

**PETROLOGICAL AND GEOCHEMICAL STUDIES OF GRANITIC ROCKS IN  
IGARRA-UGBOGBO AREA, SOUTHWESTERN NIGERIA**

**BY**

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BENIN CITY**

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**PROJECT SUBMITTED TO THE DEPARTMENT OF GEOLOGY, FACULTY OF  
PHYSICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL  
FULFIMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF  
SCIENCES(B.Sc.) DEGREE IN GEOLOGY**

**MARCH**

## CERTIFICATION

This is to certify that this project work was carried out by **Emediong Arit NYONG(Miss)** with matriculation number **PSC2003849** in the Department of Geology, Physical Sciences, University of Benin, Benin City.

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**Date**

## **DEDICATION**

This project work is dedicated to my beloved family and friends for their unwavering support, encouragement, and sacrifices throughout my academic journey. Above all, I dedicate this work to God Almighty, whose grace, guidance, and blessings have made this achievement possible.

## **ACKNOWLEDGEMENT**

I am deeply grateful to God Almighty for His love, provision and guidance during the course of this project. I give extend my heartfelt thanks to my project supervisor Dr (Mrs.) O. Odokuma-Alonge for her support guidance and assistance throughout my project work. I thank the Head of Geology Department in the person of Dr S. A. Salami. I give thanks to my course advisor, Dr. Omoruyi and all the lecturers and staff of this great department for the for their mentorship, knowledge-sharing and unwavering support throughout my study years.

I give special thanks to the Department of Geology for granting me an opportunity to be part of this great study for blessing and impacting me with new knowledge that broadened my view on the world around me.

I convey my special thanks to my parents Mr. and Dr. Mrs. Agholor and my siblings for their unwavering love, care and guidance, financial and emotional support.

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## ABSTRACTS

Five (05) granitic rock samples from Igarra-Ugbogbo area in Akoko-Edo Local Government Area of Southwestern Nigeria were obtained with the aim of determining their geochemical and mineralogical properties using XRF, XRD techniques. Results of the analysis revealed the presence of  $\text{SiO}_2$  (62.05-79.63wt.%),  $\text{Al}_2\text{O}_3$  (10.88-15.10wt.%),  $\text{Fe}_2\text{O}_3(\text{T})^*$  (0.37-6.29wt.%),  $\text{K}_2\text{O}$  (0.89- 8.248wt.%),  $\text{Na}_2\text{O}$  (0.17-10.02wt.%) and  $\text{CaO}$  (0.32-4.68wt.%). The abundance of these major oxides in the samples showed that samples OGB01 and OGB05 are felsic magma while UNE02 is probably from a pegmatitic magma and EFU03 and GBO04 are most likely formed from an intermediate magma. Using  $\text{Al}_2\text{O}_3$  classification scheme, it showed that OGB01 and UNE02 are peraluminous while EFU03, GBO04, OGB05 are peralkaline. The XRD analysis revealed the presence of quartz, alkali feldspars (microcline, orthoclase and sanidine), plagioclase feldspars (albite and anorthite), muscovite, lime, geothite. The modal composition of the quartz, alkali feldspar, plagioclase were plotted on a QAP diagram which showed that the rock falls within the granite and Quartz-rich granitoid.

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 General Statement

Igneous rock forms part of the three major types of rocks. They form from the cooling and solidification of the molten magma which are rock melts of pre-existing rocks. This rock melt occurs within the Earth's crust and becomes lava when extruded to the surface.

It forms at conditions where the temperature and pressure causes a rock to start melting. The types of igneous rock formed from each magma is dependent on the composition of the magma. It constitutes a fundamental component of the lithosphere and studying these rocks help to understand the dynamic processes that shaped the Earth. Granite is a felsic intrusive igneous rock composed primarily of a phaneritic and granular texture. It is one of the most abundant rocks in the Earth's crust and is widely distributed across continental crustal regions. The formation of granite typically occurs deep within the Earth's crust through the slow cooling and crystallization of magma. This point is reached by extreme fractionation of basalt magma, partial melting of appropriate materials or a variety of assimilation- fractional crystallization processes.

The mineral composition of granite varies, but typically includes quartz, alkali feldspar, plagioclase feldspar and muscovite mica. These are minerals which crystallize from magma last (Bowen, 1928). These minerals give granite its distinctive speckled appearance, with large, visible crystals of alkali feldspar called phenocryst embedded in a finer-grained matrix of quartz and mica give. Occasionally, some ferromagnesian minerals such as biotite, hornblende, amphibole, or pyroxene may also be present, depending on the specific geological conditions of formation. Tourmaline, apatite, pyrite, zircon, rutile are present as accessory minerals. Granite is an igneous rock which contains 20% to 60% of quartz and 35% to 90% of alkali feldspar by volume (Streckeisen, 1976). Granitoid is a broader classification encompassing various types of granite-like rocks, sharing many similarities with true granites but may exhibit differences in mineral composition, texture, or origin. Granitoids include rocks such as granodiorite, syenite, tonalite and monzonite, which have compositions intermediate between granite and other igneous rocks. These rocks often display variations in colour, grain size and mineralogy, reflecting differences in the original

magma composition and geological history. The formation of granites is closely associated with tectonic processes such as continental collision, subduction, and magmatic differentiation. These rocks are commonly found in mountain ranges, volcanic arcs, and continental rift zones, where intense geological activity has led to the generation and emplacement of granitic magma bodies.

Granite is known for its durability, strength, and resistance to weathering, making it a popular choice for construction materials, monuments, counter-tops and decorative stones. Its high silica content and crystalline structure contribute to its hardness and ability to withstand mechanical and chemical weathering processes over long periods of time.

## **1.2 Aim and Objectives**

The aim of this study is to determine the petrological classification and geochemical properties of the granitic rocks in the Ugbogbo area in Akoko-Edo LGA, Southwestern, Nigeria.

The objectives include:

1. Conducting a detailed field study to identify and collect respective rock samples.
2. Determining the chemical composition using X-ray Fluorescence (XRF) technique.
3. Determining the mineralogical composition using X-ray Diffractometer (XRD) technique.
4. Providing a petrological classification of granitic rocks in the study area.

## **1.3 Location of The Study Area**

The study area is in Igarra-Ugbogbo Area, Akoko-Edo Local Government Area located in the Northern part of Edo State. It is located between latitude N 7° 16' 52.5''- N 7° 20' 8.5'' and longitude E 6° 5' 47.8''- E 6° 6' 47.1'' (Figure 1.1: shows Location Map of Study Area). It is bound to the north by Kogi State and south by Ondo State.

#### **1.4 Topography and Drainage**

The area's terrain was defined by elevations that reached 1500 metres in the east and less than 1000 metres in the west. The topographic relief is influenced by the underlying geology. It is characterised by highland (mainly the tall ranking older granite suites) adjoining relatively lowlying plains (essentially the weathered schist belt). Depending on the landform, or relief, the drainage pattern of the study region varies. The area is drained by a system of flowing streams, flowing generally in the N-S direction. The stream channels are almost parallel to the strike of the schistose rocks suggesting they are structurally controlled. Mostly dendritic and trellis-like streams and rivers that rise from the north to the south of the map make up the drainage. Onyami River, which is structurally controlled, was the major river that was encountered.

#### **1.5 Climate**

The study area generally has a warm and muggy environment. It has two distinct seasons each year which are the wet and the dry season. The wet season runs from April through October with low to moderate rainfall. The dry season runs from November through to February.

#### **1.6 Vegetation**

The study area is situated in the guinea savannah region, known for its short trees and tall grasses. The vegetation primarily consists of scattered trees, herbs, shrubs, and grasses. Trees are mainly clustered in areas with fractures within the plutonic bodies and quartzite ridges where sufficient soil cover and groundwater retention exist. The study area is of secondary vegetation, that is, there is alteration of the natural vegetation to aid the cultivation of crops such as maize yam, cassava, pineapple, cocoa, palm trees and sugar cane etc.

## **1.7 Human Activities**

The area consists of soil types which support plant and farming activities. This is the major means of livelihood of the occupants in the study area.

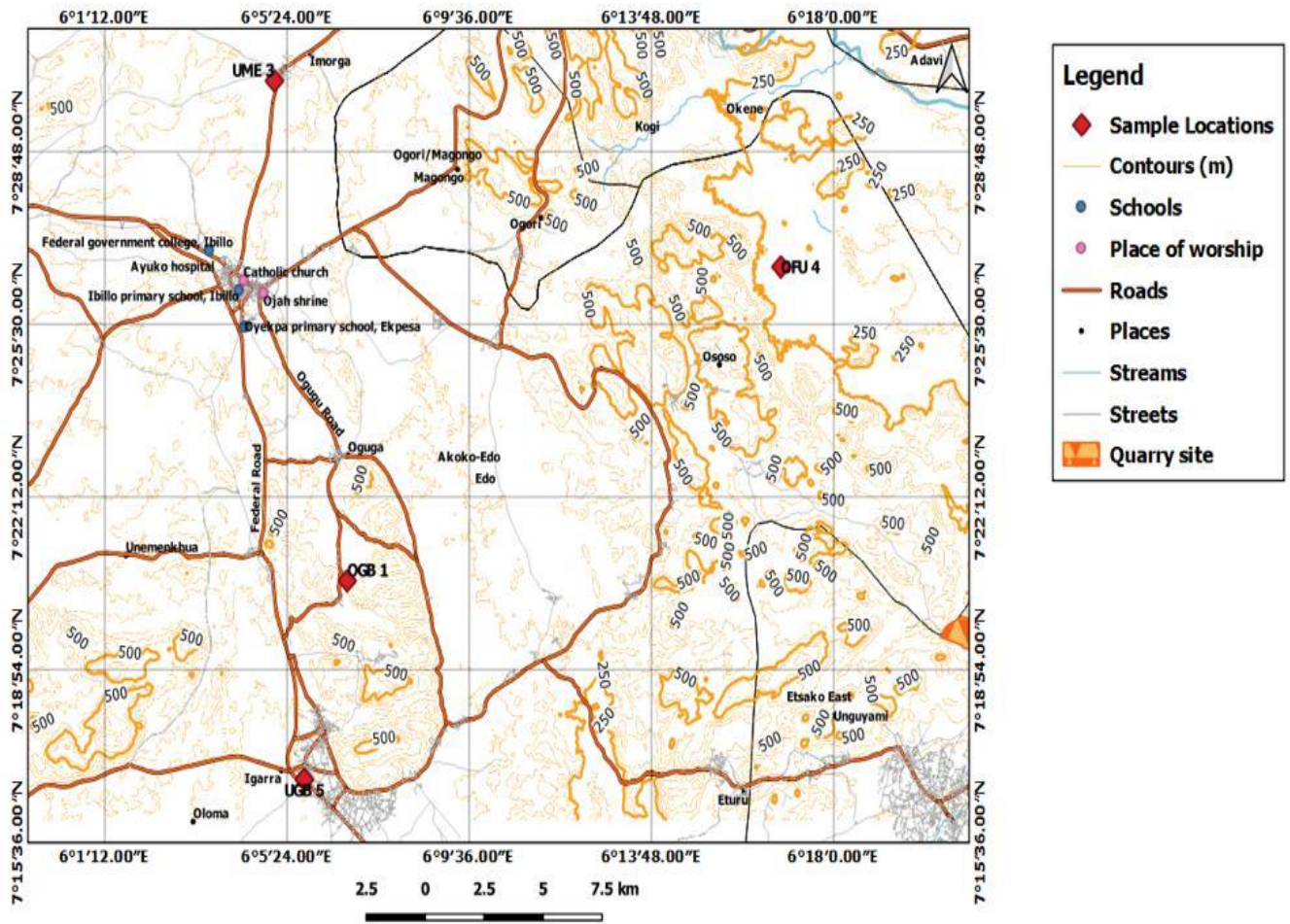


Figure 1.1: Location Map of Study Area Showing Sample Locations

## CHAPTER TWO

### 2.0 Geologic Setting

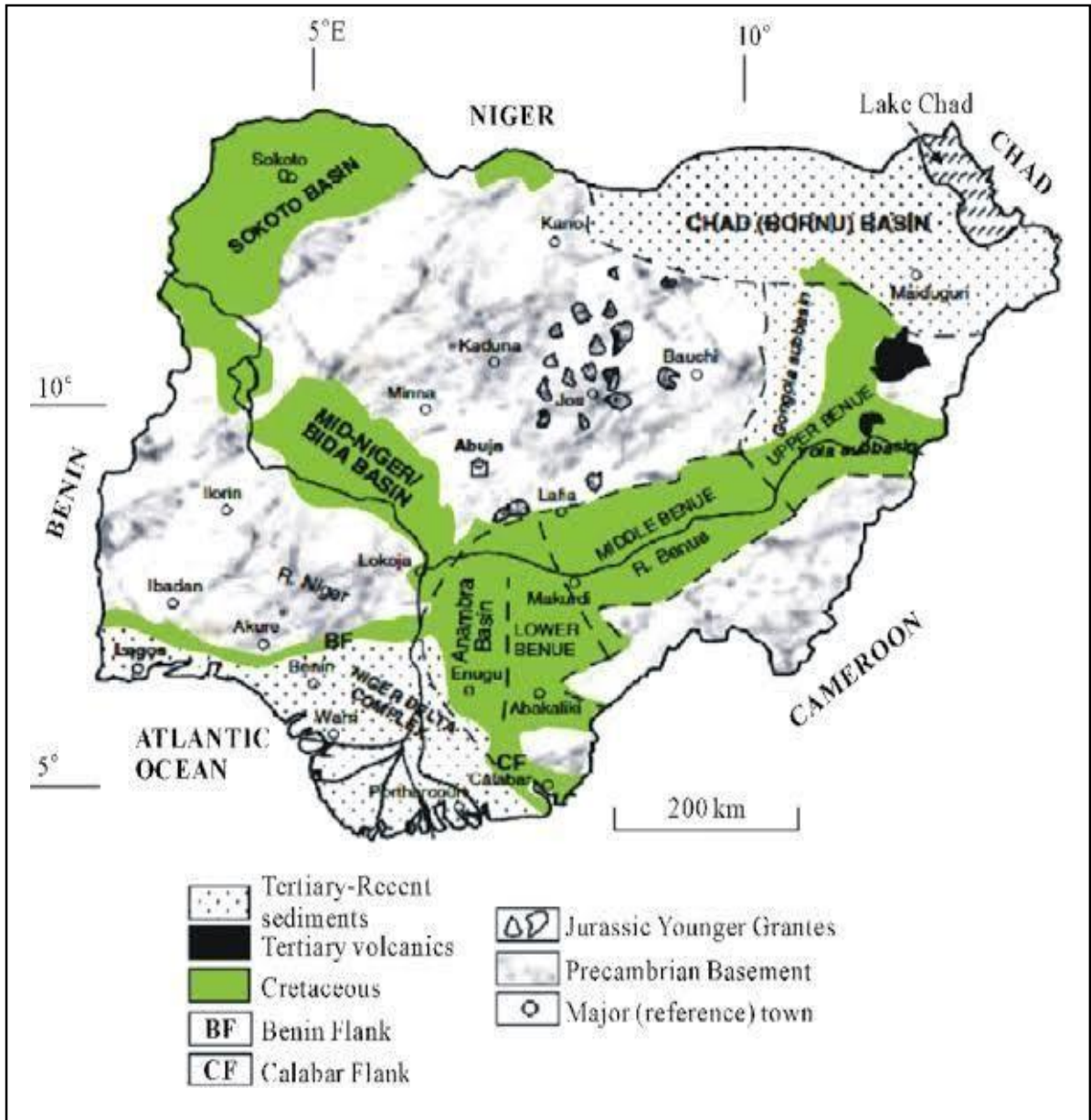
#### 2.1 General Geology

Nigeria's geological makeup consists of three primary litho-petrological elements: The Basement Complex, Younger Granites, and Sedimentary Basins. The Basement Complex, dating back to the Precambrian era, consists of the Migmatite-Gneiss Complex, Schist Belts, and Older Granites. Meanwhile, the Younger Granites encompass various Jurassic magmatic ring complexes, distinct in structure and petrology from the Older Granites. The Sedimentary Basins, comprising sediment deposits from the Cretaceous to Tertiary Periods, include the Niger Delta, Benue Trough, Chad Basin, Sokoto Basin, Mid-Niger (Bida/Nupe) Basin, and Dahomey Basin. Its geology is characterized by both crystalline and sedimentary rocks, roughly in equal proportions (Woakes *et al.*, 1983)

#### 2.2 Basement Complex Geology

The Nigerian Basement Complex is part of the southern end of the Trans-Saharan Pan African Mobile Belt located between the east of the West African Craton and northwest of the Congo Craton and south of the Tuareg Shield (Black, 1980). It resulted from the collision of the passive continental margin of the West African Craton and the active margin of the Tuareg Shield. The Nigerian Basement Complex extends westward and is continuous with the Dahomeyan Basement Complex of the Dahomey-Togo-Ghana region. Figure 2.1 shows Geological Map of Nigeria

The crystalline rocks are composed of the Precambrian Basement Complex and Phanerozoic rocks found especially in the eastern and north-central regions of the country. The basement rocks have undergone four major orogenic cycles, including the Liberian Orogeny (2800 ± 200 million years) (Grant, 1970), Eburnean orogeny (2000 ± 200 million years ago), Kibaran Orogeny (1100 ± 200 million years ago) (Odeyemi, 1988) and Pan African Orogeny (750 ± 200 million years ago). The Liberian, Eburnean and Kibaran characterised by intense deformation and regional metamorphism, followed by migmatization (Rahaman, 1976). The Pan-African orogenic event was a widespread phenomenon across the continent that resulted in the restructuring of pre-existing crust, resulting in a diverse basement and establishing predominantly N-S structural patterns in the area. It was characterised by regional metamorphism and extensive granitization. The end of the orogeny was marked by faulting and fracturing (Obaje, 2009).



**Figure 2.1:** Geological Map of Nigeria (Obaje, 2009)

The Nigerian Basement Complex can be divided into two regions: the eastern province, primarily consisting of migmatite-gneiss complex with intrusions of Pan-African granites and Mesozoic Ring Complexes (Younger Granites) in central Nigeria (Ajibade *et al.*, 1987; Kogbe, 1989).; and the western Province, located roughly west of longitude 8°E, characterised by narrow, sediment-dominated, N-S trending low-grade schist belts within an older basement of migmatite-gneiss, all intruded by Pan-African granitic plutons. The Nigerian Basement Complex rocks consist of Migmatite-Gneiss-Quartzite Complexes dating back to the Archean to Early Proterozoic era (about 2700-2000 million years ago). Additionally, there are NE-SW trending Schist belts predominantly located in the western part of the country, and Older Granite plutons from the Late Proterozoic to Early Phanerozoic period (approximately 750-450 million years ago). It has been intruded by Mesozoic per-alkaline ring complexes and overlain by Cretaceous and younger sediments. The Nigerian Basement Complex has been divided into different rock units by a variety of authors such as (Oyawoye,1964; Cooray,1974; Rahaman,1988; and Dada, 2006) Oyawoye, (1964) subdivided the Basement Complex rocks into three major rock units namely;

- a. The Older Metasediments which consist of calc-silicate rocks, arkosic quartzite and high-grade schist
- b. The Gneisses, Migmatites and Older Granites
- c. The Newer Metasediments

Cooray, (1974) subdivided the Basement Complex into three lithologic units namely;

- a. Metasediments (Older and Younger)
- b. Gneisses and migmatites
- c. Intrusives

Rahaman, (1988) subdivided the Basement Complex into six major lithologic units as

follows;

- a. Migmatite-Gneiss Complex

- b. Slightly migmatized to unmigmatized paragneisses and meta-igneous rocks
- c. Charnockitic rocks
- d. Members of the Older Granite suite
- e. Metamorphosed to unmetamorphosed calc-alkaline volcanics and hypabyssal rocks
- f. Unmetamorphosed dolerite dykes, basic dykes and syenite dykes.

Dada, (2006) presented four distinct lithologic units as part of the Basement Complex namely;

- a. Migmatite-Gneiss Complex
- b. Schist Belt
- c. Pan-African Granitoids

- d. Undeformed acid and basic dykes

### **2.2.1 Migmatite-Gneiss Complex**

The Migmatite-Gneiss Complex is considered generally as the Basement Complex “sensu stricto” (Dada, 2006). They are the most widespread group of rock and cover about 30% of the total surface area of Nigeria (Rahaman, 1988). They are the oldest basement rock and are believed to be part of an ancient sedimentary series that has been altered by metamorphic, migmatitic and granitic processes. Radiometric dating of the Nigeria Basement Complex has dated the migmatite-gneiss Complex to be of the Eburnean Orogeny (2000 ±200 million years ago) (Rahaman, 1988). There are three main petrological units within the Migmatite-Gneiss Complex namely;

- a. Biotite gneiss is commonly found and typically has a fine texture, displaying distinct layering due to the alignment of dark and light minerals.
- b. Banded gneiss exhibits alternating light and dark bands with complex folding patterns.
- c. Older metasediments, originally sedimentary, have undergone extensive metamorphism, now appearing as quartzites, marble, and other calcareous rocks, along with remnants of highly altered clayey sediments and igneous rocks.

The Migmatite-Gneiss Complex covers many areas in the northern, western and eastern parts of Nigeria. These areas include; Abuja, Keffi, Akwanga Bauchi, Kaduna, Kano, Funtua, Okenne, Egbe and Ajaokuta in the north, Ibadan, Ile-Ife, Akure, Ikerre in the west and Obudu and Oban Massif areas in the east.

### **2.2.2 Schist Belt**

The schist belts occupy generally N-S and NNE-SSW synformal troughs, the migmatite gneiss and granites terrain flank the schist belt to the east and west and separates the individual belts within the zone. The schist belts are most developed in the northwestern, southwestern and central parts of the country. They were formerly referred to as “Younger metasediments” to distinguish them from the “Older metasediments” (McCurry, 1976). Eleven main belts have so far been identified by Turner (1983) and Ajibade *et al.*, (1987) in the northwest and north central parts of Nigeria (Figure 2.2: Distribution of Schist Belt in Nigeria Obaje, 2009).

The eleven main schist belts are:

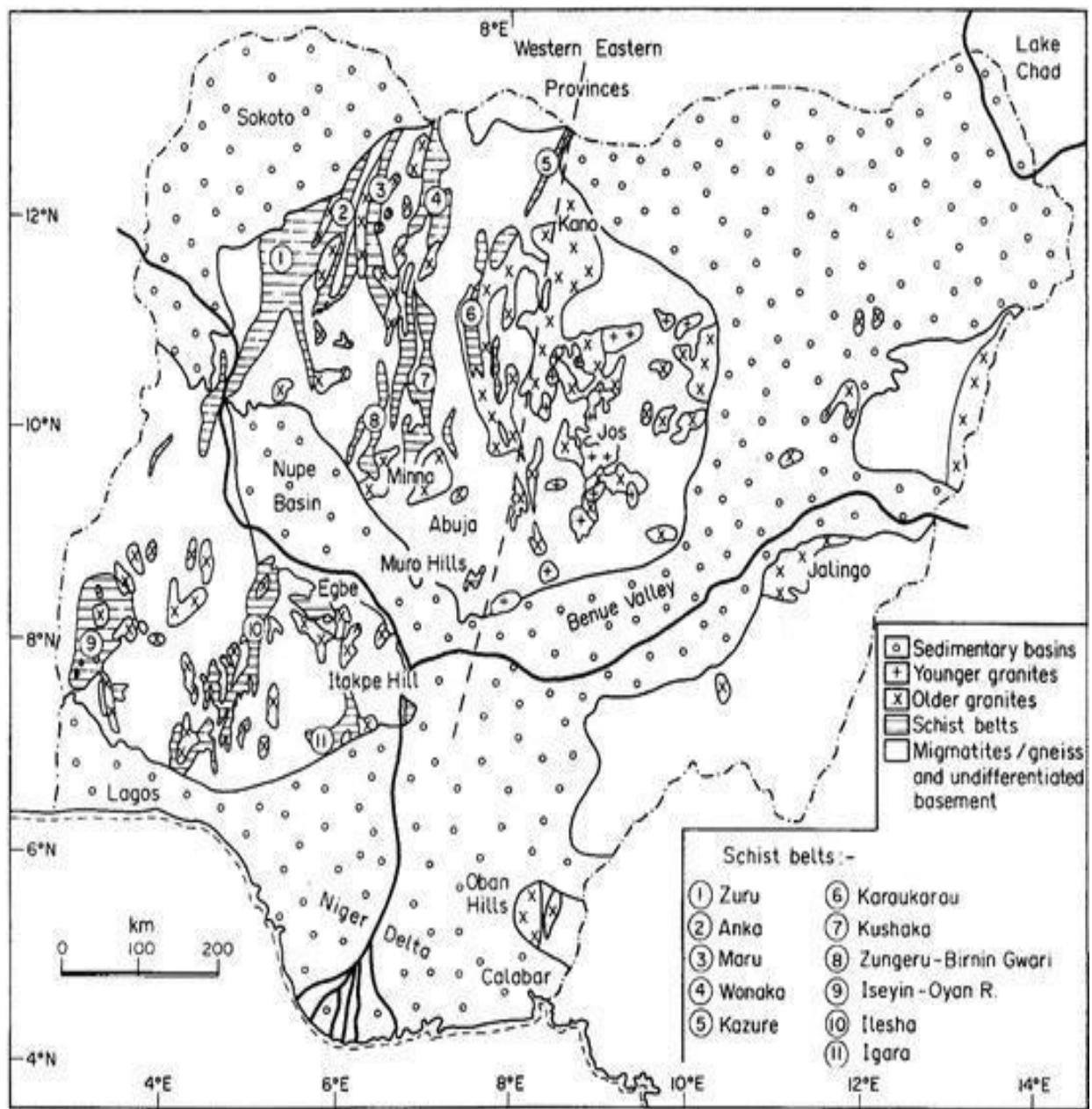
1. Birnin Gwari Belt
2. Kushaka Belt
3. Wonka Belt
4. Zuru Belt
5. Anka Belt
6. Maru Belt
7. Malumfashi Belt
8. Kazaure Belt
9. Illesha Belt
10. Igarra Belt
11. Iseyin-Oyan Belt

They are largely low-grade metasediments dominated by pelitic schist, phyllites, banded iron formation, carbonate rocks and mafic metavolcanics. A typical schist belt is the Igarra Schist belt studied by Odeyemi (1976, 1988). In this area the metasedimentary sequence consists of five main units; mica schist, quartzite, and quartz schist, metaconglomerate, calc-gneiss/marble and quartz biotite schist and phyllite is typified by a distinct fine to alternating

light and dark grey layers and in places green layers. It comprises pelitic, semi pelitic and psammitic rocks which also define a lithologic banding.

### **2.2.3 Pan-African (Older) Granite**

The term “Older Granite” was introduced by Falconer (1911) to distinguish them from the Younger Granite Ring Complex that runs in the north-central part of Nigeria. The Pan-African granites are syn-to late-tectonic intrusions into the Migmatite-Gneiss Complex and the Schist belts. They are otherwise referred to as the 'Older Granites' to distinguish them from the Jurassic granites which are also found alongside their outcrops in the Jos Plateau and adjoining localities. The Pan- African granites suite consists mainly of granites and granodiorites (Rahaman, 1976), The Older Granites are the most obvious manifestation of the Pan-African Orogeny in West Africa (Rahaman, 1988).



**Figure 2.2:** Distribution of Schist Belt in Nigeria (Obaje, 2009).

Southwest they make up about 20% of the basement rocks, eastward and northeast wards in the Akure-Okene Abuja area account for 40-60% of the surface area. They range in size from plutons to batholiths. They form circular to elliptical bodies in schists and more elongate bodies in the migmatite-gneiss. The contact between the older granite and the Basement Complex is commonly gradational and a replacive contact exists between the members. The gradational contact suggests a non-magmatic origin of possible emplacement during the last of the reactivation events to affect the Basement Complex i.e. the Pan-African Orogeny.

#### **2.2.4 Undeformed Acid and Basic Dykes**

The undeformed acid and basic dykes are the last unit of the Nigerian Basement Complex. They are widespread and cross-cut through all the other units; migmatite-gneiss complex, Schist belt and the Older Granites. They are of Late to Post-tectonic Pan-African age. The undeformed acid and basic dykes are grouped into two, which include;

A. Felsic dykes that are associated with Pan African granitoids on the terrain such as the muscovite, tourmaline and beryl bearing pegmatites, microgranites, aplites and syenite dykes (Dada, 2006).

B. Basic dykes that are generally regarded as the youngest units in the Nigerian basement. dolerite is the most common type with less frequent occurrences of basaltic, felsite and lamprophyric dykes.

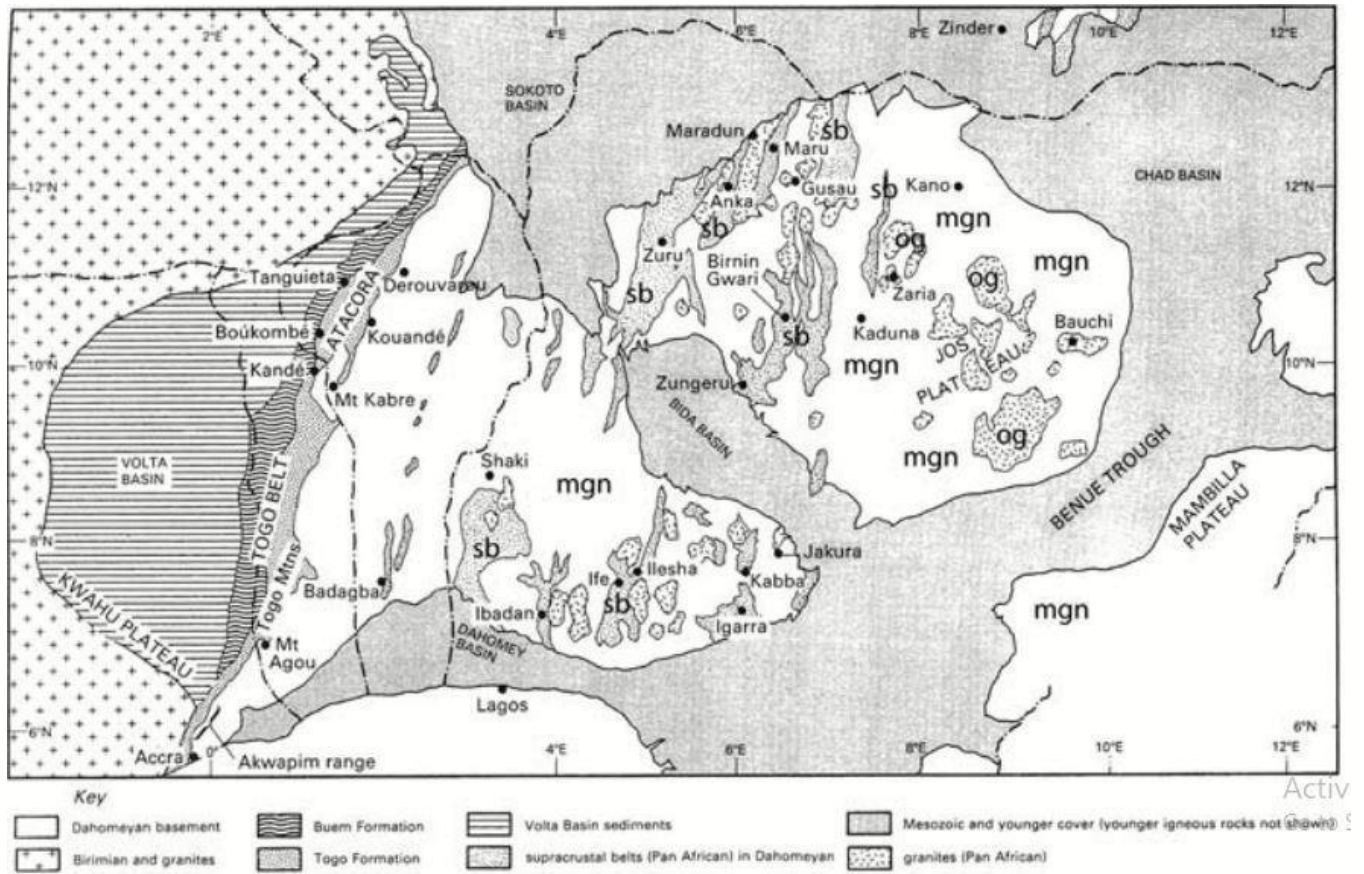
The age of the felsite dykes has been put at between 580 and 535 Mya from Rb-Sr studies on whole rocks (Matheis and Caen-Vachette, 1983; Dada, 2006), while the basic dykes have a much lower suggested age of Ca. 500 Ma (Grant, 1970). The rock units' structural and geochronological importances which have been put to immense chronological use elsewhere (Dada, 2006) are often overlooked in Nigeria. When they cross-cut basement rock, they could be used to infer relative age of metamorphic structures and rock suites and could also suggest the existence of older basement windows in the Nigerian Schist Belts, apart from the immense guide they provide in sampling for isotope geochemistry, analysis and interpretation (Dada, 2006). Figure 2.3 shows a map of the Basement Complex of Nigeria.

### 2.3 Local Geology

According to (Odeyemi,1976),the geological setting of this region comprises the

following:

- I. Syn to Late tectonic granitoids (which include porphyritic biotite and biotitehornblende granodiorites and adamellites, charnockites and gabbros; unmetamorphosed dolerites, pegmatites, aplite and syenite dykes). These are considered to be part of the Older Granites and are associated mainly with the PanAfrican orogeny.
- II. Low grade metasediments (which include schists, calc-silicate gneisses, marbles, polymitic metaconglomerates and quartzites). These are considered to be part of the schist belts of Nigeria and occupy a N-S trending belt. They have been associated with the Pan-African orogeny ( $750 \pm 200$  million years ago) and Kibaran orogeny ( $1100 \pm 200$  million years ago).
- III. A polycyclic crystalline complex of migmatites and gneisses (the migmatite-gneiss complex). The migmatite-gneiss complex includes relics of an ancient metasediments sedimentary sequence. Its evolution started during the Liberian Orogeny ( $2800 \pm 200$  million years ago).



**Figure 2.3:** Basement Complex of Nigeria: The Migmatite-Gneiss Complex (mgn), the Schist Belts (sb) and the Older Granites (og) (Obaje, 2009)

Odeyemi (1988) concluded that the Migmatite-Gneiss Complex rocks were the oldest of the three different rocks mentioned in the geologic setting of Igarra and the metasediments occur as a supra-crustal cover on the migmatite-gneiss complex and have been seen to be discernibly younger than the migmatite-gneiss complex; the contacts between the Migmatites and the meta-sediments are fault bounded in most places and have made the identification of basal unconformities difficult. The metasediments lie unconformably on the migmatite-gneiss complex. The older granites are the youngest of the three rocks in the geological setting and the granites were seen to be syn to late tectonic and that most of the granitic activity took place during the waning phase of the Pan African orogeny (Odeyemi,1988). They occur as dykes, stocks and batholiths and occupy some of the highest points of elevation in the area.

Odeyemi (1988) further classified the metasediments into the following main categories:

- a. Quartz biotite schist: This layer is the oldest and the first layer encountered in the metasediments in the area.
- b. Marble/calc-silicate gneiss: This layer is younger than the quartz biotite schist and lies above the quartz biotite schist. It often occurs as low-lying between the quartz biotite schist and metaconglomerate.
- c. Meta-conglomerate: This layer lies above the calc-silicate gneiss and is younger. It is composed of pebbles, cobbles and boulders of quartzite, marble, calc-silicate gneiss, quartz biotite schist and granite gneisses.
- d. Mica Schist: This layer is the youngest of all the layers in the metasediments and is the top most layer. It occurs as highly weathered bodies most along river channels. Recent works such as Udi *et al.*, (2023) has called this unit a quartz sericite schist due the abundance of a variety of muscovite that is formed during weathering.
- e. Quartzite: strongly foliated to massive bodies occurring as a sub-unit to inter bedded with the mica schist.

The stratigraphic relationship between them was established by Odeyemi (1988) and this was based on their position within the gently overturned anticline in Otuo area and the occurrence of clasts of schist and calc-silicate gneiss in the structurally overlying

metaconglomerate. The area was characterized by two deformational phases of which one was an early minor and the other was a late major phase. These deformational phases resulted in a series of structures (which include generation of two foliation trends and two-fold types). The first foliation trend is an E-W trend restricted in occurrence to both the quartz biotite schist and calc-silicate gneiss and their underlying basement of migmatite-gneiss and was defined by mineralogical banding and showed consistent dips towards the north. The second foliation has a general N-S trend and this trend is pervasive and occurs in all rocks in the area and shows moderate to steep western dips and as a result of the second trend on the first, both the quartz biotite schist and calc-silicate gneiss reveal a complex deformational pattern. (Odeyemi, 1988).

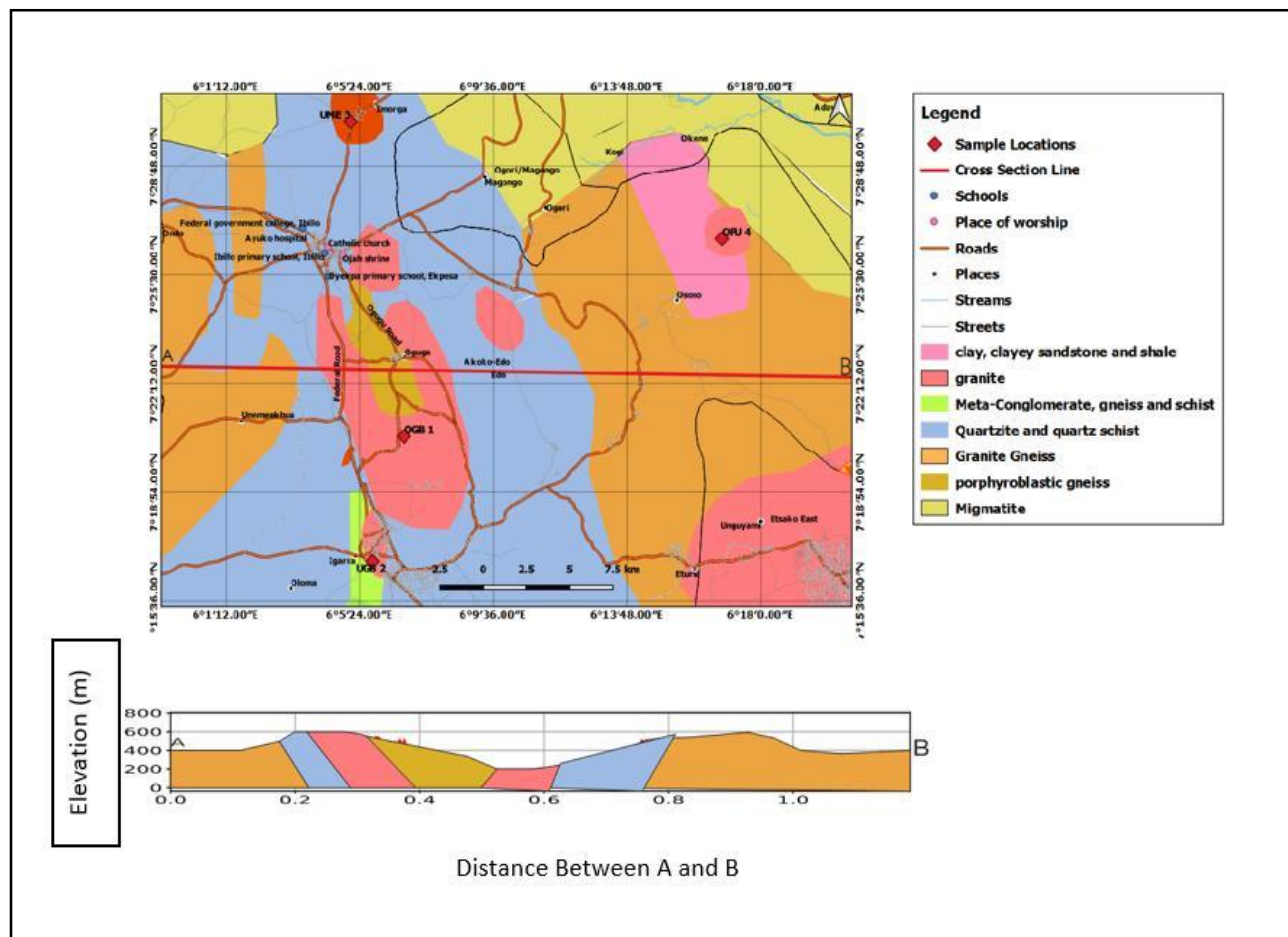
The first fold type was produced during the minor deformation phase and they are often tight to isoclinal with folded axial planes and they are reclined in style and plunge consistently in the ENE and this is restricted to quartz biotite schist, calc-silicate gneiss and matrix of metaconglomerate. The second fold trend is associated with the major deformation phase and are characterized by steep to moderately inclined axial planes which are parallel to the 2nd foliation trend in the rocks. The 2nd fold exhibit styles which vary from open to tight to isoclinal with consistent plunges towards the north but it is slightly overturned to the east. The dominant type of fold is the 2nd trend and has resulted in the refolding of F1 folds. (Odeyemi, 1988).

There are two major fault zones that occur in this region and the first occurs in the Igarra batholith and displaces a sequence of quartz biotite schist, calc-silicate gneiss, metaconglomerate and quartzite and is interpreted as a high angle fault whereas the second fault zone marks the boundary between the metasediments and the migmatite gneiss complex. (Odeyemi, 1988). The metamorphism that occurred in the area is of low grade and the major structural feature is a series of anticlinal and synclinal overfolds with roughly north to south axis.

### **2.3.1 Field Observation**

The samples were obtained from the Igarra Pluton which is composed mainly of granitic rocks. The pluton covers a large part of the sampled area. The sample OGB 01 was seen to have be coarse grain with a light grey colour with a granular texture. The sample UNE 02 was seen to be coarse grain with hummocky as the mode of occurrence and a phaneritic

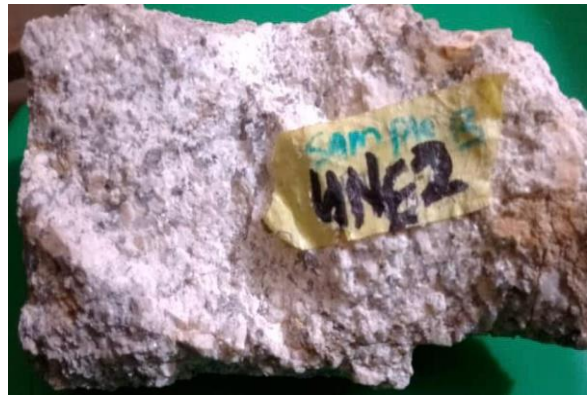
texture. The percentage of dark colour is 0-20% and light colour 80%. The sample EFU 03 was seen to be coarse grain with batholith as the mode of occurrence and a phaneritic texture with 30-60% of dark colour mineral (biotite). The sample GBO 04 was seen to be coarse grain with batholith as the mode of occurrence. The sample OGB 05 was seen to have a coarse grain with a phaneritic texture and having 30-60% of a dark coloured mineral (biotite).



**Figure 2.4:** A Geological Map of Sampled the Area.



A



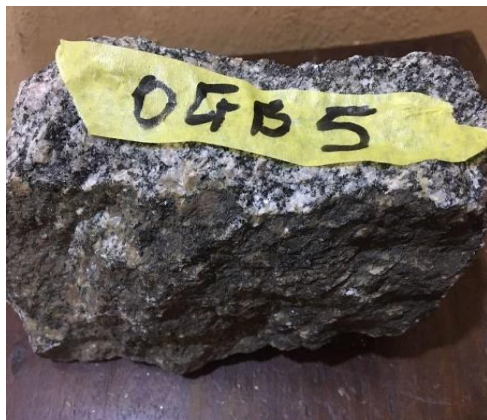
B



C



D



E

**PLATE 2.1:** Rock Samples Obtained from Igarra and Environs



**PLATE 2.2:** A Coarse Biotite Granite



**PLATE 2.3: A Porphyritic Biotite Granite**

## 2.4 PREVIOUS WORKS

Umaru *et al.*, (2023) in their work ‘Geochemistry and Petrogenesis of Pan-African Granitoids in Kaduna, North Central, Nigeria’ concluded that the granitoids are of subalkaline composition but show calc-alkaline affinity that is emplaced in a collisional tectonic setting. They are weakly peraluminous S-type granites produced by the partial melting greywacke and pelitic materials.

Akinola *et al.*, (2021) in their work ‘Petrography and Geochemical Characterization of Granite Batholith in Idanre, Southwestern Nigeria’ concluded that the Idanre Batholith is alkaline and portray peraluminous characteristics of granite belonging to the ‘withinplate’ tectonic setting.

OlaOlorun *et al.*, (2020) in their work ‘Geology and Geochemistry of Iroko Granite Southwestern, Nigeria: Implication of Provenance’ concluded that the Iroko granites show a high content of SiO<sub>2</sub>. The granite shows high potassic content associated with sub-alkaline magmatism and calc-alkaline series. They are ferroan and exhibits characteristics of I-type granitoids.

Igonor and Abimbola, (2019) in their work ‘Geochemistry of Pan African Granitoids, Southwestern, Nigeria: Evidence of Magmatic Mixing’ inferred that a large scale fractional crystallization of a single parent basic magma was responsible for the formation of all the rocks in Ado-Ekiti area are impossible. They proposed that a basic magma of calc-alkaline source which was the parent magma of these rocks underwent fractional crystallization during emplacement to produce diorite. As a result of partial melting of crustal rocks to form an acidic magma which intruded and crystallized to give syenite, syenodiorite, granodiorite and granite.

Odokuma-Alonge *et al.*, (2019) in their work ‘Geochemical Consideration of some Granitoids around Ojirami-Ogbo and Environs, Southwestern, Nigeria’ concluded that all rocks are peraluminous which indicates high Al<sub>2</sub>O<sub>3</sub> except for one and also they all plot in the granitoidal field except for one which falls within the quartz-rich field due to its high quartz content.

Ogunyele *et al.*, (2019) in their work ‘Petrochemistry and Petrogenesis of the Precambrian Basement Complex rocks around Akungba-Akoko, Southwestern, Nigeria’ concluded that the biotite granite and charnockite are of igneous or magmatic origin.

Obiefuna *et al.*, (2018) in their work ‘Geochemical and Mineralogical Composition of Granitic rock deposits in Michika Area, Northeastern, Nigeria concluded that the granites contain high alumina and falls with the S-type Igneous rock series.

Egesi and Agomuo, (2019) in their work ‘Petrography, Structural Characteristics and Mineral Resources of Igue Oke, Igarra Area, Southwestern, Nigeria’ concluded that the the granites are plutonic rocks composed of quartz, biotite/hornblende and feldspars.

## CHAPTER THREE

### 3.0 Materials and Methods

#### 3.1 Materials

The materials used during the fieldwork for sample collection are listed below:

1. Compass Clinometer
2. Global Positioning System (GPS)
3. Camera
4. Field Notebook
5. Sledge Hammer
6. Sample Bag

#### 3.2 Methods

A total of five (05) samples of granitic rocks from Igarra-Ugbogbo are were collected from their different exposures in the study location. The samples were collected with the aid of a sledge hammer, their GPS coordinates were recorded and they were well labeled. The samples were sent to the Kaduna for mineralogical analysis using Rigaku Miniflex Benchtop 600 XRD Machine. The results were interpreted using the geochemical and mineralogical data.

##### 3.2.1 Sample Collection

Field protocols taken for studying the rocks at their different exposures are as follows:

1. Area Identification: To determine the geologically significant site for examination.
2. GPS Coordination: To record the exact location using GPS equipment for future documentation.
3. Description of Surrounding Geology: To document the rock varieties in the vicinity along with their GPS coordinates.
4. Sampling Fresh Material: To collect rock samples in their fresh and significantly unweathered state to facilitate detailed analysis.
5. Analysis of Rock Attributes: To examine and note down the physical characteristics of the samples, assigning provisional names based on initial assessments.
6. Documentation of Observations: To record structural features and interrelations among various rock types in your field journal.

### 3.2.2 What Are X-Rays?

X-rays are forms of electromagnetic radiation with wavelengths of  $10^{-8}$  to  $10^{-12}$  metres which are shorter than that of visible light ( $10^{-6}$  to  $10^{-7}$  metres). They are produced by the movement of electrons in atoms and can penetrate materials to varying degrees depending on their densities and thickness.

There are primarily two types of x-rays which are;

The Hard X-rays which have higher energy level and are used mainly in industrial applications and scientific research such as X-ray crystallography. The Soft X-rays which have lower energies and are used by meteorologists and for medical diagnosis. In mineralogy, x-ray wavelength are measured in Angstroms( $\text{\AA}$ ).

### 3.2.3 X-Ray Fluorescence -How It Works?

An X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It works on wavelength-dispersive spectroscopic principles that are similar to an electron microprobe (EPMA). However, an XRF cannot generally make analyses at the small spot sizes typical of EPMA work (2-5 microns), so it is typically used for bulk analyses of larger fractions of geological materials. The relative ease and low cost of sample preparation, and the stability and ease of use of x-ray spectrometers make this one of the most widely used methods for analysis of major and trace elements in rocks, minerals, and sediment. The analysis of major and trace elements in geological materials by XRF is made possible by the behavior of atoms when they interact with X-radiation. An XRF spectrometer works because if a sample is illuminated by an intense X-ray beam, known as the incident beam, some of the energy is scattered, but some is also absorbed within the sample in a manner that depends on its chemistry. The incident X-ray beam is typically produced from a Rh target, although W, Mo, Cr and others can also be used, depending on the application.

When this primary X-ray beam illuminates the sample, it is said to be excited. The excited sample in turn emits X-rays along a spectrum of wavelengths characteristic of the types of atoms present in the sample. How does this happen? The atoms in the sample absorb X-ray energy by ionizing, ejecting electrons from the lower (usually K and L) energy levels. The ejected electrons are replaced by electrons from an outer, higher energy orbital. When this happens, energy is released due to the decreased binding energy of the inner electron orbital compared with an outer one. This energy release is in the form of emission of characteristic X-rays indicating the type of atom

present. If a sample has many elements present, as is typical for most minerals and rocks, the use of a Wavelength Dispersive Spectrometer much like that in an EPMA allows the separation of a complex emitted X-ray spectrum into characteristic wavelengths for each element present. Various types of detectors (gas flow proportional and scintillation) are used to measure the intensity of the emitted beam. The flow counter is commonly utilized for measuring long wavelength ( $>0.15$  nm) X-rays that are typical of K spectra from elements lighter than Zn. The scintillation detector is commonly used to analyze shorter wavelengths in the X-ray spectrum (K spectra of element from Nb to I; L spectra of Th and U). X-rays of intermediate wavelength (K spectra produced from Zn to Zr and L spectra from Ba and the rare earth elements) are generally measured by using both detectors in tandem. The intensity of the energy measured by these detectors is proportional to the abundance of the element in the sample. The exact value of this proportionality for each element is derived by comparison to mineral or rock standards whose composition is known from prior analyses by other techniques.

### **Strengths and Limitations of X-Ray Fluorescence (XRF)**

#### **Strengths**

X-Ray fluorescence is particularly well-suited for investigations that involve:

Bulk chemical analyses of major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) in rock and sediment. Bulk chemical analyses of trace elements ( $>1$  ppm; Ba, Ce, Co, Cr, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr, Zn) in rock and sediment.

#### **Limitations**

In theory the XRF has the ability to detect X-ray emission from virtually all elements, depending on the wavelength and intensity of incident x-rays. In practice, most commercially available instruments are very limited in their ability to precisely and accurately measure the abundances of elements with  $Z < 11$  in most natural earth materials. XRF analyses cannot distinguish variations among isotopes of an element, so these analyses are routinely done with other instruments. XRF analyses cannot distinguish ions of the same element in different valence states, so these analyses of rocks and minerals are done with techniques such as wet chemical analysis or Mossbauer spectroscopy. Plate

3.1 shows an XRF machine.

### **3.2.4 Procedure for X-Ray Fluorescence**

1. Crushing of each sample with an electric crusher and the pulverised for 60 seconds using Herzog Gyro-mill (Simatic C7-621).
2. Pellets were prepared from the pulverised sample, first by grinding 20g of each sample with 0.4g of stearic acid for 60 seconds. After each grinding, the Gyro mill was cleansed to avoid contamination.
3. One gramme (1g) of stearic acid was weighed into an Aluminum cup to act as binding agent and the cup was subsequently filled with the sample to the level point.
4. The cup was then taken to Herzog pelletizing equipment when it was passed at a pressure of 200 KN for 60 seconds.
5. The 2mm pellets were added into a sample holder of the X-ray equipment (Phillips PW 1210) for analysis.



**Plate 3.1:** MODEL: TEFA ORTEC automatic X-ray Fluorescence Machine

### 3.2.5 Operation of X-Rays in Diffraction-How It Works?

X-ray Diffraction is versatile destructive analytical technique used to analyze physical properties such as phase composition of crystal structure and orientation of powder, solid and liquid samples. In 1912, Max von Laue and his colleagues discovered that crystalline substances can function as three-dimensional diffraction grids for X-ray wavelengths similar to the spacing between planes in a crystal lattice. X-ray diffractometers consist of three basic elements: an X-ray tube, a sample holder, and an X-ray detector (Connolly, 2007).

These X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy Bragg's law:  $n\lambda=2d\sin\theta$

Where  $n$  is an integer,  $\lambda$  is the wavelength of the X-rays,  $d$  is the interplanar spacing generating the diffraction, and  $\theta$  is the diffraction angle. This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. These diffracted X-rays are then detected, processed, and counted. By scanning the sample through a range of  $2\theta$  angles, all possible diffraction directions of the lattice should be attained due to the random orientation of the powdered material. Conversion of the diffraction peaks to  $d$ -spacings allows identification of the compound because each compound has a set of unique  $d$ -spacings. Typically, this is achieved by comparison of spacings with standard reference patterns.

X-rays are generated in a cathode ray tube by heating a filament to produce electrons, accelerating the electrons toward a target by applying a voltage, and bombarding the target material with electrons. When electrons have sufficient energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced. These spectra consist of several components, the most common being  $K_{\alpha}$  and  $K_{\beta}$ .  $K_{\alpha}$  consists, in part, of  $K_{\alpha 1}$  and  $K_{\alpha 2}$ .  $K_{\alpha 1}$  has a slightly shorter wavelength and twice the intensity of  $K_{\alpha 2}$ .

The specific wavelengths are characteristic of the target material (Cu, Fe, Mo, Cr). Filtering, by foils or crystal monochrometers, is required to produce monochromatic X-rays needed for diffraction.  $K_{\alpha 1}$  and  $K_{\alpha 2}$  are sufficiently close in wavelength such that a weighted average of the two is used. Copper is the most common target material for single-crystal diffraction with  $CuK_{\alpha}$  radiation = 1.5418 Å. These X-rays are collimated and directed onto the sample. As the sample and detector are rotated, the intensity of the reflected X-rays is recorded. When the geometry of

the incident X-rays impinging the sample satisfies Bragg's law, constructive interference occurs and a peak in intensity appears. A detector records and processes this X-ray signal and converts the signal to a count rate, which is then output to a device such as a printer or computer monitor. The geometry of an X-ray diffractometer is such that the sample rotates in the path of the collimated X-ray beam at an angle  $\theta$  while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle of  $2\theta$ . The instrument used to maintain the angle and rotate the sample.

### 3.2.6 X-Ray Diffractometer Procedure

#### Sample Preparation

- a. Decide which type of sample preparation mount will be best suited to each sample.

Large volumes will utilize standard milled aluminum sample holders. Small volumes will use either a sample slurry on glass slides or double stick cellophane tape for the lowest volume samples.

- b. Grinding Procedure: Grind sample and/or standards in mortar and pestle or mechanical grinding device to a fine powder ( $\sim 75\mu/0029$  mesh).

- c. Mounting Procedure: Large volume – pour powder into milled well on aluminum holder. Press powder with glass slide to cause powder to “stick” in well. Label holder with sample number using tape and indelible marker. Enter sample number into XRD machine to identify electronic output. Analyze small volume – pour sample onto double stick tape mounted on glass slide or smear sample slurry to a uniform thickness on a glass slide at appropriate height on slide (use aluminum holder to check tape height). If using a slurry, allow sample to dry before analyzing. Label slide with sample number using tape and indelible marker. Enter sample number into XRD machine to identify electronic output. On the computer, expand ‘XRD commander’ and raise power if necessary as follows:

- a. Step kV up in increments of 5 - 10kV at 30 sec. between steps until 40kV is reached. Press the set button after each change.
- b. Step mA from 5 – 10, then increments of 5 - 10mA until 40mA is reached.
- c. Be sure that the status values and requested values (blue and black types) kV and mA match before starting to ramp up power.
- d. On the left-hand side of the window in XRD commander there <shutter> and <x-ray> buttons to open and close the shutter or turn on and off the x-rays.

The indicator to the right of the buttons gives the status of the shutter and x-ray. When the shutter light is green, the shutter is closed and the enclosure doors can be opened. Plate 3.2 shows the XRD machine model used.

Properties of minerals in plane-polarized light;

a. Colour: Minerals show a wide range of colour, from colourless minerals such as quartz and the feldspars, to coloured minerals such as brown biotite and green hornblende. Many coloured minerals are also pleochroic, and differently orientated sections of these may change colour during a complete rotation of the microscope stage.

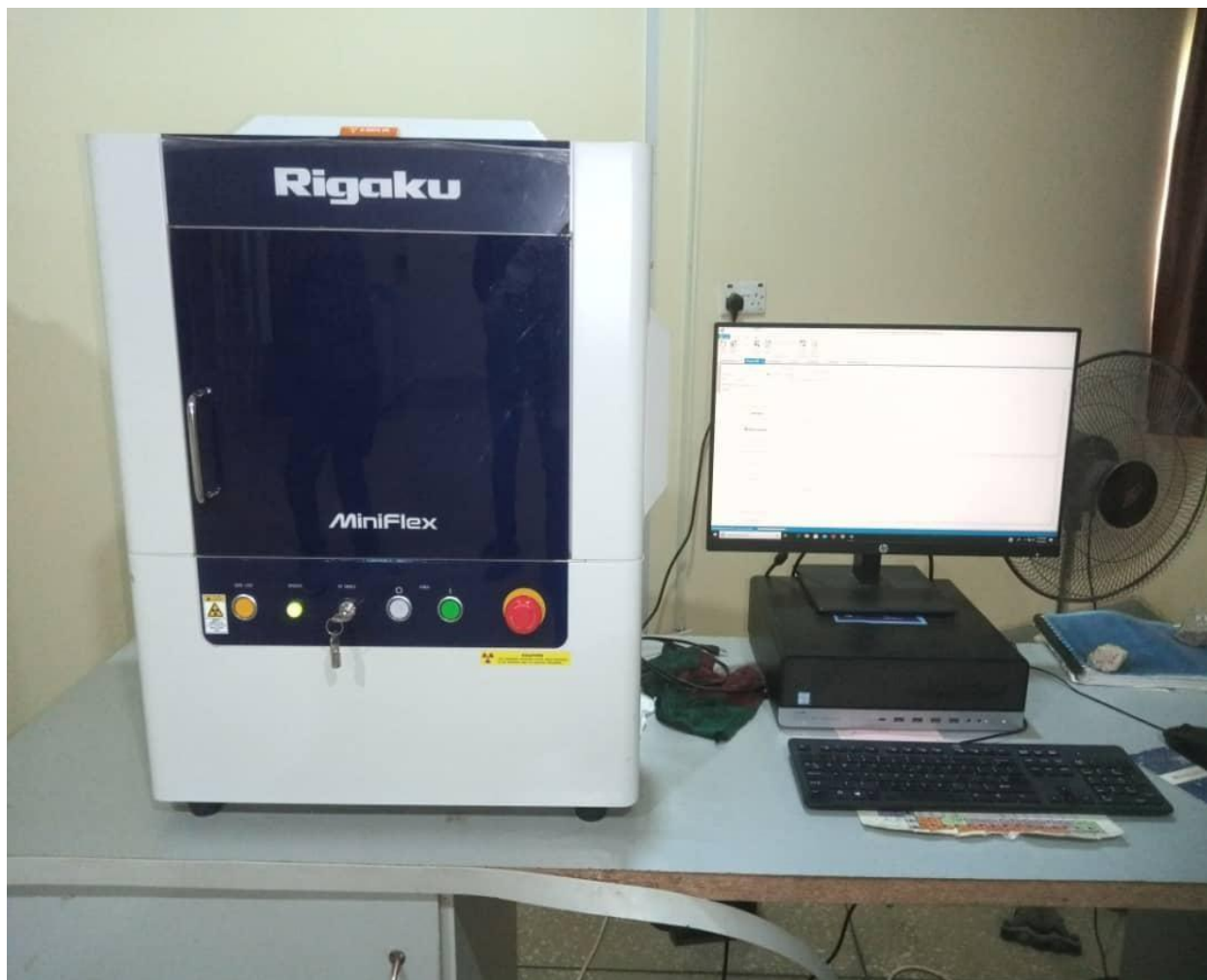
b. Form and Habit. The crystalline form of a mineral may be deduced by studying a large number of sections of the mineral, but an excellent crystal outline with welldeveloped faces is decidedly helpful. The shape of a mineral is referred to as its habit. Furthermore, a crystal in a rock may appear well shaped (euhedral), or with no crystal faces present at all (anhedral). Some crystals frequently contain inclusions, and in some minerals these are arranged in a characteristics pattern.

c. Cleavage: Cleavage appears in thin sections as one or more sets of parallel cracks, which tend to be thin, straight and evenly spaced. The number of cleavages seen depends upon the orientation of the mineral section; thus a basal section of a pyroxene will show two cleavage traces, whereas a prismatic section of the same mineral will show only one trace because both cleavages are parallel to prism faces and therefore have parallel traces in a prismatic section. When a cleavage is poorly

d. developed it is called a parting. Partings are usually straight and parallel but not evenly spaced.

e. Pleochroism: some minerals change colour between two extremes when the stage is rotated. The two extremes are seen twice during a complete rotation. Such a mineral is said to be pleochroic, and minerals such as the amphiboles, biotite, staurolite and tourmaline possess this property. Pleochroism is caused by the different degrees of absorption of light by differently orientated sections of the same mineral.

f. Relief: The relief of a mineral is directly related to the refractive index (RI). The relief of a mineral depends upon the difference between the RI of the mineral and the RI of the enclosing cement of the thin section, which is always 1.540.



**Plate 3.2:** Rigaku Miniflex Benchtop 600 XRD Machine

G. THE greater the difference, the rougher or more prominent the appearance of the mineral's surface. When the mineral and cement have about the same RI, the mineral's surface appears smooth.

**Properties of minerals under crossed polarized light;**

a. Birefringence and interference colour: the interference colour of anisotropic minerals under crossed polars varies depending upon the orientation of the mineral section.

Thus, at standard thickness, quartz may vary from grey to white, and olivine may show a wide range of colours. Birefringence is a measure of the difference between the maximum and minimum refractive indices possessed by an isotropic mineral.

b. Twinning: It is the symmetric intergrowth of two or more crystals of the same mineral, and commonly is revealed in thin section by the different crystals of the same mineral having different extinction positions or different interference colours.

## CHAPTER FOUR

### 4.0 Results and Discussion

#### 4.1 THE RESULTS FROM THE GEOCHEMICAL ANALYSIS

The results from the geochemical analysis showing the composition of the major oxides in weight percentage (wt.%) and trace elements (ppm) are presented in Tables 4.1, 4.2, 4.3 and 4.4 and discussed as follows.

**Table 4.1: The composition of Major Oxides(wt.%) and Trace Elements(ppm) from Granitic rocks in Study Area**

S/No	Element Oxides	OGB01	UNE2	EFU03	GB004	OGB05
1	SiO <sub>2</sub>	66.56	79.63	62.26	62.05	66.77
2	Al <sub>2</sub> O	10.88	15.10	11.69	12.89	11.69
3	Fe <sub>2</sub> O <sub>3</sub> (T)*	4.578	0.37	6.29	1.93	1.24
4	TiO <sub>2</sub>	0.70	0.003	0.95	0.35	0.24
5	CaO	2.91	0.32	4.39	2.49	4.68
6	P <sub>2</sub> O <sub>5</sub>	0.29	0.02	0.35	-	-
7	K <sub>2</sub> O	4.70	0.89	5.92	8.25	5.17
8	MnO	0.08	0.13	0.11	0.08	0.09
9	MgO	-	-	-	-	-
10	Na <sub>2</sub> O	0.17	3.09	6.49	10.02	8.22
	LOI	9.132	0.449	1.558	1.946	1.907
	<b>Total</b>	<b>90.865</b>	<b>99.551</b>	<b>98.442</b>	<b>98.054</b>	<b>98.093</b>

**Table 4.2: Alumina Saturation of Granitic rocks from Igarra-Ugbogbo Area (Shand, 1927).**

Sample No Alumina	Weight%/		Weight%/ Molar Mass (CaO+Na <sub>2</sub> O+K <sub>2</sub> O)	Molar Mass Al <sub>2</sub> O <sub>3</sub> /(CaO+Na <sub>2</sub> O+K <sub>2</sub> O)	Saturation
	Weight% (Al <sub>2</sub> O <sub>3</sub> )	Molar Mass (Al <sub>2</sub> O <sub>3</sub> )			
OGB 01	10.88	0.11	0.04	1.40	Peraluminous
UNE 02	15.10	0.15	0.02	3.51	Peraluminous
EFU 03	11.69	0.12	0.08	0.70	Peralkaline`
GBO 04	12.89	0.13	0.10	0.62	Peralkaline
OGB 05	11.69	0.12	0.09	0.65	Peralkaline

The average of the major oxides for OGB01, UNE02, EFU03, GBO4 and OGB05 were calculated and represented in Table 4.3

**Table 4.3: Average of Major Oxides in Study Area**

<b>Major Element Oxides</b>	<b>Range(wt.%)</b>	<b>Average(wt.%)</b>
SiO <sub>2</sub>	62.05- 79.62	67.45
Al <sub>2</sub> O <sub>3</sub>	10.88 – 15.10	2348.9
Fe <sub>2</sub> O <sub>3</sub> (T)*	0.37 – 6.29	2.88
TiO <sub>2</sub>	0.003 – 0.95	0.45
CaO	0.32 – 4.68	2.96
P <sub>2</sub> O <sub>5</sub>	0.000 – 0.35	0.13
K <sub>2</sub> O	0.89 – 8.25	4.99
MnO	0.08 – 0.13	0.10
MgO	-	-
Na <sub>2</sub> O	0.17 – 10.02	5.60

Comparing the averages of the major oxides of OGB01, UNE02, EFU03, GBO04 and OGB05 to the averages of granitic rocks found in Ojirami-Ogbo and Environs, Edo State, Idanre Granite Batholith, Ondo State and the average major oxides composition in granite. Table 4.4 show their different averages in these major oxides for these study areas.

**Table 4.4: Major Oxides Average comparison with Samples from other Study Areas.**

Major Element Oxides	Igarra-Ugbogbo (This Study)	Ojirami-Ogbo (Odokuma-Alonge <i>et al.</i> , 2019)	Idanre Granite Batholith (Akinola <i>et al.</i> , 2021)	Understanding Earth (Gass <i>et al.</i> , 1973)	Michika (Obiefuna <i>et al.</i> , 2018)
SiO <sub>2</sub>	67.45	58.26	69.03	70.80	70.58
Al <sub>2</sub> O <sub>3</sub>	2348.9	29.22	14.32	14.60	14.30
Fe <sub>2</sub> O <sub>3</sub> (T)*	2.88	7.22	3.97	3.40	2.73
TiO <sub>2</sub>	0.45	2.21	0.46	0.40	0.36
CaO	2.96	0.27	1.98	2.00	2.62
P <sub>2</sub> O <sub>5</sub>	0.13	0.07	0.14	ND	0.09
K <sub>2</sub> O	4.98	0.54	5.66	4.20	5.44
MnO	0.10	0.01	0.05	ND	0.06
MgO	-	1.60	0.54	0.90	0.81
Na <sub>2</sub> O	5.60	0.06	3.06	3.50	1.14

The results from the geochemical analysis of the rock samples from Igarra-Ugbogbo area showed that they are enriched in silica ( $\text{SiO}_2$ ). The samples OGB01, UNE 02, EFU 03, GBO 04, and OGB 05 show the highest concentration of  $\text{SiO}_2$  with values 66.56wt.%, 79.62wt.%, 62.26wt.%, 62.04wt%, and 66.77wt.% respectively, which indicates that samples OGB01 and OGB05 are felsic magma while UNE02 is probably a pegmatitic magma and EFU 03 and GBO 04 show the lowest concentration of  $\text{SiO}_2$  with values 62.26wt.% and 62.04wt.% respectively, which indicates the magma that gave rise to these rocks were probably of intermediate composition. The average value for silica ( $\text{SiO}_2$ ) is 67.45wt.% which is higher than the granitic rocks from Ojirami-Ogbo with an average of 58.26% (Odokuma-Alonge *et al.*, 2019) and the lower than the rock from the Idanre Granite Batholith with an average of 69.03wt.% (Akinola *et al.*, 2021) both from Basement Complex of southwestern Nigeria. When compared to the granitic rock from Michika area, northeastern Nigeria with an average of 70.58wt.% it is seen to be lower. Using  $\text{Al}_2\text{O}_3$  classification scheme, it showed that OGB01 and UNE02 shows that they are peraluminous while EFU03, GBO04, OGB05 are peralkaline.

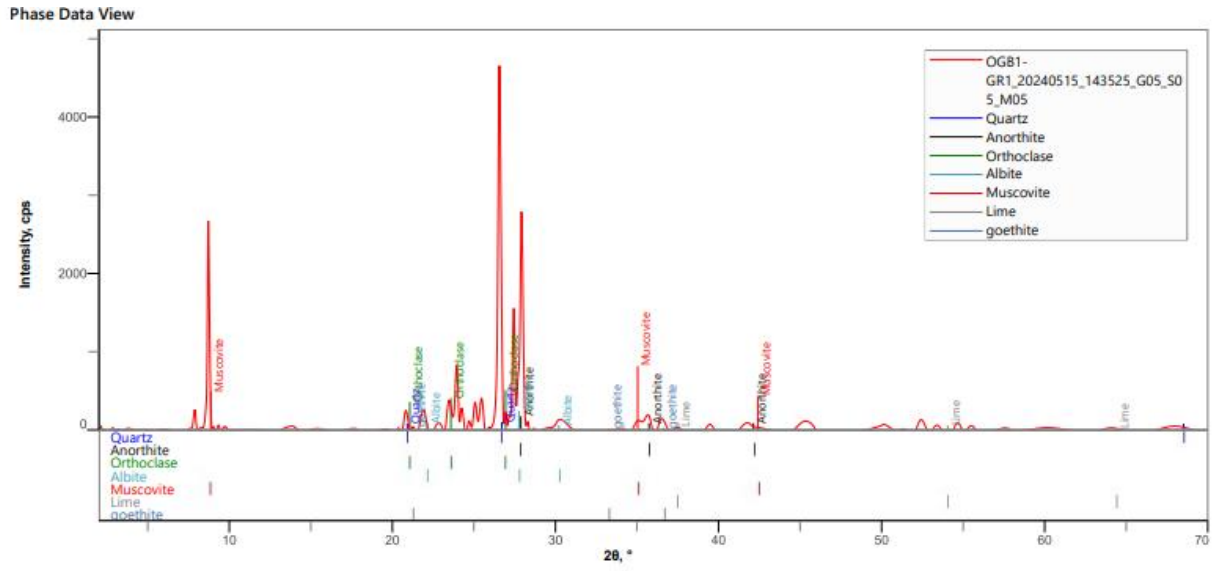
## 4.2 The Results from the Mineralogical Analysis

The results from the mineralogical analysis are shown in Table 4.5 having various peak values with their corresponding minerals. Figures 4.1 to 4.5 show x-ray diffractograms for the samples respectively.

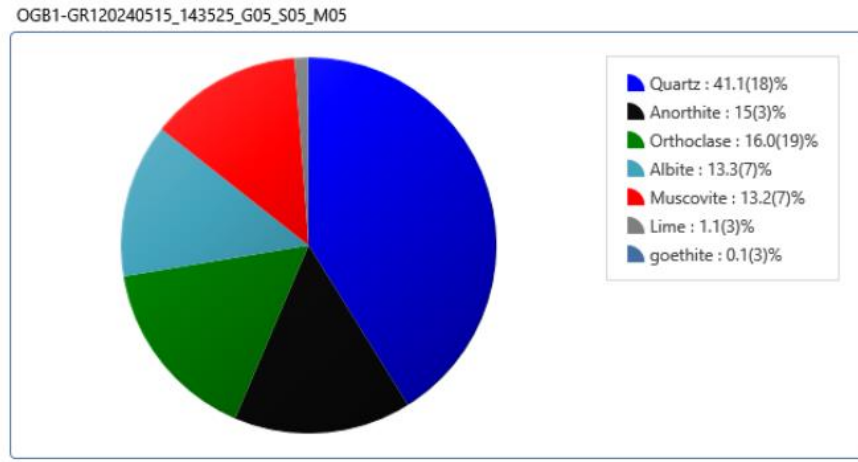
**Table 4.5: Modal Composition of the minerals in the Study Area**

Minerals	Formulas	Percentage abundance within the Sample				
		OGB01	UNEO2	EFU03	GB004	OGB05
		1	2	3	4	5
Quartz	SiO <sub>2</sub>	41.10	72.00	74.00	53.00	34.00
lime	CaO	1.10	-	2.80	1.32	-
Orthoclase	KAlSi <sub>3</sub> O <sub>8</sub>	16.00	11.00	7.30	33.00	28.00
Goethite	FeO(OH)	0.10	0.19	0.15	0.26	-
Albite	NaAlSi <sub>3</sub> O <sub>8</sub>	13.30	4.00	2.00	12.00	26.00
Anorthite	CaAl <sub>2</sub> Si <sub>2</sub> O <sub>8</sub>	15.00	11.00	-		11.00
Muscovite	K <sub>2</sub> Al <sub>4</sub> [Si <sub>6</sub> Al <sub>2</sub> O <sub>22</sub> ](OH, F) <sub>4</sub>	13.20	3.00	13.00	0.40	2.00
Others		0.2	-	0.1	0.02	-

# OGB 01

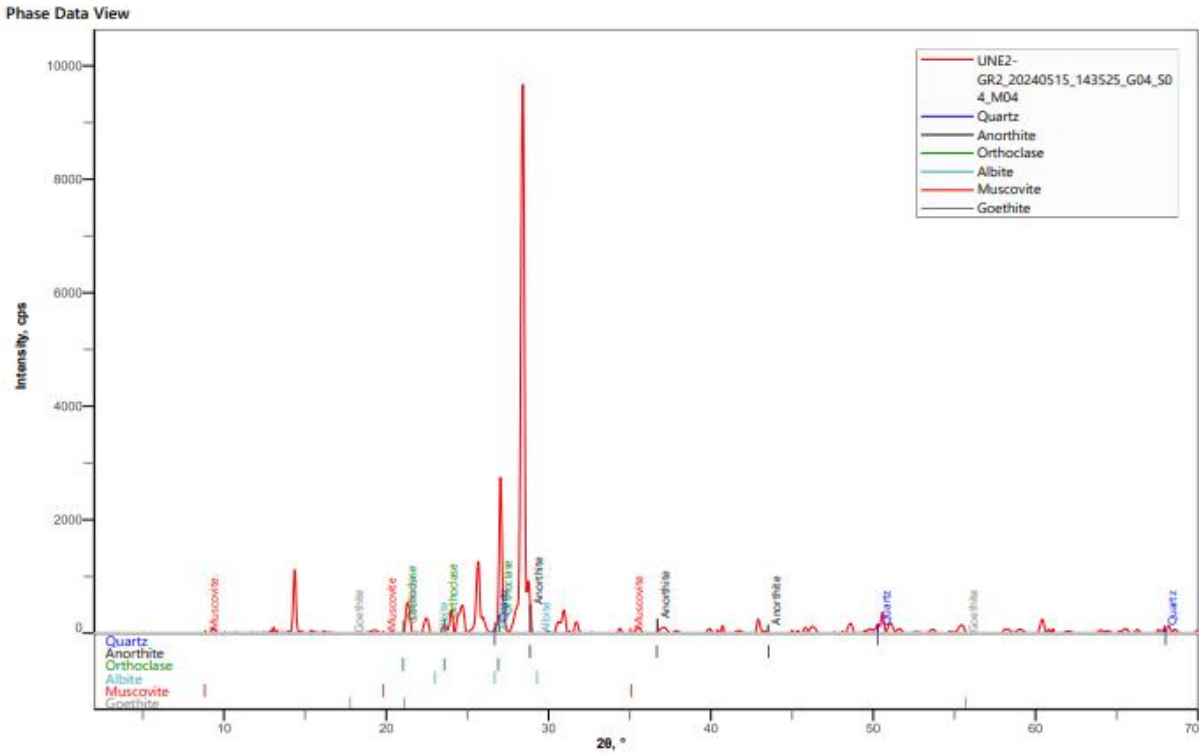


## Plot of results

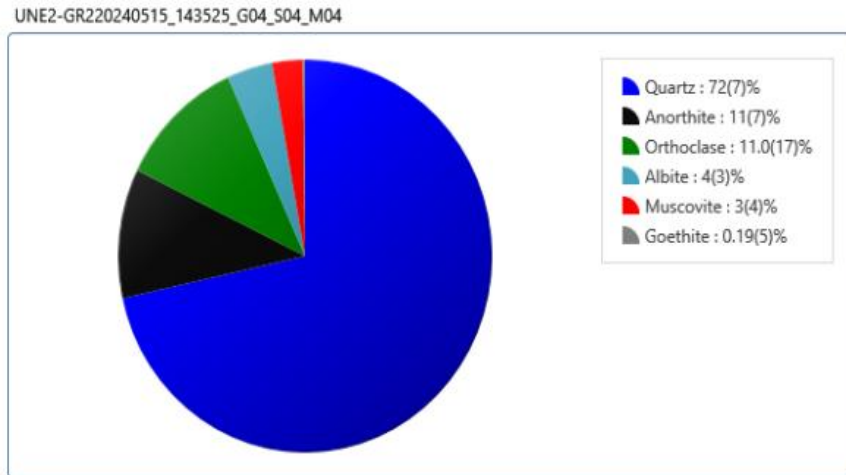


**Figure 4.1:** An X-ray Diffractogram of OGB 01 and A Pie Chart of OGB01

# UNE 02

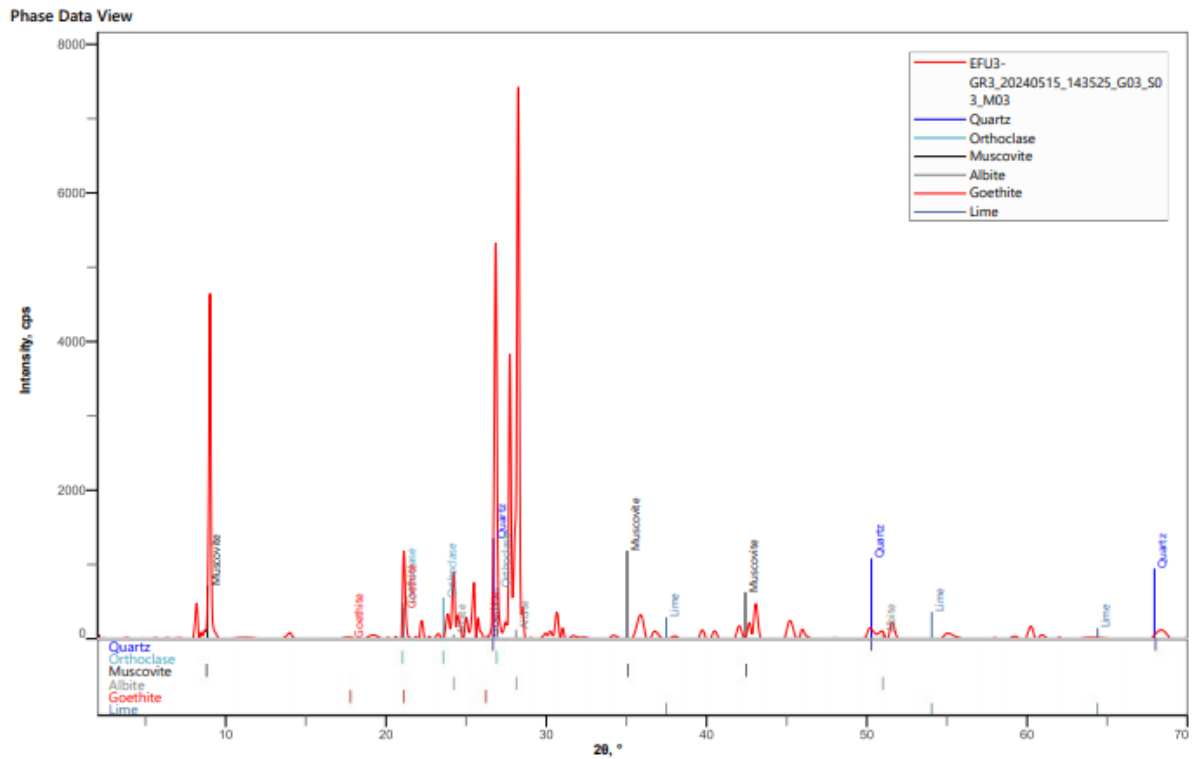


Plot of results



**Figure 4.2:** An X-ray Diffractogram of UNE 02 and A Pie Chart of UNE 02

# EFU 03



## Plot of results

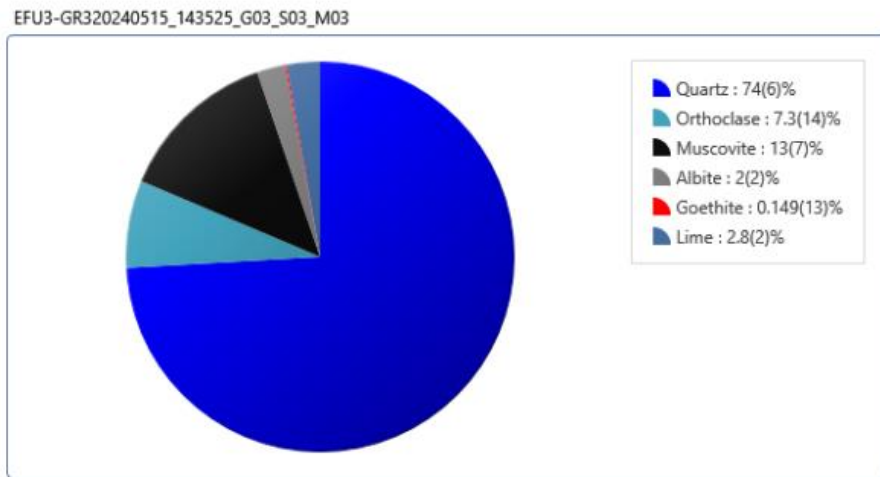
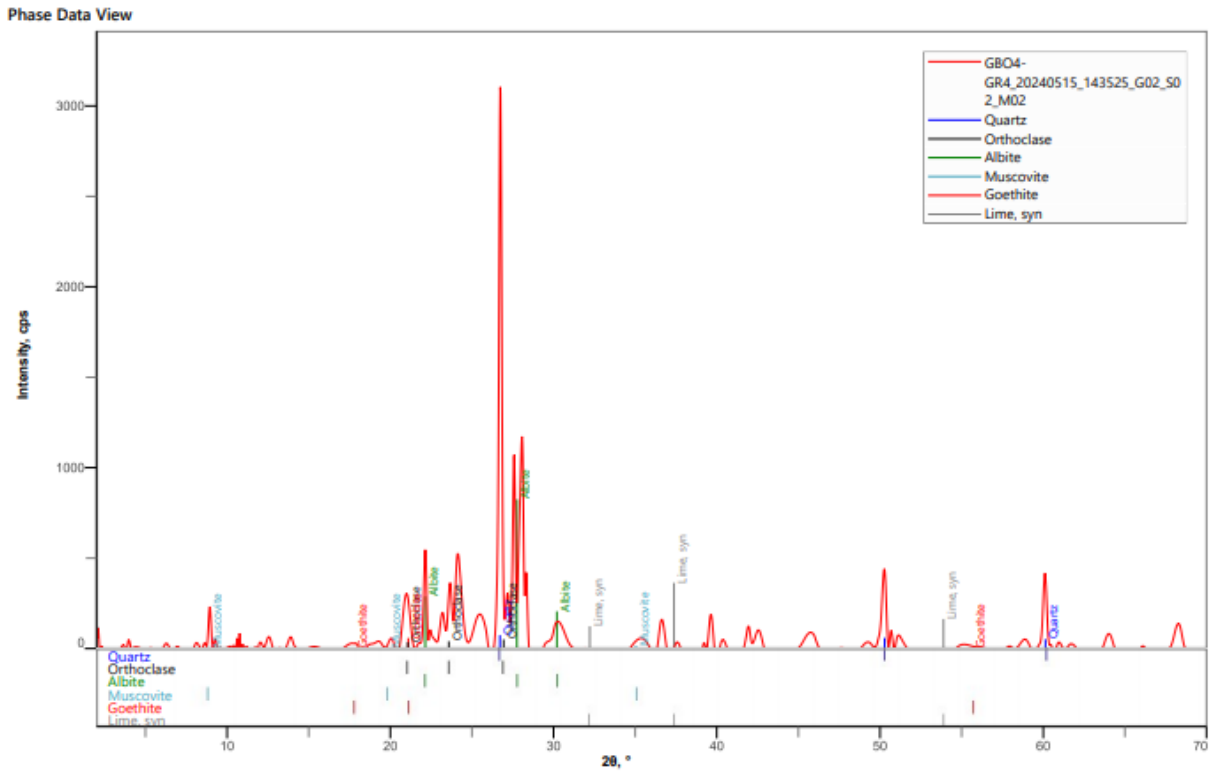
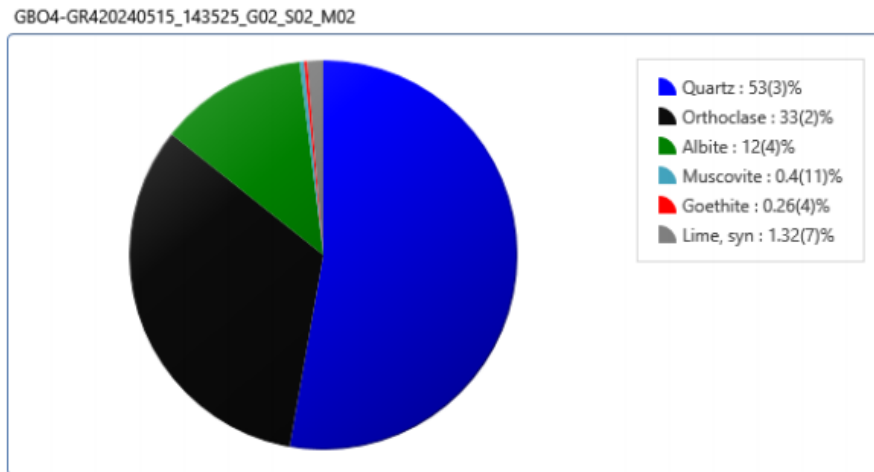


Figure 4.3: A Pie Chart of EFU 03 and An X-ray Diffractogram of EFU 03

# GBO 04

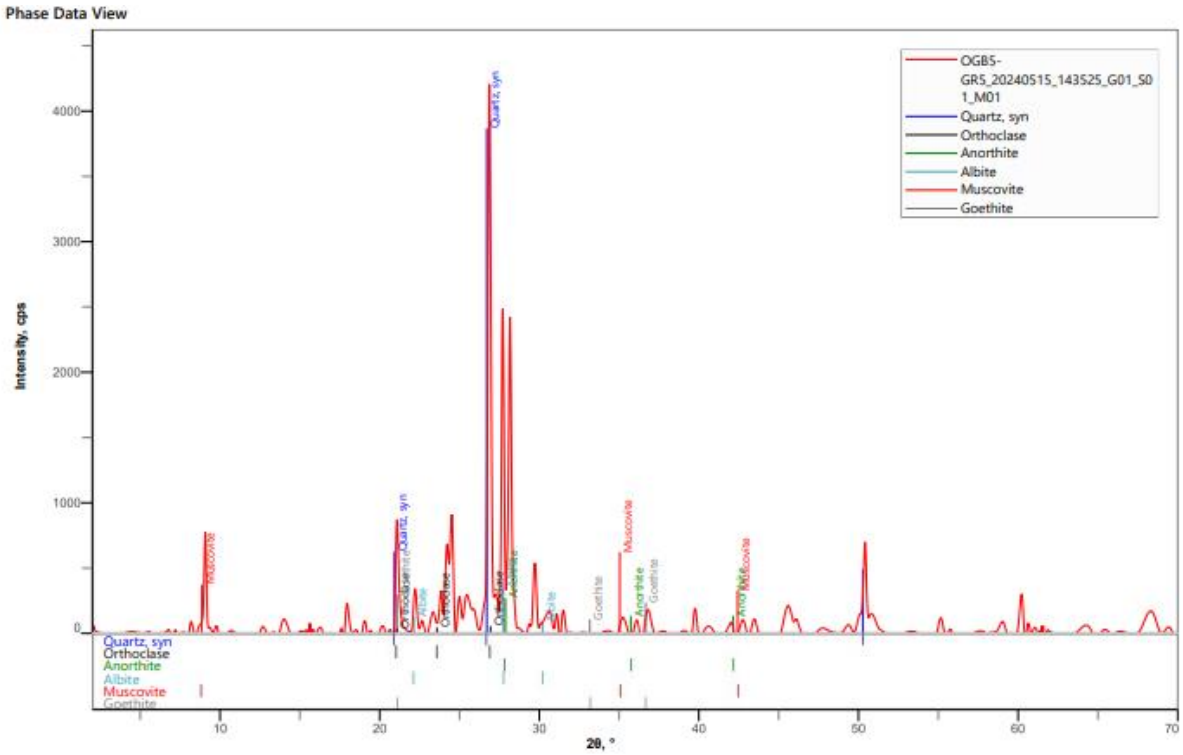


## Plot of results

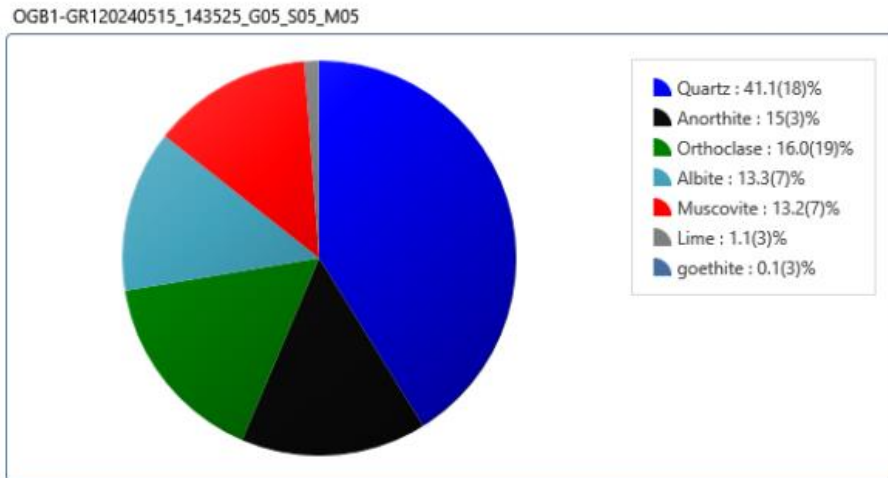


**Figure 4.4:** A Pie Chart of GBO 04 and An X-ray Diffractogram of GBO 04

# OGB 05



## Plot of results



**Figure 4.5:** An X-ray Diffractogram of OGB 05 and An Pie Chart of OGB 5

The XRD analysis showed that the rocks are enriched in the minerals; quartz, alkali feldspar (microcline, orthoclase and sanidine) and plagioclase feldspar (albite and anorthite). The modal composition of these mineral were recalculated to 100% and represented in Table 4.5. These values were used to plot QAP diagram in Figure 4.6. The QAP diagram shows that OGB 01, GBO 04, OGB 05 are granite because the quartz content is 20-60% , the UNE 02 and EFU 03 is Quartz-rich granitoid because the quartz is greater than 60%. The presence of goethite in OGB 01, UNE 02, EFU 03, GB0 04 suggests that the rock has undergone some degrees of alteration or interaction with fluids which can provide valuable information about the geological history of the area. The presence of lime in OGB 01, EFU03, GBO 04 and the presence of muscovite in OGB 01, UNE 02, EFU03, GBO 04, OGB05 provides valuable information about the geological history, magma evolution, and potential economic mineralization of the area.

**Table 4.6: The relative abundance of felsic minerals in rock samples**

<b>Sample No</b>	<b>Quartz</b>	<b>Alkali Feldspar</b>	<b>Plagioclase</b>	<b>Results</b>
OGB 01	41.10	16.00	28.30	Granite
UNE 02	72.00	11.00	26.00	Quartz-rich granitoid
EFU 03	74.00	7.30	2.00	Quartz-rich granitoid
GBO 04	53.00	33.00	12.00	Granite
OGB 05	34.00	28.00	37.00	Granite

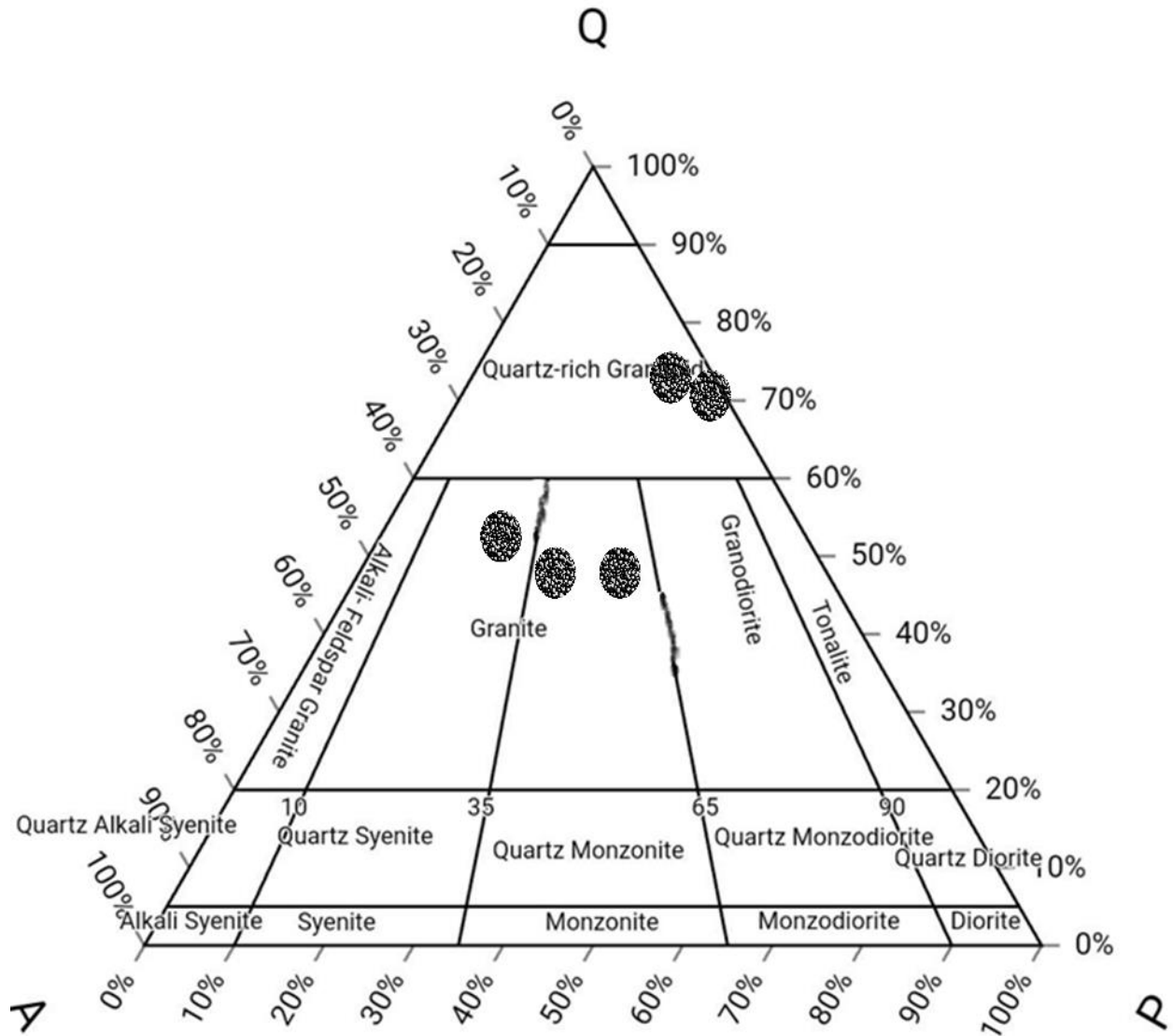


Figure 4.6: QAP Diagram showing Samples Plot.

## CHAPTER FIVE

### 5.0 Summary, Conclusion and Suggestion for Further Studies

#### 5.1 Summary

Five (05) samples of granitic rocks from Igarra-Ugbogbo area in Akoko-Edo Local Government Area of Southwestern Nigeria were obtained with the aim of their geochemical properties using XRF techniques, XRD techniques and thin section examination. Results of these analysis revealed the presence of  $\text{SiO}_2$  (62.05-79.63wt.%),  $\text{Al}_2\text{O}_3$  (10.88-15.10wt.%),  $\text{Fe}_2\text{O}_3(\text{T})^*$  (0.37-6.29wt.%),  $\text{K}_2\text{O}$  (0.89- 8.248wt.%),  $\text{Na}_2\text{O}$  (0.17-10.02wt.%) and  $\text{CaO}$  (0.32-4.68wt.%). The abundance of these major oxides in the samples showed that samples OGB01 and OGB05 are felsic magma while UNE02 is probably a pegmatitic magma and EFU03 and GBO04 are most likely formed from an intermediate magma. Using  $\text{Al}_2\text{O}_3$  classification scheme, its showed that OGB01 and UNE02 shows that they are peraluminous while EFU03, GBO04, OGB05 are peralkaline. The XRD analysis revealed the presence of quartz, alkali feldspars (microcline, orthoclase and sanidine), plagioclase feldspars (albite and anorthite), muscovite, lime, geothite. The modal composition of the quartz, alkali feldspar, plagioclase were plotted on a QAP diagram which showed that the rock falls within the granite and Quartz-rich granitoid.

#### 5.2 CONCLUSION

This petrological and geochemical study of granitic rocks in igarra provides valuable insights into the petrogenesis of the area.

The results of this study indicates that due to the field observation in the area OGB 01 is a porphyritic biotite granite because of the phaneritic texture and the percentage of biotite in the sample, UNE 02 is a pegmatite( quartzo feldspatic granite), EFU 03 is a coarsed-grained biotite granite, GBO 04 is a leucogranitoid , OGB 05 is a porphyritic biotite granite as described in the field observation

The abundance of these major oxides in the samples showed that samples OGB01 and OGB05 are felsic magma while UNE02 is probably a pegmatitic magma and EFU03 and GBO04 are most likely formed from an intermediate magma. Using  $Al_2O_3$  classification scheme, it showed that OGB01 and UNE02 shows that they are peraluminous while EFU03, GBO04, OGB05 are peralkaline. They fall within the granitoid field and have quartz greater than 20%, alkali and plagioclase feldspars between 35-65%.

This study contributes to the existing body of the knowledge and the valuable information about the geological history on the geology of Igarra and provides a foundation for future research in the area.

### **5.3 Suggestion for Further Studies**

Further geochemical and isotopic analysis should be done to constrain the petrogenesis and tectonic setting of the granitic rocks in Igarra.

Detailed structural analysis to understand the relationship between the granitic rocks and surrounding rocks.

## REFERENCES

- Ajibade, A.C., Woakes, M. and Rahaman, M.A. (1987).** Proterozoic Crustal Development in the Pan-African Regime of Nigeria. *Proterozoic Lithospheric Evolution* 17, pp. 259-271.
- Akinola, O. O., Ghani, A. A. and James, E. (2021).** Petrography and Geochemical Characterization of Granite Batholith in Idanre, Southwestern Nigeria. *Sains Malaysiana* 50(2), pp.315-326.
- Black, R. (1980).** The Precambrian of West Africa. *Episodes Journal of International Geoscience* 3(4), pp. 3-8.
- Bowen, N. L. (1928).** The Evolution of Igneous Rocks. *Princeton University Press, Princeton.*
- Chappell, B. W. and White, A. J. R. (1992).** I-and-S-type Granites in the Lachlan Fold Belt. *Earth and Environmental Science Transaction of the Royal Society of Edinburgh* 83(1-2), pp. 1-26.
- Connolly, J. R. (2007).** Introduction to X-ray Powder Diffraction, *Springer.*
- Cooray, P. G. (1974).** Some Aspects of the Precambrian of Nigeria. *Journal of Mining and Geology* 42, pp.17-43.
- Dada, S. S. (2006).** Proterozoic Evolution of Nigeria. *The Basement Complex of Nigeria and its Mineral Resources (A tribute to Prof Rahaman, M.A.O), Akin Jinad and Company, Ibadan,* pp.29-44.
- Dombrowski, A., Henjes-Kunst, F., Hohndorf, A., Kronener, A., Okrusch, M. and Richter, P. (1995).** Orthogneiss in the Spessart Crystalline Complex, North-west Barvia: Silurian Granitoid Magmatism at an Active Continental Margin. *Geologic Rundschau* 84, pp. 399-411.
- Egesi, N. and Agomuo, S. M. (2015).** Petrography, Structural Characteristics and Mineral Resources of Igue Oke, Igarra Area, Southwestern, Nigeria. *Asian Journal of Geological Research* 2(1), pp. 1-11.
- Falconer, J. D. (1911).** The Geology and Geography of the Northern Nigeria. Macmillan, London pp.135.
- Gass, I. G., Wilson, R. C. L. and Smith, P. J. (1973).** Understanding Earth: A Reader in the Earth Science. The MIT Press, pp. 21.
- Grant, N. K. (1970).** Geochronology of Precambrian Basement Rocks from Ibadan, Southwestern Nigeria. *Earth Planet Sci Lett* 10, pp. 19-38.

- Igonor, E. and Ambimbola, A. (2019).** Geochemistry of Pan African Granitoids, Southwestern, Nigeria: Evidence of Magmatic Mixing. *Journal Geography, Environment and Earth Science International* 5(4), pp. 1-17.
- Kogbe, C. A. (1989).** The Cretaceous and Paleogene sediments of Southern Nigeria. *Geology of Nigeria* 2, pp. 325-334.
- Matheis, G. and Caen-Vachette, M. (1983).** Rb-Sr Isotopic study of Rare-metal bearing and barren Pegmatites in the Pan African Reactivation zone of Nigeria. *Journal of African Earth Science* 1, pp. 35-40.
- McCurry, P. (1976).** The Geology of the Precambrian to Lower Paleozoic rocks of Northern Nigeria, In: *Geology of Nigeria*, Elizabethan Pub. Co. Lagos, pp. 15-39.
- Obaje, N. G. (2009).** *Geology and Mineral Resources of Nigeria. Springer.*
- Obiefuna, G. I., Sini, P. H. and Abubakar, M. (2018).** Geochemical and Mineralogical Composition of Granitic Rock Deposit of Michika Area, Northeast, Nigeria. *International Journal of Scientific and Technology Research* 7(4), pp.160-170.
- Odeyemi, I. B. (1976).** Preliminary report on the relationships of Basement Complex rocks around Igarra, Mid-Western State, Nigeria. *Geology of Nigeria, University of Ife, Nigeria.*
- Odeyemi, I. B. (1988).** Lithostratigraphy and Structural Relationships of the Upper Precambrian Metasediments in Igarra Area, Southwestern Nigeria. *Precambrian Geology of Nigeria, Geological Survey of Nigeria*, pp.111-122.
- Odokuma-Alonge, O., Egwuatu, P. N. and Okunuwadje, S. E.** Geochemical Consideration of some Granitoids around Ojirami-Ogbo and Environs, Southwestern, Nigeria. *Journal Applied Science and Environmental Management* 23(6), pp.1127-1131.
- Ogunyele. A. C., Oluwajana, O. A., Ehinola, I. Q., Ameh, B. E. and Salaudeen, T. A. (2019).** Petrochemistry and Petrogenesis of the Precambrian Basement Complex rocks around Akungba-Akoko, Southwestern, Nigeria, *Materials and Geoenvironment* 66(3), pp. 173-183.
- Okonkwo, C. T. and Folorunso, I. O. (2013).** Petrochemistry and Geotectonic Setting of Granitic Rocks in Aderan Area, Southwestern Nigeria. *Canadian Center of Science and Education* 5(1).

- OlaOlorun, O. A., Akinyemi, S., Oluwaleye, A. J. and Agbemuka, J. (2020).** Geology and Geochemistry of Iroko Granite Southwestern, Nigeria: Implication of Provenance. *Journal of Geological Research* 2(3), pp. 53-63.
- Oyawoye, M. O. (1964).** The Geology on Nigerian Basement Complex: A survey of our Present Knowledge of them. *Journal of Nigerian Mining, Geological & Metallurgical Society* 1(2), pp. 87-102.
- Pearce, J. A., Harris, N. B. W. and Tindle, A. G. (1984).** Trace Element Discrimination Diagrams for the Tectonic Interpretation of Granitic Rocks. *Journal of Petrology* 25(4), pp. 956-963.
- Rahaman, M. A. (1976).** Review of the Basement geology of Southwestern Nigeria, *Geology of Nigeria(Edited by Kogbe, C. A.), Elizabethan Publishers Lagos.* pp.41-58
- Rahaman, M. A. (1988).** Recent advances in the study of the Basement Complex of Nigeria, *Precambrian Geology of Nigeria, Geological Survey of Nigeria* pp. 11-43.
- Shand, S. J. (1927).** On The Relationship Between Silica, Alumina, and the Bases in the Eruptive Rocks Consider as a means of Classification. *Geological Magazine* 64(10), pp. 446-449.
- Streckeisen, A. (1976).** To each Plutonic Rock its propername, *Earth-Science Reviews*,12(1),pp. 1-33.
- Turner, D. C. (1983).** Upper Proterozoic Schist belts in the Nigerian Sector of the Pan-African province of West Africa. *Precambrian Research* 21(1&2), pp.55-79.
- Udi, E. M., Imasuen, O. I., Avwenagha, E. O. and Odukuma-Alonge, O. (2023).** Examination of the Pan-African Orogeny: Implication on the Architecture of Basement Rocks in Igarra, Southwestern Nigeria, *International Journal of Earth Sciences Knowledge and Application* 5(1), pp. 92-102.
- Umaru, A. O., Okunola, O, Umaru, A. D. and Olisa, O. G. (2023).** Geochemistry and Petrogenesis of Pan-African Granitoids in Kaduna, North Central, Nigeria. *Economic and Environmental Geology* 56(3), pp. 259-275.
- Woakes M., Rahaman M. A. and Ajibade, A.C. (1987).** Some Metallogenetic Features of the Nigerian basement, *Journal of African Earth Sciences*, 6(5), pp. 655-664.