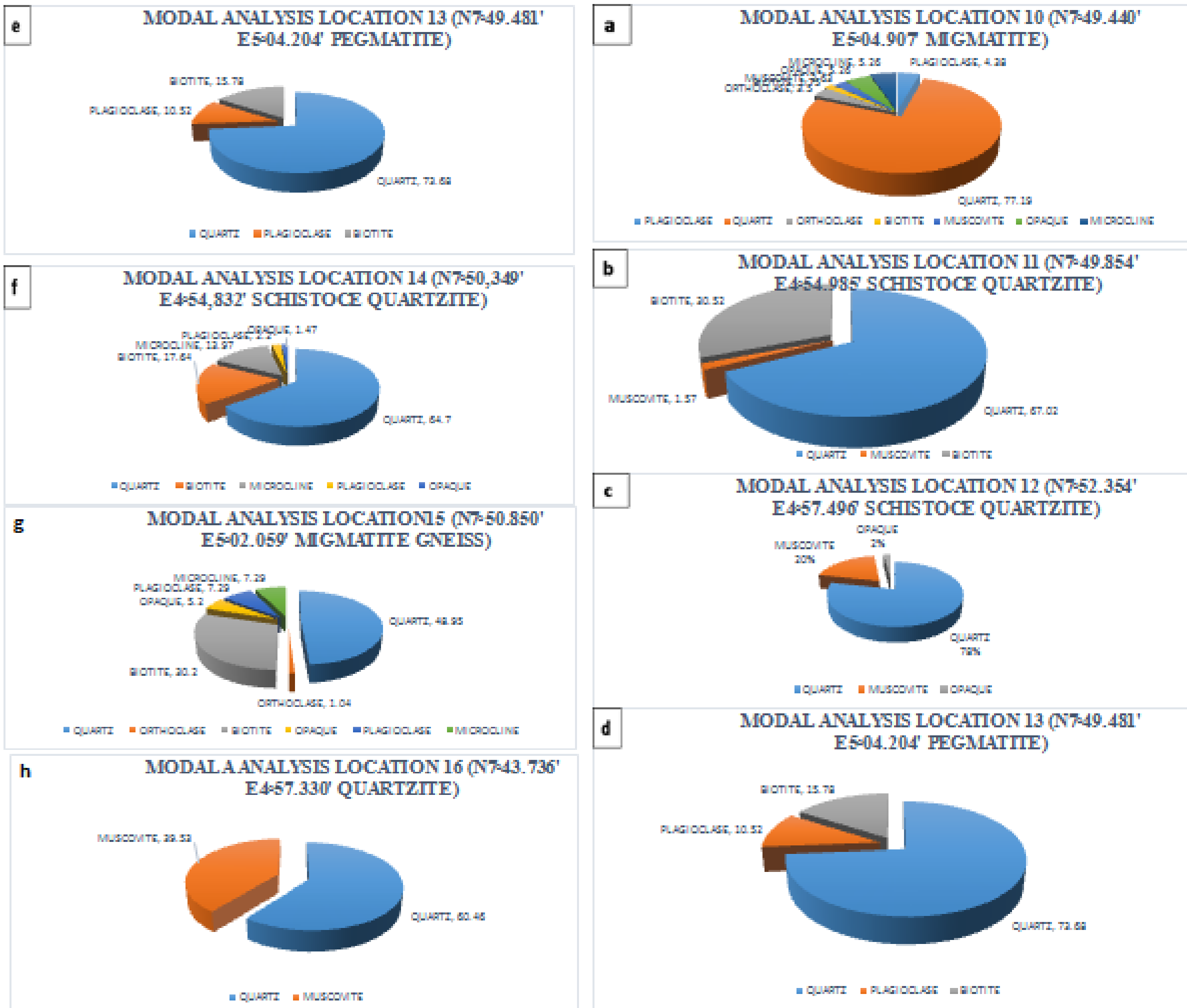

Figure : **(a)** Modal Analysis of Minerals in Migmatite-Gneiss (N7◦49.440' E5◦04.907'); **(b)** Modal Analysis of Minerals in schistose quartzite (N7◦49.854' E4◦54.985'); **(c)** Modal Analysis of Minerals in schistose quartzite (N7◦52.354'E4◦57.496'); **(d)** Modal Analysis of Minerals in Pegmatite (N7◦49.481' E5◦04.204'); **(f)** Modal Analysis of Minerals in schistose quartzite (N7◦50,349'E4◦54,832'); **(g)** Modal Analysis of Minerals in Migmatite-Gneiss (N7◦50.850' E5◦02.059'); **(h)** Modal Analysis of Minerals in Quartzite (N7◦43.736' E4◦57.330').

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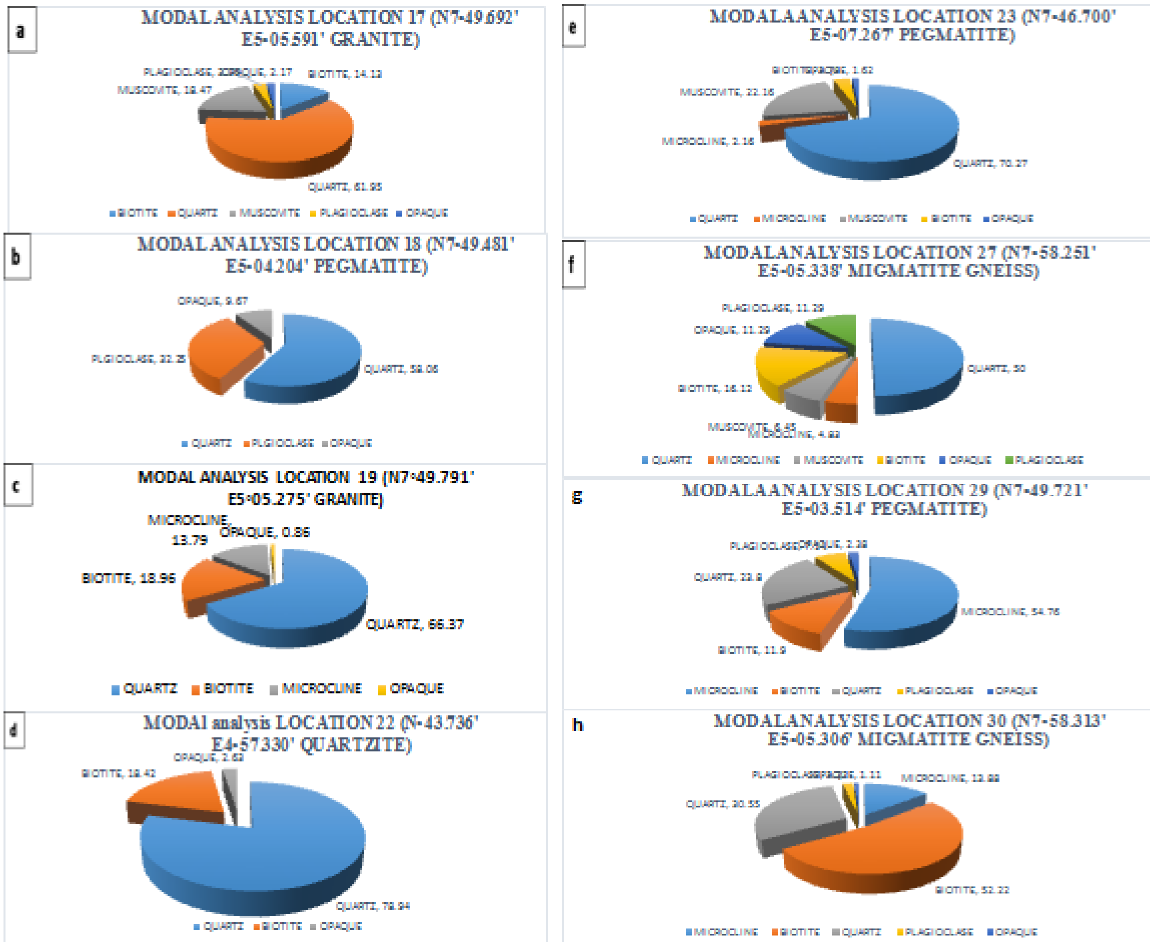

Figure : **(a)** Modal Analysis of Minerals in Granite (N7◦49.692' E5◦05.591') **(b)** Modal Analysis of Minerals in Pegmatite (N7◦49.481' E5◦04.204') **(c)** Modal Analysis of Minerals in Granite (N7◦49.791' E5◦05.275) **(d)** Modal Analysis of Minerals in Quartzite (N◦43.736' E4◦57.330') **(e)** Modal Analysis of Minerals in Pegmatite (N7◦46.700' E5◦07.267'); **(f)** Modal Analysis of Minerals in Migmatite-Gneiss (N7◦58.251' E5◦05.338'); **(g)** Modal Analysis of Minerals in Pegmatite (N7◦49.721' E5◦03.514'); **(h)** Modal Analysis of Minerals in Migmatite-Gneiss (N7◦58.313' E5◦05.306').

Structural Geology of the study area

Folding has been established to occur in the studied area (Ayodele *et al.*, 2017), which is mostly affected by the schistose quartzites (Figure 3). Other structural features mapped include fractures, joints and veins which is noticeable in the quartzites and schists. However, the fractures, joints trend and veins were measured and their orientations represented on rosette diagrams. The joints are prominent in the quartzite region of the studied area. (Figures 50) and are predominantly in the NW-SE direction which is an indication of the direction of dominant tectonic forces prevailing in the studied area. The vein orientations are mostly in the NE-SW direction (Figure 51). The fractures mapped here are minor fractures detected on the quartzite limbs and they probably developed as a result of lateral compression of the quartzites and subsequent overthrusts during the major tectonic events in the area (Figure 52). On the quartzites, fractures are shorter and are dominantly in the E-W direction. Those on granites are longer and more intersected and are in the N-S and NE-SW direction. The fractures on the schists and migmatites which are in the NE-SW, NW-SE and NNS directions are longer but fewer than those on the quartzite and granites (Ayodele, 2016). Altogether, five sets of fractures were recognized in the rocks of the studied area. The dominant ones are the E-W fractures common on the quartzites. However, there is a positive correlation between the fractures on the granites and quartzites, because their fracture patterns are similar to some extent, but dissimilar when related to the migmatites and schists. These fractures bear relationship with mineralization as they could serve as sites of ore localization and deposition (Ayodele, 2016). For example, certain fractures like the NE-SW types have been suggested by Wright (1976) to have connections with oceanic fracture zones and may harbour mineralization. In other cases, favourable mineral locations may occur where fractures intersect or where they are associated with suitable geological conditions. On the basis of prominent fractures from the study area, it is believed that fracturing postdated the folding episodes in the area and mineralization in the studied area are controlled by these fractures (Ayodele *et al.*, 2017).

Interpretation of X-ray Diffractograms

The results of X-ray diffraction (XRD) for Seven (7) rock samples and their diffractograms are presented in Figures 54-60 respectively. The work of Ayodele *et al*., (2015) reported gold showings in the schistose quartzites of Okemesi area hence, hence the selection of seven samples of schistose and massive quartzites from the bulk samples for XRD analysis. The diffractograms displayed the major minerals at different peaks of the diffractograms. The major minerals include quartz, muscovite, microcline, orthoclase and native gold. The overall results of the XRD analysis revealed that quartz is the dominant major mineral common in all the analyzed rocks, and it occurs at different peaks of the diffractograms. This is closely followed by muscovite, microcline and K-feldspar. However, there is a close relationship between the mineral occurrence in XRD and those derived from petrographic studies under transmitted light. The Gold discovered from the diffractogram is (Petrovskaite (Au Ag(S,Se)) which is displayed in Figure 56.

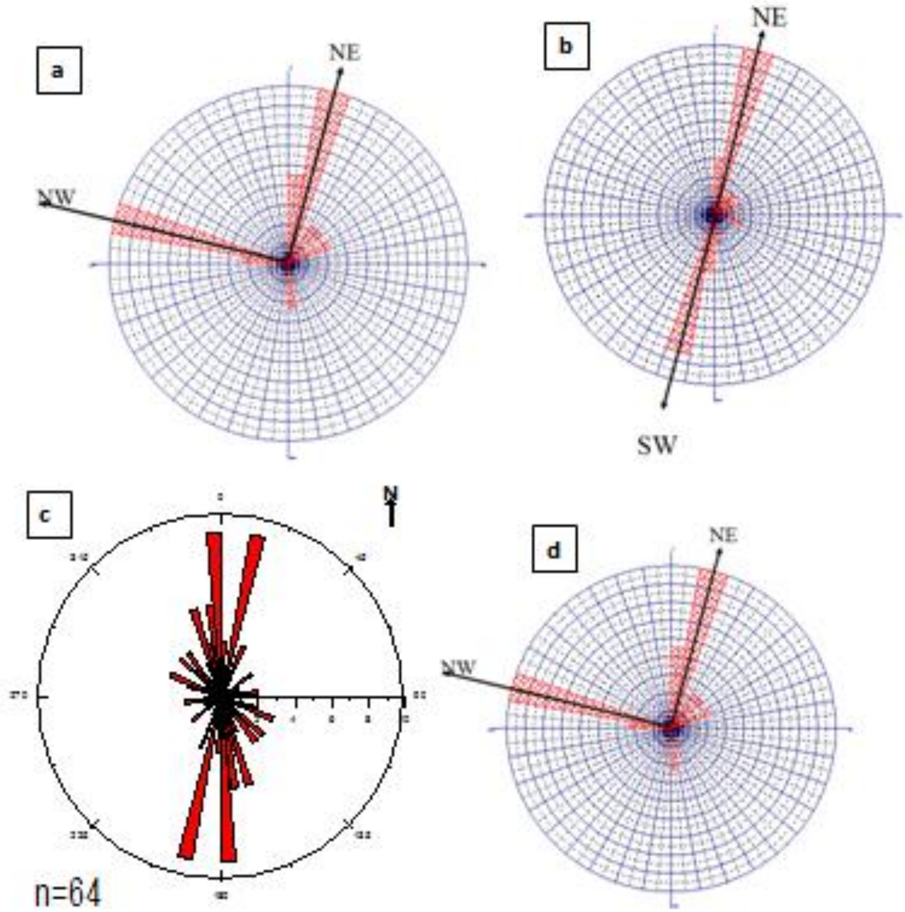

Figure: **(a)** Rosette diagram of Joints orientation in the study area; **(b)** Rosette diagram of veins orientation in the Study Area; **(c)** Rose plot showing fractures trend in the study area; **(d)** Rosette Diagram of Joint trend in the Study Area.

Economic Geology of the Study Area

The economic potentials of the various lithological units in the studied area can be used as dimension stones. Granites of the studied area which is composed of red potassium-rich feldspar orthoclase feldspar, white and cream-colored plagioclase feldspar, dark and shiny flakes of biotite mica and gray irregular quartz grains of vitreous luster. The fact that the mineral grains are tightly interlocked gives it a greater strength and makes it a good material for buildings and sculptures as well as for construction purposes. The petrographic analysis has shown that quartz occur abundantly in the studied area and thus makes quartz very useful in the silica industries, gemstone, wrist watch, floor tiles and many other compounds of commercial importance.

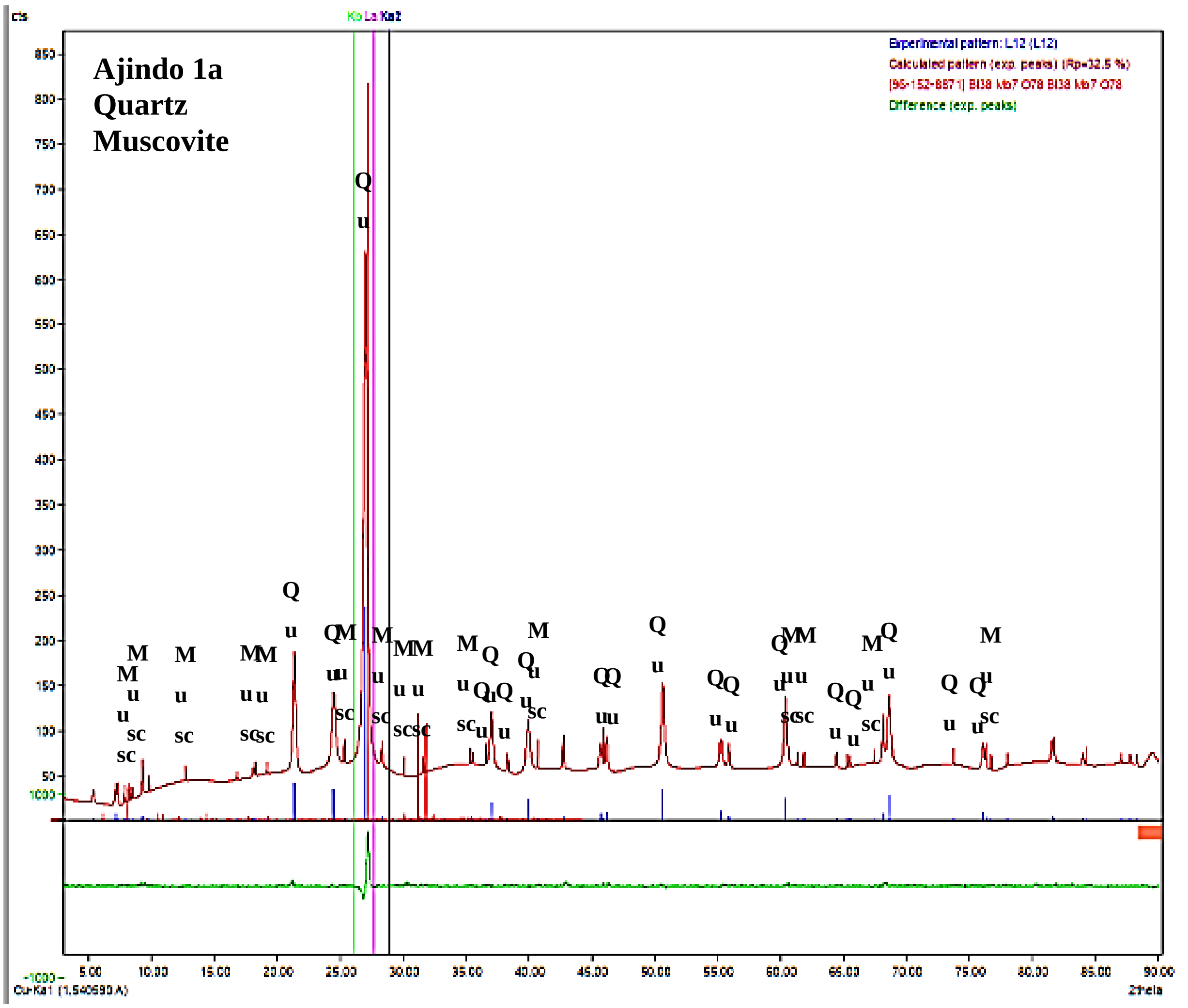

Figure 54: X-ray Diffractogram of Ajindo (1a) Schistose quartzite (Location N7◦52.354' E 4◦57.496')

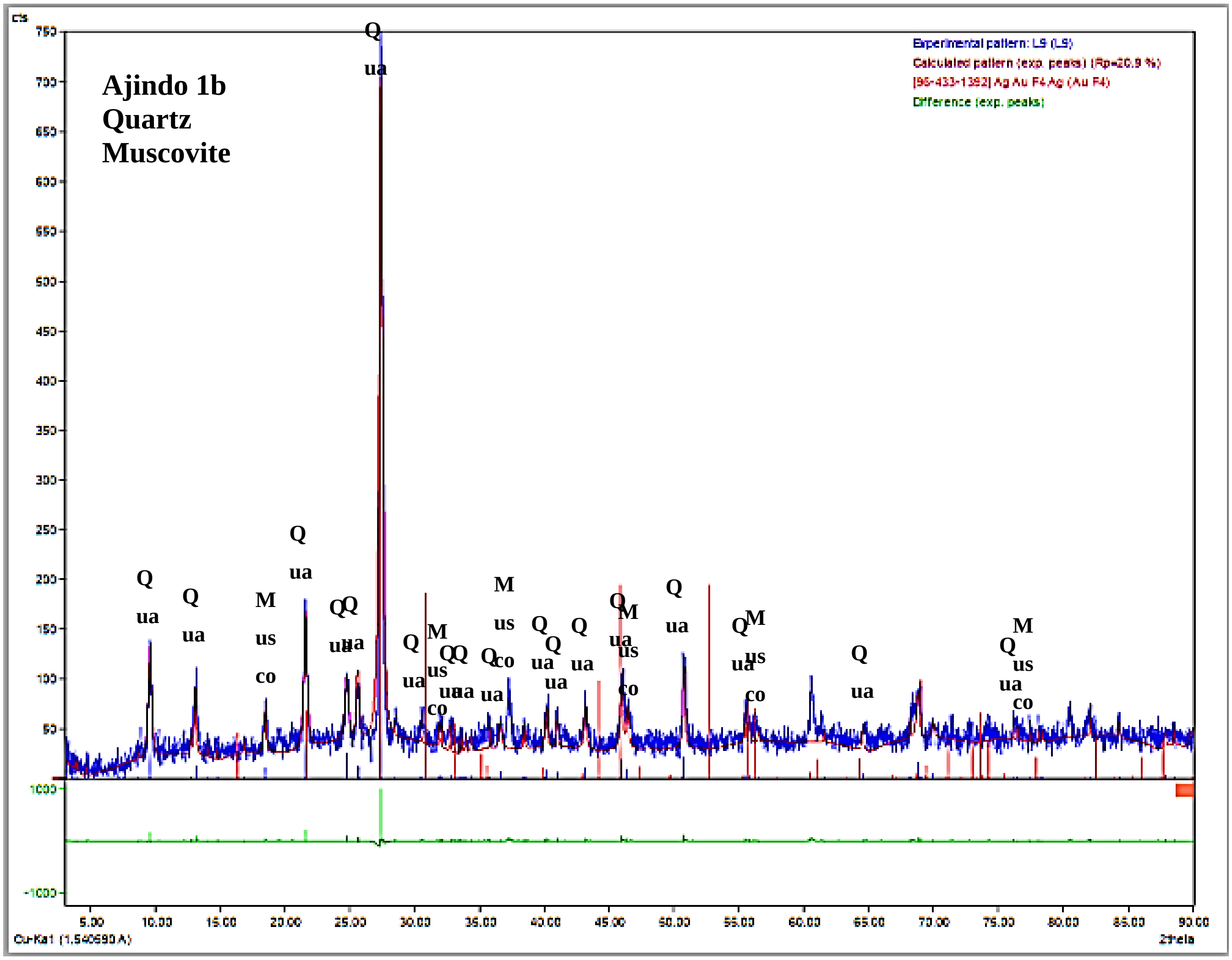

Figure 55: X-ray Diffractogram of Ajindo (1b) Schistose quartzite (Location N7◦52.381' E4◦57.535')

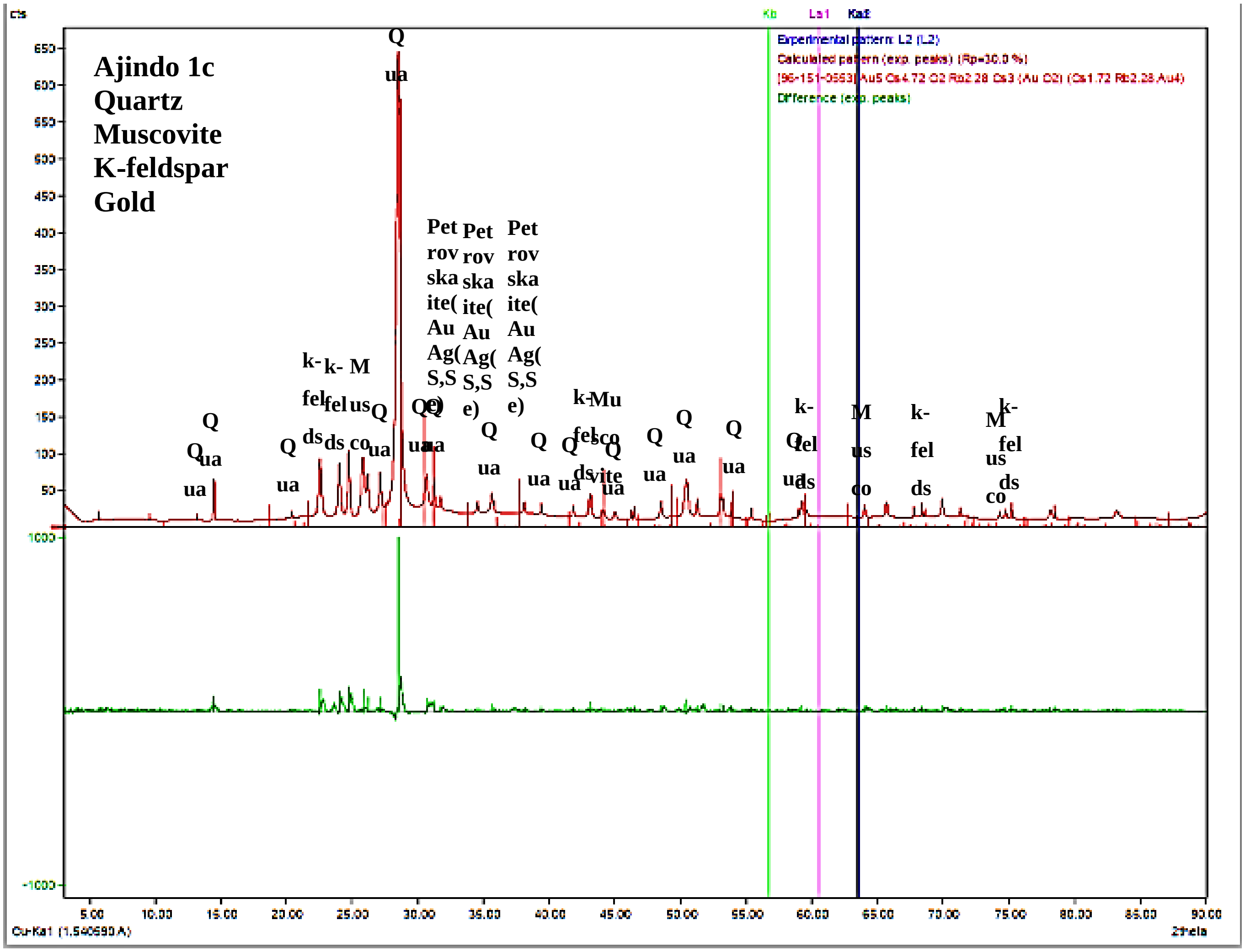

Figure 56: X-ray Diffractogram of Ajindo (1c) Schistose quartzite. (Location N7◦52.381' E4◦57.535')

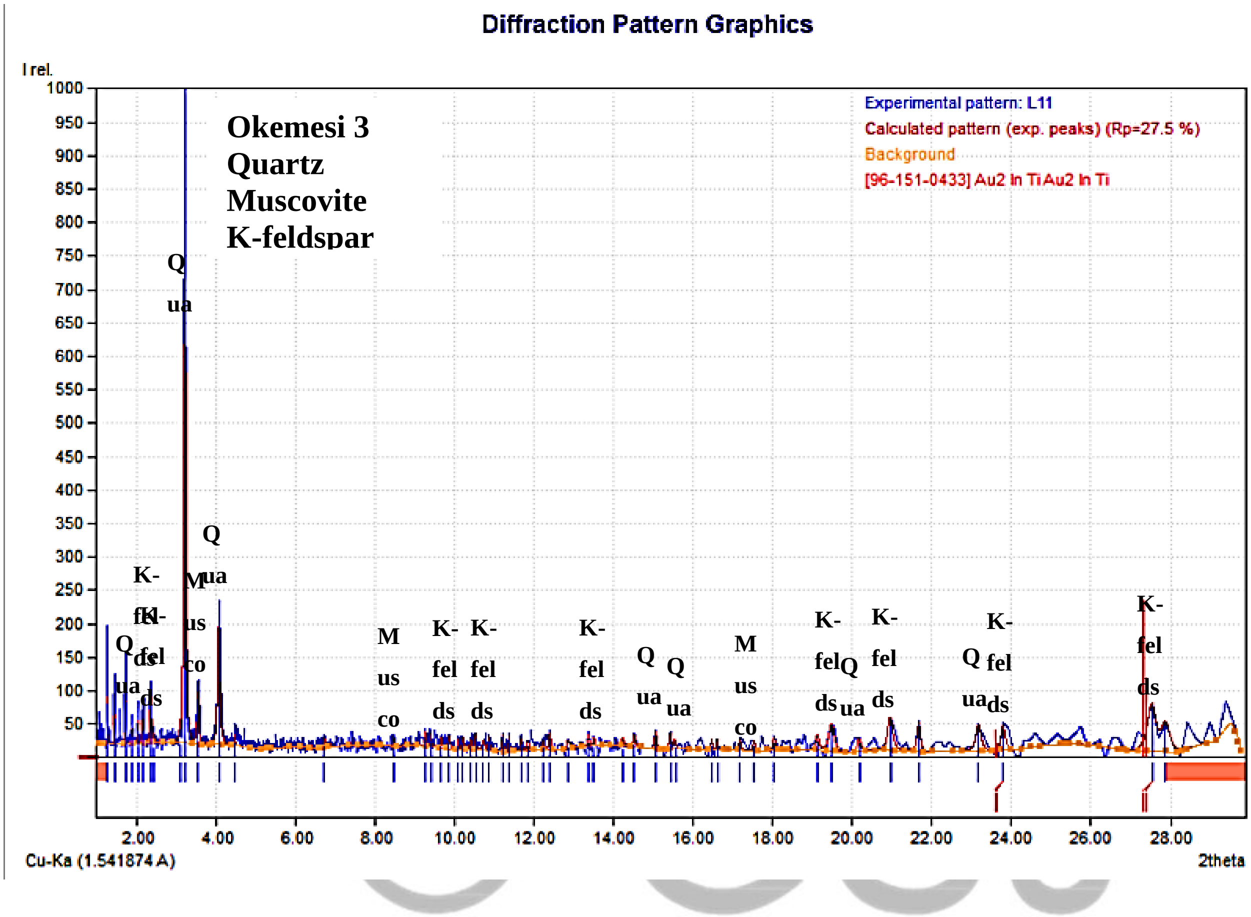

Figure 57: X-ray Diffractogram of Okemesi 3 Quartzite. (Location N7◦49.854' E4◦54.985')

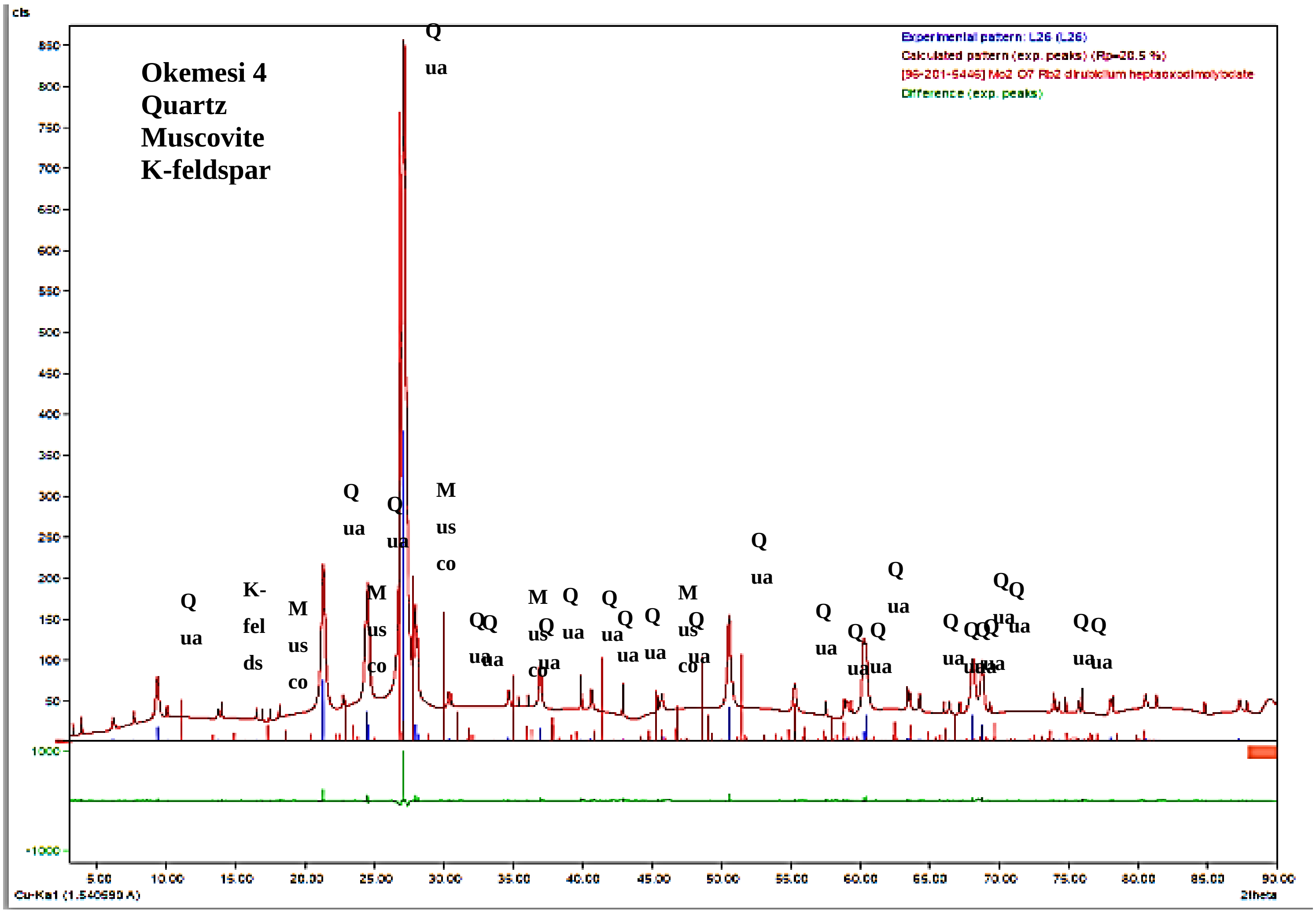

Figure 58: X-ray Diffractogram of Okemesi 4 Schistose quartzite. (Location N7◦50.340' E4◦54.832')

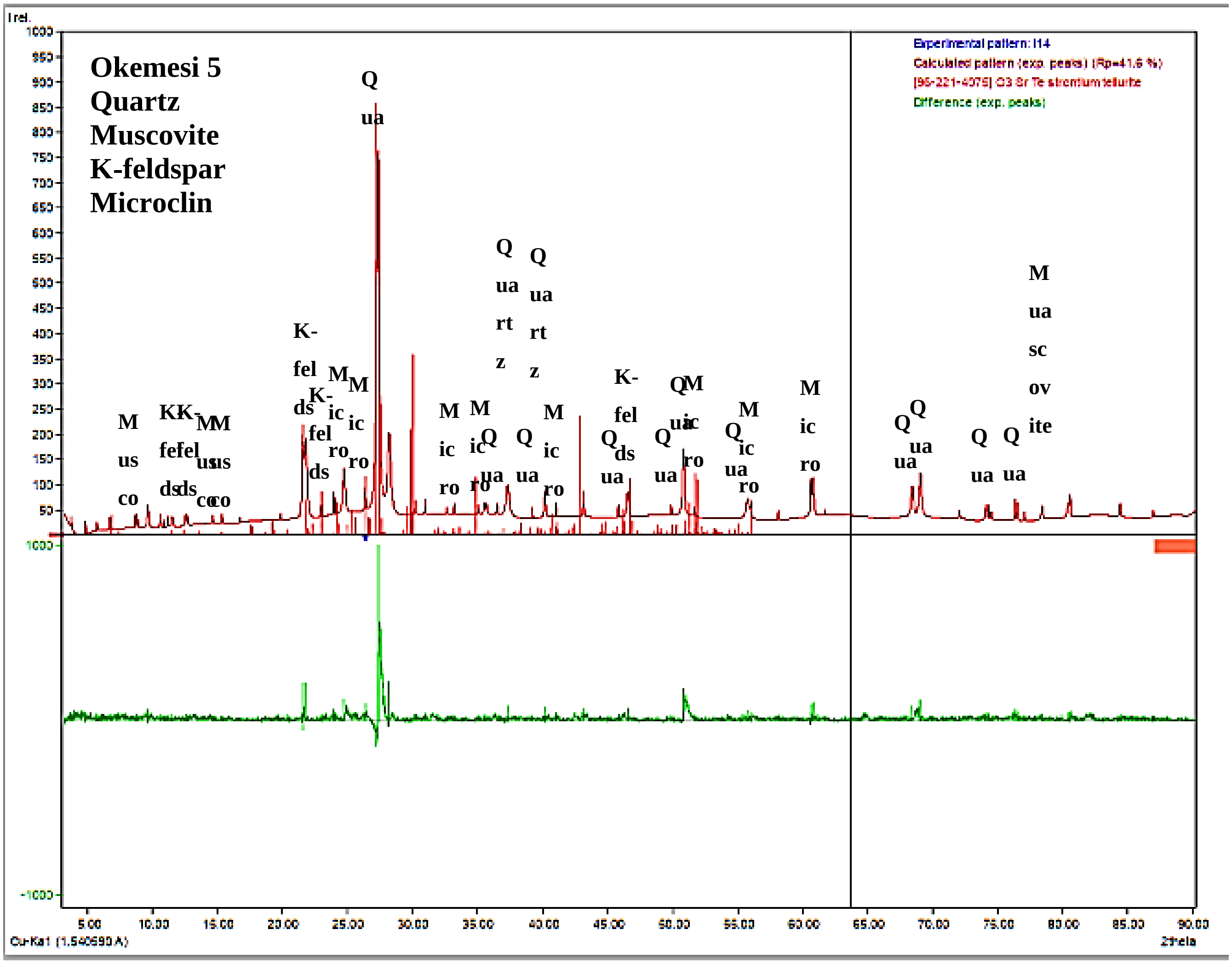

Figure 59: X-ray Diffractogram of Okemesi 5 Schistose quartzite. (Location N7◦50.349' E4◦54.832')

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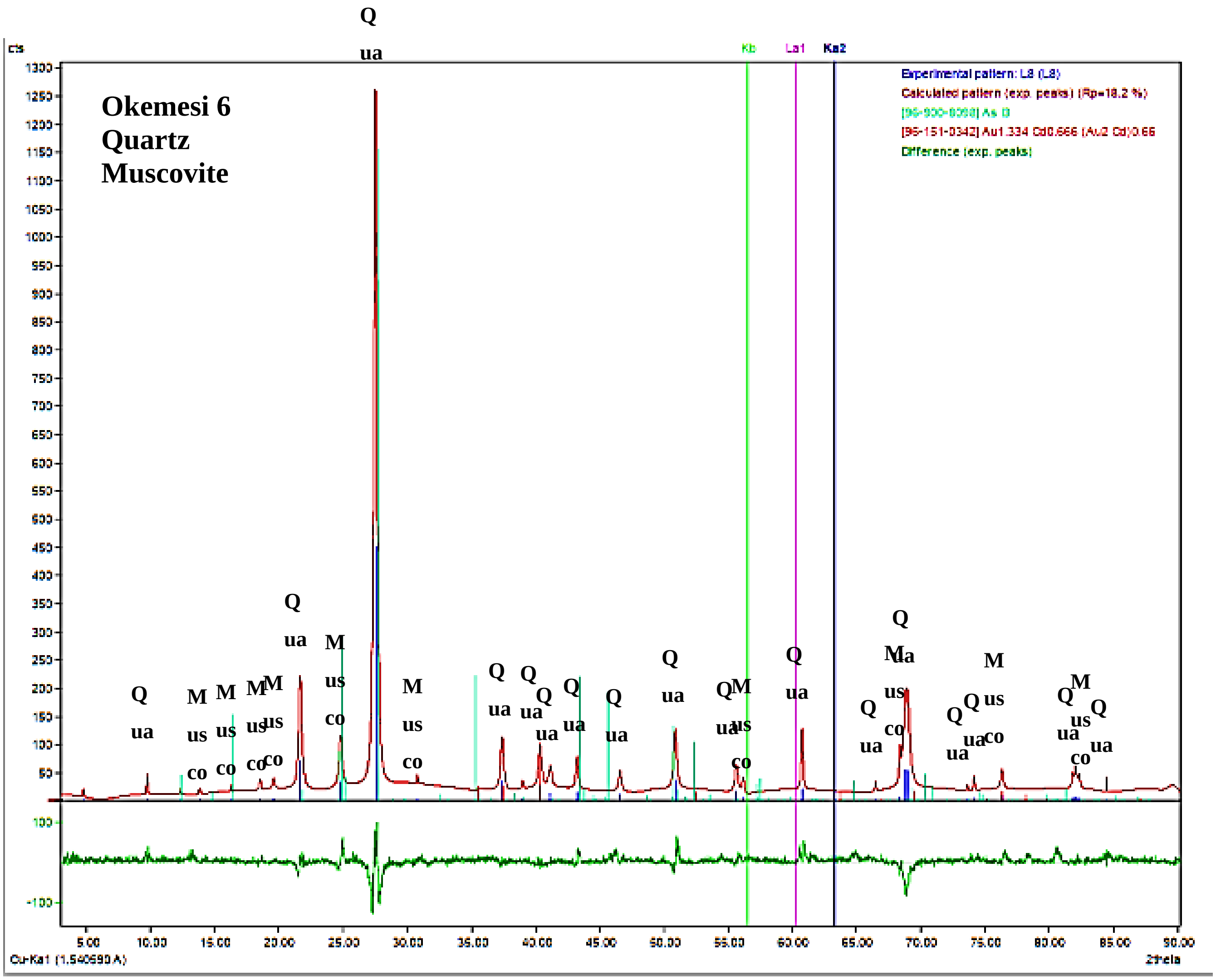

Figure 60: X-ray Diffractogram of Okemesi 6 Schistose quartzite. (Location N7◦50.398' E4◦54.812')

Mode of formation of Petrovskaite (Au Ag(S,Se)

Petrovskaite mineral is a monoclinic mineral containing gold (Au, selenium (Se) and sulfur (S). **Composition –** Molecular weight=339.25gm, Silver-31.80%Ag, Gold-58.06%Au, Selenium-1.16%Se and Sulfur-8.98%S. **Environment –** Microscopic rims on gold particles, the composition of the petrovskaite most likely result from the presence of an admixture of gold and silver sulfides or solid solutions. It can be found in Au-Ag epithermal, Au-skarn, Au-Cu volcanogenic massive sulfide and Au-quartz-sulfide deposits (Zhen-jie *et al*., (1979); Castor and sjoberg (1993); Marcoux *et al*., (1993); Dill, (1998); Al'shevskii, (2001); Grethe *et al.*, (2002); Warmada *et al.*, (2003); Chauvet *et al.*,(2006);Koneev, (2006);Majzlan, (2009); Pal'yanova, (2008); Anisimova *et al.*, (2008); Proskurnin et al., (2011); Savva *et al*., 2012; Cocker *et al*., (2013). It forms veinlets, isolated micro inclusions and 10-100μm rims occurring in native gold, rarely as single crystals and their aggregates 3-4mm in size. Reaction rims are formed when two phases or an assemblage along their interface (Fisher 1973). Petrovskaite in natural condition helps to understand the geochemistry, transport and deposition of noble metals

Conclusion

This study has actually confirmed the presence of gold mineral in the Precambrian basement rocks of Okemesi area. The magmatic origin of the precursor rocks of Okemesi-Ijero is here by established by the following; (i) the intrusive nature of the rocks which is amply spotted by sharp contact relationship displayed by various granitoid bodies with the country rocks. (ii).The development of myrmekitic intergrowths at the plagioclase-alkali feldspar-quartz triple junction, which suggested the relevance of late magmatic/deuteric crystallization in the evolutionary history of the rocks. The occurrence of microcline microperthite and complete absence of antiperthitic features in all the thin sections examined. Also, the rocks are characterized by the mineral assemblages of quartz, biotite, hornblende, plagioclase, orthoclase, microcline, myrmekite, and opaque minerals. The XRD study also revealed a strong affinity with the petrographic analysis and also indicated Au showings in Okemesi area (Ajindo Bedrock) which has now confirmed the phase of Au showings in the schistose quartzites. (Anifowose *et al*., 2006), However, In view of the research conducted in the studied area, the following recommendation is proposed to improve on the present study such as; carrying out Electron Microprobe study to get detailed ore minerals present and using Micro X-ray spectral analysis to determine the variations in the concentration of petrovskaites present.

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