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Geological Mapping and Gemstones prospecting in Deformed Precambrian Rocks, East of Okemesi Fold Belt, Southwestern Nigeria

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Abstract

The study area covered Ikogosi, Igbara odo, Ipole, Erijiyan and Araromi Ekiti respectively which are underlain by rocks that have undergone multiple episodes of tectonic deformation and formation of other deep-seated structures such as fractures, joints, veins, and foliations with steep-angle dips which are manifestations of the pervasive Pan African orogeny. The method adopted for this research includes field examination of the rocks, systematic sampling of the different rock units at a density of 100m-200m and petrographic studies of selected rocks samples using Binocular Polarizing Microscope with Topcam Digital Camera (3.1MP) and attached Computer software for taking snapshots of the rock slides for mineral indentification. Geological units of the area consist of migmatites, granites, granite-gneiss, quartzites (massive and schistose types) as well as pegmatites occurring as veins and dykes with varying lengths and sizes. The cross-sectional map of the area confirmed folding episodes which are polyphase in nature. The type of folds recognized are ptygmatic, asymmetrical, tight, and isoclinal to overturned antiformal folds. Other structures observed arose from brittle to ductile deformational events. However, the studied areas are enriched with gemstone mineralization such as garnets, blue and green tourmalines, and other specialty minerals which are hosted by the granite pegmatites in the study area. Gemstones are minerals, rocks, or organic matter that have been chosen for their beauty, durability, and rarity and are cut, faceted and polished to make jewelry or other human addornments This research also confirmed that the structural differentiation of the rocks in the studied area has contributed immensely to the ground preparation for the epigenetic mineralization (gemstones and other specialty minerals) discovered and mapped in the studied area.

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Keywords: Lithologic Units, Structures, Deformation, Mineralization

1. Introduction

Gemstones are minerals, rocks, or organic matter that have been chosen for their beauty, durability, and rarity and are cut or faceted and polished to make jewelry or other human addornments. Gemstones are also known as mineral crystals of precious stones found underneath the earth. They are naturally formed as minerals or substances of beauty when cut and polished for jewelry and partly as alternative and complimentary medicine in prehistoric times (Adesoji and Stephanie, 2018). They are hosted by pegmatites especially the complex ones which normally exhibit zoning. In addition, there are many others for example, diamonds are hosted in volcanic rocks such as kimberlites and lamproites. These pegmatites are specialized types of rocks that occurred as late stage intrusive rocks (magmatic differentiates) London (2008); Simmons et al. (2012).

They intrude pre-existing rocks such as granites, migmatites, gneisses, schists etc in southwestern Nigeria. They are widely distributed in Precambrian terrains such as those in Southwestern Nigeria and Ekiti State in particular. The Precambrian Basement of Southwestern Nigeria has undergone several episodes of deformation and metamorphism Rahaman (1988). The general north-south trend of major fractures and foliations within the Basement complex occured as a result of deformation Odeyemi (1992). Odeyemi (1977) observed that the rocks in the basement complex of Nigeria display polyphase deformation with the plutonic episode of the Pan African Orogeny being the most evident. Rahman (1988) also noted that south western basement complex of Nigeria lies within the rest of the Precambrian rocks in Nigeria. He grouped the rocks in this region as migmatite – gneiss – quartzite complex comprised largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes. Oluyide (1988) suggested that almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusive are tectonic in origin, because pre-existing primary structures have been obliterated by subsequent deformation. Anifowose et al. (2006) also noted that joints ranging from minor to major ones are found in all the rock types, some of which are filled with quartz, feldspars or a combination of both which allign generally in the NE-SW direction, In addition, (Ajibade, 1986 and Rahman, 1988) suggested that the south western basement complex of Nigeria has been affected by two phases of deformation namely D1, D2. The first phase (D1) produced tight to isoclinals folds while the second phase (D2) is characterized

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by more open folds of variable style and large vertical NNE-SSW trending fault. Also, Oluyide (1988) gave evidence that within the basement complex, tectonic deformation has completely obliterated primary structures except in a few places where they survived deformation. Okonkwo (1992).. Adesoji and Stephanie (2018) examined each stage of the gemstone value chain, issues, and opportunities that abide in each stage as well as current future status each stage has in the economy of Nigeria. Nigeria is known to have over forty-four deposits of different solid minerals including gemstones in large quantity, and the sector contributes less than 0.3% to the Gross Domestic Product (GDP) of the nation. Leviski and Sims (1997) investigated the feasibility of surface geochemical techniques applied to exploration for coloured gemstones in the MAngare area, SE Kenya, and concluded that the most cost-effective approach would involve bulk-sampling over a loose grid to define ultramafic belts. Geological mapping has been carried out in the Erijiyan axis (northern segment) to map the quartzites and the quartz-schists (Ayodele and Ajigo, 2019); however, there is paucity of information or no information at all on the nature and type of pegmatite bodies in Ikogosi and its environment which is assumed to be mineralized. Therefore, this research is aimed at carrying out detailed geological mapping and prospecting of gemstones in the deformed Precambrian rocks of the study area.

2. Description of the Study Area

The study area covering Ikogosi, Ogotun, Apapolu, Erijiyan, Araromi, Ipole and Igbara-Odo, all in Ekiti Southwest local government area, is situated in the eastern part of Okemesi Fold Belt (Figure 1). It lies within longitudes +4°57'0" and +5°5'0" and latitudes +7°31'0" and +7°37'0", covering an estimated area of 48km². The study area is accessible through a major road network and footpaths.

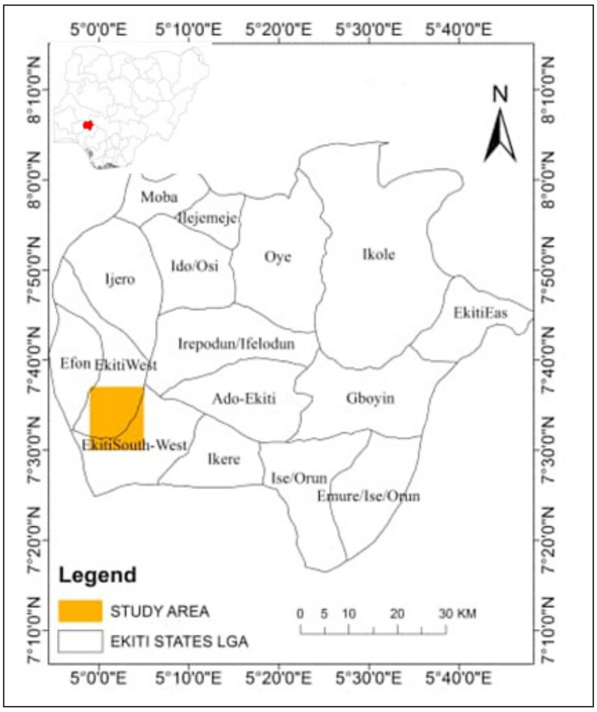

Figure 1. Map showing location of the study area. (Oyewumi, 2019)

Traversing the area was also made easy with the assistance of the local settlers who helped locate existing outcrops in initially inaccessible areas. Stream channels were also useful indicators.

The topographic map provided represents the entire study area (Figure 2) which also serves as the base map. The uneven topography is caused by the crystalline nature of the different rocks found in the area and their differential responses to weathering. The highest topographic height encountered was about 1800m above the average sea level. The study area is also characterized by relatively dense drainage which is of dendritic and trellis patterns.

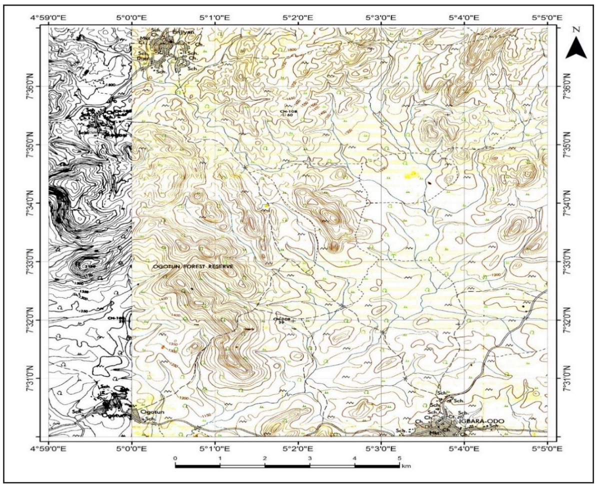

Figure 2. Topographic Map of the study area (Modified after NGSA, 2006)

3. Methods of Investigation

Geological mapping was carried out with the aid of the topographic (base) map of the study areas acquired at a scale of 1:25,000 (Figure 2). The rocks encountered in the area include quartzites (massive and schistose), migmatite-gneiss, granites, granite-gneiss and pegmatites which intruded majorly on the quartzites, granites and granite-gneisses as dykes and veins. Their accurate geographical positions were determined with the global positioning systems (GPS), and were recorded in the field notebook. The rocks were systematically sampled across the various locations and localities. The various sampling points were superimposed on the geology (Figure 3) to give a clearer synopsis of the terrain. Structures such as folds, fractures, joints were also mapped on the different rocks, and their orientations and atitudes were measured using the Compass clinometer. Fifty-two (52) bulk samples were collected for these investigation. The petrographic studies were carried out using the Binocular Polarizing Microscope with Toupcam Digital Camera (3.1MP), and Computer.

The laboratory analysis was carried out at the Petrology laboratory of the Department of Applied Geology, The Federal University of Technology, Akure. Twenty-two rock samples were carefully selected, and cut into thin sections using manual thin-section method, and were prepared as rock slides with necessary materials and reagents using the standard procedures and techniques.

Microscopic viewing with the aid of Topcam digital camera (3.1MP) under transmitted light was carried out to detect and study the mineral composition of the rocks. The purpose of the camera is to take snapshots of the slides, and produce the photomicrographs of the different slides, while analysis and identification have been carried out on the desktop computer attached to the camera to bring out the optical behavior and character of these minerals under plane polarized and crossed polarized light.

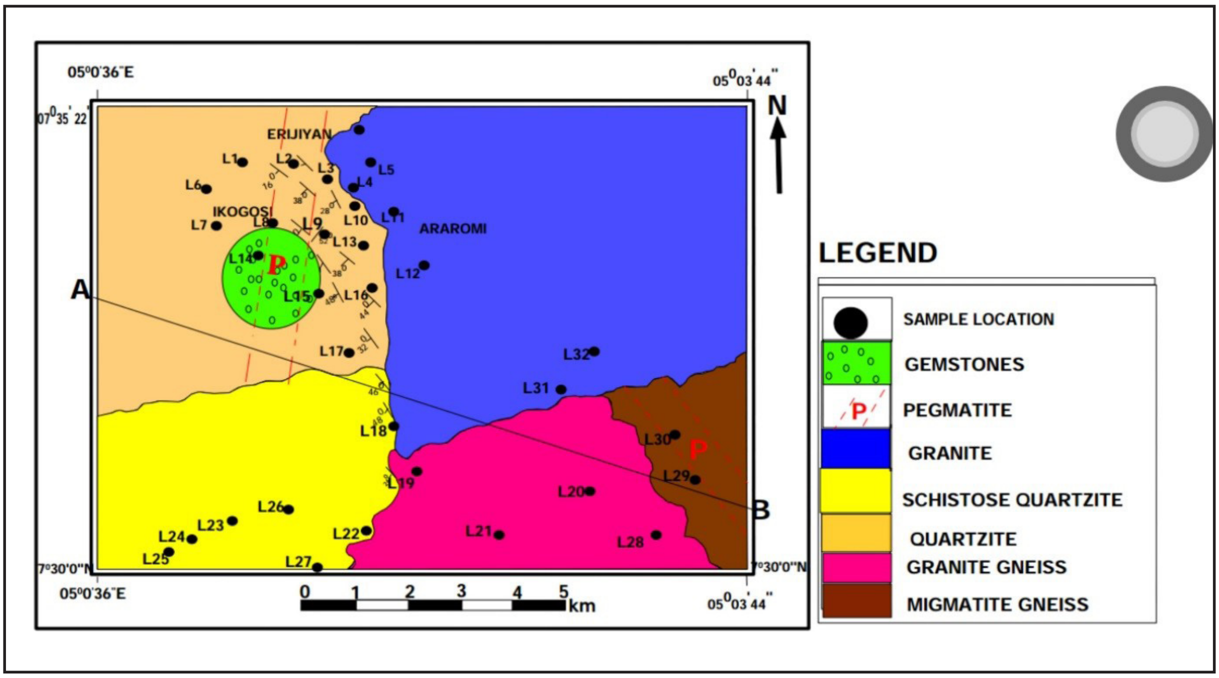

Figure 3. Sample location map of the study area superimposed on the geology.

4. Results and Discussion

4.1 Field Investigation

The geological map (Figure 4) presents the various rock units and their distribution patterns in the study area. Six major lithologic units were identified which includes the granite-gneiss to the pegmatite with well-delineated boundaries. Table 1 presents the geological field data collected which represented data from two different localities. The strike and dips were not measurd in most of the rocks because they were not foliated, some of the fabrics have been destroyed due to deformation while others have been intensely weathered occurring as boulders around the study areas (Table 1). The pegmatites are the late-stage intrusives occurring as dykes and veins on the pre-existing rocks which are products of the Pan African orogeny (Figure 4).

The cross-sectional maps confirmed folding in the study area. However, migmatite is absent from other areas because it was confined to certain locations and is not extensive like other outcrops as seen in Figure 5. In addition, some of the grantic bodies possess inclusions (xenolths) which are evidences of partial digestion of the intruding rocks. The folding episodes affected the schistose quartzites, granite gneiss, and the granite. This can be attributed to the compressive tectonics accompanying the behaviour and responses of the affected rocks to stress. (Figure 5). This also confirmed that fracturing postdated the folding episodes in the studied area. The various rock types mapped and their delineated boundaries and dipping angles were used to produce a geological and cross-sectional maps of the studied area (Figures 4 and 5).

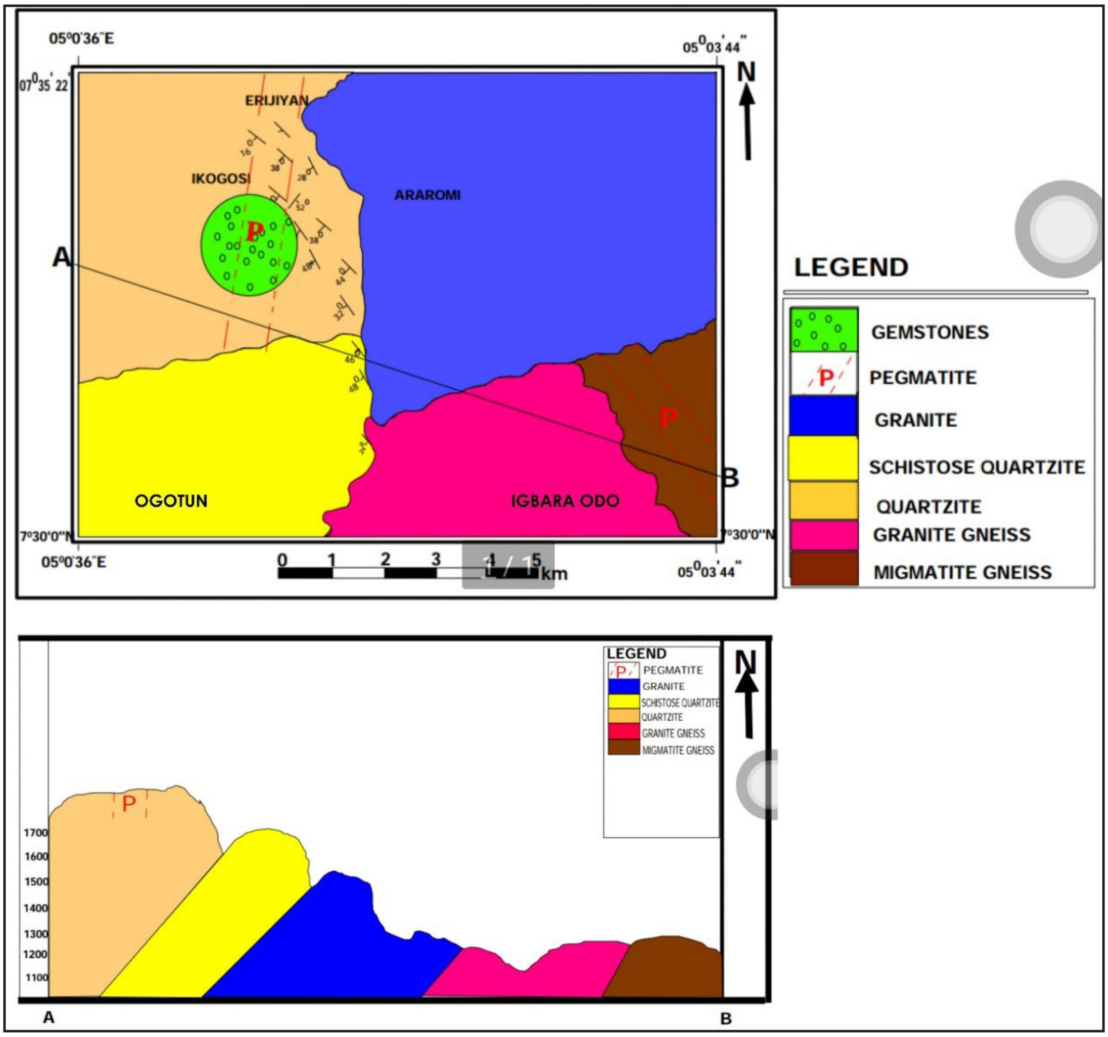

Figure 5. A cross section of symetrical fold profile generated from dip matching from other locations.

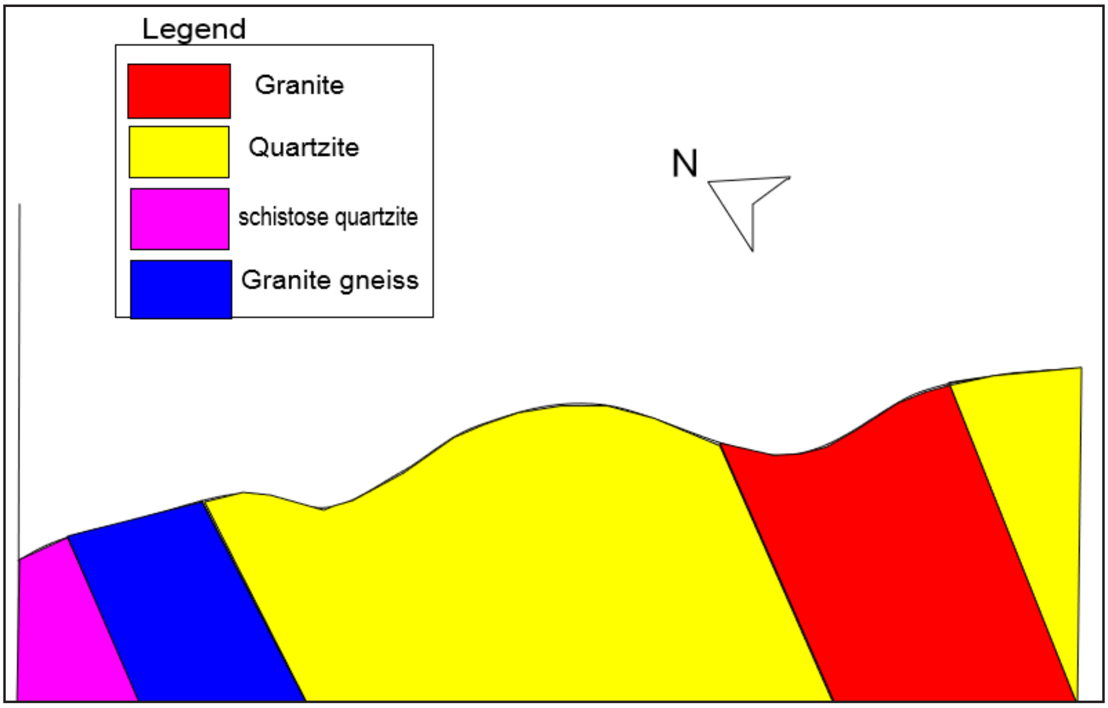

Figure 4. Geological map (above) and cross-section (below) of the study area.

Table 1. Summary of Field Data

Location	Latitude	Longitude	Rock Names	Strike and dip measurements	Joint and fractures orientations	Rock types
1	N 07^0 35’ 22’’	E 05^0 0’ 36’’	Schistose Quartzite	284^0 W, 30^0 E	Weathered	Metamorphic
2	N 07^0 35’ 22’’	E 05^0 0’ 38’’	Quartzite	-	Weathered	Metamorphic
3	N 07^0 35’ 10’’	E 05^0 0’ 53’’	Mine site for tourmaline; Quartzite with pegmatite intrusion.	-	Mining pit	Metamorphic
4	N 07^0 35’ 00’’	E 05^0 1’ 14’’	Quartzite	-	Weathered	Metamorphic
5	N 07^0 34’ 58’’	E 05^0 1’ 15’’	Quartzite	341^0 NW, 75^{0}W	Weathered	Metamorphic
6	N 07^0 34’ 43’’	E 05^0 1’ 16’’	Quartzite	-	Weathered	Metamorphic
7	N 07^0 34’ 44’’	E 05^0 1’ 17’’	Quartzite	-	Weathered	Metamorphic
8A	N 07^0 30’ 07’’	E 05^0 2’ 42’’	Granite	-	Pegmatite Veins	Igneous
8B	N 07^0 30’ 07’’	E 05^0 2’ 41’’	Granite	-	Joints and folds	Igneous
8C	N 07^0 30’ 05’’	E 05^0 2’ 41’’	Granite	-	Joints and folds	Igneous
9	N 07^0 30’ 08’’	E 05^0 3’ 30’’	Granite	-	Xenoliths folds and fractures	Igneous
10	N 07^0 30’ 08’’	E 05^0 2’ 41’’	Granite	-	Joints and folds	Igneous
11	N 07^0 30’ 11’’	E 05^0 3’ 30’’	Granite	-	Joints and folds	Igneous
12	N 07^0 30’ 24’’	E 05^0 3’ 38’’	Granite	-	Joints and fractures	Igneous
13	N 07^0 30’ 35’’	E 05^0 3’ 44’’	Contact of Granite and Migmatite Gneiss		315^0 NW, 313^0 NW, 308^0 NW, 311^0 NW, 321^0 NW	Igneous and Metamorphic
14	N 07^0 30’ 36’’	E 05^0 3’ 41’’	Contact of Granite and Migmatite-Gneiss	-	332^0 NW, 314^0 NW, 318^0 NW, 117^0 SE, 264^0 SW, 132^0 SE	Igneous and Metamorphic
15	N 07^0 30’ 45’’	E 05^0 3’ 35’’	Granite	-	Xenolith	Igneous
16	N 07^0 36’ 09’’	E 04^0 59’ 55’’	Quartzite	-	Weathered	Metamorphic
17	N 07^0 36’ 47’’	E 05^0 0’ 25’’	Quartzite	-	Weathered	Metamorphic
18	N 07^0 36’ 49’’	E 05^0 0’ 25’’	Quartzite	-	Weathered	Metamorphic
19	N 07^0 36’ 50’’	E 05^0 0’ 39’’	Quartzite	-	Weathered	Metamorphic
20	N 07^0 36’ 38’’	E 05^0 0’ 39’’	Granite	-	184^0 SE, 342^0 NW	Igneous
21	N 07^{0}35’20.6’’	E 05^0 0’40.5’’	Schistose Quartzite	342^0 NE 68^0 E	Weathered	Metamorphic
22	N 07^0 36’ 15’’	E 04^0 59’ 57’’	Quartzite	-	Weathered	Metamorphic
23	05^0 0 40.5’’E	07^{0}35’20.6’’N	Schistose Quartzite	342^0 NE	68^0 E	Schistocity
24	05^0 0’38.1’’E	07^{0}35’22.3’’N	Schistose Quartzite	156^0, 148^0 SE	60^0, 48^0 E	Schistocity

Table 1. continued

Location	Longitude	Latitude	Lithology	Strike	Dip	Texture	Structure
25	05^0 0’36’’E	07^{0}35’22’’N	Schistose Quartzite			Schistocity	Veins, Joints
26	05^0 0’37.9’’E	07^{0}35’21.7’’N	Schistose Quartzite			Schistocity	Joints
27	05^0 0’38.8’’E	07^{0}35’21.7’’N	Schistose Quartzite	352^0 NE	52^0 E	Schistocity	Veins, Folds
28	05^0 0’39.8’’E	07^{0}35’21.0’’N	Schistose Quartzite	354^0	60^0 W	Schistocity	Veins, foliation planes, folds
29	05^0 0’44’’E	07^{0}36’25’’N	Granite			Fine to medium grained	Veins, solution holes, exfoliation
30	04^0 58’47.1’’E	07^{0}35’19.0’’N	Schistose Quartzite			Schistocity	Foliation planes, joints, folds
31	04^0 58’29.5’’E	07^{0}35’30.9’’N	Schistose Quartzite	290^0, 291^0 NW	38^0, 48^0 W	Schistocity	Fractures
32	04^0 58’30’’E	07^{0}35’33’’N	Schistose Quartzite	232^0, 230^0 NW	20^0, 24^0 W	Schistocity	Fractures
33	04^0 58’26’’E	07^{0}35’34’’N	Schistose Quartzite			Schistocity	Fractures
34	04^0 58’06’’E	07^{0}35’39’’N	Schistose Quartzite	336^0, 322^0 NW	16^0, 16^0 W	Schistocity	Fractures
35	04^0 55’42.7’’E	07^{0}33’56.0’’N	Quartzite			Gritic	Joints
36	04^0 55’42.6’’E	07^{0}33’55.1’’N	Quartzite	NE-SW	E		Fractures
37	04^0 55’43.2’’E	07^{0}33’19.4’’N	Quartzite	320^0 NW	52^0 E	Sugary	Fractures
38	05^0 00’16’’E	07^{0}36’47’’N	Quartzite			Fine to medium grained	Veins, joints
39	04^0 59’57’’E	07^0 36’15’’N	Quartzite			Fine to medium grained	Veins, joints
40	05^0 00’35’’E	07^0 35’23’’N	Quartzite	178^0,174^0, 168^0, 171^0 SE	38^0, 42^0, 44^0, 46^0 E	Fine to medium grained	Veins, joints
41	04^0 55’41’’E	07^0 33’05’’N	Quartzite			Fine to medium grained	Joints
42	04^0 55’40’’E	07^0 33’09’’N	Quartzite			Fine to medium grained	Joints
43	04^0 57’21’’E	07^0 34’26’’N	Granite gneiss				
44	04^0 57’53’’E	07^0 33’56’’N	Granite gneiss				Joints, folds
45	04^0 57’49’’E	07^0 33’56’’N	Granite				Joints, folds
46	04^0 57’46’’E	07^0 34’05’’N	Granite				Joints, folds
47	04^{0}57’19’’E	07^0 34’25’’N					Xenolith, folds, fractures
48	04^{0}58’08’’E	07^0 34’37’’N	Quartzite				
49	04^{0}57’11’’E	07^0 34’37’’N	Quartzite				
50	04^{0}00’06’’E	07^0 36’30’’N	Quartzite				
51	04^{0}00’36’’E	07^0 35’22’’N	Quartzite				
52	05^0 0’53’’E	07^0 35’10’’N	Quartzite				

4.1.1 Granite-gneiss

This rock type was found mostly in contact with the granites and occurred as flat-lying rocks. They display quartz and pegmatite veins and conjugate fractures because the fractures are parallel to the foliation plane followed by another fracture sets at angle to the other. Pegmatite dykes were also seen on the outcrop. They represent the oldest rocks in the investigated locations. There are series of folding observed on the outcrop which are superimposed which is suggestive of different folding episodes. Other observable features are veins and joints. The texture of the granite-gneiss ranges between medium grained to coarse- grained. The observable minerals in the rocks are biotite, quartz, and orthoclase feldspar with no accessory minerals identified.

4.1.2 Quartzite

This is another major rock type in the study area, occupying relatively a large portion than granite. Two types of quartzites (massive and schistose) dominate the studied area. They were discovered in the north eastern to the central part of the area. The massive ones are dark to reddish brown in colour due to alteration and are volumetrically extensive. Some road cut outcrops mapped are highly weathered and show the presence of muscovite foliations and pegmatite veins. Folding occurred on these outcrops based on the dipping angles of their limbs in opposite directions (Table 1). Such folds include ptygmatic and recumbent folds. However, the schistose quartzite dominated a larger part of the studied area. They are intensely weathered and crumble easily and are to be found in the North eastern part on the map. The quartzite is buried beside a farmland making it very difficult to see, but their presence is recognized by the quartz rubble seen along footpaths and ridges. It was highly weathered, and there were no observable features. Schistose quartzites occur as low-lying beside the road. The rock is highly weathered, though the foliation planes are still clearly observable. The dip directions of the outcrop suggest multiple folding episodes followed by numerous pegmatite intrusions occurring as veins.

4.1.3 Granites

Granites are the second most dominant rock type in the area. They are fine-grained, low-lying outcrops with fractures and joints. They occur in the form of dislodged boulders. They contain a dark brown colored weathered surface and minerals such as quartz, feldspar, and biotite. In addition, they consist of quartz and pegmatite veins with xenoliths showing relics of the oldest rock. The accessory minerals in the granites are zircon and Fe-oxides (such as magnetite).

4.1.4 Migmatite-gneiss

These were discovered in the western part of the study area, and occur as a low-lying outcrop and are extensive. Migmatite-gneiss is medium-grained with mineralogical banding of quartz, biotite and feldspar. It is the contact rock with the granite; structures mapped include a pegmatite intrusion in the form of veins, ptygmatic and chevron folds with fractures and solution holes.

4.1.5 Pegmatite

These are late stage intrusions in the studied area mostly as veins and not as massive as other rocks. In terms of their nature, both simple and complex types are present in the studied area. However, field observations revealed that complex pegmatite dominated areas outside the designated locations. This paved the way to extending sampling to abandoned pits and active mining sites; samples recovered from these sites revealed that the actual mining of gemstones is confined to certain locations where complex pegmatites are found. Remnants collected from these sites showed that they contain blue and green tourmaline, feldspar, and garnet.

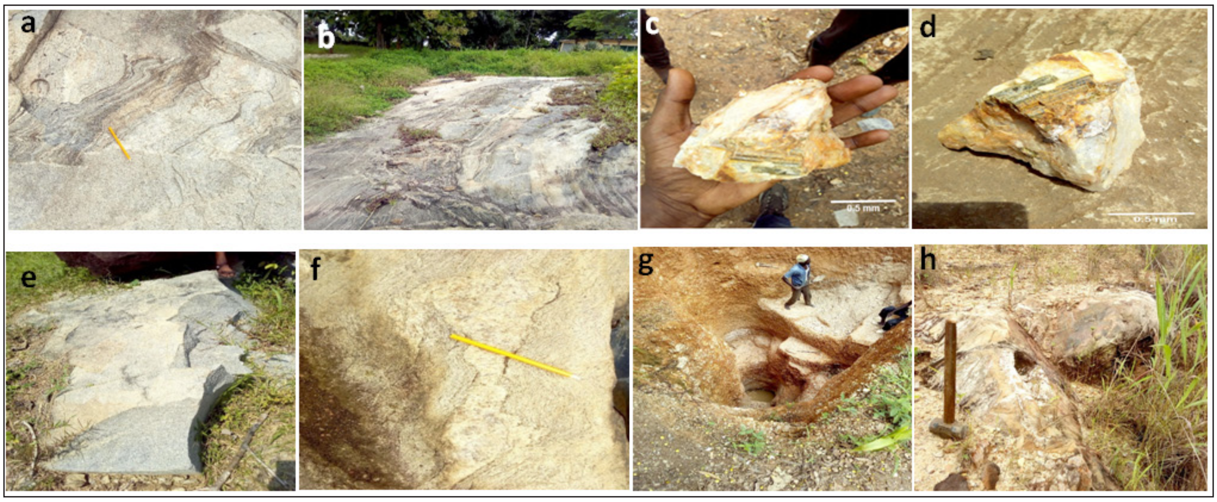

Figure 6. (a and b) Granitic and migmatitic gneisses displaying gneissocity; (c and d) Hand specimen tourmaline inclusion in quartzite; (e and f) folded intrusive quartzo-feldspathic bodies on granite; (g and h) Occurrence and mining pit for tourmaline.

4.2. Laboratory Investigation

Petrographic investigations of the various rock units in the locations revealed the following rock forming minerals: biotite mica, muscovite mica, plagioclase feldspar, hornblende, microcline feldspar, (locations 1 and 2), quartz (showing angular shape), and opaque minerals such as iron oxide. The distribution of the different minerals is presented in Table 2. The photomicrographs of the different rocks are shown in slides Figures 6 a, b, and c. Observations were made under plane polarized light (PPL) and crossed polarized light (XPL). They displayed diagnostic minerals present in each slides. Generally, the minerals identified are typical of the major rock forming minerals such as quartz, feldspar (plagioclase, orthoclase and microcline), hornblende, muscovite etc. Only locations Ik1, Ik2, and Ik3 slides have tourmaline and garneti-ferous minerals such as grossularite and almandine because the rocks in these areas are intruded by complex pegmatites. Petrographic studies of thin sections also revealed the distribution of minerals in the rocks (Table 2). It is observed that quartz is the most dominant mineral followed by biotite and muscovite, microcline, and other minerals which suggest that quartzite is the most prevalent rock in the study area.

Table 2. Mineral Assemblages of the Studied Samples for Rocks

Slide Number	Mineral(s)	Rock Name
L1	Muscovite Microcline Feldspar Quartz	Weathered Gneiss
L2	Quartz	Quartzite
L3	Quartz	Quartzite
L5	Quartz, Muscovite	Quartz-Mica Schist
L6	Quartz	Quartzite
L7	Biotite Opaque Mineral Muscovite Plagioclase	Biotite Schist
L8	Biotite Quartz Plagioclase	Granitic Gneiss
L8A	Biotite, Hornblende, Muscovite, Microcline, Feldspar, Quartz	Fine Grained Granite
L9	Biotite, Muscovite, Microcline Feldspar, Quartz	Gneiss
L13A	Biotite, Plagioclase, Quartz	Granite
IK1	Quartz, Tourmaline, garnets	Quartzite
IK2	Quartz, Tourmaline, garnets	Quartzite
IK3	Quartz, Tourmaline, Garnets	Complex Pegmatite
IK4	Quartz Muscovite	Weathered Quartz-Mica Schist
IK5	Quartz	Quartzite
IK6	Quartz	Quartzite
IK7	Quartz Muscovite	Quartzite
IK8	Quartz	Quartzite
IK9	Quartz	Quartzite
IK10	Muscovite, Quartz	Quartzite
IK13	Biotite, Muscovite, Quartz, Microcline, Feldspar	Weathered Granitic Gneiss

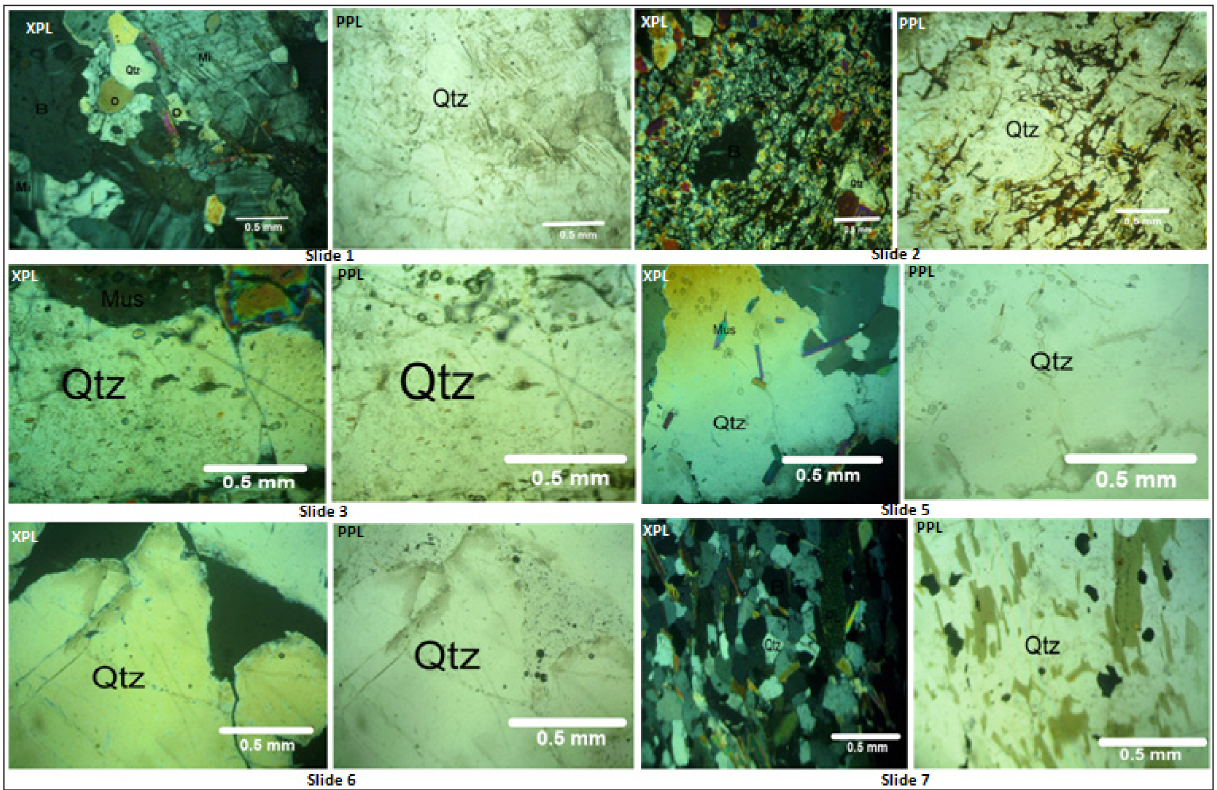

Figure 7. a. Photomicrographs from thin section of selected rock samples under PPL and XPL

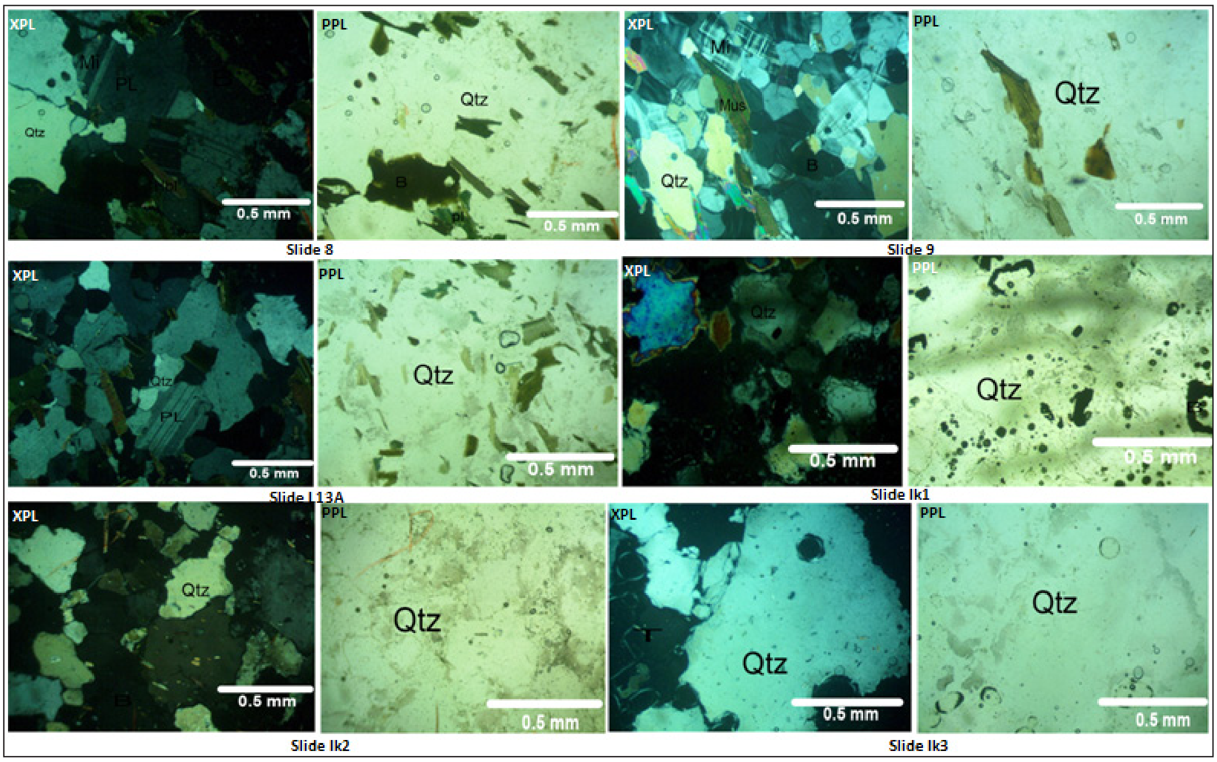

Figure 7. b. Photomicrographs from thin sections of selected rock samples under PPL and XPL

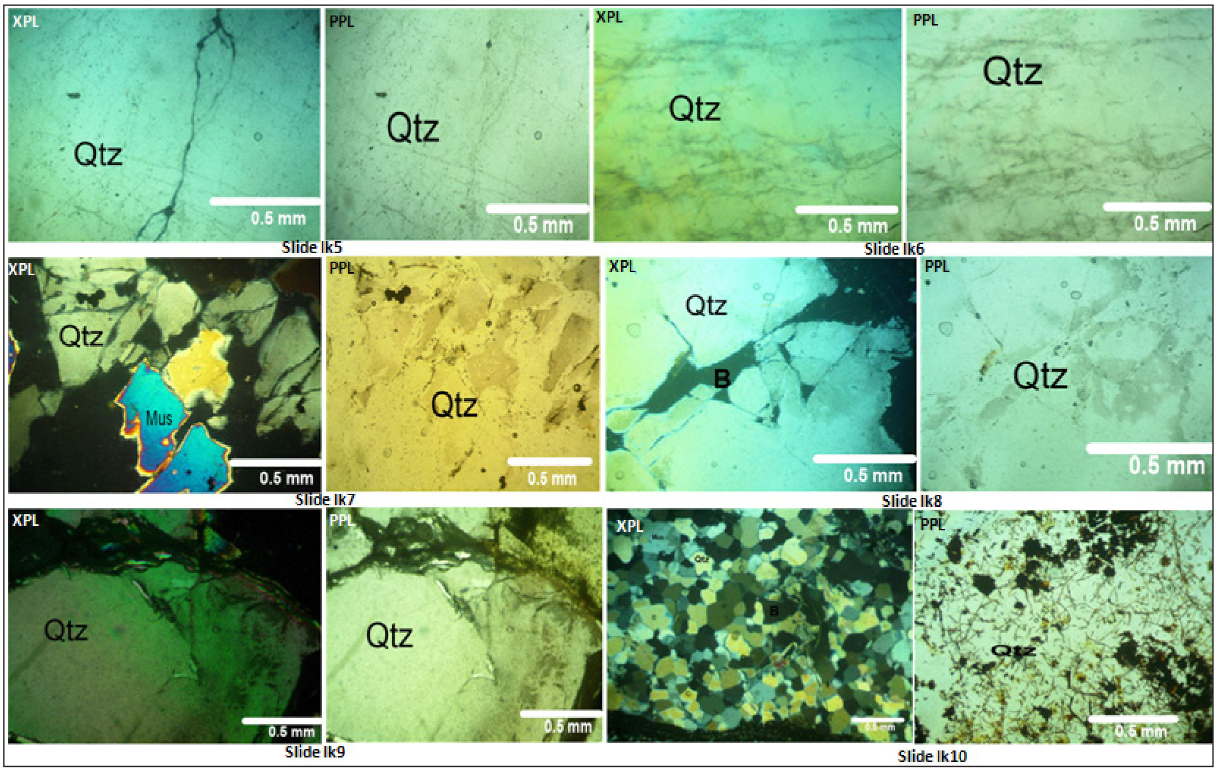

Figure 7. c. Photomicrographs from thin sections of selected rock samples under PPL and XPL

Microcline – Mi; Quartz- Qtz; Muscovite – Mus; Hornblende – Hbl; Orthoclase – O; Biotite – B; Tourmaline – T; Gt- garnets; MC- Mineral composition, XPL- Crossed Polarized light, PPL- Plane polarized light

4.3. Structural Analysis of the Study Area

Most of the basement complex rocks of Nigeria have been affected by polyphase deformation which has led to the re-orientation of the initial structural grain of the basement complex (Oluyide, 1988). These deformations left their imprints on the rocks affected which can be used to re-write the geological history of those rocks. Most of the quartzites and granites and gneisses in Nigeria have been affected by several orogenies; the latest being the Pan African orogeny 600±150 Ma (Burke and Dewey, 1972; Dada, 2006) resulting in the formation of structural features such as fold, fractures, and joints. Structural elements such as veins, fractures, folds, foliations, and faults were observed and mapped in the rocks of the study area. The structures occurred mainly in all rock types, but most prominently in the granite-gneiss. From the analysis of structural data collected, it can be inferred that at least three major orogenic cycles of deformation, metamorphism, and remobilization have affected the area followed by a last stage of tectonic jointing and faulting which led to the formation of the fractures and veins in the gneisses.

The outcrops of gneissic origin and the schistose quartzites exhibit folded surfaces from tight, ptygmatic and isoclinal folds to recumbent and overturn antiformal folds as revealed from field observations and measurements (Figure 9). In some of the outcrops mapped, it was observed that some of these folds are older than the joints that cut across, and some folds are younger than the fractures which also confirmed the three episodes of tectonic deformation proposed earlier. Most of the folds observed are composite, asymmetrical, parasitic, and isoclinal folds. These could be attributed to a series of deformation and several metamorphic episodes that have pervaded the studied area which led to successive restructuring of the inherent minerals in the rocks. In the process of the deformation and metamorphism, minerals which could not withstand the heat of metamorphism became decomposed or converted to less stable minerals, while others were resistant to the heat and deformation, thereby, forming secondary minerals or being altered to clay bodies or form a coat on other minerals. It could be inferred that the gneiss outcrops have been affected by three episodes of deformation denoted as D1, D2, and D3. The D1 deformation produces tight to isoclinals and asymmetrical folds. The second D2 phase produces ptygmatic and disharmonic folds, this is characterized by steep to moderately-inclined axial planes. Finally, the third D3 deformation produces refolded folds which are superimposed on the ptygmatic fold (Figure 6f).

Several fracture orientations were obtained from the rocks at different locations in the field, and their measurements were used to produce a rose diagram which indicated that the direction of the tectonic force is in the NW-SE. These fractures were clearly displayed and observed on the schistose quartzite, granite-gneiss and on most quartzite materials. However, some fractures are linked with mineralization especially the NW-SE, NE-SW, E-W, NNS and N-S fractures Wright, (1976). The granitic rocks are synonymous with N-S fractures and are mostly interconnected. Quartzites are commonly associated with E-W fractures known for gold mineralization Anifowose et al. (2006), while the schists and gneisses have paucity of fractures due to their ductile nature.

Joints are present in nearly all rock surfaces and are generally more toward the vertical than the horizontal. The most prevalent causes of jointing are tensional and shearing stress forces set up by crustal movement within the earth's crust. Although, they can occur individually, they most frequently occur as joint sets and systems. In some folded rocks, the joints that lie at the right angles to the fold hinges are known as cross joints. The joint orientations gathered on the field were used in plotting rose diagrams for the joint sets (Figure 8). Joints were mostly observed on the granitic gneiss outcrop. The veins present in the study area are majorly of pegmatite, quartz, and quartzo-feldspathic composition which are commonly associated with the gneiss unit as late intrusions (Anifowose et al. (2006). They are also can be continuous or discontinuous. Some of the veins are mutually cross-cutting each other; they are sometimes absent in individual outcrops. Quartz veins are most abundant. A majority of the veins are concordant to the trend of foliation of the rock in which they occur. Some are crosscutting and do not follow the general trend of the outcrops. On some outcrops, the direction of some veins cannot be easily deduced because of the fact that the rocks in which they form has undergone deformation, hence distorting the rocks' foliation and fabric and also the orientation of the veins present. However, it should be noted that a large percentage of all the veins are in the same direction as the general trend of foliation of the rocks on which they exist. The boundary between the veins and the rocks are sharp, though there are few exceptions on some of the rocks where the boundaries between the rocks and the veins are gradational. Some of the veins are very long, extending up to 15m throughout the length of the outcrops on which they occur, while some of them are short extending only a few centimeters. Also, some are relatively wide and some are thin. Most of the veins were formed after the rock was formed. While a few of them were segregated during the cooling of the rock. The formation of most of the concordant and discordant quartz veins are associated with the late faulting and fracturing in the area (Gandu et al., 1986). The foliation planes which are pervasive planar surfaces within a rock are well-developed in the gneisses, but due to extensive weathering conditions in the area, there is limited foliation surfaces for the measurement of strike and dip. However, strike and dip values were recorded at points of good foliation planes. The general dip direction is towards the east and is also slightly dipping to the west (Table 1). The strike direction is slightly varying depending on the position in the area. These structures are only observed as gneissosity and foliation in the shear zones of gneissic outcrops. This foliation appears to be the result of the pervasive parallel arrangement of the platy minerals in the studied rocks.

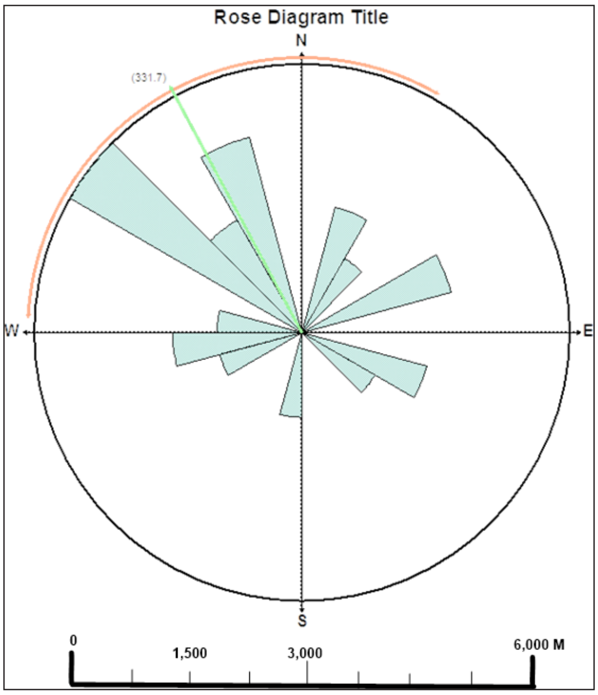

Figure 8. Rose diagrams plotted from joint orientations measured in the field.

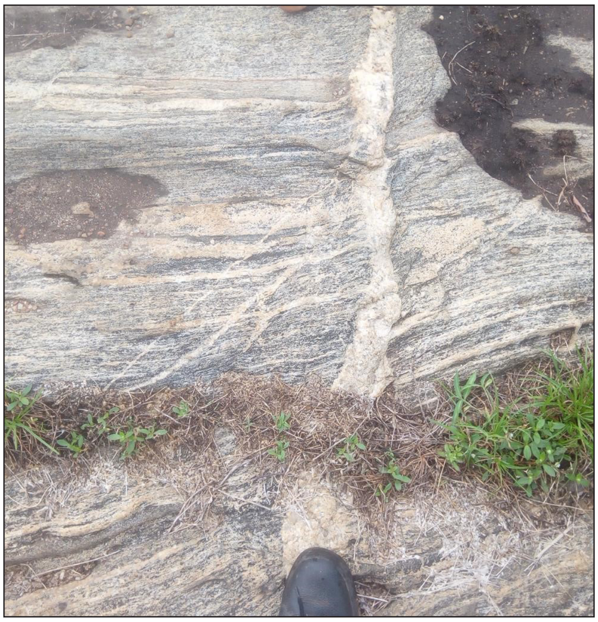

Figure 8. Different generations of veins and folds as observed on the gneissic rocks of the study area

4.4. Gemstone Prospectng

Gemstones are formed in different geological environments in the earth, resulting in various types of deposits including magmatic, pneumatolytic, metamorphic, sedimentary (alluvial), hydrothermal, pegmatites, and greissen gems. For the formation of each kind of gem, a specific, and unique combination of five factors are required in their respective environments. These are: temperature, pressure, space, chemical elements, and time. In other words, gems are, in general, rare, but some are rarer than others (Nyako et al., 2014). For example, silicon and oxygen are the two most abundant elements of the earth's crust and the conditions for the formation of quartz (SiO2) are relatively common so it is understandable that quartz is found widely, while Axinite on the other hand, which is also a silicate gem requires (in addition to silicon and Oxygen) Ca, Fe, Mg, B, and Al for its formation, which makes such a gem considerably rarer than quartz, (Abaa, 1990). These rare conditions in cracks, fractures, faults, and shear zones where gemstones are formed which makes the latter very rare to find, and therefore quite precious. They are used for ornamentation and as jewelleries when cut and polished. Some traditions are connected with sentiments, beliefs, and superstitions associated with gems, to the effect that some gems carry the power of driving out evil spirits and providing all sorts of luck or fortune, (Aga and Ashano, 2008).

Geological exploration for gemstones and other specialty minerals was carried out in the study areas as part of the investigation. There are two types of pegmatite mapped in the locations which are the mineralized and non-mineralized types. The mineralized types are often the targets of local and artisan miners in the studied area because of the gemstones and other specialty minerals found in them. Many pits and mine sites were discovered in the process of mapping and traversing and as a result of this, sampling was extended beyond the initial locations to ensure wider coverage. This led to the discovery of the location of gemstone sites hosted by the quartzites and quartz schists intruded by the complex pegmatites. The coordinates of this location are (7^0 35' 10''N, 5^0 00 53''E). This location revealed the actual site of gemstones and other allied minerals in the study area which are promising sites for further exploration (Figure 4). The samples picked contain blue and green tourmaline crystals. On the contrary, the cadastral already acquired for gemstone prospecting is not economically viable for its intended purpose for the following reasons: (i) The rocks are entirely weathered and have turned into clay (ii) The underlying rocks are extremely fractured which enables water to gush out (iii) The sites has undergone intense deformation which affected the rocks and their fabric.

5. Conclusions

The study area forms part of the Precambrian basement complex of southwestern Nigeria that has been affected by multiple episodes of deformation. However, geological mapping and assessment of the rocks in the study area revealed various levels and phases of deformation. The various phases of these deformational events can be detected by the dipping angles of the rocks, orientations of the fractures and joints, and evidence of migmitization and granitization and gneissocity observed on the outcrops. Since the study area is located east of Okemesi fold belt, there are similarities regarding the rock types and folding patterns/ episodes to the belt with the limbs dipping in the same direction in some places and to the opposite direction in other places suggesting the superimposition of refolded folds on the earlier folded phases depicting polyphase patterns of deformation. Also, the search for gemstones has been made possible due to the ground preparation culminating to structural differentiation of the host rocks that provided pathways for the permeation of the mineralizing fluids and its eventual solidification. The type of gemstones discovered in the studied area are the blue and green types (aquamarine and Turquoise) and the blue and red tourmaline crystals.

However, research in the study area is still ongoing. We believe that further research will provide information on the gemstone type, minerals (name and composition), physical and optical features including colour, sizez, habits (purity, companion phases), mode of occurrence, and scale of deposit. In addition, the effects of tropical weathering accelerated by high humidity have altered most of the rocks into in-situ clay deposits and boulders. it is therefore impossible to carry out geochemical exploration in the studied areas; however, the petrographic study revealed the presence of some of the major rock-forming minerals such as quartz, feldspar, micas, and opaque minerals such as iron oxides etc. The rocks of the study area are fairly suitable for quarry activities.

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