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Dear Editorial Manager,

I am enclosing herewith a manuscript entitled "*GEOCHEMICAL SURVEY AND POTENTIAL MINERALIZATION INVESTIGATION OF ILERO AND ITS ENVIRONS OYO STATE, NIGERIA*.

This work reflects research on deciphering possible mineralization in the Ilero and its environments, Oyo State to its role in mineral exploration and exploitation.

I believe this submission will be useful to your readers, as it addresses some critical methodologies for discovering economic minerals. The research stands to benefit students researching Earth Science Studies.

GEOCHEMICAL SURVEY AND POTENTIAL MINERALIZATION INVESTIGATION OF ILERO AND ITS ENVIRONS OYO STATE, NIGERIA

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Abstract

Ilero and its environs are part of the Kajola local Government area, Oyo State, and fall within the basement complex of southwestern Nigeria. The research work was focused on the geological mapping of the area and the study of the different rock and minerals units to determine the mineral resources of the area using petrographic, geochemical, and XRD analysis. The geochemical analysis showed the rocks and minerals to be diversely composed of 54-97% SiO_2, 0.1-20% Al_2O_3, 0.8-4% MgO, 0.5-6% Fe_2O_3, < 1% K_2O, TiO_2 and minor amounts of trace elements including copper, manganese, and lead. The mineralogy of the rocks and ore mineral comprised of quartz, biotite, hornblende, alkali feldspars, and tourmaline. There are also indications of the presence of chlorite and some ferromagnesian minerals such as pyroxene and olivine. The rocks are predominantly acid rocks along with a few basic rocks

Key word: Petrographic, Provenance, Mineralization, Rocks, Ore Mineral**.**

1. Introduction

The studied area is in the northwest of Okeho and llero, in Kajola local Government area, of Oyo-State. These areas fall within the Iseyin Schist belt, in the southwestern part of the Precambrian Complex geological province of Nigeria (Rahaman, 1976). As a result of less detailed work on the study area, not much information is available, and therefore the need for the delineation of various rock types of the different units of the basement complex in the area as well as the need for detailed petrographic and geochemical studies on the rocks for assessment of their petrogenesis. The project work is aimed at revealing the mineralization potential of the Ilero area.

1.1 Geology and Location

The studied area is located around Ilero within, Kajola local Government area, Oyo State. It lies within longitude 003^0 15'00'' to 003^0 26'00 and latitude 008''0500'' to 008^0 01 '0^0'N. The study area falls within the Precambrian Basement Complex of Southwestern Nigeria and in the Iseyin Schist Belt of southwestern Nigeria. It is characterized by occurrences of biotite granites, syenites, talcose, amphibolites, and bodies of pegmatites and quartz-veins. The study area is accessible from Oyo-Iseyin, Okeho- Ilero, Igana, and Shaki -Ipapo -Otu Road (Rahaman, 1976). Numerous footpaths and un-tarred rural roads were also accessible. The study area is more accessible during the dry season when the field aspect of this study was carried out. Accessibility would have been difficult during the rainy season when the drainage channels would have been overflown and the forest will be thick thereby causing coverage of exposures and making navigation within the area difficult.

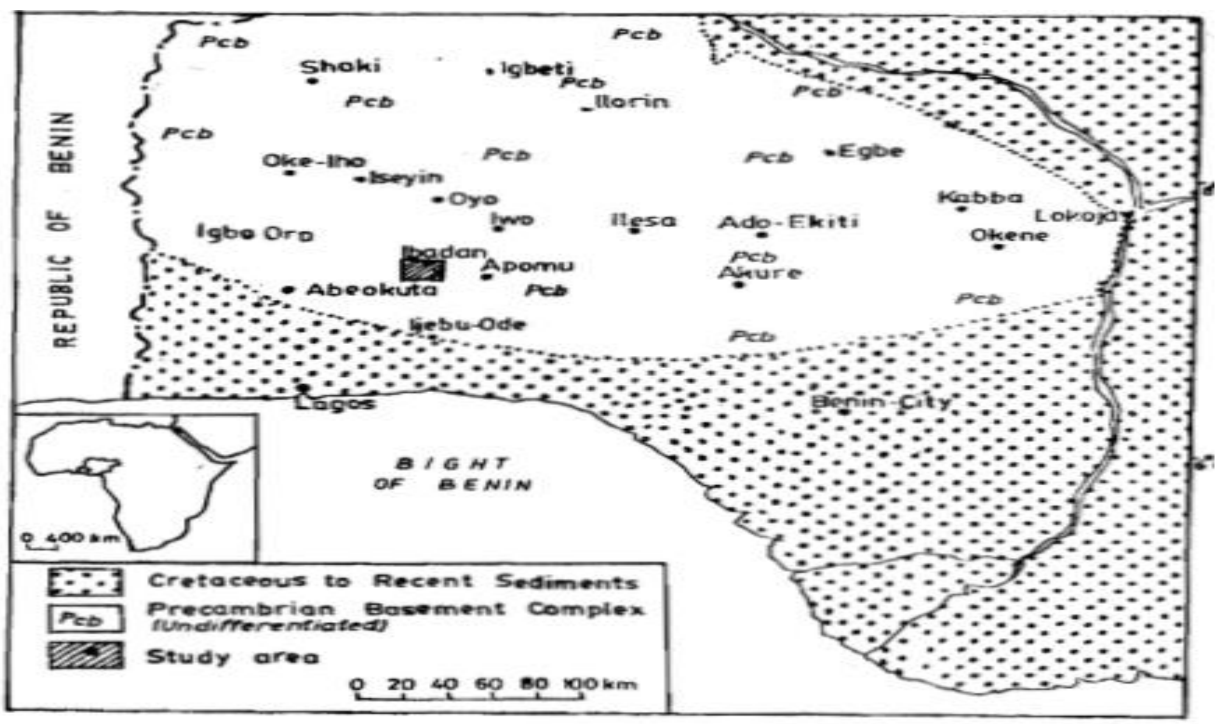

Fig. 2 Map of Regional Geology of the Study Area (Oyo State) within the basement complex in southwestern Nigeria (Rahaman, 1976).

2. Materials and Methods

2.1 The Petrographic Analysis

The petrographic analysis was used to study the mineralogical composition of rock samples by studying the behavior of these minerals under the plane and crossed polarized light (Ekeleme, 2017). This study involves cutting a thin section of rock samples and critically studying these thin sections under a polarizing microscope to determine the optical properties of the samples. Basically, the thin section is made of a glass slide, a thin film of a rockslide (30 microns), and a cover slip. The minerals used in the preparation of thin sections include Canada Balsam, Carborundum powder of 400, 600, and 800 grits, and Araldite. The equipment used was the Logitech rock cutting machine, hot plate, smooth glass, glass slide, diamond pen, etc. (Nwachukwu, 2011). The rock samples to be studied were first cut into slices of thickness 3mm -4mm using the thin section (Logitech) machine, then the surface of the rock was then smoothened by continuously grinding its surface on a glass plate using coarse grit carborundum (Folorunso, 2013). The planned surface of the rock sample is then mounted on a glass slide with the use of Araldite and pressed together to remove air bubbles using forceps and placed on the hot plate for a few minutes. The other end of the rock sample is further lowered by cutting a certain thickness off using the cutting machine and is then ground on the glass plate using coarse grit carborundum powder followed by fine grit carborundum powder until the desired thickness of 30 microns (0.03mm) is achieved. At this thickness, light can pass through the rock sample thereby revealing the mineral composition of such rock sample. A cover slip is used to cover the section with the aid of the Canada balsam to prevent the composition from being altered. After the thin section of the rock, samples have been successfully prepared, then the mineralogical composition of these rock samples is observed under a polarizing microscope.

2.2 Geochemical Analysis

The first step in carrying out a geochemical analysis is pulverization. After the rock samples are selected for geochemical analysis, they are broken into small fragments with each fragment obtained from the cleanest, freshest portion of the entire rock sample to obtain distinct compositional results of the samples (Black, 1980). These small rock fragments are then pulverized (ground) such that there are no conspicuous grains observed in the sample. It is important to immediately transfer the pulverized sample into a tight sample holder to protect the composition of the bulk (Caby, 1981). The geochemical analysis is basically used to analyze rock geochemistry, especially for the major, mir, and trace elements present in the rock and ore samples (Cox, 1979). The essence of geochemistry is to relate mineralogy with the chemistry of the rock. The major, minor, and trace element geochemical compositions were obtained by X-Ray fluorescence (XRF) while X-Rays diffraction (XRD) was used for mineralogical composition (Dada, 2006).

2.3 X-Ray Diffraction (XRD)

X-Ray diffraction is one of the important techniques for material characterization. The diffraction experiments using x-rays help to study the structural properties of materials on an atomic scale (Ahmed, 2015). The techniques are also used to measure crystallite size and calculate lattice strain, and chemical composition, and determine phase diagrams as well (Arif, 2017). They are also one of the most useful in the characterization of crystalline materials, such as metals, inter-metallic, ceramics, minerals, polymers, plastics, or other inorganic or organic compounds., X-ray diffraction techniques can be used to identify the phases present in samples from raw starting materials to finished product and to provide information on the physical state of the sample, such as grain size, texture, and the crystal perfection. Most x-ray diffraction techniques are rapid and non-destructive, some instruments are portable and can be transported to the sample (Ahmed, 2015). The type of information obtained from x-ray diffraction studies ranges from sample composition to details of the crystal structure or the state of orientation of the crystallites. Phase identification can be conducted on virtually all single crystal or powder samples (Arif, 2017). Also, useful are measurements of the physical state of a sample that detect differences from the ideal crystal (presence of defects, strain, etc). In powder diffraction, finely ground and homogenized samples are used. The sample may be held in thin-walled glass or cellophane capillary tubes (Zandomeneghi, 2010). The x –rays (usually, K-radiation of wavelength 1.5418A emitted from copper) required for diffraction are mono-chromatized by filtering with the help of foils or crystal mono-chronometers. These x-rays are collimated and directed onto samples (Rahman, 2016). In powder form, a significant number of crystallites can be expected to be oriented to fulfill the Bragg condition for reflection from every possible interplanar spacing.

3. Results and Discussion

3.1 Geochemical

The geochemical analysis showed the rocks and minerals to be diversely composed of 54-97% SiO_2, 0.1-20% Al_2O_3, 0.8-4% MgO, 0.5-6% Fe_2O_3, < 1% K_2O, TiO_2 and minor amounts of trace elements including copper, manganese, and lead. These geochemical concentrations values obtained within the study area are close to that reported by (Danbatta, 2007) for Precambrian rocks/ minerals in the Zuru Schist Belt characterized by extremely low K_2O; high Al_2O_3; and low TiO_2, Cs, Ge, and Rb contents which were in accordance with the orogenic nature of the Pan-African event.

The results of the geochemical analysis show that altered pegmatite (SO-1), syenite (SO-2), and quartz vein (SO-4) are constituted with 54.8%, 63.61%, 98.86%, SiO_2, low concentrations of

K_2O, CaO, Fe_2O_3, MgO, TiO_2, K_2O, $Na_2O$and P_2O_5 and minor trace elements (Table 1 and Fig. 3a-e). These geochemical composition values suggest that the rocks underlying the area of Ilero and Okeho possess a high abundance of silica that would support the granitic origin of the rocks (Dada, 2006). The amphibolite (SO-3) is however significantly rich in iron oxide, magnesia, and calcium oxide as to be appreciated to be basic lithology. The Tourmaline ore mineral (SO-5) is a ubiquitous accessory mineral in rocks of the Earth's crust. They can adjust their composition to suit a wide variety of environments, and therefore display a remarkable range of instability in terms of pressure, temperature, fluid composition, and host-rock composition.

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Table 1. Result of Geochemical Analysis of Rocks and Minerals from Ilero Area.

	SO-1	SO-2	SO-3	SO-4	SO-5
Rock/Mineral	Altered Pegmatite	Syenite	Amphibolite	Vein Quartz	Tourmaline (Ore mineral)
SiO_2	54.80	63.61	39.23	96.86	61.82
TiO_2	0.05	0.70	0.97	0.02	0.59
Al_2O_3	20.67	14.99	21.16	0.10	12.15
Fe_2O_3	0.57	5.19	30.98	0.54	3.72
MnO	0.02	0.32	1.32	0.03	0.37
MgO	4.20	3.82	3.69	0.79	5.85
CaO	0.45	0.44	4.38	0.04	3.66
Na_2O	3.36	1.50	0.05	0.00	2.00
K_2O	9.00	3.08	0.10	0.07	4.59
P_2O_5	0.12	0.15	3.61	0.31	0.50
LOI	22.12	3.00	2.60	0.60	2.12
SO_2	0.04	0.05	0.08	0.00	0.08
CuO	0.03	0.01	0.03	0.00	0.03
PbO	0.01	0.02	0.00	0.07	0.01
Rb_2O	0.01	0.02	0.00	0.00	0.01
Cs_2O	0.02	0.00	0.02	0.03	0.00
GeO_2	3.08	1.00	1.03	0.40	1.00

Table 2: Correlation between Ore Minerals of the Study Area

	Al	Fe	S	Ti	Cu	Pb	Rb	Ge
Al	1							
Fe	0.50	1						
S	0.69	0.58	1					
Ti	0.49	0.78	0.81	1				
Cu	0.80	0.39	0.79	0.36	1			
Pb	-0.16	-0.36	0.40	0.10	0.25	1		
Rb	-0.05	-0.26	0.51	0.18	0.37	0.99	1	
Ge	0.64	-0.19	0.07	-0.33	0.56	-0.16	-0.10	1

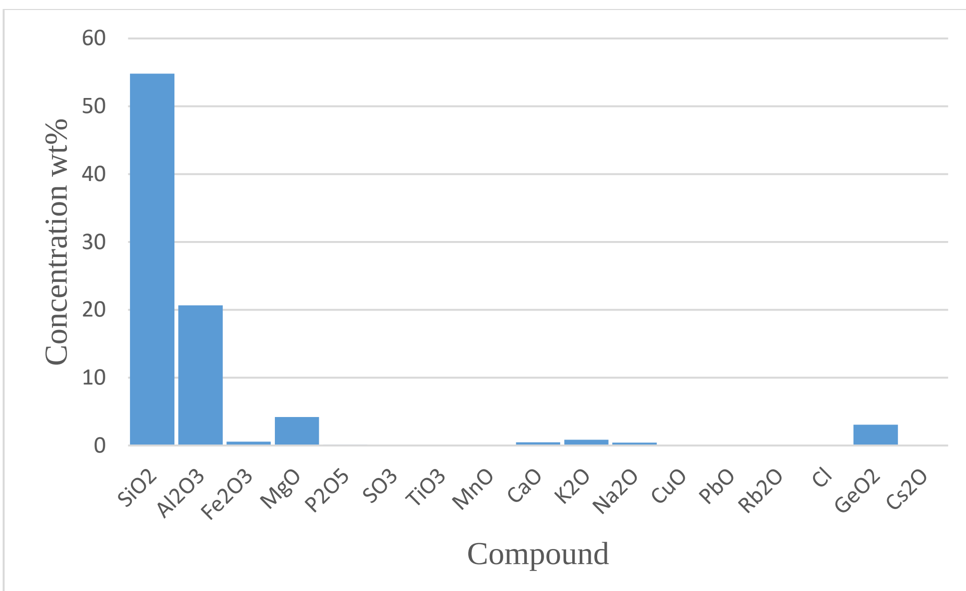

Fig 3a. Distribution of Major Oxides in Tourmaline (Ore Mineral).

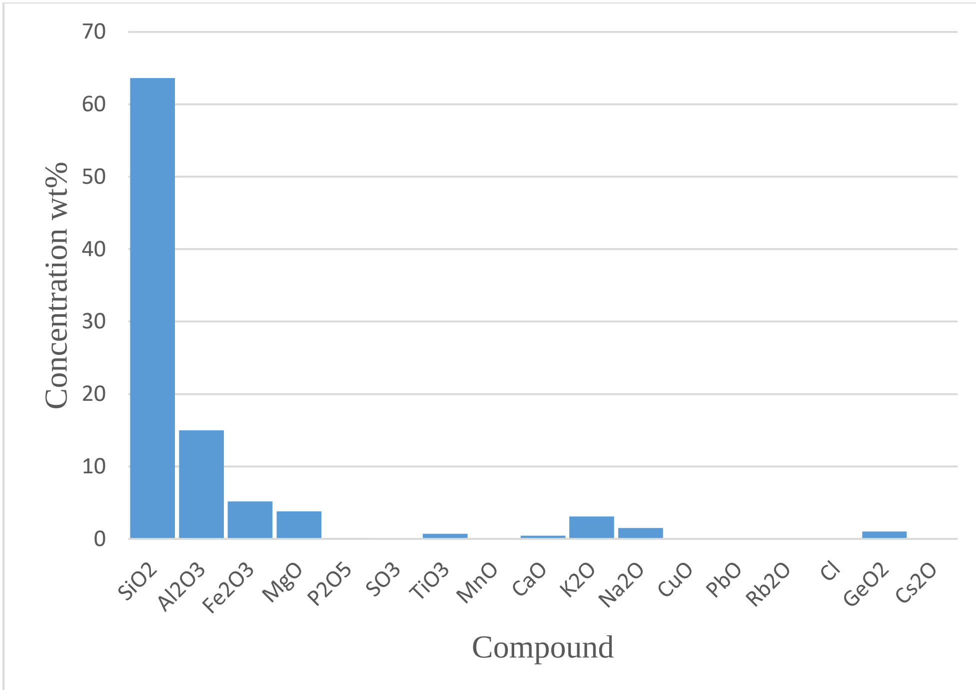

Fig 3b. Distribution of Major Oxides in Altered Pegmatite.

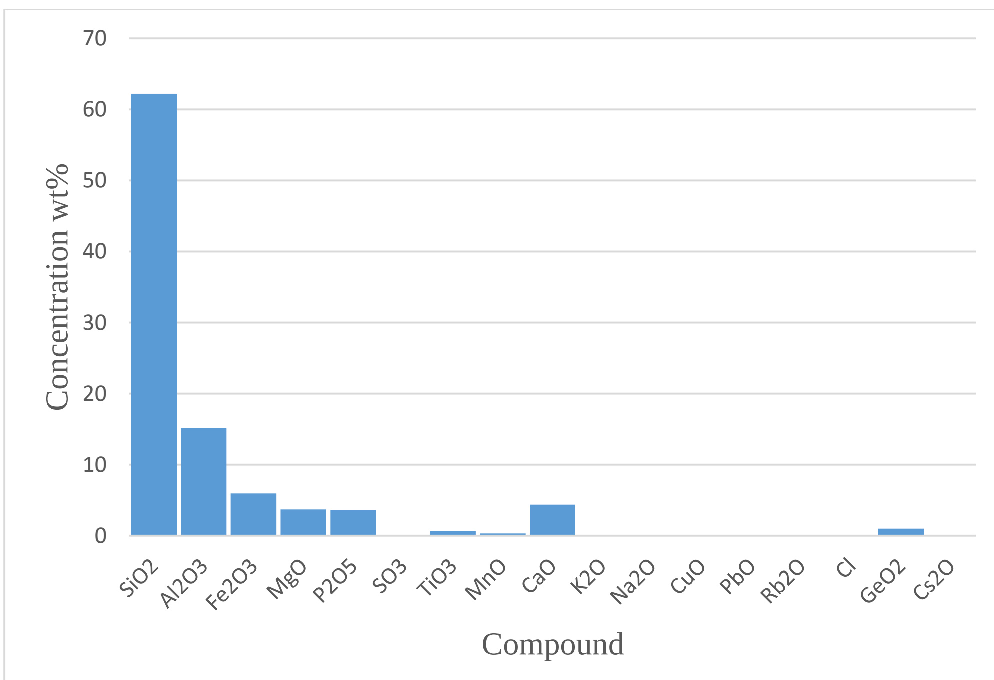

Fig 3c. Distribution of Major Oxides in Syenite.

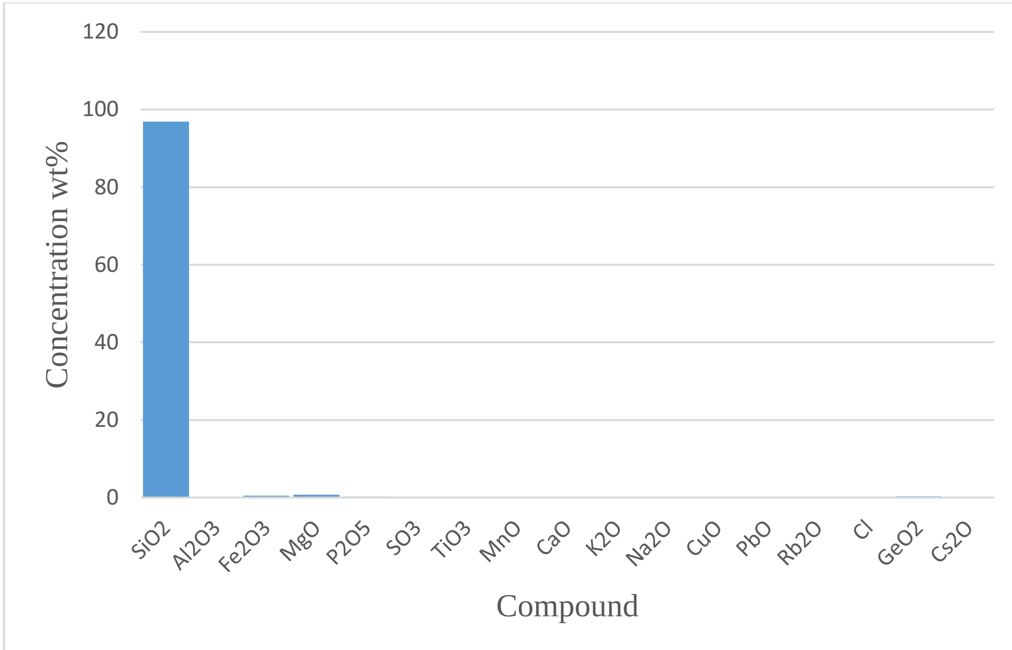

Fig 3d. Distribution of Major Oxides in Vain Quartz

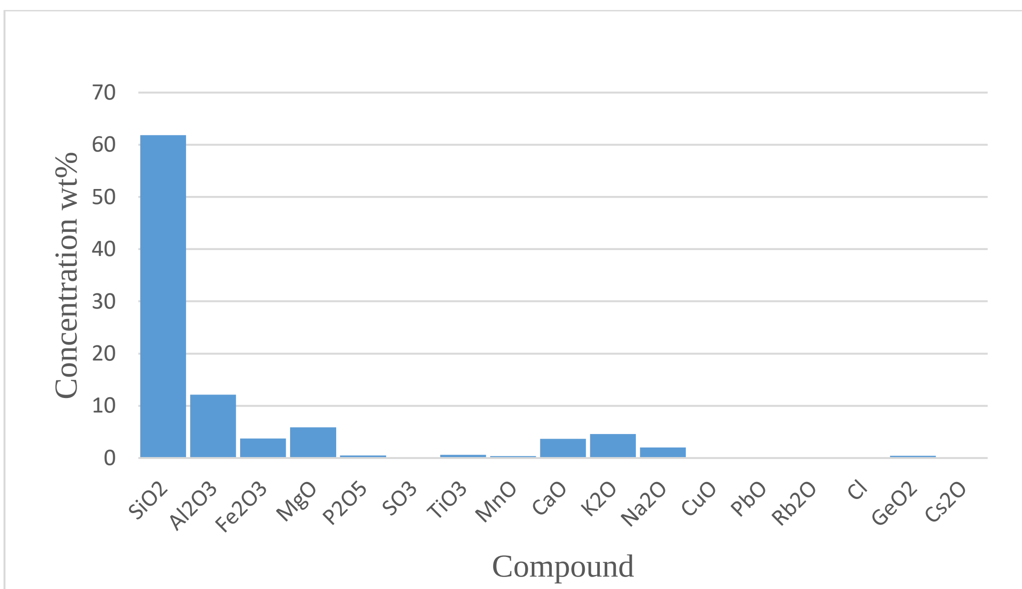

Fig 4e. Distribution of Major Oxides in Amphibolite

3.2 X-Ray Diffraction Analysis (XRD)

The x-ray diffraction results are presented as charts in Figs. 4a-c. The mineral phases were identified with respect to the International Committee on Powder Diffraction File (ICPDF) and their abundances computer calculated (Zandomeneghi, 2010).

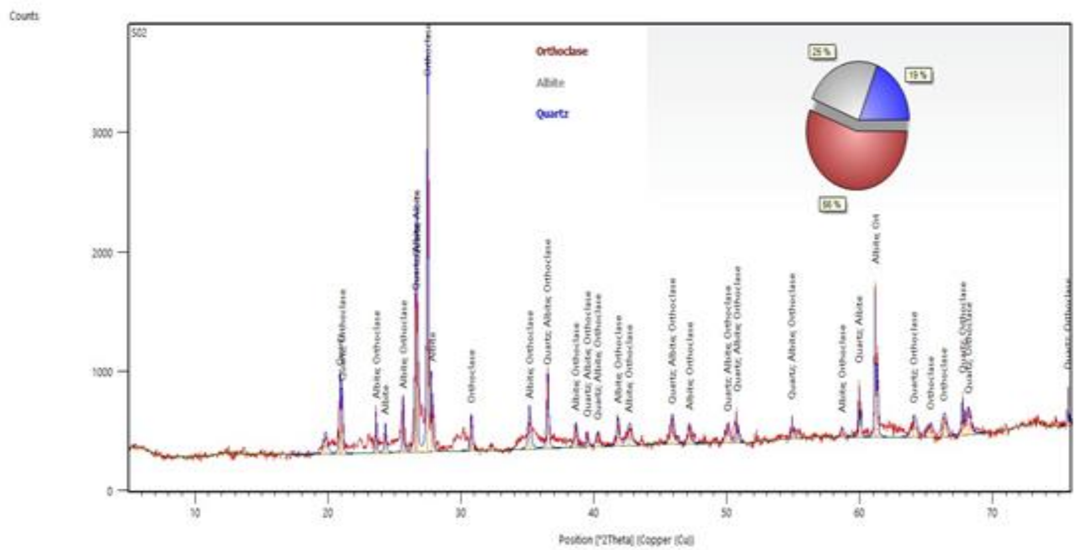

Fig. 4a. XRD result of Syenite.

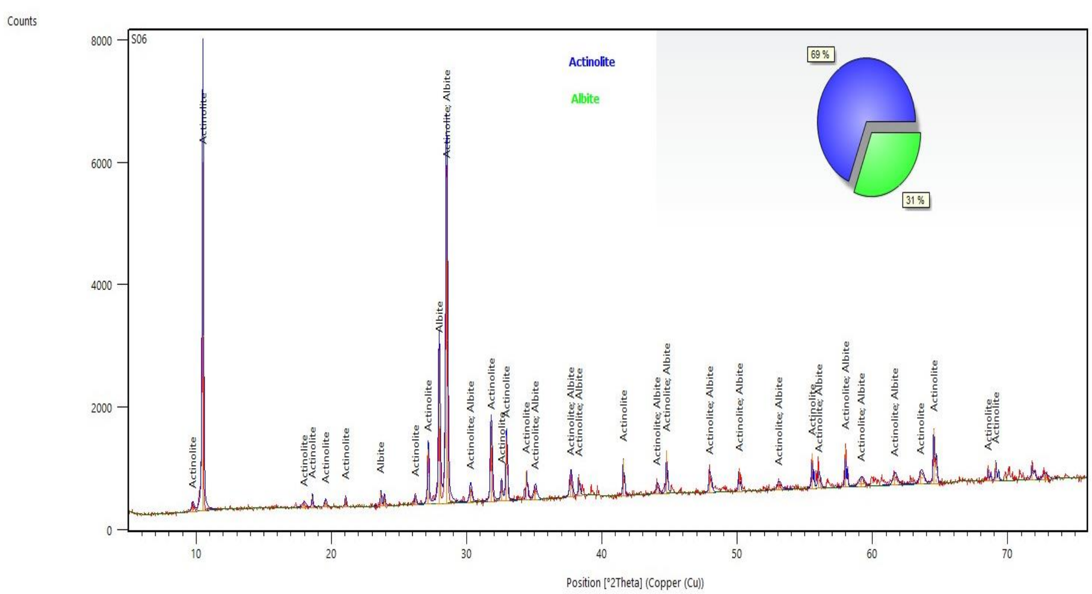

Fig. 4b XRD Chart of Amphibolite.

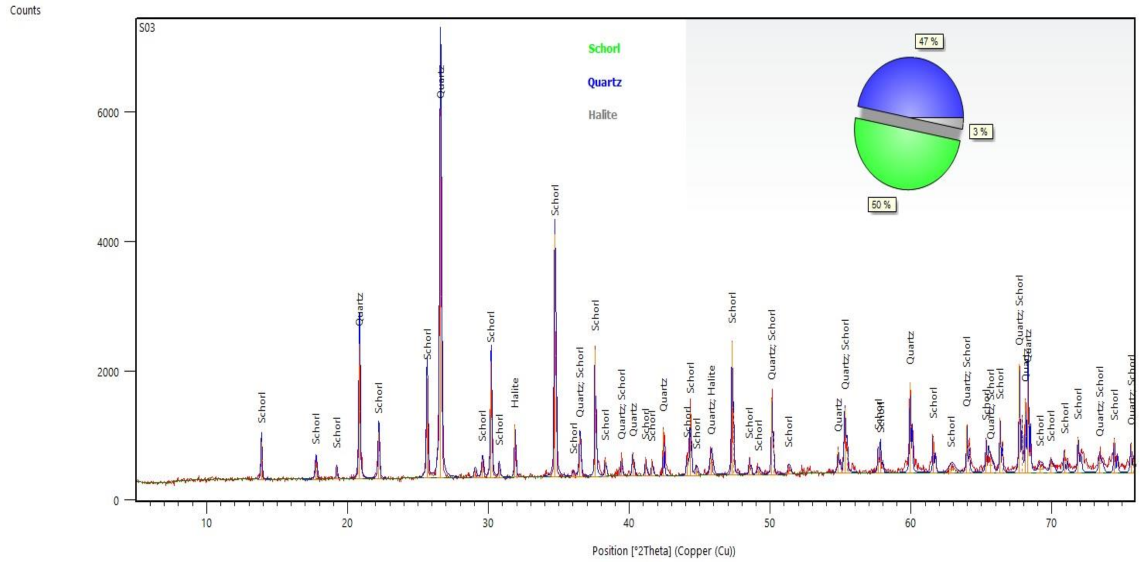

Fig. 4c. XRD result of Tourmaline (Ore mineral)

Table 3. Minerals Identified (Names of compounds and formulae) in Sample by X-Ray Diffraction

Sample I.D	Mineral Identified	Chemical Formula	Crystal System	Percentage (%)
SO-2	Orthoclase Albite Quartz	$KAlSi_3O_8$ $NaAlSi_3O_8$ SiO_2	Tectosilicate Tectosilicate Hexagonal	56% 25% 19%
SO-3	Schorl Quartz	$NaFe^{3+}Al_6(BO_3)_3Si_6O_{18}(OH)_4$ SiO_2	Prismatic Hexagonal	50% 47%
SO-6	Actinolite	$Ca_2(Mg_5Fe^{2+})\ Si_8O_{22}(OH)_2$	Monoclinic	69%

(Table 3) showed the XRD results of the mineral composition of the rocks within the Ilero area. The XRD results showed that Albite ($NaAlSi_3O_8$) is found except for Tourmaline (Rahman, 2017). The Syenite apart from being rich in Orthoclase had quartz (SiO_2) and Albite. Syenite is a coarse-grained intrusive igneous rock with a general composition like that of granite, but deficient in quartz, which, if present at all, occurs in relatively small concentrations (< 5%). Amphibolite had Actinolite and Albite. Amphibolite is a dark green foliated rock predominantly composed of green hornblende, plagioclase, and quartz, and a minor occurrence of black pyroxene, quartz, and epidote. Tourmaline (ore mineral) showed Schorl, and Quartz (Rahman *et al.,* 2017; Arif, 2017). Tourmaline generally occurs as a minor, accessory phase in rocks, but tourmalines, where tourmaline is a major mineral, are well known (Arif, 2017). Tourmaline forms in a wide variety of settings, including as a diagenetic mineral in buried sedimentary basins, as a gangue mineral in ore deposits, associated with a contact, regional and subduction-related metamorphism, in metasomatism, and as a significant mineral typically crystallizing in fractionated igneous bodies (Arif, 2017). The peaks on the diffraction spectra (Fig. 4.6-4.8) signified the abundance of each of these minerals in their different samples.

3.3 Petrology and Heavy Mineral Study

Thin sections of rocks and ore minerals (Tourmaline (Ore mineral) from Ilero environs studied under the petrological microscope showed the rocks (Altered Pegmatite, Syenite, Amphibolite, and Vein Quartz) to be coarse-grained textured with euhedral mineral crystals (Nwachukwu, 2011). In general, the minerals present include quartz (20%), orthoclase (6%), hornblende (7%), tourmaline (2%), and biotite (40%) (Black, 1980). (Fig 5a-j) shows the minerals observed both in plain polarized light (PPL) and under crossed Nicol (XPL). Quartz and biotite are the most abundant minerals observed. Quartz constitutes about 20% of the mineral content of the Vein Quartz and its morphology rarely forms euhedral crystals except in some veins which are anhedral (Danbatta, 2007). Quartz is an extremely common mineral in continental crustal rocks such as Granite, Pegmatite, etc. It is the most common vein-forming mineral. Biotite is one of the most common rock-forming minerals (Folorunso, 2013). It is a major constituent of rocks of intermediate composition, such as granodiorites, diorites, monzonites, and some nepheline syenites.

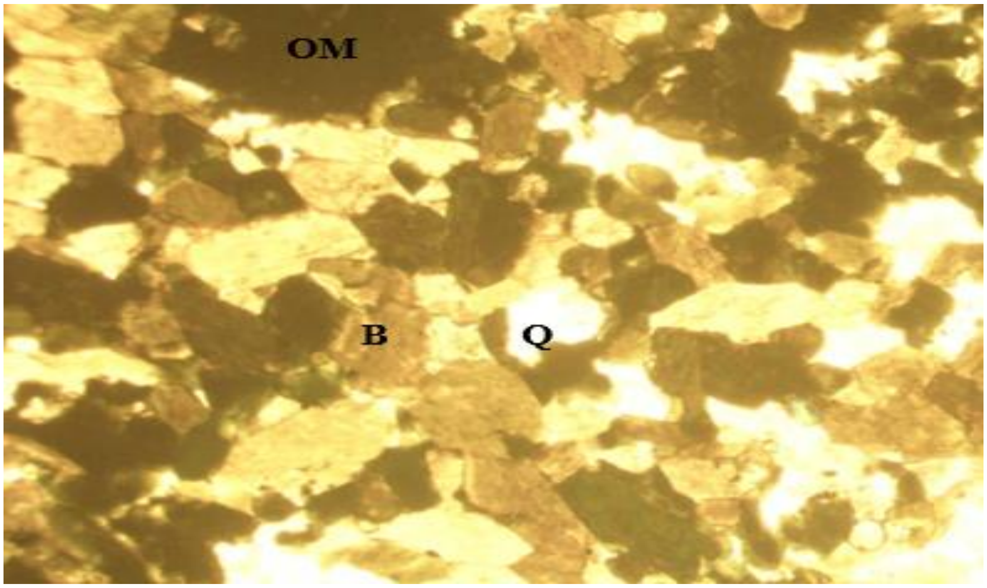

Fig 5a: Photomicrograph of sample Vein Quartz. showing Q-Quartz, B- Biotite, OM-Opaque Mineral Magnification x4.

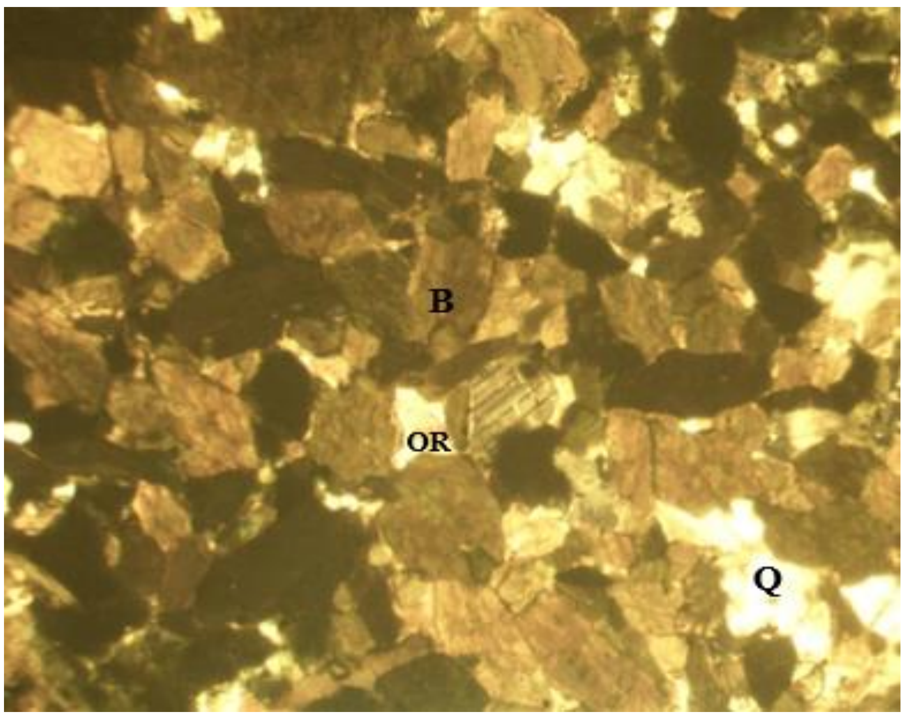

Fig 5b: Photomicrograph of sample Altered Pegmatite. showing Q-Quartz, B-Biotite, OR-Orthoclase Feldspar Magnificationx4.

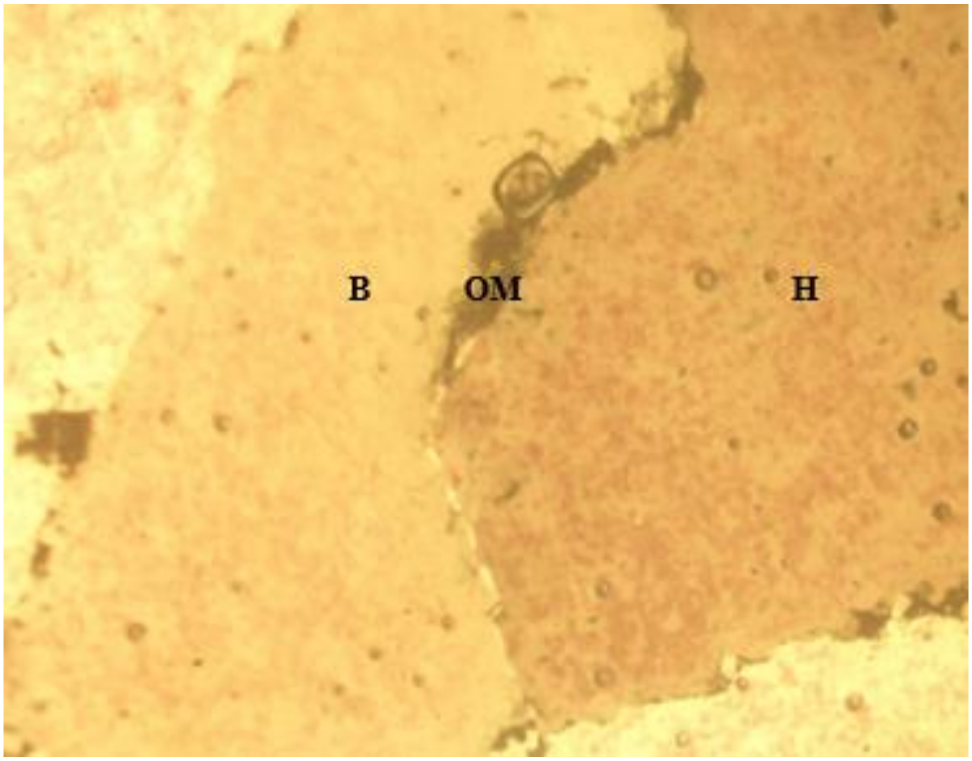

Fig 5c: Photomicrograph of Amphibolite showing B-Biotite, H-Hornblende. Magnification x4

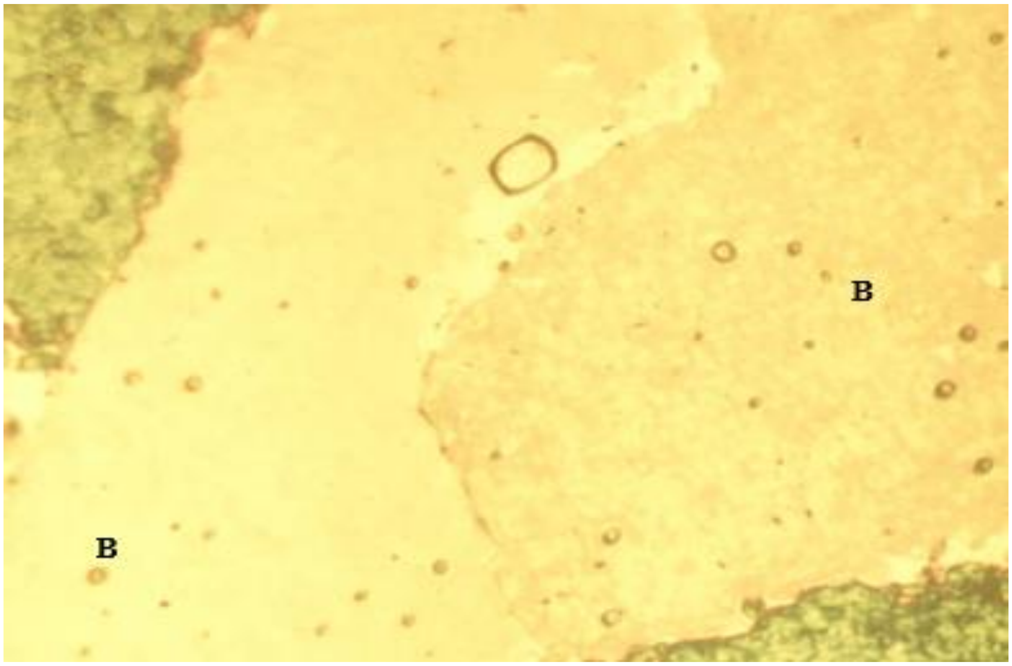

Fig 5d: Photomicrograph of Vein Quartz, showing B-Biotite. Magnification x4

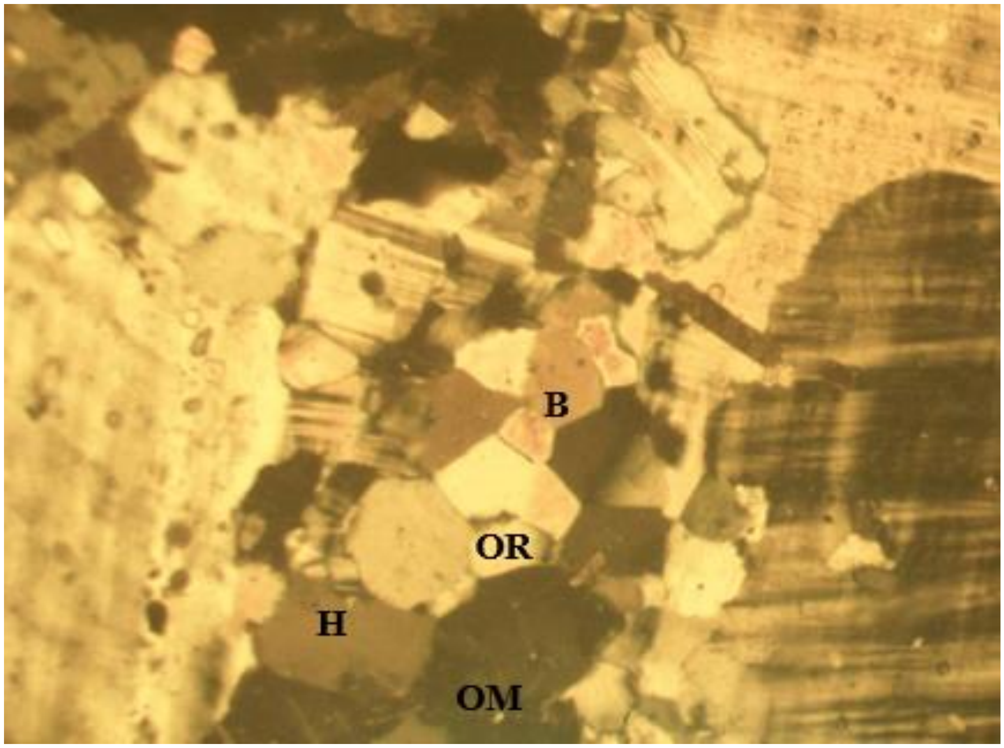

Fig 5e: Photomicrograph of Amphibolite showing B- Biotite, OR-Orthoclase Feldspar, H- Hornblende, OM-Opaque Mineral. Magnification

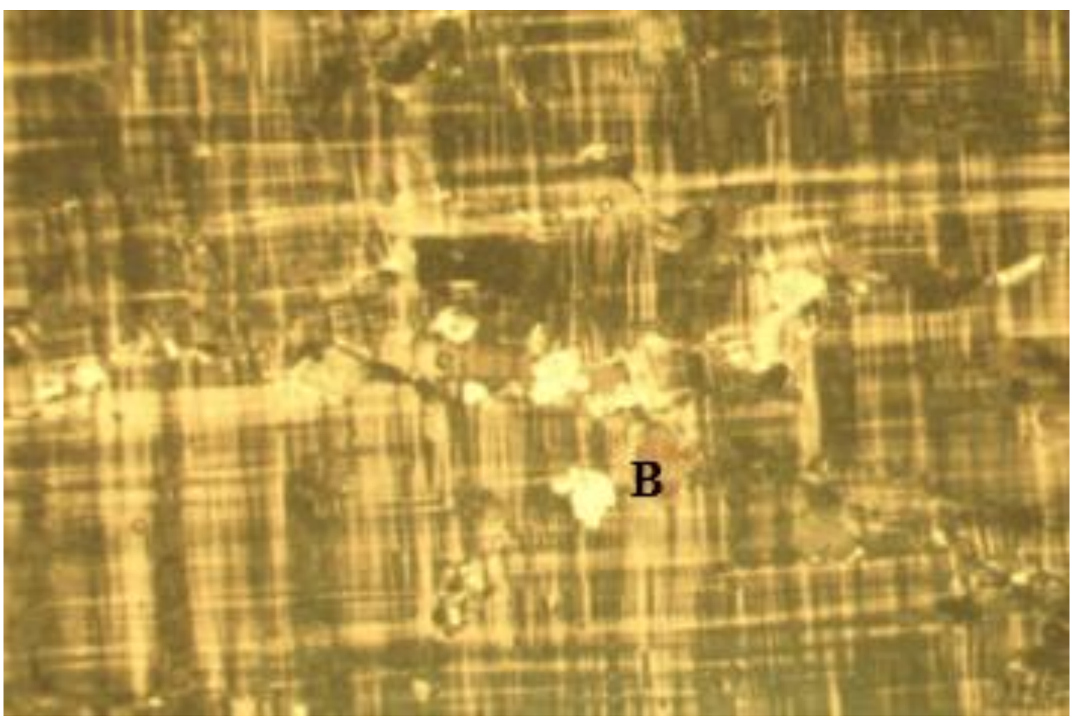

Fig 5f: Photomicrograph of sample Vein Quartz showing B-Biotite Magnification x4

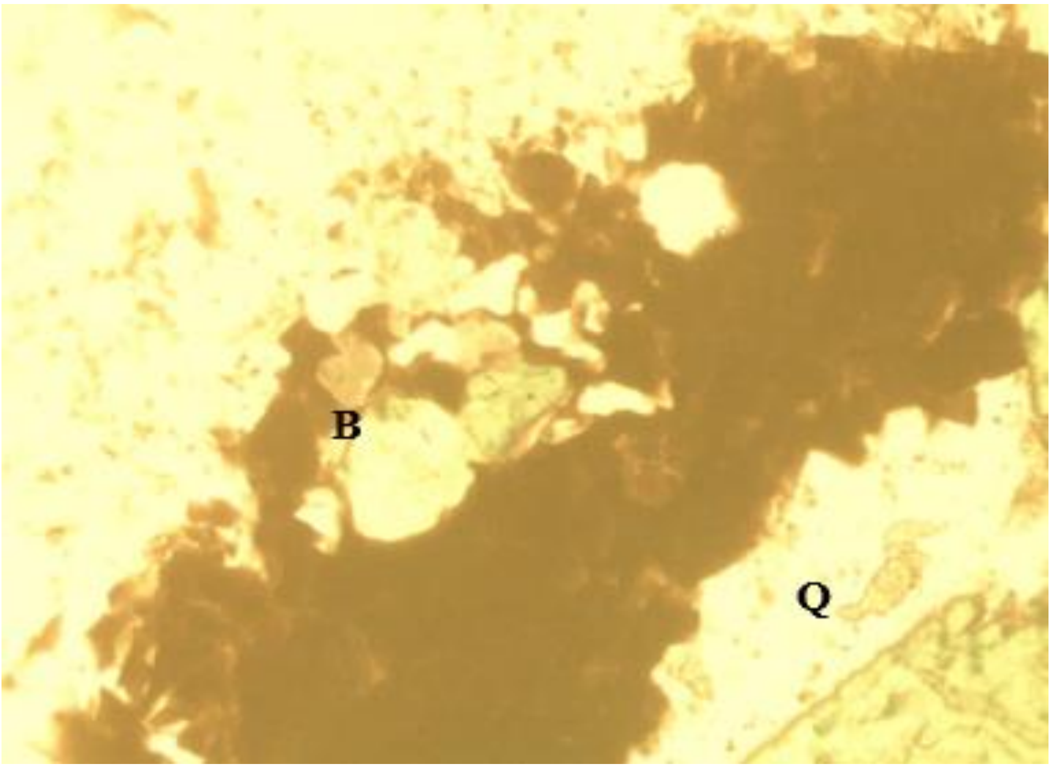

Fig5g: Photomicrograph of Vein Quartz showing B-Biotite, Q- Quartz Magnification x4

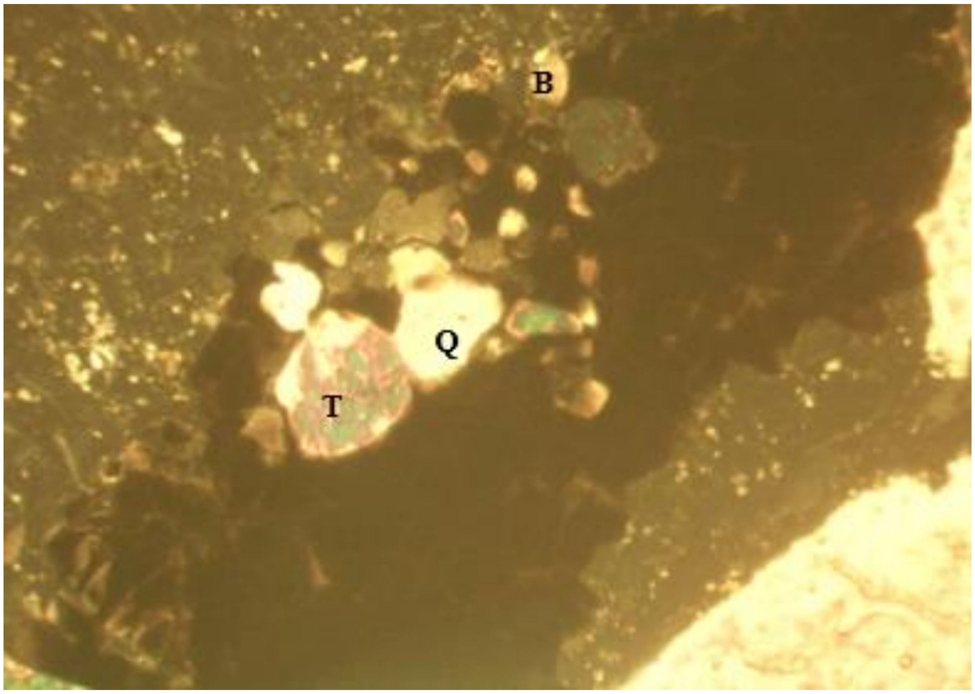

Fig 5h: Photomicrograph of Tourmaline (Ore Mineral) showing B-Biotit, T-Tourmaline, Q-Quartz. Magnification x4

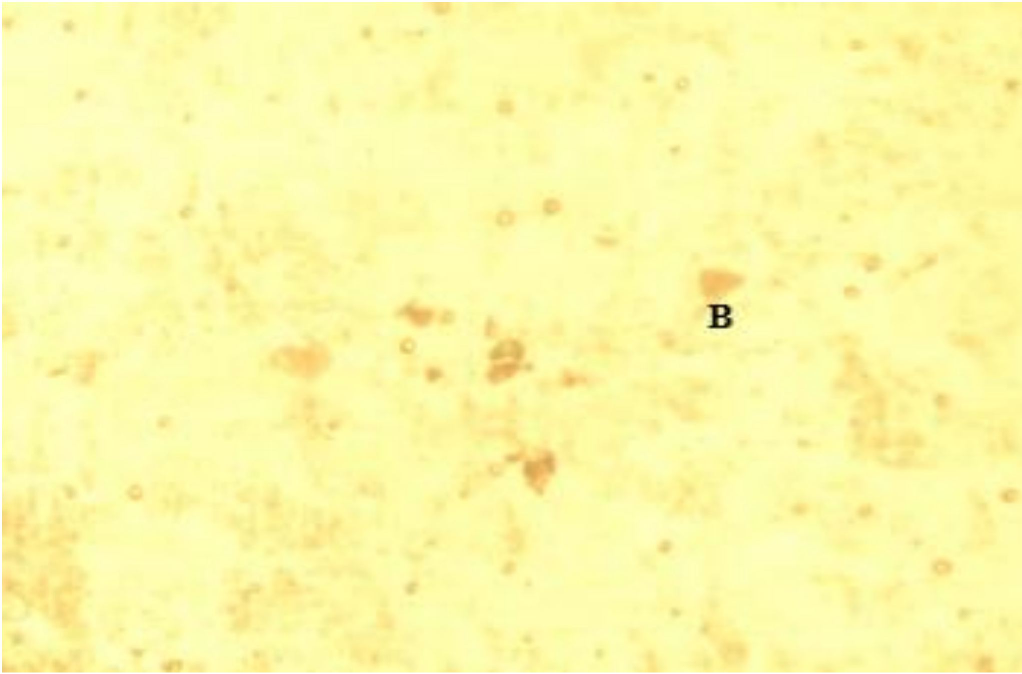

Fig 5i: Photomicrograph of Vein Quartz showing B-Biotite. Magnification x4

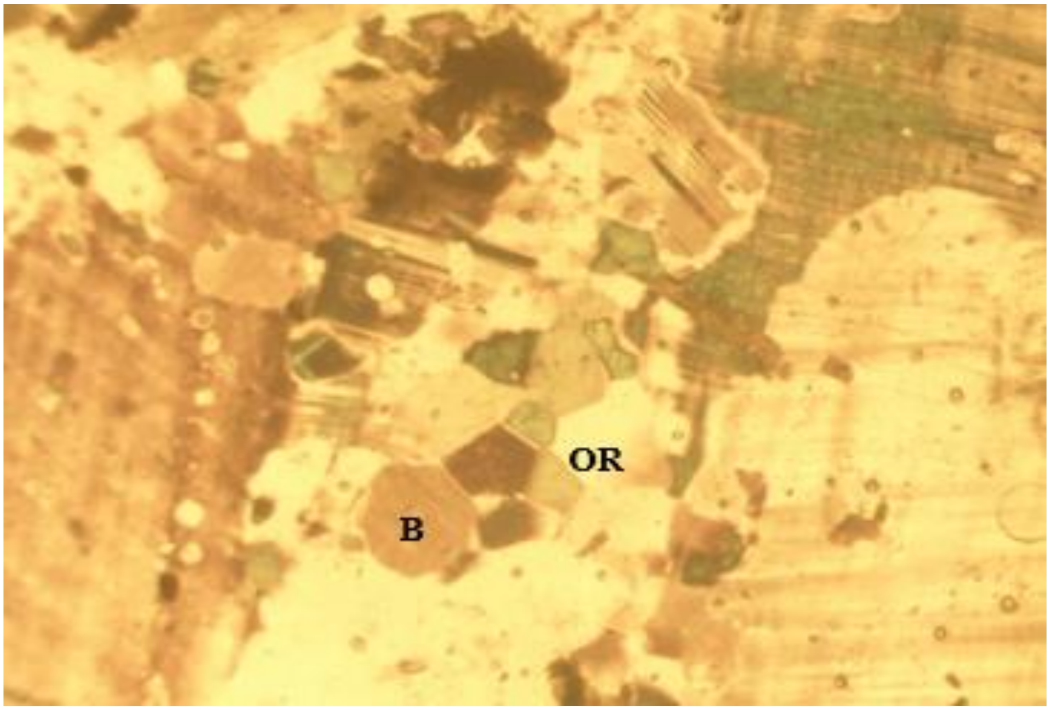

Fig 5j: Photomicrograph of sample Altered Pegmatite showing B-Biotite, OR-Orthoclase Feldspar. Magnification x4

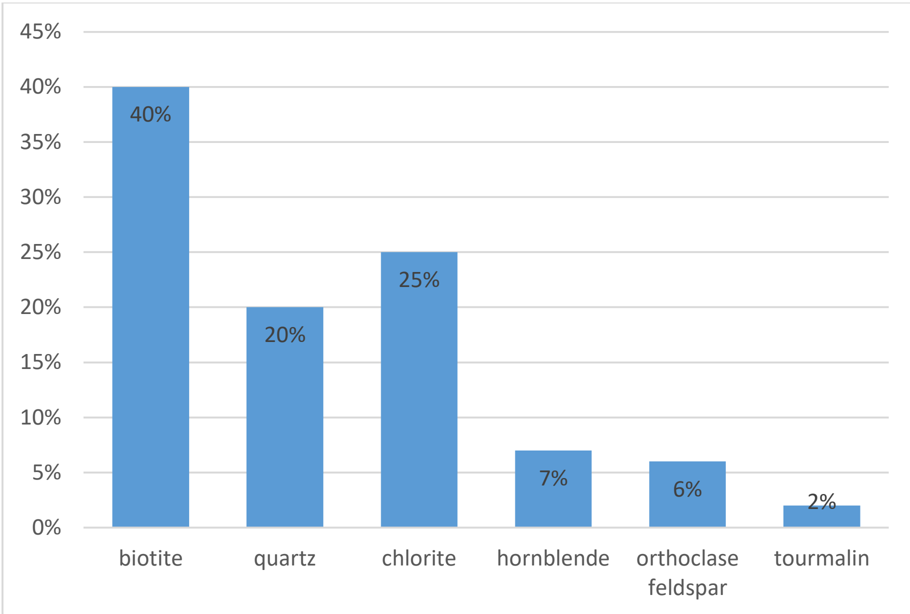

Fig 5: Bar chart showing estimated modal mineralogical composition of granite under the microscope.

Table 4.: Petrographical Analysis of Ilero Samples

Minerals	Optical Properties	Crossed Polarized (xpl)	Plane Polarized (ppl)	Percentage in Thin Section
Quartz	Color	Bluish to milky	Colourless	20%
	Relief:	Low relief		
	Form/size	Anhedral		
	Inclusion	Absent		
	Cleavage	Absent		
Biotite	Color	Brown	Brown	40%
	Relief:	Low		
	Form/size	Euhedral		
	Inclusion	Absent		
	Cleavage	Two (2) cleavage direction		
Chlorite	Color	Green	Green	25%
	Relief:	Low		
	Form/size	Euhedral		
	Inclusion	Absent		
	Cleavage	Present		
Hornblende	Color	Brown	Brown	7%
	Relief:	High		
	Form/size	Prismatic		
	Inclusion	Present		
	Cleavage	Present		
Tourmaline	Color	Dark Brown /Yellow	Dark Brown	2%
	Relief:	High		
	Form/size	Slender Prism		
	Inclusion	Absent		
	Cleavage	Present		
Orthoclase Feldspar	Color	Grey	Grey	6%
	Relief:	Low		
	Form/size	Prismatic		
	Inclusion	Present		
	Cleavage	Present		
Total				100%

3. Conclusion

The correlation analysis of some selected elements from the result of the geochemical analysis shows Ti, Fe, S, Cu, Al, Rb, and Pb among others to be strongly correlated. The conclusion drawn from the integration of the geochemical analysis, and correlation analysis in this study is that the study area is mineralized with gibbsite-cuprite-pyrite-galena-cassiterite-pollucite. The result of the petrographic study reveals that the rocks and ore minerals in the study area are predominantly whitish-grey-greenish in color with the textural compositions of porphyritic to fine-grained structures. Petrographically, the rocks and ore minerals in the study area are composed of major rock-forming silicate minerals such as quartz, biotite, hornblende, tourmaline, and feldspars. The XRD results showed that Albite, Orthoclase, quartz, Schorl, and Actinolite are possible mineralized minerals in the samples of the study area. Based on the petrographical, XRD, and geochemical analysis obtained, the results suggest that the study area possesses highly mineralized with economical minerals.

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