Ayeni et al (2017) Nigerian Mining Journal, (15) 19 - 27
© Nigerian Society of Mining Engineers, ISBN 1117 - 4307

Geotechnical and Petrographic Assessment of Supare Rocks as Dimension Stone, Ondo State, Southwestern Nigeria

J. K. Ayeni*, I.M Ogunbajo, A.N. Amadi, C.M Okobi and S. H. Waziri

Department of Geology, Federal University of Technology, Minna, PMB 65, Niger State, Nigeria

***Corresponding Author:** kaysonmec@gmail.com

Abstract

A study of the geology and the geotechnical properties of rocks in Supare, part of Owo sheet 265 NW, Ondo State South Western Nigeria was carried out to identify rocks as dimension stone. The suitability of different rocks types assessed was based on the physical and the mechanical properties of the outcrops. A total of ten rock samples were analysed for physical and mechanical properties. The samples examined showed good compressive and tensile strength properties suitable for block production in accordance with standard specification. The compressive strength ranges between 149.71 N/M^2 and130.51 N/M^2. The high values of water absorption (1.27%) and porosity (0.88%) for L3 reduces its quality and suitability for use as dimension stone production. The examination carried out to determine the mineralogical composition of the rock samples which also provided information on weathering condition shows that all sampled rocks are free of flaws and deleterious minerals. The major minerals in the rocks are quartz, feldspar and mica.

Keywords: Dimension stone, geotechnical properties, petrography, and mineral composition, physical and mechanical properties.

Introduction

Dimension stone is any hard rock or natural stone specially cut, trimmed to a specification and polished. This term applies to natural rock quarried or cut for the purpose of block or slab that meet dimension in term of size and shape. The term Natural stone includes rocks having fine colour and pattern, having the required strength and weathering resistance such as granite, marble, sandstone, slate, quartzite, limestone, granodiorite, dolomite, serpentinite, gabbro, gneiss, etc. It is however worthy of note that not all natural facing rocks are suitable for dimension stone production (Lapedes, 1978). Among the target features of any dimension stone, mechanical and the physical properties are of tremendous relevance. The major yardstick for the geotechnical assessment or evaluation of dimension stone include compressive strength, tensile strength, porosity and water absorption. The aim of this work is to study selected outcrops in Supare, Ondo State which are typical of certain lithologies and have the potential for use as dimension stone. Exterior cladding must be free of deleterious minerals which are subject to chemical and or physical weathering. Sulphide tends to oxidize, leaving streak and stain on the surface. Soft minerals such as olivine and pyroxene, formed at great depth and temperature, are unstable under conditions found on the earth's surface. They erode and leave a pitted surface. Other minerals such as epidote, were created during alteration or metamorphism and occur as softer inclusion in the rock.

In dimension stone production, flaws refer to the assemblage, pattern and distribution of joints fractures, faults and microcracks. Although, flaws are not desirable in dimension stone products, parallel joints which intersect at right angles and that are not closely spaced may aid dimension block mining (Selonen, 2000). Therefore any rock for dimension stone application must be free of flaws and deleterious minerals for marketability of the products (Loudes, 2000).

Geology of the Study Area

The study area lies between latitude 7°27' – 7°29' N and longitude 5°40' – 5°42' E on Owo sheet 265NW on a scale of 1:12500. It covers an estimate of area of about

13.4km². Supare Akoko lies within the undifferentiated migmatite-gneiss complex of Nigeria Basement rock as classified by Rahaman (1973) and these account for over 99% of the basement rock in the terrain The rock under study are located in Northern district of Ondo State as shown in Fig 1. This area is dominated by three rock type: granite-gneiss followed by granite and migmatite. The geological map of the area of study is represented in Fig 2.

According to Kogbe (1979), the basement complex rocks of Nigeria are composed predominantly of magmatic and granitic gneiss, quartzite, slightly migmatised to unmigmatised metasedimentary schists and metaigneous rocks, charnockitic, gabbroic and dioritic rocks and the member of the Older Granite, granodiorite and syenite. Migmatite are found to be abundant in southwestern Nigeria. Supare granite outcrop is described as granite gneiss, where the granitic material takes the form of indefinite impregnation.

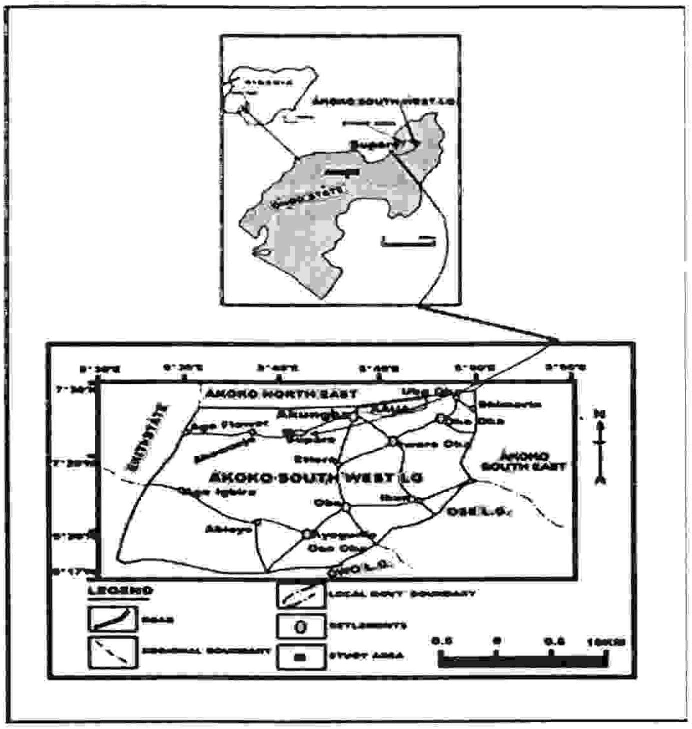


Figure 1: Location map of the study area (Department of Earth Sciences, Adekunle Ajasin University, Ondo State.).

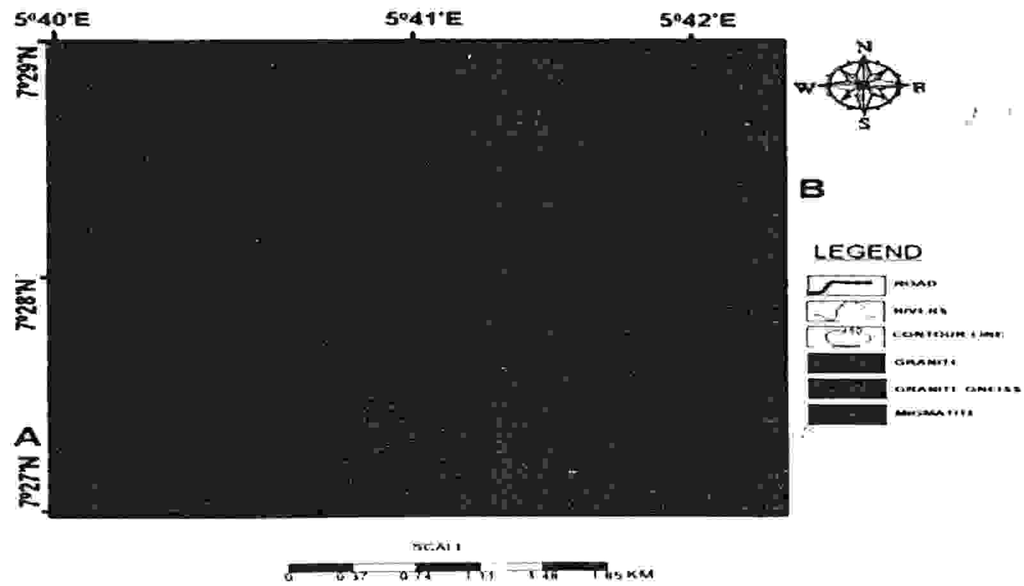


Figure 2: Geological map of the area of study

Material and Methods

The research was conducted through field work and laboratory analyses of samples collected from nine outcrops and additional samples from SUTOL Crushed Rock (an existing dimension stone industry) as control sample. Global Positioning System (GPS) was used to locate the coordinate of the study area. Sample preparation which involved rock coring and machining for mechanical and cutting to sizes for physical properties in accordance with the procedure given in International Society of Rock Mechanics, 1981 was strictly adhered. Parameters determined include; porosity. Unconfined (uniaxial) Compressive Strength, Tensile Strength, Water Absorption and Thin Section

Porosity

Three specimen of irregular form from a representative sample rock was prepared. The specimen mass was 50g and labelled A. The volume (V) was calculated from the average value of several caliper reading, the specimen was saturated by immersion for a period of an hour in a vacuum of less than 800pa. The specimen was removed and surface dried using moistens cloth with caution to ensure no fragments were lost. The mass of specimen plus container (B) was determined with an accuracy of 0.01g; the specimen was dried in an oven to constant mass at temperature of 105°C. After closure of container and cooling in a desiccator for 30 minutes, the mass (C) of the dry sample with container and lid was determined with an accuracy of 0.01g. The container with the 1.0g was cleared and dried and its mass (A) was determined with accuracy of 0.01g.

The porosity was calculated as follows:

Dry mass of saturated surface M_{sat}= B-A

Mass of dry specimen

Ms= C-A

Volume of the pores, Vv =

Msat- Ms

Density of water

Therefore, Porosity = n= Vv/VX 100%

Where V=Specimen bulk volume; Msat= Saturated mass; Ms= Saturated submerge mass;

A= Mass of sample only; B= Mass of sample plus container and C=Mass of dry sample plus container.

Unconfined (uniaxial) Compressive Strength

The test was carried out by loading a right spherical cylinder with the ratio of height diameter 2.5 and a diameter of approximately 50mm axially until the specimen fails. The cylinder sides was smooth end and freed of irregularities and straight end to 0.5mm over the full length of the specimen, the specimen diameter and the height of the cylinder was established to approximately 0.1mm. Specimen was tested at their natural water content and the maximum load of the specimen was in accuracy of 1% recorded in Newton.

The strength of the rock specimen is given by International standard of rock mechanics as uniaxial compressive strength (U.C.S)

$$= \frac{P\,max}{\pi * (\frac{D}{2})2}$$

where P_{max} is equal to the peak load on specimen (in N)

$$\pi * (\frac{D}{2})2$$

where D is the diameter of the average specimen (in m), the U.C.S is given in Mpa; while = Sectional area of specimen(m^2).

Tensile Strength of Rock Material

Specimen of cylindrical form was made from a representative rock sample with end faces at the right angle to the axis. The specimen diameter was at minimum 10 times the average grain size, the load on the specimen was applied at a regular rate until failure occurs.

Splitting tensile strength is given by the formula

$$t_s = 2p/\pi LD \text{ in (mpa)},$$

where t_s = (indirect) tensile strength in mpa; P equals the maximum load at the point of failure expressed in (KN); L is the specimen length represented in (m) and D is the diameter in (m) of the specimen.

Water Absorption

The specimen was dried in an oven (in the open container) at temperature of 105°C for twenty four (24hr) hours, after cooling and closure of the materials in a desiccator for half an hour.The mass (c) of the only sample with the container was calculated with an accuracy and precision of 0.01g. The specimen was saturated by in water (water immersion) in a vacuum of lesser in amount than 800pa for a duration of at least 24hours and weighed.

The water absorption is given / calculated as the percentage tape of dry mass as follow:

$$\text{Water Absorption} = \frac{Msat - ms}{Ms} \times 100\%$$

where M_{sat} is saturated mass and M_s is dry mass .

Thin Section and petrography

The procedures involve cutting, lapping, frosting, mounting, trimming and thinning. Rock chips were prepared using dynamo cutter or slab diamond saw to cut into uniform dimensional sizes from the rock specimen. The rock was trimmed to a specific shape by trimming machine to reduce the size considerably from size obtained from the diamond trim saw. Following the trimming process is the lapping process. It involves obtaining a flatten and smoothen surfaces of the rock samples attached to the glass through grinding. In this section, three phases were mandated. The phases entail rubbing the surfaces with different specification of caborundum 400,600 and 1000 respectively until a very fine rock sample was obtained. Frosting as a process involve grinding of the glass slide for surface roughen or flatten it out and roughen the surface for proper binding by Canada balsam.

At this stage the specimen was fixed on slab of the glass, prior to this the slab was also rubbed with 1000 caborundum and later canalda basalm (alradite) ensuring the removal of all air bubble. The mounted specimen and the slab were warmed and later allow to cool. The slide was further grinded again mildly to correct thickness of about 0.003mm. With care the slide is grinded with addition of ater and continuous viewing under microscope to ensure desired section. At the achievement of 0.003mm, excess gum and abrasive were removed via blade and thorough washing.

Clarity of the slide was increased under the petrographic microscope with addition of a glass cover slip to keep the thin section from damage. The thin sections were subjected under two lighting conditions using a petrographic microscope. These are crossed polarizers and plane polarized light. Plane polarized is a restricted light to a simple plane. With crossed polar, properties like twinning, isomorphism, extinction angle, zoning, isomorphism and dispersion were sorted for.

Results and Discussion.

Field Observation

Structural investigation of the study area was undertaken to select outcrops suitable for dimension stone production. In the study area, granite gneiss, granite and migmatite were mapped. Table 1 shows the locations, rock type, and elevation with their respective orientation. Sutol Crushed Rock Limited is an existing dimension stone industries where control sample was obtained for analysis.

Mechanical and Physical Properties of

Selected Rocks

Table 2 shows the results of the mean value obtained for physical and mechanical properties of the selected outcrops.

Table 1: Average Physical and Mechanical properties of Selected Rocks

Sample Rock type	Sample location	Porosity, n (%)	Uniaxial Compressive strength (Mpa)	Tensile Strength (Mpa)	Bulk Density, Q^B (kg/m^3)	Water Absorption, wa,(%)
1 .Granite gneiss	L2	0.64	149.71	14.99	2683.0	0.84
2. Granite gneiss	L3	0.88	131.53	15.33	2702.5	1.27
3. Granite gneiss	L6	0.54	136.32	16.46	2697.5	0.77
4. Granite gneiss	L1	0.56	140.10	14.18	2665.5	1.01
5. Granite gneiss	L9	0.73	145.55	15.56	2684.5	0.94
6. Granite	L8	0.72	142.82	16.91	2732.0	0.93
7. Migmatite	L7	0.73	137.38	14.20	2707.0	0.97
8. Granite	L5	0.66	130.51	14.65	2698.0	0.88
9. Granite gneiss	L4	0.73	139.30	16.23	2678.5	0.91
10. Control sample (Sutol quarry)	-	0.71	138.63	15.56	2686.0	0.93

Uniaxial Compressive strength (U.C.S)

Table 2 shows results obtained from laboratory for U.C.S and presented graphically in Figure 3. All sampled rocks from the nine outcrops examined and a sample control obtained from Sutol Crushed Rock (an existing dimension stone quarry, near the study area) showed a reasonable U.C.S in comparison to generalized properties of rock used as building stone, proposed by Winkler (1973). Winkler suggested value range for granitic rocks to be 96-310MN/m^2, which is in agreement with results obtained from laboratory. According to descriptive term from Geological Society Engineering group working party (1977), very strong rocks are classified between 100-200MN/m^2 .Therefore all rock samples under consideration are very strong and suitable for dimension stone.

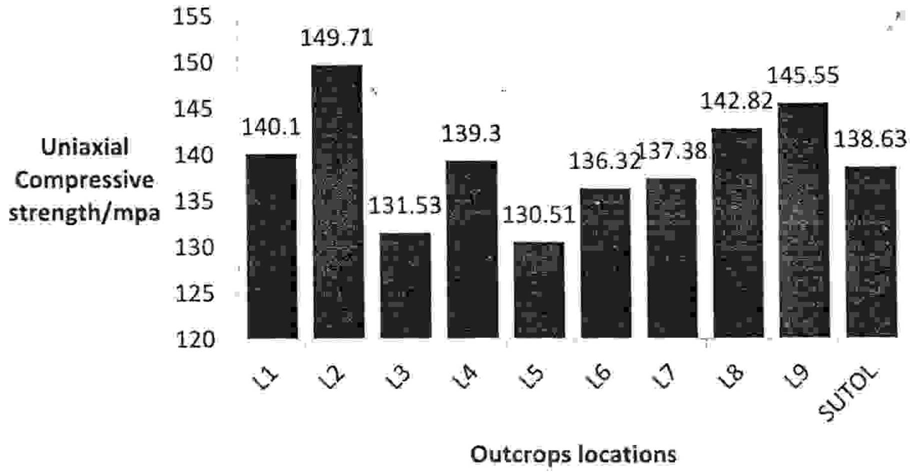


Figure 3: Uniaxial compressive strength per outcrop

The results also indicated L2 as the strongest rock type in the study area with UCA of 149.71N/M^2 follow by L9 with UCA 145.55 N/M^2 and L5 with 131.51N/M^2 as the least.

Tensile strength

The test is aimed at determining the splitting strength of rock materials. The tensile strength of rock samples examined exhibited reasonable result in agreement with ASTM specification standard for dimension stone and generalized properties of rocks used as building stone suggested by Farmer (1968). The result obtained correlated with Farmer suggested value range of 5-20MN/m^2, as outlined in Table 2 and represented graphically in Figure 4

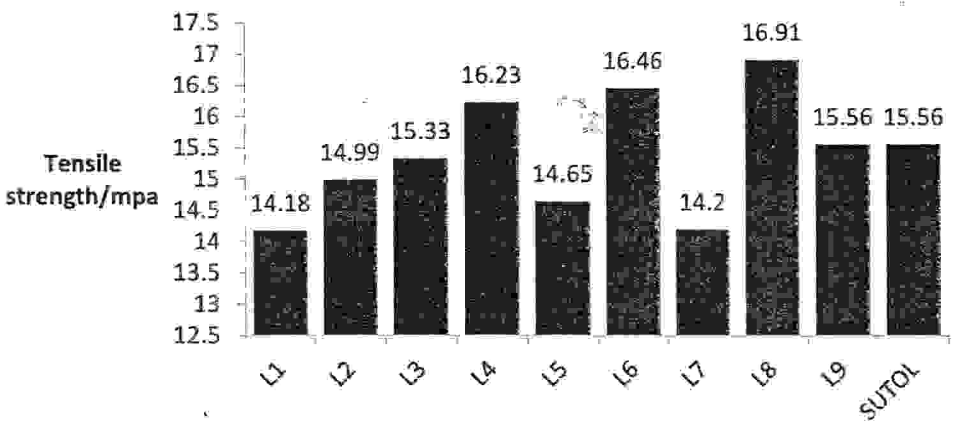


Figure 4: Tensile strength of selected rock samples

Porosity, Density and Water Absorption

The Water content or absorption shows an idea of strength of aggregates. It is the quantity of water stone can absorb under specific immersion condition. Stone aggregates with higher water absorption are tend to be more porous in nature and therefore generally considered not suitable except found acceptable on a pedestal of strength and hardness test. The flow of water would be less to penetrate non-porous stone type and therefore unable to cause significant damage (Sobhi, 2015). Porosity or low water absorption values generally exhibits rocks that are strong and durable. Water is one of the main agents of weathering. High absorption indicates more permeability which reduces dimension stone strength.

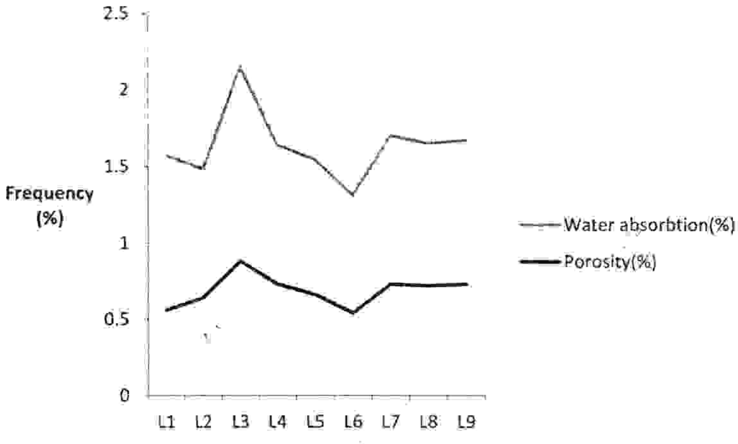


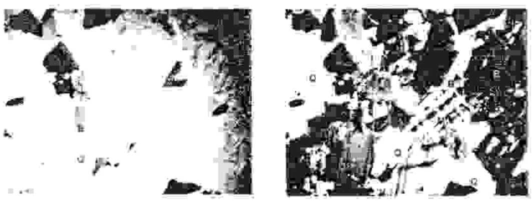
Figure 5: Water absorption and Porosity of selected rock samples

Figure 5 indicates that for the selected rock samples, water absorption is directly proportional to porosity. L3 exhibited highest water absorption of 1.27% and Porosity of 0.88% while L6 recorded the lowest of 0.77% and 0.54% respectively. The high values of water absorption and porosity of L3 makes it unsuitable for dimension stone. The bulk density (mass per unit volume) is a function of porosity and also mineral density of its composition or components. The determination of bulk density is needful to calculate the weight of the stone in wall or constructional element. As a standard, lower density with higher porosity and water absorption, the stone is likely to be less in durable for dimension stone production. and less stain resistant, and more prone to frost and salt attack.

Table 2: Estimated Modal Composition

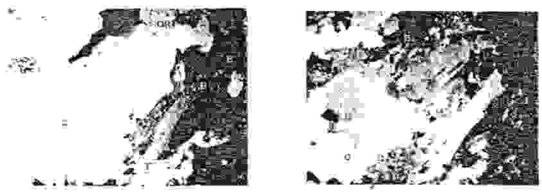
Minerals	L2	L3	L6	L1 L1	L9	L8	L7	L5 L5	L4 L4	Sutol
	1	2	3	4	5	6	7	8	9	10
Quartz	39%	38%	32%	99%	38%	32%	36%	34%	38%	37%
Microcline	38%	-	31%	-	28%	7%	3%	29%	31%	33%
Orthoclase	12%	16%	9%	-	6%	11%	6%	29%	6%	8%
Plagioclase	-	25%	12%	-	11%	25%	29%	19%	10%	9%
Opaque Mineral	3%	2%	4%	1%	3%	3%	3%	4%	3%	2%
Hornblende	-	1%	3%	-	2%	8%	4%	3%	1%	1%
Biotite	8%	18%	9%	-	12%	14%	19%	11%	11%	10%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Photographic Micrograph of Selected Rocks



(a) (b)

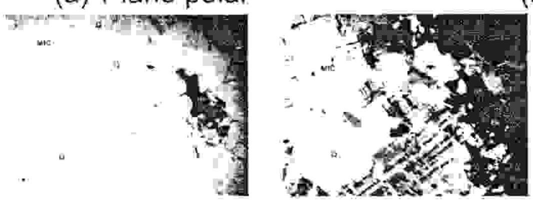
Plate I: Photomicrograph of L2



(a) b)

Plate II: Photomicrograph of L3

(a) Plane polar (b) cross polar



(a) (b)

Plate III: Photomicrograph L6

(a) (b)

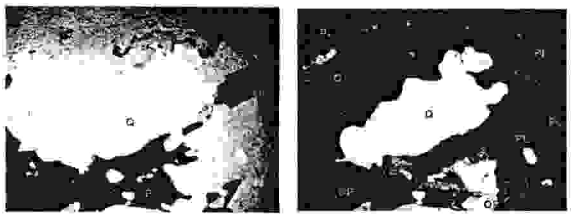
Plate IV: Photomicrograph L1

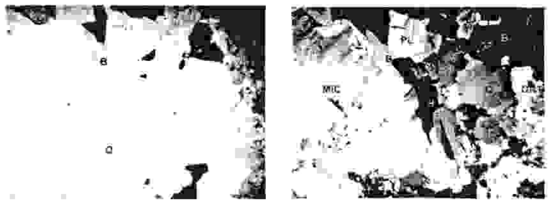
(a) Plane polar (b) cross polar

(a) (b) (a) (b)

Plate V: Photomicrograph of L9 **Plate VI: Photomicrograph of L8**

(a) plane polar (b) cross polar

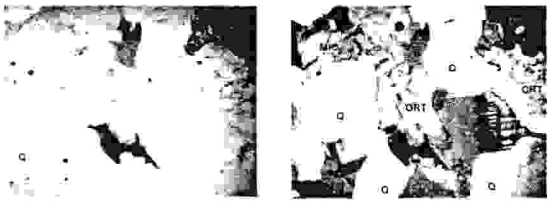




(a) (b) (a) (b)

Plate VII: Photomicrograph of L7 **Plate VII: Photomicrograph of L5**

(a) Plane polar (b) cross polar



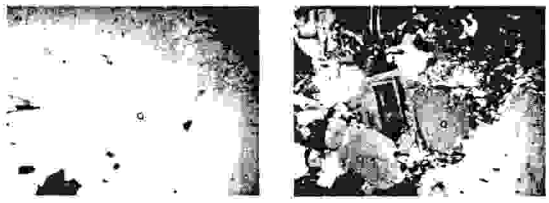


Plate IX Photomicrograph L4 **Plate X Photomicrograph Sutol sample**

(a) (b) (a) (b)

(a) Plane polar (b) cross polar

Note: B = Biotite, Q = Quartz, MIC = Microcline, OP = Opaque Mineral, H = Hornblende, ORT = Orthoclase, PL = Plagioclase.

Petrography

In assessing of a rock for use as a dimension stone, following the fracture characterization the next requirement is petrographic study to identify its mineralogy, grain size, texture, fabric and weathering states. All these processes are in turn determined by the geological processes which formed the rock. A good understanding of these processes and its corresponding effects will enable one to determine a rock's suitability, availability and consistent production. The petrography study showed that all the sampled rocks of interest (granite, granite gneiss and migmatite) revealed absence flaws and irregularities. In dimension stone production, flaws refers to the distribution of joints, microcracks, pattern and assemblage while irregularities (deleterious minerals) like mica, iron and sulphide inclusion will oxidize leaving stain on the surface. Soft minerals like pyroxene and olivine will erode and leave pitted surface. It is therefore imperative that any materials for dimension stone application must be free from flaws and irregularities for best marketability of finished product.

Conclusion

Dimension stone forms an attractive range of unique natural products that vary in their inherent characteristics. Mechanical and physical properties are noted to be key controlling factors in the dimension stone selection. Field observation and laboratory analysis conducted revealed that the area explored is dominated by medium to coarse grained granite, granite-gneiss and migmatite with granite-gneiss dominating the study area. An examination carried out to determine the mineralogical composition of rock sample which also provided information on weathering conditions and to determine micro-cracks and deleterious minerals in all rock samples indicated that they are void of flaws and irregularities. The summary of the physical and mechanical properties indicates that not all sampled outcrops are suitable for dimension stone production. The compressive strength and the tensile strength of sampled rock are relatively good according to standard specification from International Society of Rock Mechanics. Granite gneiss exhibited highest compressive strength, follow by granite and migmatite respectively. The granite gneiss exhibits better physical, mechanical and geological properties than the migmatite and granite. The observed high porosity and water absorption in L3 granite-gneiss will enhance permeability which will eventually reduce the strength of the dimension stone and make it incompetent for dimension stone production.

References

Department of Earth Sciences, Adekunle Ajasin University (AAU), (2016). Drainage Map of Supare Part of Owo Sheet 265 NW, Southwestern, Nigeria..

Farmer, I. W. (1968). *Engineering Properties of Rocks. E & FN Spon Ltd.* London..

Geological Society of Engineering Working Party, (1977). The Description of Rock Mass for Engineering Purposes. *Quarterly Journal of Engineering Geology* .10, 355-388..

Kogbe, C.A. (1979). *Geology of Nigeria.* Elizabeth and publishing house Lagos, Nigeria.

Lapedes, D.N. (1978). *Mc-Graw-Hill encyclopedia of the geological sciences.* McGraw-Hill.

Loudes, H. S, Selonen, O., & Ehlers. C. (2000). *Evaluation of Dimension Stone in Gneissic Rock-a Case History from Southern Finland. Engineering Geology* 58(2), 209-223.

Sobhi, N (2015). Geotechnical Assessment of Dimension stone Resources in Oman *International Journal of Chemical, Environmental and Biological Sciences,* Vol.3(6), 2320-2340.

Winkler, E. M. (1973). *Stone: Properties, Durability in Man's Environment. Springer,* Vienna.