

# **A Petrographic and Physico-Chemical study of crystalline rocks from Southeastern Nigeria and their significance to contemporary engineering construction sustainability.**

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## **Abstract**

*The infrastructure deficit brought on by the growing population and quick growth is becoming more urgent. Geo-materials are used in the building and foundation of these constructions. In contrast to conventional engineering materials, these geo-materials include structural flaws such joints and fractures, bedding planes, foliation planes, schistosity, and favoured mineral alignment that might impair the functionality of buildings built on top of or beside them. The mineralogy and geochemistry of geo-materials are linked to these distinctive characteristics. Therefore, the goal of this study is to examine how petrography and rock chemistry affect the mechanical and physical characteristics of particular crystalline rocks in the Oban Massif and Ikom region of southeast Nigeria. Thirty-six (36) representative rock samples are from eight (8) sites and five (5) rock types were collected. Evaluating their appropriateness for civil engineering construction is the goal. The non-destructive Energy Dispersive X-ray Fluorescence (ED-XRF) technology was used to perform geochemical assessments of key oxides.*

*The most prevalent minerals in every sample examined are quartz and feldspar, according to the findings of the petrographic investigations. Granite has the greatest modal content, averaging 29%, whereas basalt has the lowest, averaging 6%. To determine the connection between petrography and mechanical characteristics of crystalline rocks, the quartz to feldspar ratio (QFR) was calculated.*

*Similarly, SiO<sub>2</sub> is the most prevalent oxide in all of the rocks in the study region, according to the findings of the geochemical investigations. The result falls between 48.22 to 68.86 weight percent. The greatest SiO<sub>2</sub> value, ranging from 61.97 to 68.86 weight percent, is found in granites. Out of all the rock samples examined for the research region, basalts had the lowest SiO<sub>2</sub> content. The readings fall between 48.22 and 50.39 weight percent. The rocks in the research region have an average silica content of granite > granodiorite > amphibolites > gabbro > basalt. SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, MgO, K<sub>2</sub>O, Na<sub>2</sub>O, CaO, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, and MnO were the principal elemental oxide concentrations that were discovered to be in decreasing order for the rock samples from the research region.*

*In order to improve human safety, design aesthetics, and long-term durability, all of the values fall within acceptable ranges for contemporary civil construction materials appropriate for sustainable projects like pavements, buildings, tunnels, bridges, dams, etc.*

**Keywords:** *Petrography, Geochemistry, Crystalline rocks, Mechanical properties, Quartz–feldspar ratio (QFR), Silica (SiO<sub>2</sub>), Mineral composition, Civil engineering construction, Sustainability.*

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## **I. INTRODUCTION**

The engineering performance of building and foundation materials is closely linked to their mechanical and physical characteristics. By examining their physicochemical characteristics, this research seeks to determine if crystalline foundation rocks from Southeast Nigeria are suitable for engineering building. The results of this study are significant because they will aid in the selection of suitable rock materials for a range of engineering uses in the area.

This research evaluates important chemical composition and abrasion and impact resistance with empathy. Critical evaluations must be conducted to comprehend the behaviours of materials under certain circumstances in order to assess their appropriateness for engineering building. Some new characteristics, meanings, and effects on society are continually developing, despite the fact that their fundamental roles have essentially not altered for centuries. Among the earliest mineral raw materials to be extracted, processed, and used

by humans were geo-materials for building. They contributed to the advancement of humanity's creative and technical abilities. Here, accessibility, workability, and serviceability are seen as their primary functional characteristics, linked to human abilities to locate them, extract and process them, and then use them appropriately.

Rocks, which are used in various forms such as concrete, aggregate, building stone, and armour stone, are significant building materials of significant geological importance. Rocks break down to create soils, which are equally vital to the building sector. Examining these geo-materials will save building costs, promote environmental safety, enhance sustainable development, and greatly increase engineering project safety. Critical evaluations must be conducted to comprehend the behaviours of materials under certain circumstances in order to assess their appropriateness for engineering building. Rocks, which are used in various forms such as concrete, aggregate, building stone, and armour stone, are significant building materials of considerable geological importance. Rocks break down to create soil, which are equally vital to the building sector.

Furthermore, engineering designs are based on a vast engineering science foundation that includes a thorough and in-depth examination of materials and how they behave under various loads and strains. It's time for engineering design to include ecological science and the connections between different ecosystems and their products. This implies that ecological science and materials science must get equal priority in academic curricula. The fundamental variables that engineer consider while designing, building, and using their constructions are environmental safety and economic concerns. Their initiatives' possible effects on the environment need to be evaluated. This entails controlling waste, lowering noise and visual effects, and minimizing pollution (air, water, and land). They must also guarantee the buildings' and their surroundings' long-term viability. One aspect of the economic consideration is balancing the cost of materials, building, and upkeep with the project budget. To guarantee that the environment is considered by people developing major engineering projects, Environmental Impact Statements have been implemented globally in recent years.

However, environmental factors are still marginalized in the design process. However, the environmental factors that should be taken into account at the design stage of every product and project, regardless of size, such as the selection of materials, layout, and processes, as well as the consequences that follow, are still overlooked, even though environmental impact statements may address the broad effects of developments on the environment.

### 1.1.1 Literature Review

Engineering geology aims to achieve economy and safety in construction by ensuring all geological factors affecting structures are properly identified and evaluated. Safety is enhanced through the selection of suitable sites and materials, while economic efficiency is achieved by avoiding unnecessary overdesign.

When local materials are insufficient, transporting materials increases costs; therefore, using local alternatives or combining materials is recommended to improve cost efficiency. Engineering materials—such as bricks, wood, cement, steel, and plastics—are essential for constructing structures like buildings, bridges, and roads and can be grouped into categories including customary, alternative, composite, and intelligent materials.

A key requirement for engineers is a thorough understanding of material properties, as proper knowledge of these characteristics is crucial for selecting appropriate materials for construction projects.

**Table 1: Summary of Properties of materials**

Group	Properties
Physical	Shape, Size, Density, Specific Gravity etc.,
Mechanical	Strength, Elasticity, Plasticity, Hardness, Toughness, Ductility, Brittleness, Creep, Stiffness, Fatigue, Impact Strength etc.,
Thermal	Thermal conductivity, Thermal resistivity, Thermal capacity etc.,
Chemical	Corrosion resistance, Chemical composition, Acidity, Alkalinity etc.,
Optical	Colour, Light reflection, Light transmission etc.,

Acoustical	Sound absorption, Transmission and Reflection.
Physiochemical	Hygroscopicity, Shrinkage and Swell due to moisture changes

The main goals of engineering geology research are to meet the fundamental engineering principles of economy and safety. The environmental and structural safety concept guarantees that all geological elements that may impact engineering installations' performance are identified, sufficiently examined, and provided for use in engineering practice. In order to promote safety, this entails choosing appropriate locations and materials. By choosing the right building materials, economic consideration during engineering installations aims to minimise overdesign.

Sometimes the materials on the site are woefully insufficient for a certain building. Moving supplies from different locations can be necessary for this. This is significant since it raises building costs due to logistics and transportation. Local alternatives and the mixing of resources on site with more appropriate materials from other areas may be recommended in order to alleviate this predicament and enhance engineering economy. For building, a number of materials are needed. Engineering materials, often known as building materials, are the materials used in the construction of engineering structures including buildings, bridges, and roads. Bricks, wood, cement, steel, and plastics are among them. The following categories may be used to study the materials used in civil engineering structures.

1. Customary materials

2. Different construction materials

3. Materials that are composite

4. Intelligent materials

5. An engineer must be familiar with the characteristics of engineering materials. Only when the qualities of the materials are well known can the right choice of materials be made for a building project. The following categories include some of the most significant characteristics of construction materials.



In the equation above, Sodium (Na) or Calcium (Ca) may be present in place of Potassium (K) if the mineral in question is plagioclase or any other type of feldspar.

The engineering implication of this is that with the increasing rate of weathering, rock materials may gradually lose its mechanical strength which will in turn affect its overall performance when used as foundation or construction material.

### 1.1.2 Variations in Mineralogy and Rock Type

Many minerals found in crystalline rocks, such as quartz, feldspar, and ferromagnesian minerals, respond to weathering processes in distinct ways. Because certain minerals disintegrate more easily than others, the rock weathers unevenly and becomes weaker. Depending on their mineral makeup, crystalline rocks have quite different weathering susceptibilities. For instance, rocks with a high concentration of ferromagnesian minerals, such as biotite, often weather more quickly than quartz-dominated rocks. Chemical weathering often results in the production of new minerals, such as clay minerals, which may change the permeability and strength of the rock. The initial rock composition and weathering conditions also affect the kind and quantity of these secondary minerals.

Rock's texture and mineralogical makeup play a major role in determining its strength. The Mohs scale of mineral hardness is a basic, qualitative, ordinal scale with a range of 1 to 10 that describes the scratch resistance of minerals by measuring the capacity of a harder substance to scratch a softer one. For engineering, construction, and mining, an understanding of mineralogy and rock strength is essential since these elements dictate a rock's longevity, stability under stress, and appropriateness for construction. Rock's strength and resistance to weathering are determined by its mineral makeup. For instance, aggregate made of hard minerals like quartz is more durable

than aggregate made of soft minerals like calcite. As a result, rocks rich in carbonate or clay often have a lower compressive strength than rocks with a high concentration of hard minerals like quartz or feldspar.

### **The Mohs Scale of Hardness**

The scale ranks minerals from 1 (softest) to 10 (hardest):

- **10 - Diamond** (Hardest)
- **9 - Corundum**
- **8 - Topaz**
- **7 - Quartz**
- **6 - Orthoclase Feldspar**
- **5 - Apatite**
- **4 - Fluorite**
- **3 - Calcite**
- **2 - Gypsum**
- **1 - Talc** (Softest) 

**Figure1: Moh's scale of Hardness (Source: Wikipedia)**

## **1.2 COMPARATIVE REVIEW ANALYSIS**

**1.2.1** While existing studies provide valuable insights into mineralogical composition, weathering effects, and geochemical characteristics of rocks, this research stands out by explicitly linking these parameters to engineering performance and sustainable construction practices, thereby bridging the gap between geology and civil engineering applications.

Furthermore, this research integrates petrographic analysis and geochemical characterization (ED-XRF) to establish relationships between mineral composition, oxide chemistry, and mechanical performance of rocks used in construction.

A comparison with the work of **Mallo and Sani (2012)** shows that both studies emphasize the influence of mineralogy and rock fabric on engineering properties. While Mallo and Sani specifically investigated granite porphyry in North Central Nigeria and linked mineral fabric to strength characteristics, the present study advances this by quantitatively relating quartz–feldspar ratios and oxide composition to engineering performance across multiple rock types (granite, basalt, gabbro, granodiorite, amphibolite). This broader lithological scope makes the current research more comprehensive.

Similarly, **Turgrul (2004)** examined the impact of weathering on pore geometry and compressive strength of rocks. Although his work clearly established that weathering reduces strength, it focused primarily on physical degradation processes. In contrast, the present study integrates petrographic observations with geochemical analysis to explain not only how but why such strength variations occur, particularly through mineral stability and chemical composition (e.g., feldspar alteration to clay and silica dominance).

In comparison to **Adegbuyi et al. (2018)**, who studied petrology and geochemistry of basement rocks in Southwestern Nigeria, both studies share a regional geological focus and utilize geochemical data. However, Adegbuyi et al. were primarily concerned with petrogenesis and geochemical signatures, whereas the current study uniquely links these findings directly to engineering applications and construction sustainability. This practical orientation distinguishes the present work from purely petrological studies.

**Alexander et al. (2016)** contributed by analyzing and characterizing the mineral composition and quality of rocks and soils in Mubi South, providing insight into their geochemical properties and economic potential.

The uniqueness of this study lies in its integrated multidisciplinary approach. It combines petrography, geochemistry, and engineering implications within a sustainability framework. Unlike previous works that often treat these aspects independently, this research correlates mineral composition, oxide chemistry, and mechanical suitability in a single framework, providing actionable insights for construction material selection in Southeastern Nigeria. Furthermore, the inclusion of comparative geochemical data from global provinces strengthens its scientific relevance and applicability.

### 1.2.2 Location and Geology of the Study Area.

A portion of the southeast Oban Massif is included in the research area. It includes the Cross River State local government areas of Akamkpa, Yakurr, and Ikom. Geographically, it is located between latitudes 0501012311N and 0505813811N of the equator and longitudes 00800510511E and 00804510511E of the Greenwich Meridian. Its estimated total area is 10,000 km<sup>2</sup>. Rock outcrops, rock exposures along water channels, and both active and abandoned quarries were among the locations visited. The research region continues into the dense tropical rainforest and is delineated by a strong sedimentary basement contact at Awi.

The main Calabar-Ikom highway provides access to the region. Numerous minor roads that were built as a result of quarrying operations and other local agricultural and socioeconomic activities further improved accessibility. Other parts of the research region were difficult to reach due to their undulating landscape and deep forests. Traverses have to be cut in order to reach the regions of interest in these circumstances. To reach several outcrops situated amid the challenging and thick terrain, local pathfinders were hired.

The research area's geologic location indicates that it is part of Nigeria's Precambrian Basement Complex. During the Precambrian, the Nigerian Basement Complex saw many periods of deformation. It is believed that the deformation and metamorphism occurred simultaneously. (Oyawoye, 1972).

Crystalline igneous and metamorphic rocks with a variety of categorised mineral assemblages make up Nigeria's basement complex. They may be roughly classified as either older granites plus minor rocks, the Pan-African intrusive series, the schist, or the ancient gneiss-migmatite complex (Adeyemi & Oyediran, 2005). Crystalline igneous and metamorphic rocks with a variety of categorised mineral assemblages make up Nigeria's Basement Complex. They may be generically classified as older granites plus minor rocks, the Pan-African intrusive series, the Schist, and the ancient gneiss-magmatite complex (Adeyemi & Oyediran, 2005). According to Dada et al. (1998) and Elueze (2000), the Schist belts are mostly found in Nigeria's western half, while some have been identified in the country's center and southern regions.

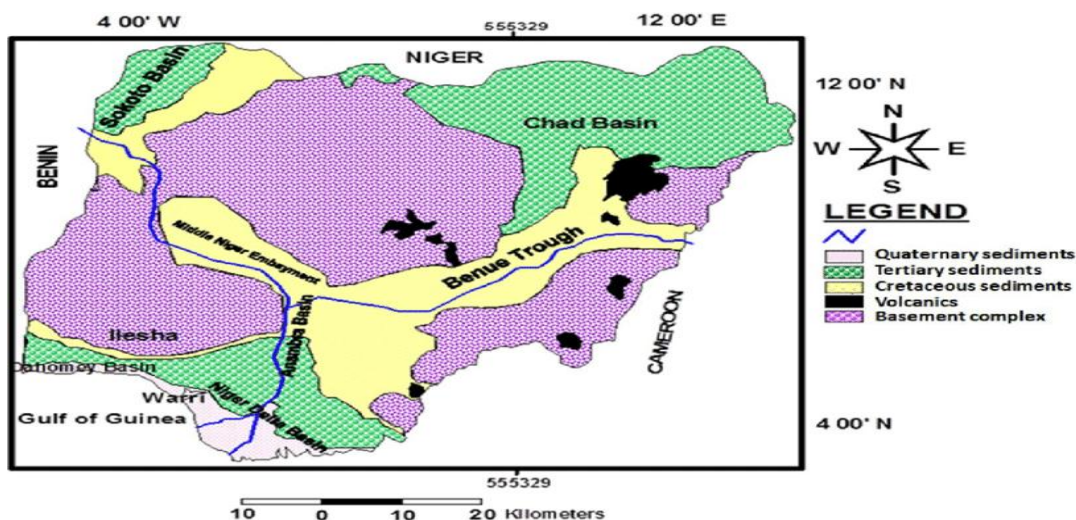


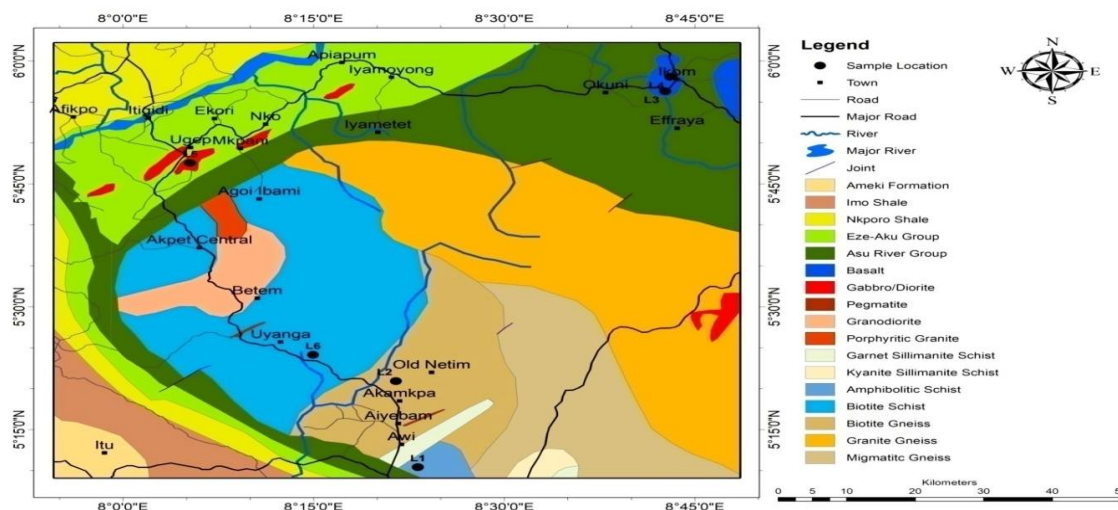
Figure 2: Map of Nigeria showing the location of Basement rocks (Nwajide, 2013)

The geology of the Ikom Embayment, the research region, and the Oban Massif will be taken into account in the local geology. Three primary rock units make up the Oban Massif, according to research done by Rahman et al. (1981) and Ekwueme and Onyeakocha (1985). These are:

- Phyllites, quartzite, amphibolites, pegmatites, gneisses, and migmatite rocks
- Granodiorite and granites are among the older intrusive granites.
- Dolerites without metamorphosis

Granites, pegmatites, granodiorites, and diorites have intruded into these rocks in some locations. The Oban Massif has a variety of gneisses. These consist of migmatite, biotite, and kyanite gneiss (Ekwueme, 1989); the Oban Massif also contains quartzite. Their strong resistance to weathering is what makes them stand out.

Columnar basalt makes up the majority of the Ikom region. These columnar basalts are believed to have originated from basaltic flow, cooled, and quickly solidified, giving them a fine-grained appearance. Olivine, pyroxene, and a little amount of hornblende are the predominant minerals. The dark hue of the basaltic rocks is caused by the presence of calcic plagioclase with a very low quartz concentration.



**Figure 3: Geologic map of the study area (Source: ArcGIS generated)**

As previously mentioned, the geology of the Oban Massif and its surroundings is similar to that of Nigeria's other Basement Complexes. The rocks of the Oban Massif were similarly impacted by the same orogenic events that affected other complexes, with Pan-African being the most prevalent, while other orogenic imprints were also seen. This manifests itself as structural orientation. The majority of structures have significant N-S and NE-SW

orientations with minor NW-SE orientations, including the linear structure, joints, faults, veins, and other structures like foliations. In order to provide crushed aggregates for building, these rocks are being quarried. Additionally, there are artisanal miners who extract valuable minerals like amethyst and lepidolite. Their operations are unregulated, and if they are not quickly observed, they might pose a threat to the environment. The research area's geology map is shown in Figure 3.

The research area's two main wind systems are in charge of the local climate. These are the harmattan and the south-west wind, which bring the rain, and the north-east trade wind, which brings the dry season. Streams overrun their boundaries during the rainy season, which peaks in July and early August. However, NIMET reports that the average annual rainfall is around 3000 mm (Agabi, 2016).

The temperature never rises over 35 degrees Celsius and often falls between 24 and 28 degrees. The vegetation in the study region is significantly impacted by changes in the local climate. Tall trees, bushes, and undergrowths are among the many plant species that have emerged as a result of the high rates of precipitation and the prolonged rainy season. The tropical rainforest is one of the nation's richest ecosystems because of its natural variety. Numerous tree species have canopies that decrease insolation. These provide the study area's wild animals shade. Additionally, there are grasses and bushes, some of which reach heights of two to five meters. In the jungle, some trees may reach heights of 30 to 50 meters, while emergent trees can reach much higher heights. In the research region, secondary vegetation was also noted. The residents' socioeconomic activities are to blame for this. A typical vegetation of the research region is shown in Figure 4.



**Figure 4: Typical vegetation of the study area (Sources; field work pictures)**

## 1.2.2 Research Methodology

### Desk Study

This study was designed in three stages. Desk work was part of the initial phase. This stage included compiling the corpus of current information on the topic. In order to provide context and current knowledge, pertinent literature was studied during this desk research phase. This data came from both published and unpublished works, maps, direct conversations with locals, business owners and operators such as quarry owners and operators, construction workers and consultants, and other stakeholders whose contributions provided context for this work's comprehension and presentation. As a result, the topographic and geology maps of Cross River State and southeast Nigeria were relied upon.

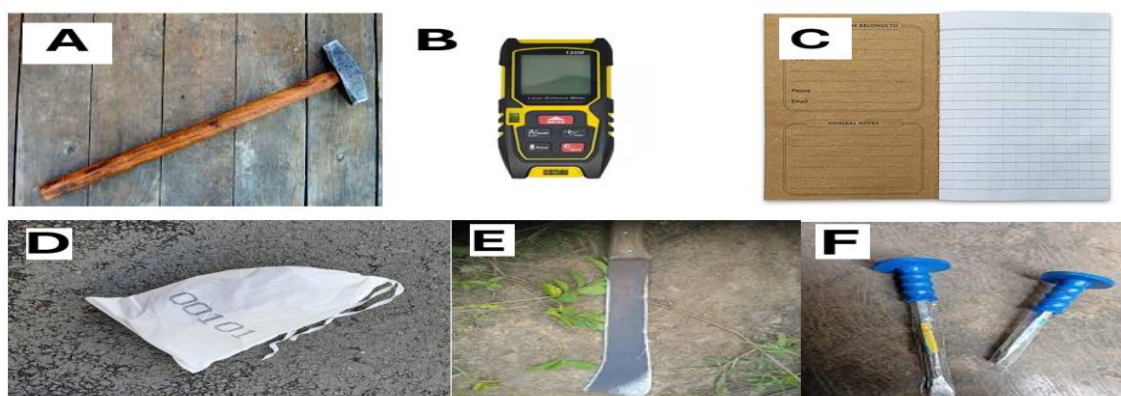
### Field Work

Fieldwork was the second part of this study. This was done in two parts. The reconnaissance survey was the initial part, and it happened immediately after the desk job was finished. In order to gather basic information, such as the locations of quarries, rock outcrops, rock kinds and their characteristics, the socioeconomic activities of the locals, and how this would impact certain field exercises, among other things, this part of the field work entailed trips to the research region.

Old Netim, Okomita, and Uyanga in the Akamkpa local government area, Idomi in the Yakurr local government area, and Ikom local government area, all in Cross River State, southeast Nigeria, comprise the particular research

site. In order to get representative samples for the next stage of the research—laboratory studies—the field activity included gathering observations in the field.

The Global Positioning System (GPS), which provided the coordinates (latitudes and longitudes), the elevation of the research region, and sample location points, was one of the field equipment utilised for the exercise. Samples were chipped and collected with the use of a chisel, cutlass, sledge hammer, and geologic hammer. The field notebook was used to record the information gathered. Sites, outcrops, and other interesting geologic features were photographed using a digital camera. Permanent markers and masking tapes made it easier to properly identify the samples that were gathered.



**Figure 4: Field work equipment: A=sledgehammer B=digital aeromagnetic GPS C=field notebook. D=sample collection bag E=Cutlass F= reinforced alloy chisel Source: Field work**

## 1.2.3 Sample Preparation

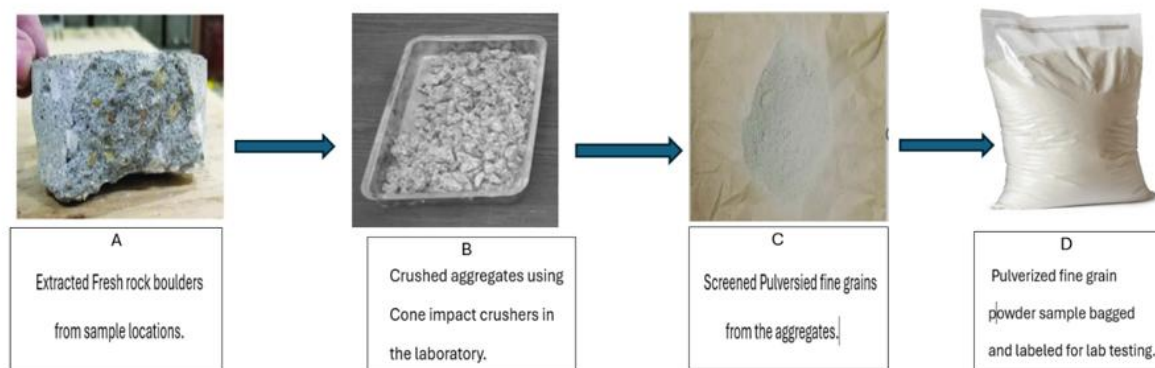
Every rock sample that was gathered from the research area was put through the appropriate sample preparation procedures in compliance with the guidelines for every test set. Using a jaw crusher, samples for geochemical analysis were crushed to aggregate sizes, then ground into a fine powder, sieved, and placed in a zip-lock sample bag that was appropriately labelled before being shipped to a geochemical laboratory.

## 1.2.4 Thin slices and petrographic studies

Selecting representative samples and cutting them into thin section slides are necessary steps in the petrographic analysis of the crystalline rocks. The following tools were used to prepare this thin piece for petrographic analysis: a grinding motor, a diamond saw, a mounting table, a band saw, impregnating medium (Canada balsam), turpentine, glass slides, a Bunsen burner, a knife, silicon carbide and a fine Carmel's hairbrush.

The process entailed using a diamond saw to cut and grind a specimen that was about 1/8 inch thick. After using impregnating media to bond the rock slice to the glass slide, it was set on the mounting table and heated until the

hardened media applied with the mounting rod spread readily. After that, silicon carbide was used to grind the attached rockslide on the lap. This was done to enable grinding to be thinned or decreased to  $30\mu$ , which is the point at which the section becomes light-transparent. In order to get rid of any silicon carbide particles that could have been lodged in the medium surrounding the section, the cover glass was then carefully cleaned using a Carmel's hairbrush soaked in turpentine. Twelve (12) thin section slides in all were made. The modal content of each mineral was noted when these thin slices were placed under the petrologic microscope. A camera installed on the microscope was used to take a photomicrograph of every thin segment. Both Plain Polarise Light (PPL) and Cross Polarise Light (CPL) were used for photomicrographs. Finding the typical rocks' mineral composition and how it can impact their mechanical characteristics was the main goal of the petrographic investigations.



**Figure 5: Pulverize sample preparation prior to Geo-chemical test & analysis**

### 1.2.5 Geochemical Analyses using X-ray Diffraction Analysis

Out of 36 collected samples, 12 were selected for geochemical analysis—2 samples from each rock type, except basalt, which had 4 due to its distinct columnar fracturing and potential impact on construction suitability. The samples were ground to a fine powder using a jaw crusher before analysis. The main geochemical test focused on determining the principal elemental oxide composition to assess its influence on the mechanical properties of the crystalline rocks. Analysis was conducted using Energy-Dispersive X-ray Fluorescence (ED-XRF), a non-destructive method that identifies elemental composition by measuring secondary X-rays emitted when the sample is excited by a primary X-ray source.

No further grinding was needed, so samples were sieved through a  $60\mu\text{m}$  mesh and pressed into pellets with deionized water. After air drying, the pellets were analyzed in a vacuum chamber using Energy Dispersion X-ray Fluorescence Spectrometry. Results were reported as oxides, parts per million (PPM), and trace elements. The method detects elements from PPM levels up to 100%, analyzes all elements simultaneously in under 100 seconds, and is non-destructive, allowing samples to be reused. The main oxides analyzed were  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{TiO}_2$ ,  $\text{MnO}$ , and  $\text{P}_2\text{O}_5$ .

### 1.2.6 Analyses of Petrography

From the representative rock samples, six rockslides were created for petrographic examinations. Most of the samples were granitic rocks, except for one that was metamorphic (amphibolites). The petrologic microscope was used to investigate these rock samples. **Wu et al. (2024)** investigated the influence of mineral composition on the mechanical properties and brittleness of surrounding rocks in soft coal seams, demonstrating that minerals such as quartz and clay play a crucial role in determining rock strength and deformation behavior.

Table 2 displays the modal compositions of typical samples of the main rocks. Quartz, feldspars, and mica are the most common minerals in the samples examined, according to the modal count table. The two most prevalent minerals in the mica category are muscovite and biotite. There are also opaque minerals, and the accessory minerals with extremely low modal counts include glass, olivine, chlorite, and augite.

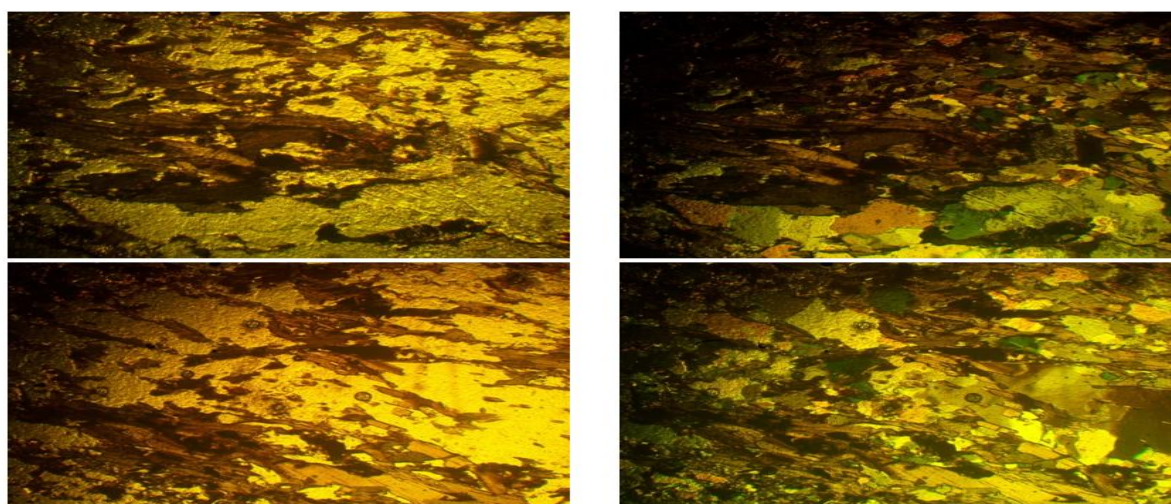
Oban Massif's Awi region is where the amphibolite from the research area was discovered. Hornblende is the predominant modal count in this medium-to-fine-grained melanocratic rock, which is rich in dark-coloured minerals.

Plagioclase has a modal count of 14%, whereas hornblende has a modal count of around 52%. The modal compositions of quartz, biotite, and muscovite are 13%, 8%, and 3%, respectively. Chlorite has a modal count of 3%, whereas opaque mineral has a modal count of 4%. Glass, augite, and hypersthene are absent. The amphibolites from the research region have a distinctive black hue due to the prevalence of the dark-coloured mineral.

Amphibolite photomicrographs in Plain Polarise Light (PPL) and Cross Polarise Light (XPL) are shown in Figure 6.

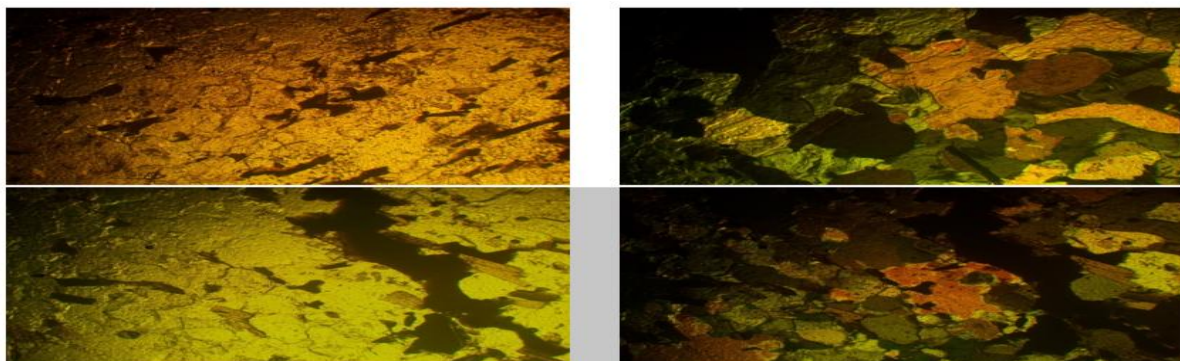
**Table 2: Pre-petrographic modal counts (in percentage) of representative samples**

Minerals	L1	L2	L3	L4	L5	L6
	Amphibolite	Granite	Basalt	Basalt	Gabbro	Granodiorite
<b>Quartz</b>	13	29	8	4	6	24
<b>Plagioclase</b>	14	37	48	61	13	31
<b>Biotite</b>	8	18	2	1	16	21
<b>Hornblende</b>	52	14	3	3	24	16
<b>Muscovite</b>	3	4		-		7
<b>Opaque</b>	4	3	1	4	6	2
<b>Augite</b>	-	-	13	13	10	-
<b>Hypersthene</b>	-	-	18	18	6	-
<b>Olivine</b>		-	6	4	8	-
<b>Chlorite</b>	3	-	1	2	5	-
<b>Glass Accessories</b>	3	-	5	6	-	



**Figure 6: Photomicrograph of amphibolites in PPL and XPL (Source: Geochem lab pictures)**

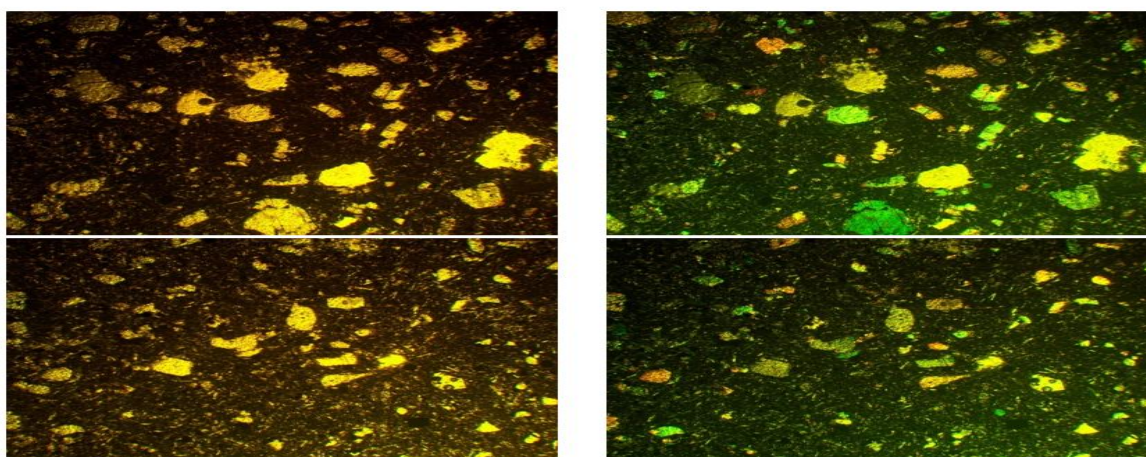
The granites of the study area are medium grained intrusive rocks with xenoliths of amphibolites. They have abundant of quartz with the average modal count being 29%. Feldspar which is a combination of K-feldspar and plagioclase has a modal count of 37%. Biotite has modal composition of 18% while hornblende accounted for 14%. The high percentage of hornblende in granites of the study area can be attributed to its association with the country rock which is amphibolites, a metamorphic rock with abundant hornblende. Accessory minerals have the modal count of 3%. FIG.8 shows the photomicrograph of granite in both Plain Polarize Light (PPL) and Cross Polarized Light (XPL).



**Figure 6: Photomicrograph of granite in PPL and XPL. (Source: Geochem lab pictures)**

The basalts were mostly found in Ikom area. It occurs as columnar hence sometimes referred to as columnar basalt. It is thought to have been formed from basaltic flow, cooled and solidifies rapidly hence it has fine grains. Dominant minerals include feldspars, olivine, pyroxene, hornblende and biotite with augite, glass and hypersthene as accessory minerals. The modal count of quartz ranges from 4-8%, feldspar has a modal count of 48-61%, augite from 13-15%, hypersthene, 18-22%, olivine 4-9% and glass with modal count as high as 5-6%.

When the basaltic rocks weather, the by-products are reddish brown materials. However, the fresh rock is dark in colour and glassy as a result of high amount of ferromagnesian minerals and high glass content. The strength of basaltic rocks may be attributed to their fine-grained dense structure and specific mineral composition. The basaltic rocks are suitable for civil construction purposes. Figure 7 shows the photomicrograph of the basaltic rocks from the study area in both the Plain Polarize Light (PPL) and Cross Polarize Light (XPL)

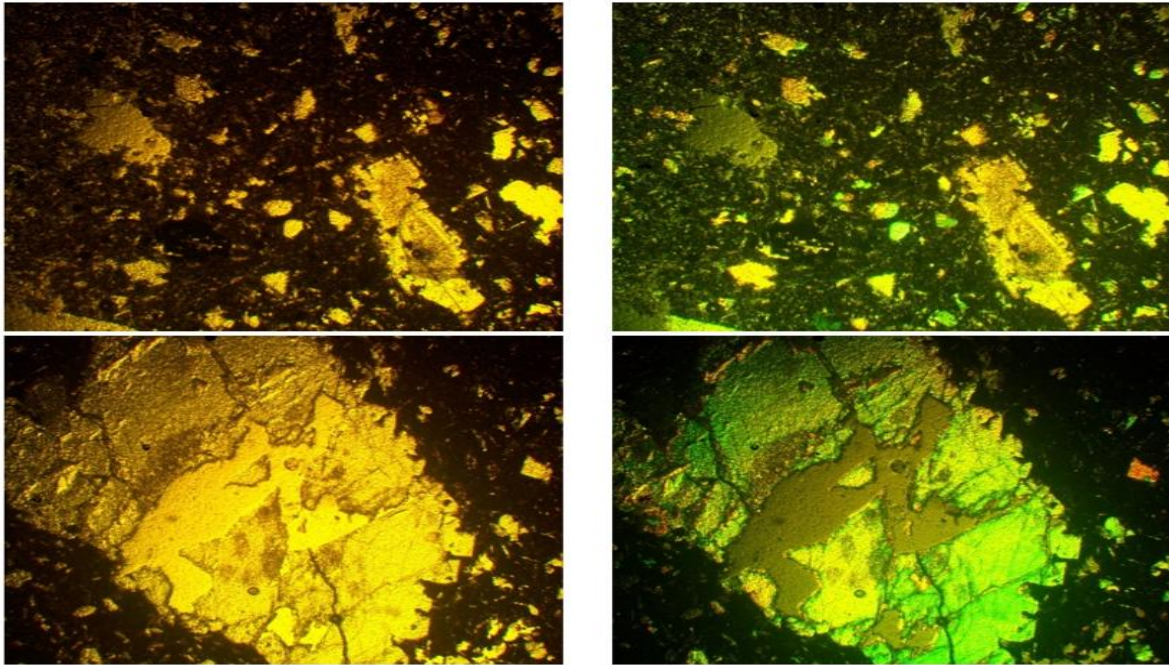


**Figure 7: Photomicrograph of basalt in PPL and XPL. (Source: Geochem lab pictures)**

The gabbro rocks were obtained in the Ugep –Idomi area of the study location. It is a coarse-grained intrusive rock with dominant minerals like olivine, pyroxene, hornblende, feldspars with low quartz content. It is thought to have been formed from the slow cooling magma which is deep seated, hence the crystal structures of minerals are well defined. This accounts for the coarse-grained size.

The modal composition of quartz in gabbro rock from the study area is 6% that of plagioclase is 13%, biotite has the modal count of 16% while that of hornblende is 24%. There is presence of augite, hypersthene and chlorite. However, glass is absent in the gabbro rocks of the study area. The mineralogy of gabbro is similar to that of basalt hence, basalt is seen as the volcanic equivalent of gabbro.

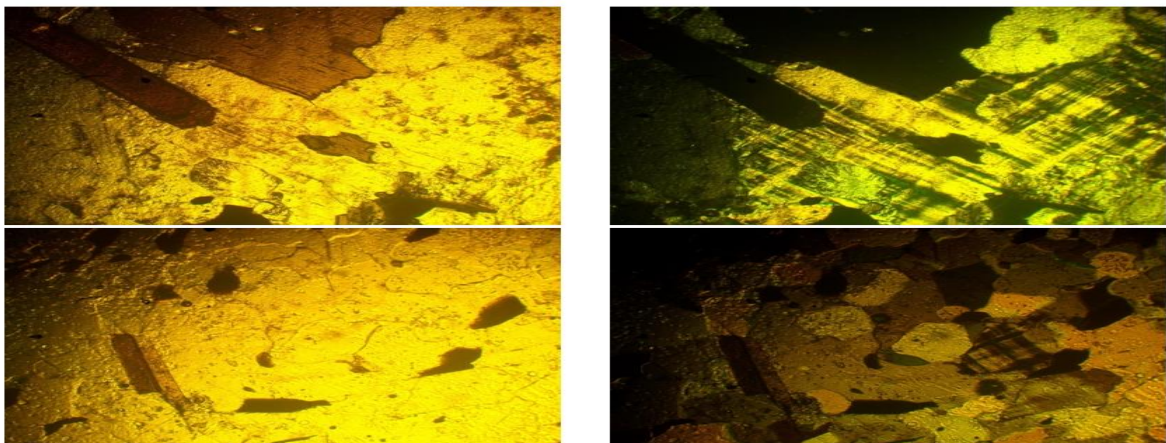
The presence of abundant mafic minerals in gabbro gives it a characteristic dark color in hand specimen. Typical weathering observed on the gabbro rocks is exfoliation or spheroidal weathering. Figure 8 shows the photomicrograph of gabbro rocks from the study area.



**Figure 8: Photomicrograph of gabbro in PPL and XPL (Source: Geochem lab pictures)**

The granodiorites were mapped at the Unyanga area of the study location. Granodiorites are coarse grained intrusive rocks with quartz and feldspars as dominant minerals. The modal composition is given in Table 3 and the photomicrographs both in Plain Polarize Light (PPL) and Cross Polarize Light (XPL) is shown in FIG. 4.5. Quartz has modal composition of 24%. The modal composition of plagioclase is 41% while that of biotite is 21% Opaque and other accessories constitute about 2%.

As typical of granodiorite, there is more plagioclase than K-feldspar while that biotite and hornblende occur as subordinates. It is medium to coarse texture, very hard in hand specimen and having very high values of in-situ strength as obtained with the use of the Schmidt Hammer.



**Figure 8: Photomicrograph of granodiorites in PPL and XPL (Source: Geochem lab pictures)**

## II. RESULT AND DISCUSSION

Geochemical analysis of rock samples identified major oxide compositions to assess how they influence the geo-mechanical behavior of crystalline rocks, especially for civil engineering use.

The results obtained are as discussed below:

**Table 3: Quartz/feldspar ratio of rocks from the study area**

Rock types	Q	F	O	Q/F
Amphibolite	13	14	73	0.93
Granite	29	37	34	0.78
Basalt	8	48	44	0.17
Basalt	4	61	35	0.07
Gabbro	6	13	81	0.46
Granodiorite	24	41	35	0.59

Q, Quartz, F, Feldspar O, other minerals

Q/F, Quartz to feldspar ratio

For this present study, the geochemical method used is the Energy-Dispersive X-ray Fluorescence (ED-XRF).

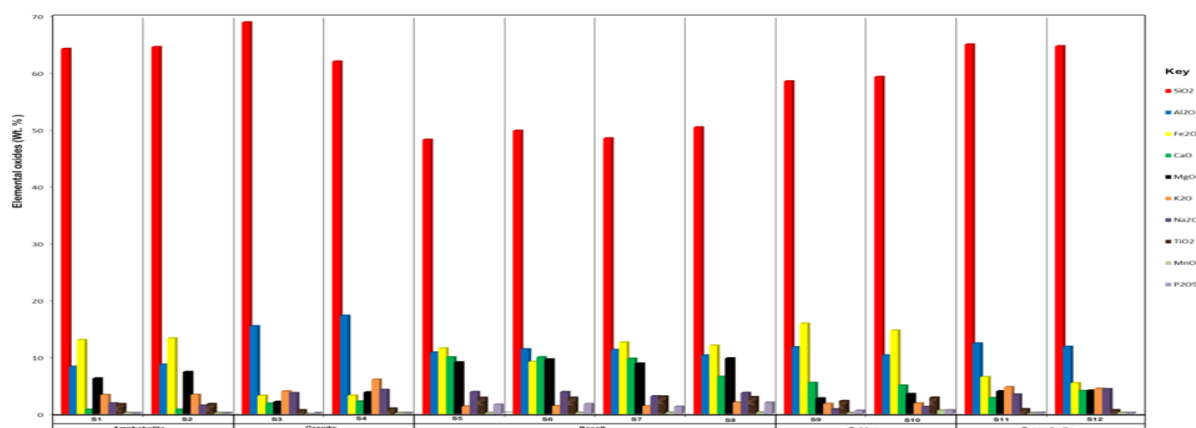
The elemental composition of rock materials may be ascertained using this non-destructive analytical method. These investigations are based on the idea that a sample's chemistry may be ascertained by measuring the fluorescence (or secondary) X-ray that the sample emits when it is stimulated by a primary X-ray source. When this happens, electron shell transitions often take place. As a consequence, photons with energy similar to its constituent makeup are released. Table 4 and Figure 11 show the geochemical analysis findings.

Twelve (12) typical rock samples were examined based on the table. These consist of two samples of granite, two samples of amphibolites, four samples of basalt, two samples of gabbro, and two samples of granodiorite. Only the amphibolites are metamorphic among the aforementioned rock types; the others are granitic. Basalt is an extrusive igneous rock, while granite, gabbro, and granodiorite are intrusive igneous rocks.

SiO<sub>2</sub> is the most prevalent oxide in all of the rocks in the study region, according to the geochemical analysis findings. The result falls between 48.22 to 68.86 weight percent. The greatest SiO<sub>2</sub> value, ranging from 61.97 to 68.86 weight percent, is found in granites. Out of all the rock samples examined for the research region, basalts had the lowest SiO<sub>2</sub> content. The readings fall between 48.22 and 50.39 weight percent. The rocks in the research region have an average silica content of granite > granodiorite > amphibolites > gabbro > basalt.

**Table 3: Results of geochemical analyses of representative rock samples (in wt. %)**

	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12
Oxides	Amphibolite	Amphibolite	Granite	Granite	Basalt	Basalt	Basalt	Basalt	Gabbro	Gabbro	Granodiorite	Granodiorite
SiO <sub>2</sub>	64.20	64.50	68.86	61.97	48.22	49.79	48.46	50.39	58.48	59.26	64.97	64.65
Al <sub>2</sub> O <sub>3</sub>	8.31	8.67	15.43	17.26	10.81	11.37	11.25	10.28	11.74	10.30	12.40	11.82
Fe <sub>2</sub> O <sub>3</sub>	13.00	13.30	3.19	3.24	11.54	9.17	12.59	12.02	15.89	14.66	6.50	5.42
CaO	0.74	0.76	1.83	2.20	9.96	9.99	9.71	6.53	5.46	5.00	2.81	4.04
MgO	6.25	7.39	2.13	3.81	9.08	9.59	8.86	9.78	2.74	3.52	4.00	4.12
K <sub>2</sub> O	3.35	3.37	3.99	6.04	1.32	1.38	1.37	2.02	1.78	1.86	4.71	4.46
Na <sub>2</sub> O	1.88	1.48	3.68	4.23	3.87	3.86	3.12	3.71	0.84	1.24	3.42	4.37
TiO <sub>2</sub>	1.76	1.77	0.67	0.96	2.85	2.87	3.08	2.98	2.29	2.89	0.85	0.68
MnO	0.18	0.15	0.03	0.14	0.20	0.23	0.26	0.29	0.18	0.62	0.10	0.25
P <sub>2</sub> O <sub>5</sub>	0.07	0.09	0.10	0.14	1.65	1.76	1.29	2.00	0.60	0.66	0.23	0.19



**Figure 9: Bar chart showing average concentration of major oxides in the study area**

Rock specimen progressively darkens with decreasing silica content with granites being lighter and basalt being the darkest of all the rocks studied within the area.

The Al<sub>2</sub>O<sub>3</sub> ranges from 8.31 wt % to 17.26 wt %. The lowest value is recorded for amphibolite, a metamorphic rock while the highest is recorded for granite. However, the values of Al<sub>2</sub>O<sub>3</sub> for all the granitic rocks seem to overlap. Fe<sub>2</sub>O<sub>3</sub> is another oxide which is dominant for all the rock samples from the study area. It ranges from 3.19 wt% to 15.89 wt%. The lowest value is recorded for granites while gabbro has the highest concentration. MnO is the least abundant of all the major oxides analyzed from rocks of the study area. The value ranges from 0.03 wt % for the amphibolites to 0.29 wt % for basalt.

On average, the concentrations of the major elemental oxides obtained for the rock samples from the study area were found to be in the decreasing order of SiO<sub>2</sub> > Al<sub>2</sub>O<sub>3</sub> > Fe<sub>2</sub>O<sub>3</sub> > MgO > K<sub>2</sub>O > Na<sub>2</sub>O > CaO > TiO<sub>2</sub> > P<sub>2</sub>O<sub>5</sub> > MnO. However, gabbro had higher concentration of Fe<sub>2</sub>O<sub>3</sub> (14.66 – 15.89wt %) compared to other rock types.

The rocks of the study area appear to be higher in SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> compared to other oxides. To discriminate the relative abundance of Silica, alumina and iron, silica ratio and alumina ratio proposed by Alexander et al., (2016) was utilized. Here, silica ratio is given by;

$$SR = \frac{SiO_2}{Al_2O_3 + Fe_2O_3}$$

$$AR = \frac{Al_2O_3}{Fe_2O_3}$$

Where SR is the Silica ratio and AR is the alumina ratio (TABLE 4 and FIG 10). Silica ratio (SR) observes the variation of silica compared to Al and Fe. Alumina ratio (AR) presents the abundance of aluminum compared to iron. From FIG 4.7, granite has relative abundance of Al<sub>2</sub>O<sub>3</sub> compared to Fe<sub>2</sub>O<sub>3</sub>, whereas other rock units of the study area have higher values of Fe<sub>2</sub>O<sub>3</sub> compared to Al<sub>2</sub>O<sub>3</sub>.

A comparative study was carried out to appraise the major elemental oxides of granites, basalts and gabbro of the study area with that of similar rocks in other geologic provinces of the world. This information is presented in TABLES 4. and 5. Some of the values from the study area conform with other geologic provinces while others show slight marked differences.

**Table 4: Silica Ratio (SR) and Alumina Ratio (AR) of rocks from the study area**

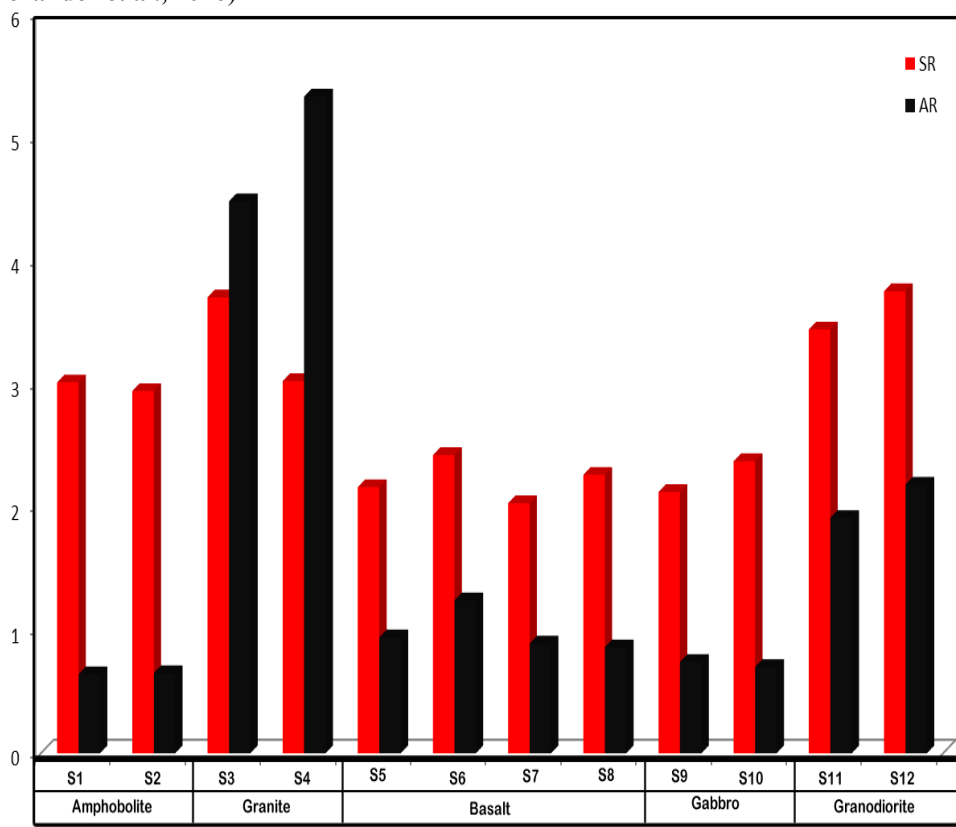
	SR	AR	ROCK TYPE
S1	3.01	0.64	<b>Amphibolite</b>
S2	2.94	0.65	<b>Amphibolite</b>
S3	3.70	4.48	<b>Granite</b>
S4	3.02	5.33	<b>Granite</b>

S5	2.16	0.94	<b>Basalt</b>
S6	2.42	1.24	<b>Basalt</b>
S7	2.03	0.89	<b>Basalt</b>
S8	2.26	0.86	<b>Basalt</b>
S9	2.12	0.74	<b>Gabbro</b>
S10	2.37	0.70	<b>Gabbro</b>
S11	3.44	1.91	<b>Granodiorite</b>
S12	3.75	2.18	<b>Granodiorite</b>

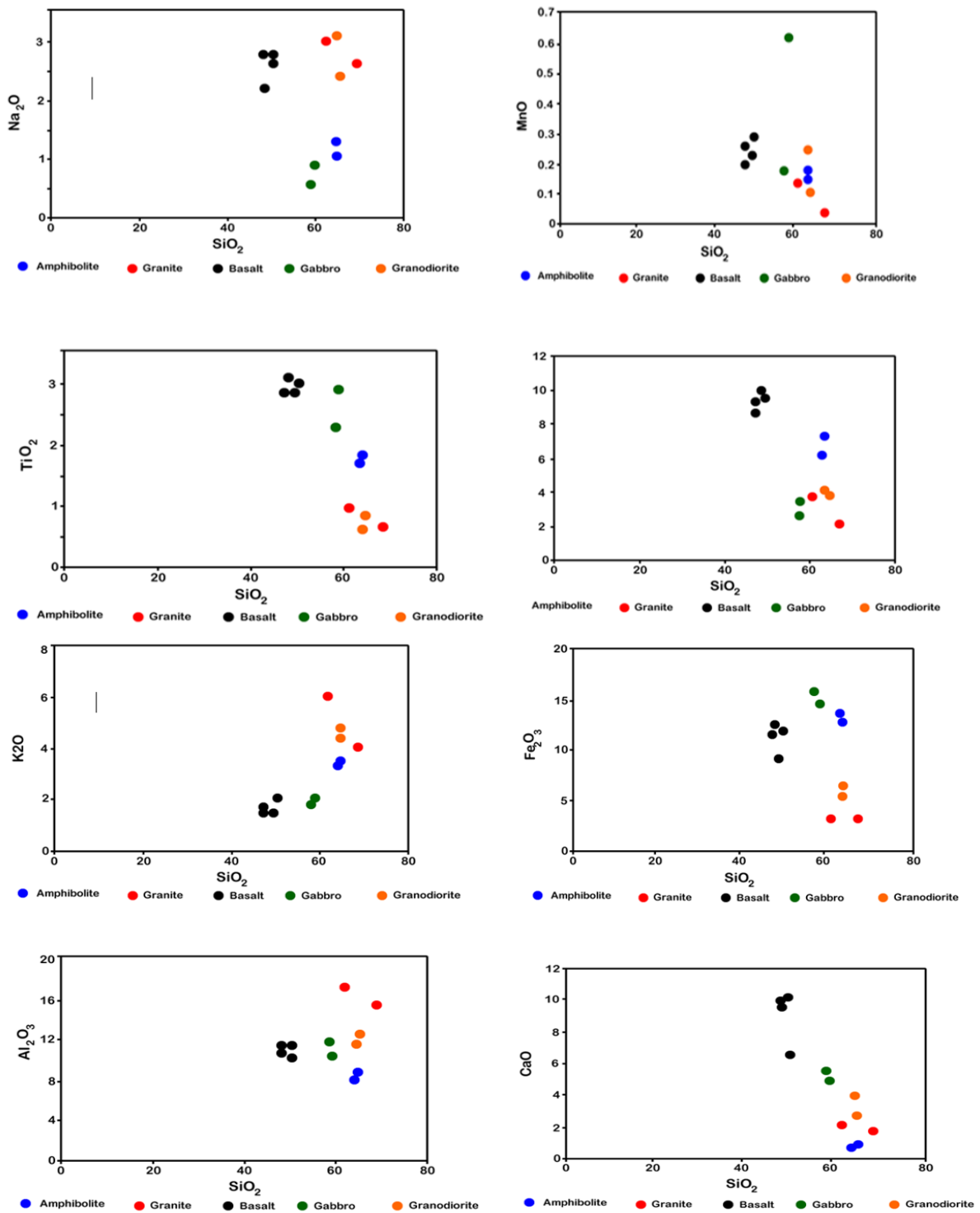
$$\text{Silica Ratio (SR)} = \frac{\text{SiO}_2}{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}$$

$$\text{Alumina Ratio (AR)} = \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3}$$

(After Alexander et al., 2016)



**Figure 9: Bar chart showing silica and alumina ratio (Alexander et al, 2016)**



**Figure 10: a-h: Silica variation diagram (Harker plot) showing variation of silica with other oxides**

**Table 5: Comparison of average major oxides composition of granites of the study area with similar rocks in other geologic provinces**

	A	B	C	D	E	F
SiO <sub>2</sub>	65.42	72.04	68.77	73.66	69.67	63.31
Al <sub>2</sub> O <sub>3</sub>	16.35	14.42	13.75	14.35	15.17	15.12
Fe <sub>2</sub> O <sub>3</sub>	3.22	1.22	5.18	0.94	1.34	2.00

CaO	2.02	1.82	2.45	1.32	1.71	3.88
MgO	2.97	0.71	0.41	0.11	0.04	1.56
K <sub>2</sub> O	5.02	4.12	4.28	4.11	2.28	4.10
Na <sub>2</sub> O	3.96	3.69	3.33	3.53	2.56	2.93
TiO <sub>2</sub>	0.82	*	*	0.65	*	0.04
MnO	0.09	*	*	*	*	*
P <sub>2</sub> O <sub>5</sub>	0.12	*	*	*	*	*

- \* - Data not available  
A - Present study  
B - Worldwide average proportion of different chemical components in granite (**Blatt & Robert, 1996**)  
C - Granite from Toro Charnockite complex (TTC), Northeastern Nigeria (**Dada, et al., 1995**)  
D - Anatectic Granites from Northern Cameroon (**Toteu, 1990**)  
E - Igbeti coarse porphyritic granite, Southwest, Nigeria (**Rahaman et al., 1983**)  
F - Jato Aka Monzogranites from SE Nigeria (**Umeji, 1991**).

**Table 6: Comparison of average major oxides composition of basalts of the study area with similar rocks in other geologic provinces**

	A	B	C	D	E
SiO <sub>2</sub>	49.22	44.50	48.39	49.82	48.30
Al <sub>2</sub> O <sub>3</sub>	10.92	15.39	13.98	14.66	13.03
Fe <sub>2</sub> O <sub>3</sub>	11.33	3.81	12.63	11.20	6.84
CaO	9.05	8.83	9.16	12.16	7.72
MgO	9.32	7.80	6.92	7.81	10.91
K <sub>2</sub> O	1.52	1.84	0.79	0.07	5.46
Na <sub>2</sub> O	3.64	*	2.50	1.94	0.51
TiO <sub>2</sub>	2.95	2.43	*	1.28	2.59
MnO	0.25	4.37	*	0.18	0.23
P <sub>2</sub> O <sub>5</sub>	1.68	0.83	*	0.15	0.26

- \* - Data not available  
A - Present study  
B - Jos Plateau basalt, north central Nigeria (Lar and Tsalma, 2006)  
C - Egyptian basalt. (Hassaan, et al, 2015)  
D - Basalt from east pacific rise, France (Cambon and Bougault, 2005)  
E - Worldwide average proportion of different chemical components in basalt (R. Gill, 2010)

Granites from the Toro Charnokite Complex in northeastern Nigeria (**Dada et al., 1995**), Anatectic Granites in Northern Cameroon (**Toteu, 1990**), Igbeti coarse porphyritic granite in South West Nigeria (**Rahaman et al., 1983**), and Jato Aka Monzogranites in southeast Nigeria (**Umeji, 1991**) were among the granites found in the study area. The granites found in the research region are somewhat similar to those found in northern Cameroon, southwest Nigeria, and southeast Nigeria. The fact that they are all members of the same Pan-African mobile belt that underwent the same tectonism may be the cause of their similarities.

The study area's basaltic rocks were compared to basaltic rocks from other parts of the world, including basalt from Egypt (Hassaan et al., 2015), basalt from the East Pacific Rise in France (Cambon and Bougault, 2005), and basalt from Biu, Plateau, north central Nigeria (Lar and Tsalma, 2006). The composition of basalt from the research region is comparable to that of Egyptian basalt (Table 6), a crucial raw material for Egypt's glass-ceramic sector. This special basalt may be further investigated and used to support the growth of the glass-ceramic sector in the research region since it is plentiful there. Rapid economic growth, job opportunities, and other financial advantages related to the discovery and utilization of geo-materials will result from this.

Additionally, these materials may be quarried and utilized for the building industry since there is almost no quarry business in the research region where basaltic rock is plentiful. Case studies of basaltic rocks being used for different construction applications have been recorded. This will lower the financial burden of transporting aggregates from other granitic rock-quarrying regions in the research area to basalt-rich locations.

A correlation between the major oxides, such as SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub>, and the uniaxial compressive strength and other mechanical characteristics of the rocks can be used in preliminary site investigation where engineering behavior of the rock is required in-situ, before laboratory testing, to assess the suitability of these basaltic rocks for civil engineering construction.

### III. CONCLUSION

Crystalline rocks from several regions of southeast Nigeria were subjected to physico-chemical investigations. Examining its effects on engineering construction was crucial. In doing so, the behavior of certain crystalline rocks from regions of Southeastern Nigeria was investigated in relation to rock chemistry and petrography of mineral fabrics. This was done in order to determine the geological characteristics that influence how well engineering construction work.

Both in the field and in the lab, thirty-six (36) representative samples from eight sites representing five different rock types—amphibolites, granites, basalt, gabbro, and granodiorites—were examined. According to petrographic investigations, the predominant minerals include feldspars and quartz. The two most often seen types of mica are biotite and muscovite. Because quartz has a great resilience to weathering, samples with more quartz were shown to have better uniaxial compressive strength values. Feldspars lose their mechanical importance when exposed to water and weather, turning into clay. When used as base materials in geotechnical engineering, quartz and feldspar are the main minerals in rock aggregates that have a direct impact on mechanical strength, durability, and performance. In general, all the sample aggregates under study have a high quartz content, which is correlated with high hardness and compressive strength values. Conversely, a low feldspar content value indicates that the aggregates under study can offer rigid stability when used as construction bases, but they are less likely to weather, increasing their mechanical significance and acceptability.

ED-XRF was used for geochemical analysis. SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, MgO, K<sub>2</sub>O, Na<sub>2</sub>O, CaO, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, and MnO were determined to represent the decreasing order of the relative concentrations of the main elemental oxides collected for the rock samples from the research region. Rock chemistry has a huge impact on the strength characteristics of rocks, according to a link between the main oxides and the mechanical properties of rocks. If these basement rocks are to be used as building and foundation materials, it is necessary to comprehend how their petrogenesis and geochemical makeup impact their mechanical and physical characteristics.

### Suggestions

Presenting rock and soil descriptions in engineer-friendly terms is a crucial first step. The research shows that geology alone, or lab and field tests alone, don't ensure the safety of structures built on or with rock. However, combining engineering geological mapping with petrographic and geochemical studies makes it possible to reasonably predict how rocks will behave mechanically. Civil engineers should also avoid classifying all basement rocks as granitic. Rock composition, weathering degree, and structural orientation heavily influence mechanical behavior and performance.

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