

**THE STRUCTURAL ANALYSIS AND SEQUENCE OF  
GEOLOGICAL EVENTS IN THE BASEMENT  
COMPLEX OF THE IGARRA AREA, SOUTHWESTERN  
NIGERIA:  
UNDERSTANDING THE EVOLUTION OF THE  
BASEMENT COMPLEX**

**BY**

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**MARCH, 2025**

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**A PROJECT WORK SUBMITTED TO THE  
DEPARTMENT OF GEOLOGY, FACULTY OF  
PHYSICAL S CIENCES, UNIVERSITY OF BENIN, IN  
PARTIAL FULFILMENT OF THE REQUIREMENT FOR  
THE AWARD OF BACHELOR OF SCIENCE DEGREE  
(B.Sc) IN GEOLOGY.**

**MARCH, 2025**

## CERTIFICATION

This is to certify that this project work was carried out by **Nestor Oluwatobiloba JACOB** with matriculation number PSC2008253 of the department of geology, University of Benin, Benin city.

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**Date**

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**Dr. S. A. Salami**  
(Head of Department)

**Date**

## **DEDICATION**

This work is dedicated to God Almighty and to my parent for their love, care and guidance all through the course of this program.

## **ACKNOWLEDGEMENT**

I would like to express my sincere gratitude to everyone who contributed to the success of this project. Your support, guidance, and encouragement played a vital role in the completion of this work.

First and foremost, I would like to thank Dr. A. Ogbamikhumi and Dr. Charles, for their invaluable guidance, feedback, and support throughout the project. Their expertise and experience helped shape the project and improve its overall quality.

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Thank you all again for your contributions to this project.

Nestor Oluwatobiloba JACOB

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## **ABSTRACT**

This study presents an in-depth structural analysis of the Ugbobo area and its environs, situated within the Igarra Basement Complex in southwestern Nigeria. The primary objective of this research is to shed light on the geological events that have shaped this region, providing valuable insights into its deformational and geological history. To achieve this goal, Landsat imagery was utilized to systematically gather and examine fracture data through various analytical techniques. These techniques include rose plots, stereonet, and pole plots, which enabled the assessment of structural orientations and deformations in the study area.

The results obtained from the rose plot analysis revealed a dominant NNE-SSW fracture trend, indicating deformation that can be attributed to the pre-Pan African orogeny. This finding suggests a polyphase deformational history, pointing to significant tectonic activity in the region. Furthermore, the analysis of pole plots showed clustering of poles in the western and eastern directions. The stereonet analysis revealed that the fracture lines are concentrated towards the eastern and western quadrants, indicating that many of these planes are dipping steeply in those directions.

The comprehensive understanding of these structural patterns is crucial for reconstructing the deformational and geological history of the terrain. This study contributes significantly to the existing knowledge of the Igarra Basement Complex, providing new insights into the region's tectonic evolution. The findings of this research have important implications for future geological investigations and exploration activities in the area.

# CHAPTER ONE

## INTRODUCTION

### 1.1 General Introduction

The Igarra Basement Complex is characterized by its complex petrological and structural features, which reflect varying degrees of metamorphism, orogenies, and structural transformations. It has been established that the Precambrian basement complex of Nigeria including Southwestern Nigeria is polycyclic in nature, (Ajibade and Fitches 1988). The southwestern Nigeria basement complex had undergone 4 major orogenesis:

- i. Liberian (Archaean) 2500Ma-2750± 25Ma
- ii. The Eburnean orogeny (Early Proterozoic), 2000Ma-2500Ma
- iii. The Kibaran orogeny (Mid Proterozoic), 1100Ma-2000Ma
- iv. The Pan African Orogeny, 450Ma-750Ma

The belt has been affected by two phases of orogeny (deformation): the first phase (D1) produced tight to isoclinal folds with north-southerly direction while the second phase (D2) that was characterized by more open folds of variable style with large vertical NNE-SSW trending fault. Fractures ranging from minor (joints) to major ones were ubiquitous among the metasediments and the intrusives, some of which were filled by quartz veins trending generally in NE-SW direction, (Boesse et al, 1992).

It carries a long and dynamic geological history, primarily shaped by the Pan-African orogeny. This history is represented by a variety of high-grade metamorphic rocks, such as migmatites and gneisses, as well as metasedimentary units like quartzites, schists, and marbles (Odeyemi, 1981).

By studying fractures, faults, and other discontinuities in rocks, researchers can gain insights into the mechanical characteristics of rocks and the direction, spacing, and distribution of fractures. The study area and its surroundings are characterized by four main groups of rocks (Odeyemi, 1976):

1. The migmatite-gneiss complex,

2. Metasediments comprising schists, calc-gneisses, quartzites, and metaconglomerates,
3. Porphyritic Older Granites, and late discordant non-metamorphosed syenite dykes.

## **1.2 Aim**

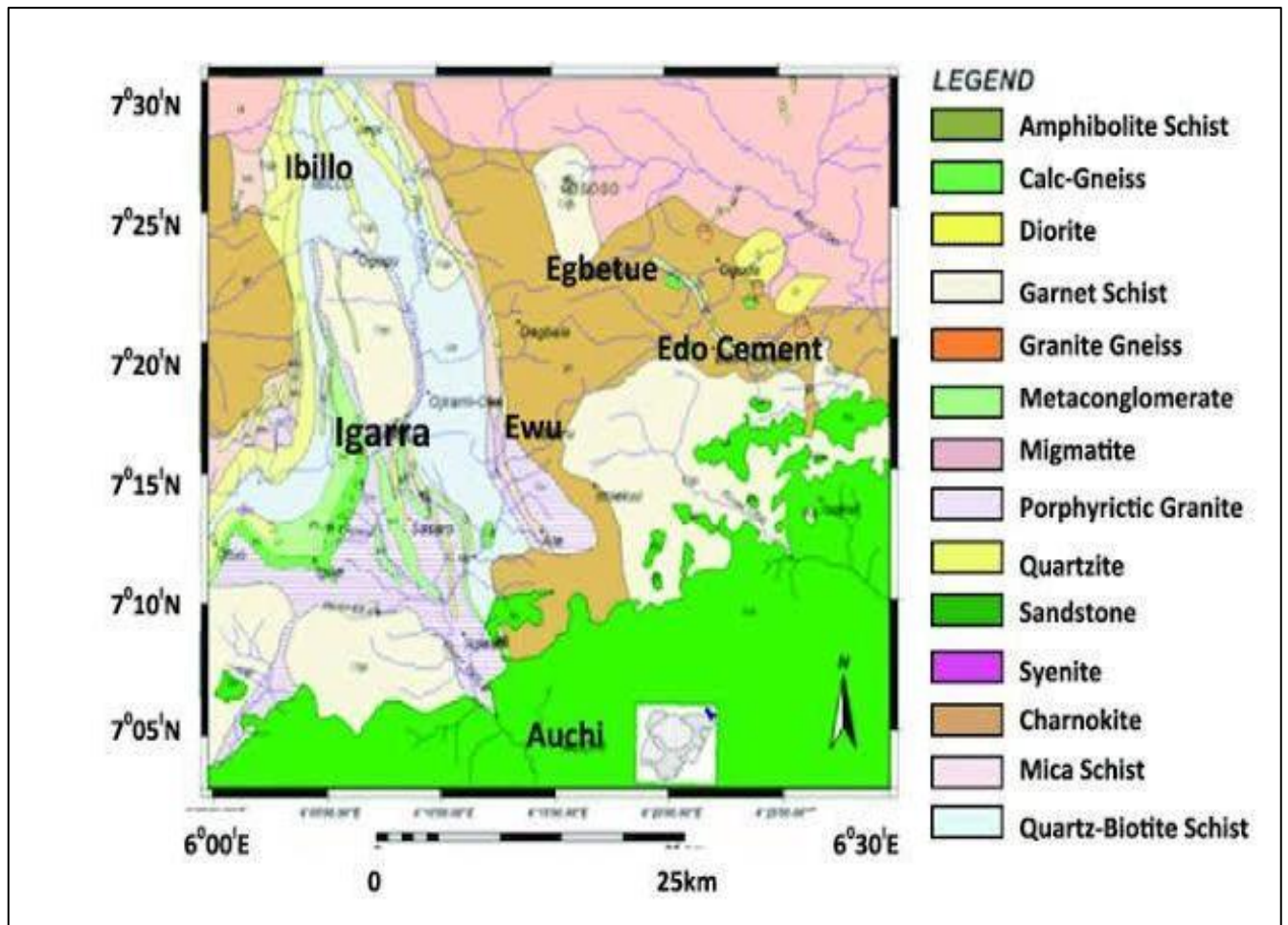
This project's goal is to recreate the geological history of the Basement Complex of Igarra in southwest Nigeria by identifying the order and structure of the geological events that shaped the region.

## **1.3 Objectives**

- i. Generate rose plots for the fractures
- ii. Use fracture trends to constrain tectonics of the study area, and the possible implication for groundwater and mineral exploration in the study area.
- iii. To examine the deformational history of the Basement Complex rocks in the Igarra and environs, South Western Nigeria.

## **1.4 Location and Size**

The southwest portion of Nigeria's Precambrian Basement Complex is home to the Igarra schist belt. Latitudes  $07^{\circ} 15'$  to  $07^{\circ} 20' 12''$ N and longitudes  $06^{\circ} 00'$  to  $06^{\circ} 12'E$  define the region, which is roughly 230 2 km. While the metasediments are found in plains and low-lying places, particularly in stream channels like the Onyami River, the Older Granite suite is well exposed on picturesque hills. Folds and fractures are examples of secondary structural characteristics that are frequently



*Figure 1: Location of study area (Anifowose et al., 2006)*

## **1.6 Topography**

The area's terrain was defined by elevations that reached 1500 meters in the east and less than 1000 meters in the west.

## **1.7 Accessibility**

Igarra, located in a rural area of Edo State, Nigeria, presents accessibility challenges due to its remote location. The nearest airport, Benin Airport (BNI), is approximately 120 km (75 miles) away, with taxis and buses available for onward travel to Igarra.

The road network connecting Igarra to nearby cities is underdeveloped, leading to prolonged journey times due to poor road conditions. Several bus companies, including Okpoki Transport and Edo City Transport, operate daily services from Benin City to Igarra. Taxis and motorcycle taxis (okadas) are also available for shorter distances.

It's crucial to plan ahead, researching transportation options and staying informed about local conditions, as public transportation options may be limited during peak travel seasons. Private car hire services are also available from Benin City to Igarra, with the journey taking around 2-3 hours by car. Overall, accessing Igarra requires careful planning and flexibility.

## **1.8 Human Activities**

In Igarra, farming is a major occupation, with locals cultivating crops including cassava, yams, and maize. The town's market is crowded with vendors offering textiles, handicrafts, and culinary items. Traditional crafts including ceramics, blacksmithing, and woodcarving are practiced by artisans in Igarra. There are also small-scale enterprises such block building, cassava processing, and palm oil processing. There are numerous primary, high, and vocational schools since education is prized. The town is served by healthcare services, including private clinics and a government-run health facility. Weddings, cultural festivities, and traditional festivals are examples of community activities that unite locals. Churches, mosques, and traditional shrines are the venues for religious events. Igarra's social fabric is woven together by social events such as funerals, birthday parties, and group meetings. The rich cultural legacy of the community is displayed via customs like the Igarra Festival.

## **1.9 Geography and Morphology**

Igarra is located in the tropical region of West Africa, in Edo State, Nigeria. The town is situated in the northern part of the state, approximately 120 km (75 miles) from Benin City. Igarra lies in the Akoko-Edo Local Government Area, near the borders with Kogi and Ondo states. The town is nestled in a valley, surrounded by hills and mountains, including the Ososo Hills. The terrain is generally undulating, with elevations ranging from 200 to 500 meters (660 to 1,640 feet) above sea level. The soil is fertile, with a mix of clay, sand, and loam, suitable for agriculture. The climate is tropical savanna, with high temperatures and humidity throughout the year. The town is drained by several rivers and streams, including the Ososo River and its tributaries. The vegetation is lush, with dense forests and woodlands, as well as cultivated areas. Igarra's geography and morphology make it a scenic and fertile region, suitable for farming and other economic activities.

# CHAPTER TWO

## LITERATURE REVIEW AND GEOLOGY

### 2.1 Review of Previous Works

Odeyemi, (1988), In his work titled preliminary report on the field relationship of the basement complex around Igarra, Midwest state classified the rock types into four mayor groups;

1. Migmatite-gneiss complex
2. The metasediments comprising Schists, Calc-gneiss, Metaconglomerate and Quartzites.
3. The porphyritic older granites
4. The late discordant unmetamorphosed Syenite dykes believed to be the youngest.

According to Agomuo M. S and Egesi N (2016), the area is composed of metasedimentary rocks, including schist, amphibolite, calc-silicate, and marble, which have undergone polyphase deformation. These rocks were subsequently intruded by post-tectonic granitic rocks of Pan-African age ( $600\pm 150\text{Ma}$ ). Mineralogically, the average modal composition reveals that the rocks in the area are primarily composed of quartz, k-feldspar, plagioclase, mica, muscovite, and calcite, with opaque minerals as accessories.

The Igarra schist belt's exposed rock types can be divided into two suites, according to Ogbe et al. (2018): intrusives and metasediments. Concordantly interbanded quartz-biotite schist, quartz-sericite schist, marble, calc-silicate gneiss, quartzite, and metaconglomerate make up the metasediment. The intrusive is composed of syenite, aplite pegmatite, and porphyritic-granite. In this region, folds with joints filled by subsidiary intrusions, such as quartz veins, are the main features. The two folds (wide crescent folds and tight-isoclinal folds) phase with primarily NNE-SSE (almost N-S) axial plane foliation succeed the initial planar metamorphic fabric. The schist belt's metamorphic footprints include amphibolites facies and green schist. Sedimentary piles that underwent tectonic action and magmatic intrusion that shortened the piles, followed by weathering and erosion that wore them down to the current reliefs, are the source of the metasediments.

In their article titled "Structural Framework and Deformation Episodes in the Igarra Schist Belt, Southwest Nigeria," Omang et al. (2022) came to the

conclusion that the Igarra Schist Belt's structural framework is made up of brittle (primarily fractures) and ductile (foliation, cleavage, folds, lineation, strain markers) structures. Two significant instances of transpressional deformation that impacted the schist belt are shown by the geometry of these formations. A younger brittle–ductile, E-W tectonic shortening deformation closed deformations in the Igarra schist belt, deforming both the metasediments and granitoids, producing nearly all of the brittle structures in the belt. The older, dominantly ductile deformation with NW–SE  $\lambda 1$  developed foliations, cleavage, folds, and mineral/stretching lineation, deforming only the metasediments. Minor fracture patterns in marble and gneisses that are not connected to any of the major periods of deformation and E-W transposition foliation are remnants of an unidentified, potentially earlier deformation episode. Because there are few ductile and semi-brittle shear zones in the Igarra schist belt and they typically occur on a small scale (outcrop scale), they do not represent a significant episode of deformation. Pegmatite and quartz are the principal mineralization found in the Igarra schist belt, and they are often found in fractures with industrial minerals like marbles.

According to Udi et al. (2023), of all the tectonic episodes that impacted the Nigerian Basement rocks, the Pan-African orogeny was the most widespread. The Pan-African granites are structurally controlled intrusions in the host metasedimentary rock sequence, according to field mapping of the region. The evolution of the rocks has been influenced by the syn to late tectonic emplacements of the Pan-African granitoids throughout the Pan African age (600 Ma  $\pm$  150 Ma). With the injection of magmatic materials into dilation zones in the metasediments and fault breccias within Igarra and the surrounding area, the granite intruded the folded metasediments in a N-S direction, and their emplacements reactivated the E-W fault zone in the country rocks.

Ogbamikhumi et al. (2024) came to the conclusion that the main rocks found during the fieldwork were metasediments such as mica schist, quartzite, and gneiss, as well as earlier granite. Plotting the orientation of the structures on rose diagrams and stereonet allowed for the investigation of the features found in the rocks. The findings demonstrate that the rocks, which include both pre-Pan African and Pan-African orogeny, underwent polyphase deformation. The pre-Pan African orogeny often has a NW-SE trend that was found to be more frequently connected with

only the metasediments, but the Pan African orogeny left an impression of NE-SW trend that was seen in all the rocks.

## 2.2 Geology Of The Area

Igarra is part of the vast geological formation known as the Basement Complex, which underlies much of southwest Nigeria. It is made up of crystalline rocks that developed during the Precambrian eon, which began more than 541 million years ago. These rocks have a complicated and intriguing geological past because of their extensive metamorphosis and igneous rock intrusion.

The Basement Complex in Igarra is primarily composed of:

- Metasediments: These are sedimentary rocks that have been subjected to intense heat and pressure, transforming them into metamorphic rocks like schist and gneiss.
- Igneous rocks: These are rocks that have crystallized from magma or lava. Common igneous rock types in the Igarra Basement Complex include granite and pegmatite.

The Pan-African Granites invaded the Basement Complex, which includes the Igarra schist belts, along with other rock suites including the migmatite-gneiss complex. The basement's supracrustal surface is made up of metasediments, which include marble, mica-schist, metaconglomerate, and quartzite. (Ajibade et al., 1987). Odeyemi (1976) divided the basement rocks surrounding Igarra into three categories: granitoids, low grade metasediments, and the migmatite-gneiss complex. Apart from the intrusives, the basement rocks of southwest Nigeria have foliations that have a tectonic origin (Odeyemi, 1988). The rocks in the study area were deformed during four main tectonic events (Ayodele et al, 2017);

1. The original bedding surface (S<sub>0</sub>) undergoes the first episode of deformation (D<sub>1</sub>) and produced folds (F<sub>1</sub>) which are isoclinal recumbent folds. There is also an indication of ductile deformation due to mylonitic foliation in sheared granite.
2. A folding event F<sub>2</sub> which refolded S<sub>1</sub> surface and produced S<sub>2</sub>, F<sub>2</sub> etc.
3. The F<sub>2</sub> elements were refolded by F<sub>3</sub>. F<sub>2</sub> and F<sub>3</sub> folds from type

4. Interference patterns. These events are also a phase of ductile deformation 5)  
The fourth deformation leads to the formation of crenulation cleavage fold produced from the strikeslip crenulation.

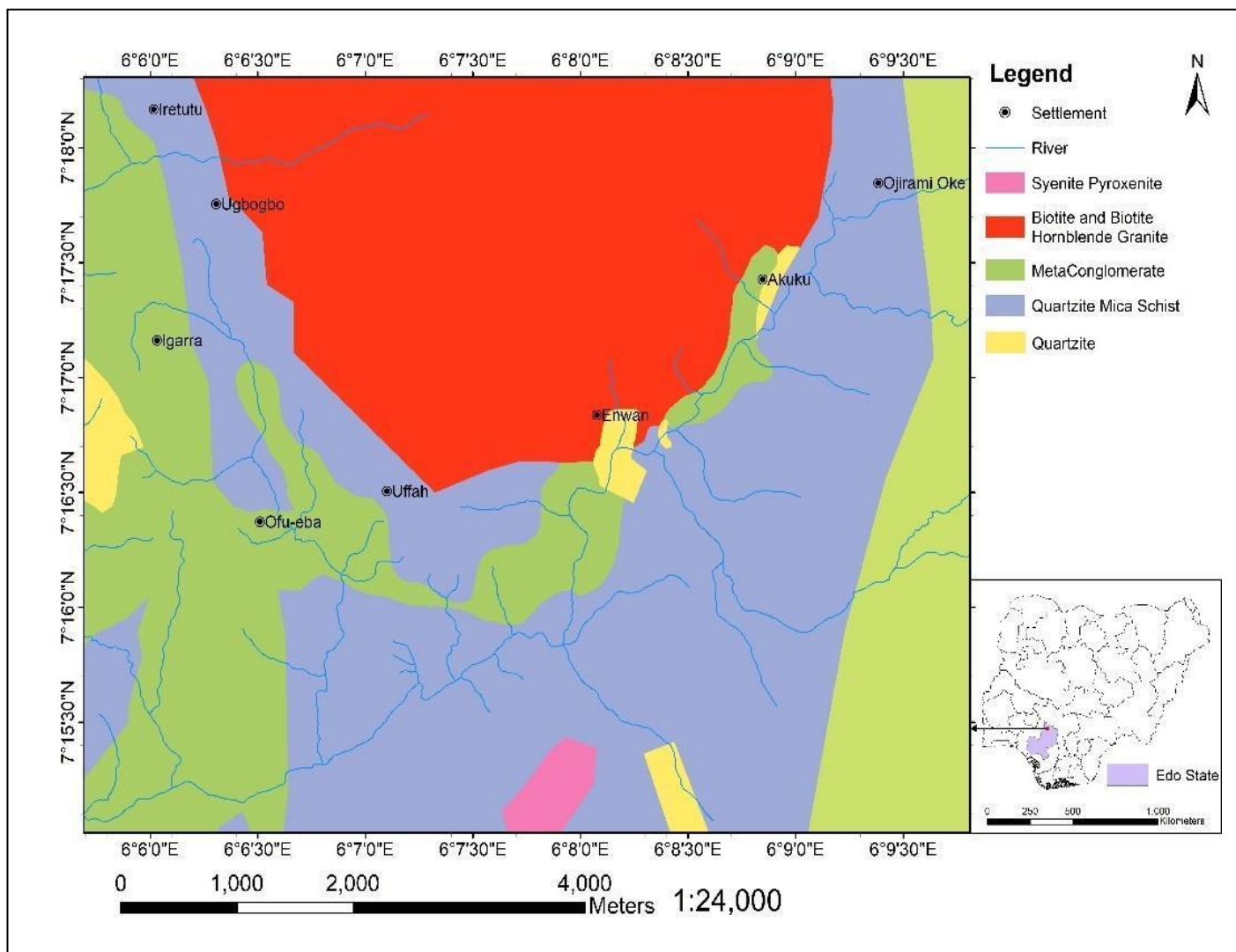
Two phases of orogeny (deformation) have impacted the belt, according to Ocan (1992). The first phase (D1) produced tight to isoclinal folds with a north-southerly direction, while the second phase (D2) was visualized by more open folds of variable style with a large vertical NNE-SSW trending fault. There were numerous fractures in the metasediments and intrusives, ranging in size from minor (joints) to major ones. Some of these were filled with quartz veins that tended to trend NE-SW.

### **2.3 Geology Of Study Area**

The region is located in Edo State, in the southwest of Nigeria, and is part of the basement complex of Igarra and its surroundings. The Igarra basement complex, which is a part of Nigeria's Precambrian Southwestern basement complex, contains a variety of rock types, the most notable of which are Pan-African granite plutons. These plutons have mineral veins and fractures that provide information about the region's history of deformation (Hockey et al, 1986).

The Liberian 2700+200 Ma, the Eburnian orogeny (Early Proterozoic), the Kibaran orogeny (Mid Proterozoic), 1100Ma–2000Ma (Fitches et al, 1985), and the Pan African orogeny, 450Ma–750Ma (Rahaman, 1976) are the four main orogenesis it has experienced. However, two significant events that altered the Precambrian Geology of the Southwest Nigerian Basement Complex were the Eburnean and the Pan African (Rahaman, 1988). The area has the following rock types;

1. Syenite pyroxenite
2. Biotite and Biotite hornblende granite
3. Metaconglomerate
4. Quartzite mica schist
5. Quartzite



*Figure 2. Geologic map of local study area*

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Materials**

The outcrops in the study area were studied and the attitude of fractures were measured using standard structural analytical tools. The methodology employed for this research includes;

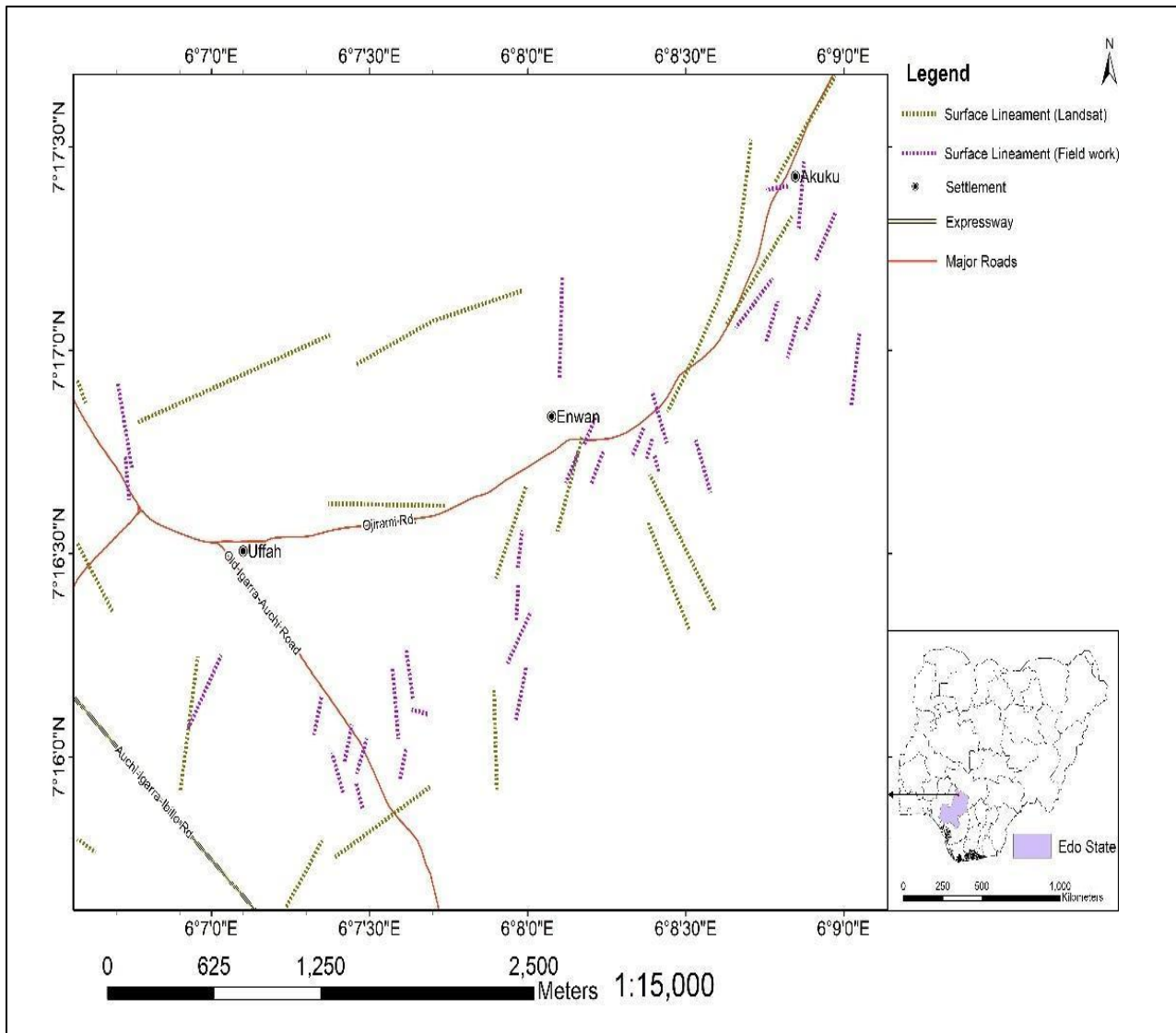
- **Global positioning system (GPS):** The Global Positioning System (GPS) was used to determine the rocks' precise location. It was used to obtain altitudes and position coordinates. Additionally, geological maps are created with it.
- **Compass clinometer:** The compass-clinometer was used to determine the orientation of the veins and fractures.
- **Fracture mapping:** This was accomplished through fieldwork. Using a base map, compass, clinometer, and GPS, the field survey was conducted by walking along existing trails or creating new ones. The outcrops' lithology and location were recorded, and the orientations of the structures were measured.
- **Plotting of Data Set:** The GeoRose software was used to analyze the available data set, which includes the fracture orientation. The application GeoRose is a rose diagram and stereo net plotting tool that can plot equal area and equal angle stereo net diagrams as well as structural geology rose diagrams. Rose plots for the fissures in the research area's basement rocks were created using this method. The understanding of what must have happened to the rocks in the research locations is aided by the examination of the different plots.
- **Structural Analysis:** The rose plots were used to determine the fracture analysis. The studied area's deformational history is ascertained by this examination.

#### **3.2 Available Data**

The data set contains information on the different types of rocks, their locations, and strike. The total number of 24 data were extracted (see. Table 1), from certain location on the map (see figure 3).

Table 1. Available data extracted from satellite

| FID | Longitude   | Latitude    | Strike | Sid  |
|-----|-------------|-------------|--------|------|
| 1   | 6.121076179 | 7.261195048 | 35.54  | LS1  |
| 2   | 6.12202124  | 7.262547812 | 34.99  | LS2  |
| 3   | 6.110077833 | 7.263023335 | 120.73 | LS3  |
| 4   | 6.125676424 | 7.263993966 | 240.42 | LS4  |
| 5   | 6.115472075 | 7.267994778 | 189.69 | LS5  |
| 6   | 6.110521244 | 7.274026217 | 146.82 | LS6  |
| 7   | 6.13162628  | 7.267419705 | 178.15 | LS7  |
| 8   | 6.14074499  | 7.274117964 | 154.13 | LS8  |
| 9   | 6.132454649 | 7.275895092 | 203.20 | LS9  |
| 10  | 6.141482849 | 7.275477852 | 148.63 | LS10 |
| 11  | 6.135563669 | 7.277879854 | 199.03 | LS11 |
| 12  | 6.141508651 | 7.282118665 | 32.28  | LS12 |
| 13  | 6.142851251 | 7.284431047 | 28.07  | LS13 |
| 14  | 6.143922849 | 7.286673956 | 23.96  | LS14 |
| 15  | 6.144784428 | 7.289931967 | 9.46   | LS15 |
| 16  | 6.117824515 | 7.282171628 | 250.88 | LS16 |
| 17  | 6.130699142 | 7.285167225 | 255.58 | LS17 |
| 18  | 6.12629777  | 7.283648536 | 246.57 | LS18 |
| 19  | 6.145551945 | 7.286616484 | 218.23 | LS19 |
| 20  | 6.147217999 | 7.291438101 | 35.84  | LS20 |
| 21  | 6.148765518 | 7.293548494 | 37.57  | LS21 |
| 22  | 6.149499212 | 7.294506145 | 40.24  | LS22 |
| 23  | 6.125932922 | 7.277005655 | 91.25  | LS23 |
| 24  | 6.109815337 | 7.281647727 | 156.37 | LS24 |



**Figure 3. Map showing location of data collected**

### **3.3 Methods**

The methodology employed for this research can be summarized into;

- Fracture extraction from remotely sensed data
- Fracture trend plotting and analysis using a rose plot software (Rosenet).
- For fracture mapping, a field survey was done by traversing along footpaths with the aid of a base map, compass clinometers and global positioning system (GPS).

In this study, remote sensing data from Landsat imaging and aeromagnetic data were used. The regular processing methodology was then applied to the remotely sensed data in order to extract the fractures and create a lineament map. Rosenet software was used to create rose plots for fractures in the basement rocks (granite and meta-sedimentary rocks) in the research area using the fracture orientations from the obtained lineament map.

# CHAPTER FOUR

## PRESENTATION AND DISCUSSION OF RESULT

### 4.1. Rose Plot

The direction of the identified lineaments exhibits a distinct pattern, as demonstrated by the rose plot created from the Landsat data. According to the plot, the majority of the features line up from **north-northeast (NNE)** to **south-southwest (SSW)**, which are assumed to be associated with the pre-Pan African orogeny (Ogbamikhumi et al, 2024)

There appears to be a strong structural or geological influence in the direction of **0° to 30°**, as indicated by the **tallest bars** in the distribution, which show the most common orientations. The symmetry across the diagram's center is due to the data's bidirectionality, which means that every trend is mirrored.

In terms of numbers, the lineaments' mean direction is 12.5°, and the longest segment in one of the bins reached a count of 20 lineaments. With a total length of 96.0 units (either kilometers or meters, depending on the data size), the dataset contains 48 features.

This pattern might show how tectonic faulting, regional stress fields, or lithological boundaries have influenced the formation of fractures and other linear landscape characteristics. Since the lineaments are highly orientated and their distribution is not very random, the high R-magnitude value (0.97) supports the notion that a dominant structural control is at work.

There are several fields where this kind of analysis is useful. In groundwater investigations, these lineaments may indicate water-flowing fracture zones. They might indicate structural channels for fluids that mineralize in mineral prospecting work. These directions may also be useful in identifying weak spots that may be vulnerable to landslides or erosion in land stability evaluations.

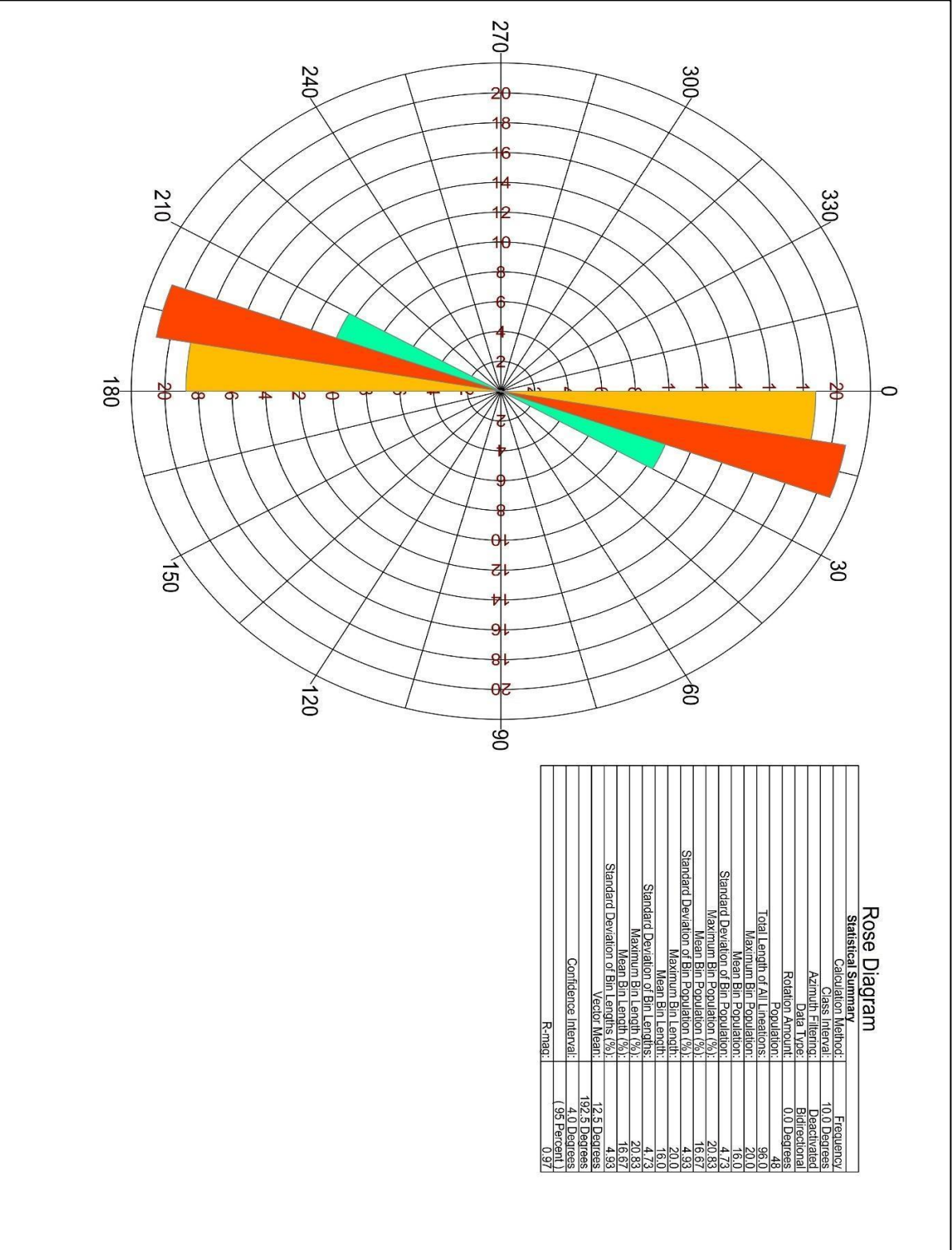


Figure 4. Rose plot showing fracture trend in the NNE -SSW direction

## 4.2. Stereonet Data

The stereonet plot, a 2D representation of 3D plane and line orientations, was generated from the landsat data. This plot is commonly used in structural geology, geophysics, and engineering to analyze features like rock layers, fractures, faults, and folds.

The plot displays a network of curved lines within a circular grid, representing planes in space projected onto the stereonet. The outer circle marks the horizon, with cardinal directions labeled, providing reference points. The distribution of these lines reveals important details about the dominant orientations of the geological features being analyzed.

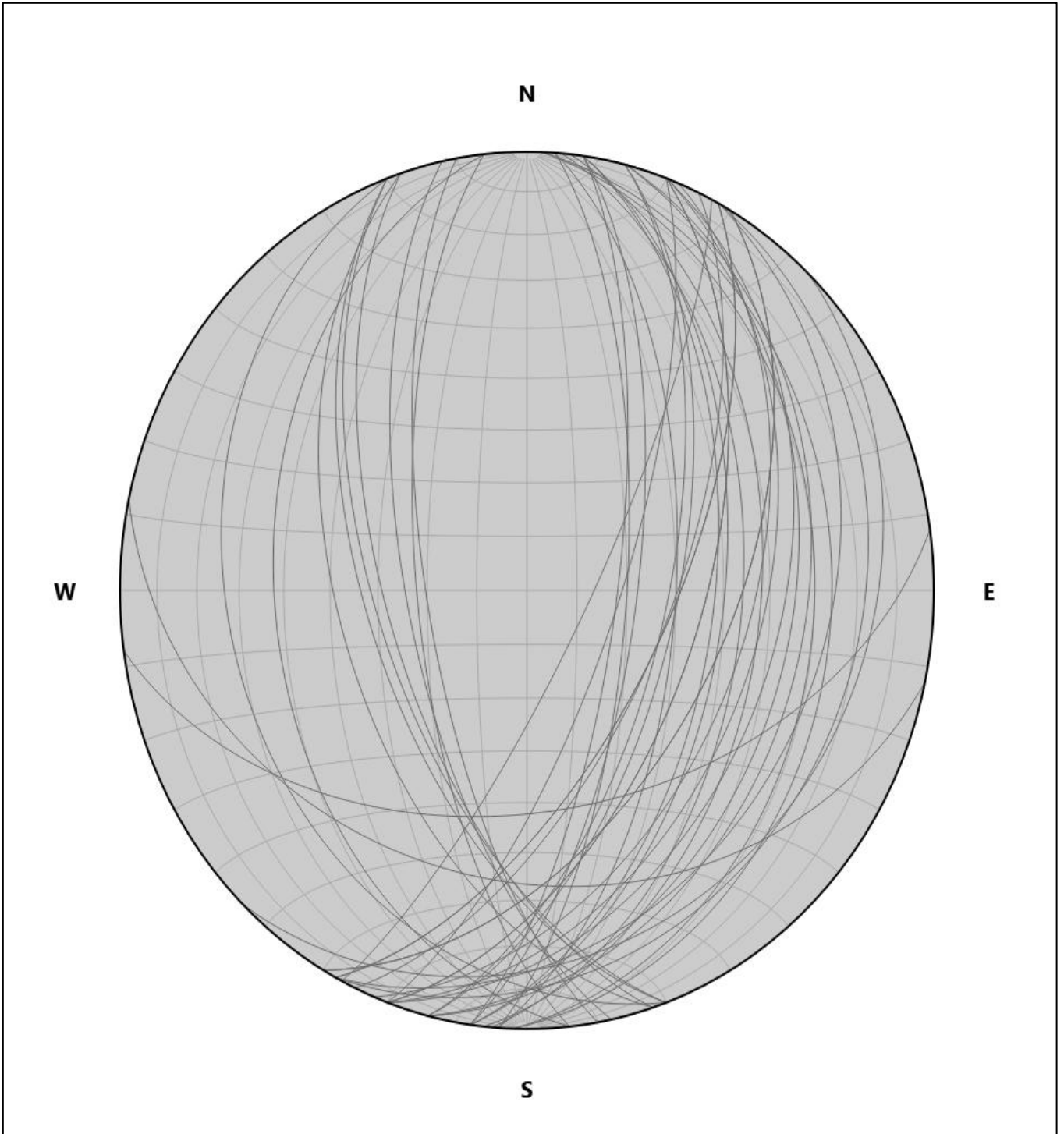
In this case, the lines are concentrated towards the eastern and western quadrants, indicating that many of these planes are dipping steeply in those directions. The overall pattern suggests a preferred structural alignment, rather than a random distribution of features.

Since generated from Landsat-derived lineament data, this stereonet likely represents the orientations of faults and fractures in the area. The clustering of these features suggests that the region has been shaped by tectonic forces, creating a dominant fracture pattern that could influence erosion, groundwater flow, or mineralization.

If the data came from field measurements of rock layers, this stereonet could be showing the orientation of bedding planes or foliations. The pattern of the planes might indicate folding, with layers dipping consistently in certain directions due to past deformation.

Understanding the orientation of fractures and faults is crucial for resource exploration, as many natural resources accumulate along these features. In construction and infrastructure projects, knowing rock orientations is key to stability analysis for tunnels, slopes, and foundations. Fault orientations also help identify areas prone to earthquakes.

This stereonet provides a clear visualization of structural trends, revealing a strong directional preference in the features. This insight is essential for making informed geological and engineering decisions.



*Figure 5. Stereographic plot*

### 4.3. Pole Data

A pole data analysis was conducted to examine the orientation of geological features, such as bedding, faults, or fractures, by representing their perpendicular vectors. The resulting diagram displays individual poles as "+" symbols, providing a clearer visualization of dominant structural trends.

The distribution of poles reveals a notable clustering towards the western and eastern quadrants, indicating that most planes are dipping eastward or westward. The variability in dip angles, reflected by the spread of poles, suggests that the structures are non-uniform and exhibit a range of inclinations.

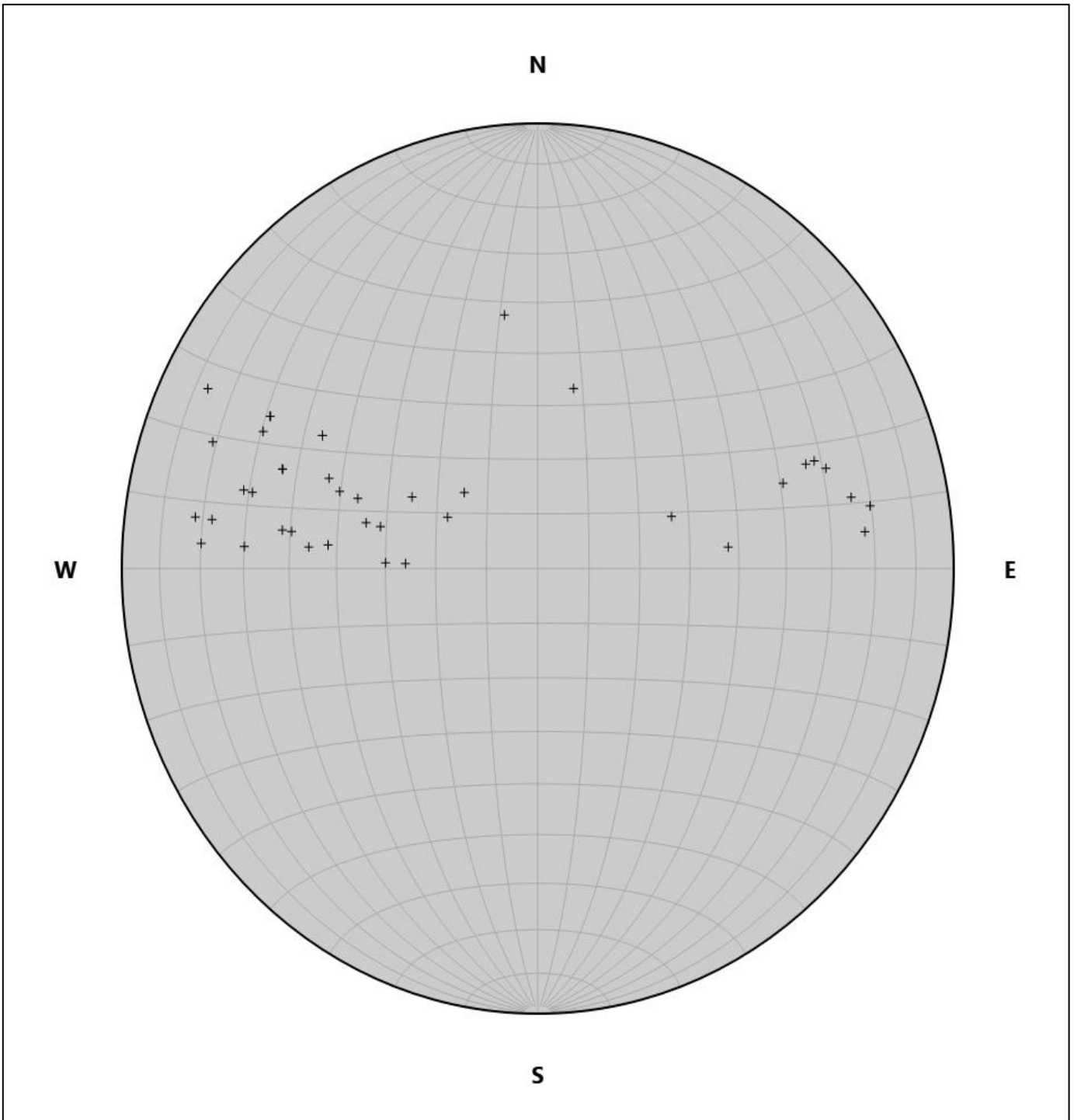
This type of distribution is commonly associated with folded rock layers, faulted terrains, or regionally developed fracture sets. The presence of distinct clusters, rather than a random spread, implies that these structures are influenced by a dominant stress regime.

If the data represents fractures, their orientation may align with regional tectonic forces, indicating zones of weakness where deformation has concentrated. Alternatively, if the poles correspond to bedding planes, the pattern could be related to sedimentary deposition followed by structural modifications, such as tilting or folding.

Understanding these orientations is critical for several applications:

- **Hydrogeology:** Fractures and faults often control groundwater movement, influencing aquifer flow paths.
- **Engineering and Slope Stability:** Rock orientations determine potential failure planes in construction projects such as tunnels, slopes, and foundations.
- **Resource Exploration:** Many mineral deposits and petroleum reservoirs are structurally controlled, making pole orientation analysis vital for exploration.

Overall, this pole data provides valuable insight into the geological framework of the area, highlighting the directional preferences of rock structures and their potential implications for various geological and engineering applications.



*Figure 6. Stereographic projection of poles concentrated in the western and eastern portion of the hemisphere*

#### **4.4. Geological Implications**

The pole data illustrates the orientation of geological planes in the area, revealing patterns shaped by forces like folding or faulting. Clustering of poles indicates preferred directions, helping geologists understand the region's evolution over time.

The stereonet of planes provides a broader perspective by displaying full surfaces, highlighting consistent structural patterns if planes are grouped in similar directions. Conversely, scattered planes suggest multiple shifts and deformations.

The rose diagram simplifies this further by showcasing the most common directions of fractures or faults. Longer bars indicate frequent orientations, revealing how past forces shaped the landscape.

Together, these three visualizations provide a comprehensive understanding of the region's structure. This information is crucial for predicting groundwater movement, planning construction projects, and exploring mineral and oil resources.

Fractures dominating in a particular direction can control water flow or mineral accumulation, making this data valuable for engineers, geologists, and environmental planners to make informed, safe, and efficient decisions.

#### **4.5. Sequence Of Geologic Event**

The geological history of the Igarra area is a result of multiple tectono-thermal events, primarily the Kibaran Orogeny and the Pan-African Orogeny. These events played crucial roles in shaping the region's deformation, metamorphism, and igneous body emplacement.

The Kibaran Orogeny was the earliest recognized event, leading to regional metamorphism of pre-existing sedimentary sequences, resulting in the formation of Quartzite Mica Schist and MetaConglomerate units. This event was characterized by medium- to high-grade metamorphism, intense deformation, and folding and foliation of rocks.

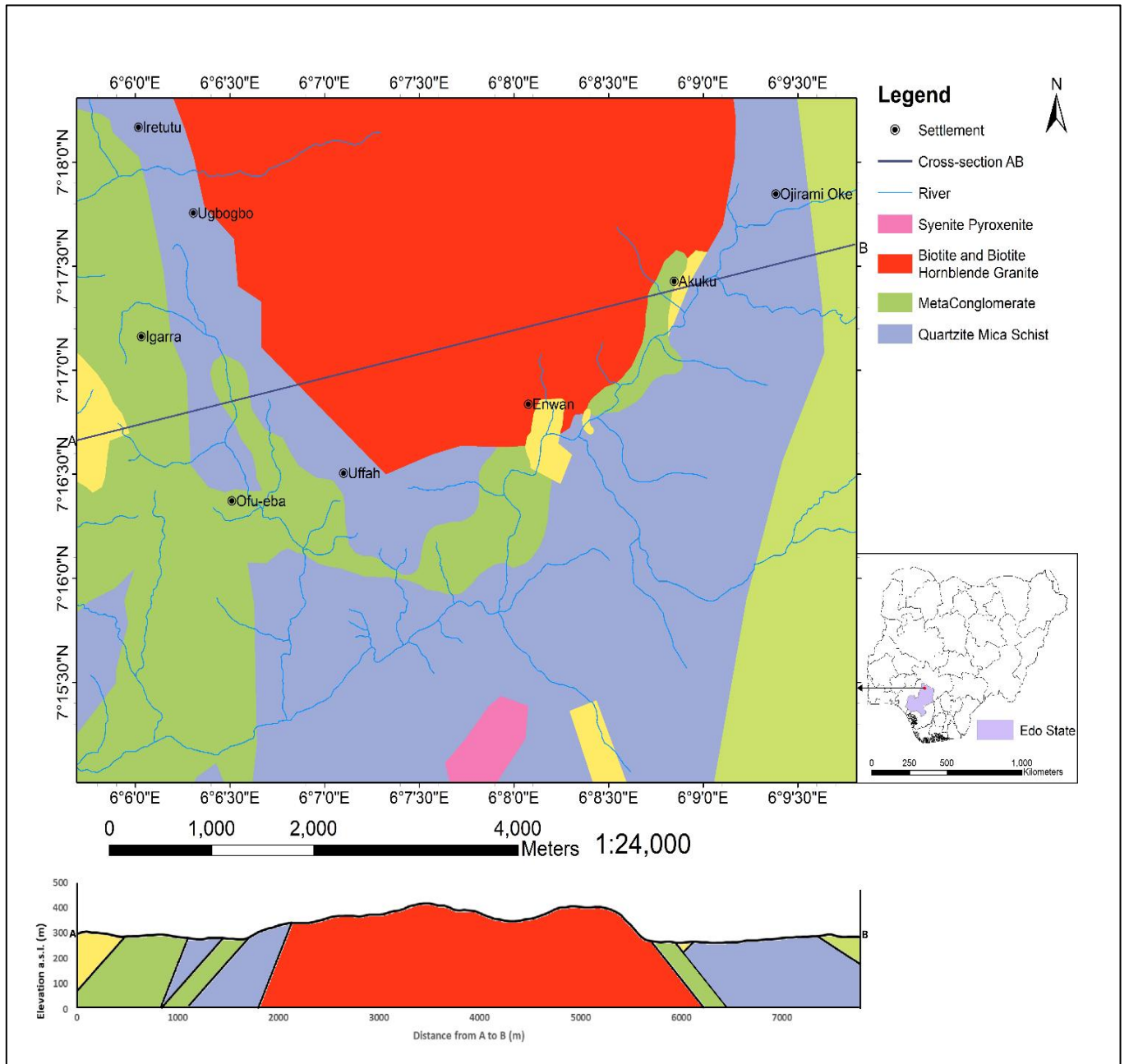
The Kibaran deformation imposed a strong structural fabric on the metasedimentary units, forming a distinct trend that influenced subsequent tectonic overprints. Following a period of relative stability, the region experienced renewed tectonic activity during the Pan-African Orogeny.

This orogeny was associated with crustal reworking, magmatism, and the emplacement of Biotite and Biotite-Hornblende Granites, as well as Syenite

Pyroxenite intrusions. The granitic bodies intruded into the already metamorphosed Kibaran-aged rocks, leading to contact metamorphism and localized metasomatic alterations.

This phase of plutonism was accompanied by further deformation, evidenced by shearing and localized folding observed within both the granitic and metasedimentary units. Post-orogenic uplift and exhumation exposed the region to extensive erosion, which selectively removed less resistant lithologies while preserving more competent units.

Structural trends from both orogenic episodes remain imprinted on the region, influencing modern drainage patterns and geomorphology. The current landscape reflects a complex interplay between lithological resistance and erosional processes, with more resilient granitic and quartzitic units forming topographic highs, while more friable schists and metaconglomerates are preferentially eroded.



## CHAPTER FIVE

### SUMMARY, CONCLUSION AND RECOMENDATIONS

#### 5.1. Summary

The Igarra area's geological and structural data, including rose diagrams, stereonet, pole plots, and geological maps, reveal a complex history shaped by multiple tectonic events. The Kibaran Orogeny played a crucial role in forming and metamorphosing the metasedimentary units, establishing the region's foundational structural fabric.

The Pan-African Orogeny introduced a new phase of tectonic activity, marked by the emplacement of granitic and mafic to ultramafic intrusions. These intrusions disrupted the pre-existing metasedimentary units, leading to localized contact metamorphism and further structural modifications.

The interaction between the different rock units is evident in their spatial distribution and cross-sectional profiles. The rose diagram and stereonet plots confirm the dominant structural orientations, showing preferred fracture and lineation trends. The pole plots reinforce these trends, highlighting the region's tectonic fabric.

The geological map and cross-section illustrate the lithological relationships and topographic expressions of the various rock types. The more resistant quartzites and granites form topographic highs, while the schists and metaconglomerates occupy more eroded areas. The river systems appear structurally controlled, aligning with major fracture and foliation trends.

#### 5.2. Conclusion

The Igarra area's geological history is characterized by multiple deformation phases, resulting in a polycyclic and tectonically complex terrain. The Kibaran Orogeny initiated this process by metamorphosing and deforming sedimentary rocks into schists and quartzites, establishing an initial structural framework.

The Pan-African Orogeny subsequently overprinted these structures, leading to the emplacement of granitoids and mafic intrusions, which further modified the region's structural and lithological characteristics. Statistical plots and geological

mapping reveal dominant NE-SW and NW-SE structural orientations, reflecting the interplay of these tectonic events.

The region's current morphology is primarily a result of differential erosion acting on the structurally and lithologically diverse rock units. This detailed analysis provides valuable insights into the Igarra region's tectonic evolution, offering a framework for future research on its economic geology, including mineralization potential, and geohazard assessment, encompassing stability and water flow pathways.

### **5.3. Recommendations**

#### **1. Radiometric Dating for Chronological Reconstruction**

- Utilize radiometric dating techniques such as U-Pb zircon dating, Ar-Ar dating, or Rb-Sr dating to establish precise ages of metamorphic and igneous events in the Igarra Basement Complex.
- Correlate the obtained ages with regional orogenic events to better understand the evolution of the basement complex.

#### **2. Structural Kinematics and Deformation Modeling**

- Perform kinematic analyses of fault and fold structures using advanced techniques like strain analysis and fault-slip inversion to reconstruct the stress regime responsible for deformation.
- Develop 3D structural models to visualize deformation episodes and their impact on subsurface geology.

#### **3. Hydrogeological and Geotechnical Investigations**

- Study the influence of fractures, faults, and joints on groundwater flow and storage potential in the region.
- Assess the implications of structural discontinuities on slope stability and foundation integrity for engineering applications.

#### **4. Remote Sensing and GIS-Based Structural Mapping**

- Integrate high-resolution satellite imagery and GIS techniques to refine lineament mapping and structural interpretation.

- Utilize digital elevation models (DEMs) and aeromagnetic data to identify hidden geological structures.

## **5. Economic Geology and Mineralization Potential**

- Investigate the association of structural features with mineral deposits (e.g., quartz veins, pegmatite-hosted minerals, and potential economic ores).
- Conduct geochemical exploration to assess the potential for rare earth elements, gold, or other valuable minerals in the region.

## **6. Seismotectonic and Geodynamic Studies**

- Evaluate the seismic activity of fault systems within the Igarra Basement Complex to determine their potential role in regional geodynamics.
- Use geophysical methods such as seismic tomography and gravity surveys to study subsurface structures and their implications for tectonic evolution.

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