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INVESTIGATIONS INTO AESTHETIC PROPERTIES OF SELECTED GRANITES IN SOUTH WESTERN NIGERIA AS DIMENSION STONES

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Abstract

The visual and aesthetic features of dimension stones affect both their marketability and applications in the construction industry. Assessment or evaluation of the aesthetic features is done by using the colour, texture and grain size, flaws and irregularities. South western Nigeria falls within the basement complex of Nigeria with abundant granites of various colours. Despite this, little exploitation has been undertaken. This study is carried out to determine some granite rocks' suitability for use as dimension stones. Dimension stones are classified in the International Smarket as single-coloured or multi-coloured. The colour is the major parameter that determines the price, besides other physical properties. Colour identification was done using the mineralogical composition and colour spectrum. Variation in colour was observed to be as a result of differences in the mineralogical composition of the granite rocks. Five of the granites investigated are single-coloured (Awo, Ewu, Supare and Ikere), while the Ore granites are multi-coloured and the texture of all the granites are either porhyritic or equi-granular. It was observed that none of the samples exhibits any form of microcrack. Scanining Electron Microscope (SEM) investigation shows that only the Awo granites have small percentage of sulphide mineral which restricted their use as external claddings.

Keywords: Aesthetics, Dimension stones, Granites, Mineralogy, Spectrum, Marketability.

1. Introduction

Dimension stone is any hard rock or natural stone specially cut, shaped to a specific size and/or polished. The term applies to natural rock quarried or cut for the purpose of blocks or slabs that meet specifications in terms of size and shape.

They are produced from "natural facing stone". Natural facing stone is a term representing a catalogue of rocks having fine colour and pattern, possessing the required strength and weather resistance, etc. The range includes granite, marble, sandstone, slate, quartzite, limestone, granodiorite, dolomite, serpentinite, gabbro, gneiss, etc. It is however noteworthy that not all natural facing stones qualify for the production of dimension stone [1]. Among the target features of any dimension stone, the visual and aesthetic features are of tremendous relevance because they affect both the marketability and application of stone. The visual and aesthetic features delineate the physical properties or appearance of the sample rocks and relate them to the globally acceptable standards. The major yardsticks for the assessment or evaluation of visual and aesthetic features are the stone colour, its texture and grain size, flaws and irregularities [2].

According to Nikolas et al. [3], granite rocks are differently coloured, varying between the white Norwegian granite and the black African one, coming in a wide range of various colors such as bluish, pearly-gray, cream, pink, red and green granites. Some of these are unique in colour and have a highly decorative value. Due to their aesthetic qualities revealed through processing, granites are suitable for making various decorative-functional products needed for the construction industry.

2. Geology of the Study Area

The study area lies in southwestern Nigeria as shown in Fig. 1. The granite rocks under study are located in Ekiti State (Ikere, Ewu and Ikole Ekiti), Ondo State (Ore), Osun State (Awo). The Nigerian Basement complex extends westwards and is continuous with the Dahomeyan of the Dahomey–Togo–Ghana region. To the east and the south the basement complex is covered by the Mesozoic–Recent sediments of the Dahomey and Niger Coastal Basins.

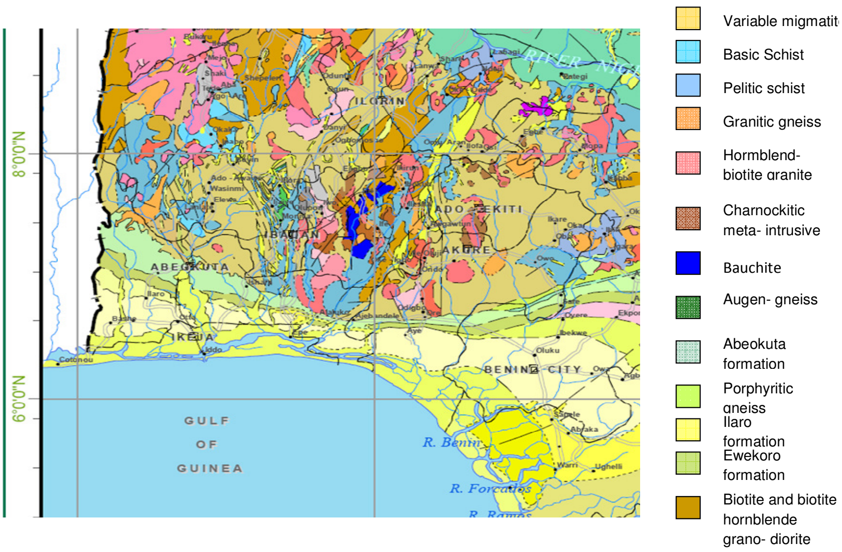


Fig. 1. Generalized Geological Map of South West Nigeria (Scale 1:4, 402, 912).

According to Kogbe [4], the Basement Complex rocks of Nigeria are composed predominantly of migmatitic and granitic gneiss; quartzites; slightly migmatised to unmigmatised metasedimentary schists and metaigneous rocks; charnockitic, gabbroic and dioritic rocks; and the members of the Older Granites, granodiorite and syenites. Migmatites are found to be abundant in southwestern Nigeria.

Ikole Ekiti outcrop is described as granite gneiss, where the granitic material takes the form of indefinite impregnations. At Ikere Ekiti the charnockites appear on a slightly weathered surface to have been broken up into xenolithic blocks by foliated porphyritic granite. On the fresh surface, however, the contact between the granite and the charnokite is often indistinguishable as the feldspars of the granite have the same greenish colour as the feldspars in the charnockite. This discolouration fades away from the charnockite and as the rock becomes weathered.

Ewu and Awo outcrops belong to charnockitic rocks which are composed of three main parts that may be observed on a single outcrop. They occur as discrete individuals bodies in the migmatite-gneiss complex. The centres of the charnockite bodies are more coarse-grained than the margin. The charnockites are composed of quartz, alkali feldspar, plagioclase, orthopyroxene, clinopyroxene, hornblende, biotite and accessory amount of opaque minerals like apatite, zircon and allanite. Randomly oriented inclusions of various rock types occur within the charnockite bodies. Finely foliated amphibolites inclusions are common in the charnockite occurrences at Awo Kogbe [4].

2.1. Colour

Dimension stones are natural and as such, have unique performance characteristics. Quite unlike other building and construction products, the stone colour can vary widely within the same batch; this emphasizes the unique nature and originality of each stone. Consequently, selection of stone should not be based on a single specimen, rather the complete range of colour should be viewed. Dimension stones in the world market are classified based on their colour as single- coloured stone and multi-coloured stone. Luodes et al. [5] noticed that for a stone to be classified as one coloured, stripes, inclusions or veins of a differing colour couldn't be accepted in a 'first grade' stone. However, if a stone is classified as a multi-coloured type, an appropriate variation of the colours is required, also in this case the colour and the design of the stone must be homogeneous so that the market can identify it as one and the same product.

The colour of a stone plays a significant role if a stone is to be exploited for the international market. Most of the export quality stone of the world ends up in polished slabs on floors, walls and tombstones. The colour here is far more important in the pricing of the stone than other physical properties. Predominantly, rare colour such as blue, yellow, pure white, zebra, gold and black are highly priced, whilst rocks of more 'ordinary' colour, such as pink and gray, obtain lower prices [6].

Other studies by Kogbe [4] on Older Granites showed that they occur as purple, pink, yellowish brown and dark grey because of the feldspar-rich component of the granite. Gneiss occurs as light or dark colour depending on the amount of mafic minerals in it.

Visual means can be used for the field identification of dimension stones but this is not enough for a detailed study as variations in individual abilities to identify colour can affect the results. To solve this problem, Luodes et al. [5] utilized polished rock sections to identify the colour of studied stones. The colour of dominant mineral represents the colour of the rock sample. Using polished sections for colour identification has an advantage over visual inspection as it gives the colour of dominant minerals in rocks under consideration.

In assessing the colour of a stone, care must be taken not to use a weathered sample. Luodes et al. [5] noticed that the true colour of a stone does not come out on the weathered surface and therefore the extent of weathering must be known and a representative sample of the stone to be used must be taken using core drill or drill-and-blast at few meters below the surface.

2.2. Textures and grain size

Rock texture has been defined as 'the degree of crystallinity, grain size or granularity and the fabric or geometrical relationship between the constituents of a rock' [7]. Waller and Ersoy [8] described textural characteristics as the geometrical features of rock particles such as grain size orientation, relative areas of grain and matrix (packing density) and compositional features such as mineral content, cement type and degree of cementation or crystallization and bonding structure. The texture (and/or grain size) of rock is/are a function of crystallization before, during and after crystallization or formation.

Plutonic igneous rocks are coarse grained (3-5 mm) owing to the delayed rate of cooling, being intrusive, containing predominantly feldspar, quartz and mica. This may have porphyritic texture.

Extrusive igneous rock has a fine grain texture (<1 mm) traceable to the quicker rate of cooling, e.g gabbro and basalt. This can also occur as porphyritic, amygdaloidal and vesicular texture, based on the condition of crystallization [9].

Hypabyssal igneous rocks are medium grained (1-3 mm). This type of formation occurs in sills and dykes where natural block shape is columnar, which makes it difficult to produce well-shaped block [9]. It was observed by [9] that porphyritic texture rocks are good material for dimension stone while amygdaloidal texture rocks, owing to the fact that they are weakening volcanic rocks, are rarely used as dimension stone. Dolerite, though is a porphyritic texture but is not commonly used as dimension stone in the United Kingdom because it rapidly oxidizes to dark brown because of its iron content. Daniel [1] noticed that the textural characteristics of rock significantly affect the mechanical performance of rock. To this effect, Brace [10] found that the strength of rocks was greater for finer grained rock, which suggests why basalt is worldwide accepted as flooring materials.

Many methods have been used to determine the texture of materials. X-Ray diffraction method was employed by [11] to investigate the texture of metals; synchrotron X-Ray were used by [12] for texture of polymers and biological materials; neutron diffraction was used by [13] for magnetic structure of steel, while

Transmission electron microscope was used by [14] for the grain rocks, and scanning electron microscope (SEM) is widely used for all types of rock grain [15].

The SEM has the advantage of automation, which makes the technique comparative inexpensive with accurate results [15]. The method involves examination of polished thin sections under a polarized microscope to determine the mineral constituents, grain size, grain shape, bonding structure, type and degree of crystallization (i.e. texture).

2.3. Flaws and irregularities

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 [16].

The presence of irregularirites such as iron, mica and sulphide inclusions will stain the surface of the product; therefore any material for dimension stone application must be free of all these flaws and irregularirities for marketability of the product Luodes et al. [5].

3. Materials and Methods

Samples were collected from each rock mass using blasting technique. Colour identification was done using the mineralogical composition and colour spectrum. In mineral composition, the colour of the dominant mineral is taken as the colour of the rock. In order to give a more detailed colour classification, colour spectrum was utilized. Here, the number of the peak as it was read from the graph of Number of colour against colour intensity gives the colour classification for any particular rock under study (Colour Spectrum).

The colour analyses using the spectrums of the colour composition gave the results in form of mean, mode and standard deviation of Red, Green and Blue colours in each granite, based on their respective position/location on the spectrum. One peak denotes one-coloured while multiple peaks denote multi-coloured. Thin section of each of the sample was done and petrographic analysis was carried out using transmitted light microscope. It was however observed that the mineralogy of some opaque minerals could not be identified using this method.

The SEM was therefore used in the examination of polished thin sections to determine the mineral constituents (including opaque minerals), grain size, grain shape, bonding structure, type and degree of crystallization (i.e. texture). The images obtained are produced for detailed analysis.

4. Results and Discussion

4.1. Texture

The texture exhibited by these granite samples under transmitted light microscope is as shown in Fig. 2(a)-(f). Figure 2(a)-(f) is a thin section of Ikole granite under transmitted light microscope. The crystal of alkaline feldspar, Quartz, Plagioclase and other accessories minerals are equi-granular. The texture of this rock is then defined as equi-granular texture.

The Awo granite as shown in Fig. 2(a) shows equi-granular texture as a result of equal grains of all mineral crystal that made up the rock. The Ewu granite as shown in Fig. 2(b) shows largest percentage of phenocryst with small equi-granular mica, quartz and plagioclase in the groundmass. It therefore exhibits porphyritic rock texture.

The Supare granite (Ivory-White) as shown in Fig. 2(c) shows a large crystal of alkaline feldspar (phenocryst) with small crystal of quartz, mica and plagioclase in the groundmass. This shows a porphyritic rock texture.

Ore granite sample, as shown in Fig. 2(d) is having equal grain ground mass of Quatz, mica and plagioclase but with a pronounced large crystal of alkaline feldspar (phenocryst). The presence of phenocryst gives the rock porphyritic texture.

Ikere sample as shown in Fig. 2(e) is another type of equi-granular texture rock. The crystals of the minerals are equi-granular only with a crystal of bubble resin noticed on the upper part of the thin section. Average grain size of the granite rocks studied was shown in Table 1.

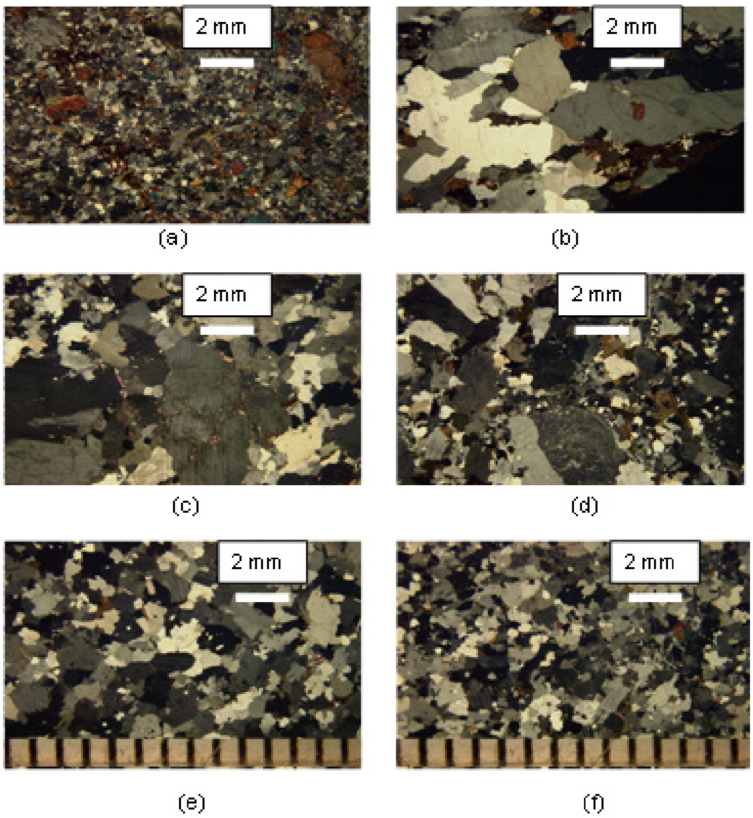


Fig. 2. Texture of Selected Granites in S/W Nigeria under Crossed Polarized Light.

Table 1. Average Grain Sizes of Selected Granites.

Granite location	Range of grain sizes	Average grain sizes
Ewu	1.00-8.40 mm	3.00 mm
Ore	0.56-3.70 mm	1.25 mm
Awo	0.37-1.50 mm	0.55 mm
Gold	0.37-1.67 mm	1.13 mm
Ivory-White	0.75-4.64 mm	1.39 mm
Zebra	0.56-1.50 mm	0.85 mm

4.2. Flaws and irregularities

From the thin section of all the samples of the granite studied as shown in Figs. 2(a)-(f), the possibility of occurrence of microcrack was critically observed for the entire granite samples. It was observed that none of the samples exhibits any form of microcrack. This was further investigated from the picture of the polished section and no microcrack was also noticed. It therefore means that all the rocks under consideration are free from microcracks.

The result of mineralogical analyses under scanning electron microscope is as presented in Table 2. The opaque minerals as observed under transmitted light microscope are subjected to SEM analysis to ascertain the nature of the mineral that made of the opaque mineral. Investigation of the Ikole granite showed the presence of Monazite and Zircon but the sample is free of sulphide mineral. The Ewu granite shows Amphibole as trace mineral with no sulphide minerals. Awo granite shows presence of Zircon, Ilmenite and Apatite. In addition to this, Pyrite was observed in some quantities. The Ikere granite shows only Zircon as trace mineral with no sulphide mineral present.

Table 2. Result of Scanning Electron Microscopic Analyses of Some Selected Granite Outcrops in S/W Nigeria.

Granite Location	Trace Minerals	Occurrence of sulphide
Ewu	Amphibole	Not identified
	Zircon 20 μm	
Ore	Ilmenite 30 μm	Not identified
	Apatite 100 μm	
	Zircon 10-20 μm	
Awo	Apatite 150 μm Ilmenite 20 μm	Pyrite 150 μm
	Hornblende 20 μm	
Gold	Zircon 50 μm	Not identified
Ivory-White	Cassiterite 50 μm	Not identified
	One grain of muscovite	
Zebra	Monazite 20 μm	Not identified
	Zircon 50 μm	

4.3. Colour

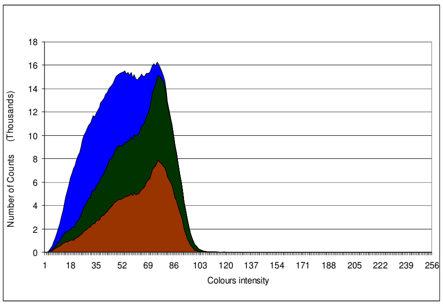
The variation in colour of the granites was as a result of the differences in the mineralogical composition of the granite rock types as shown in Table 3. Ewu granite shows dark-green colour. This was observed to be as a result of the presence of amphibole and the biotite that were altered to chlorite.

Table 3. Mineralogy of Selected Granite Outcrops in the Study Area.

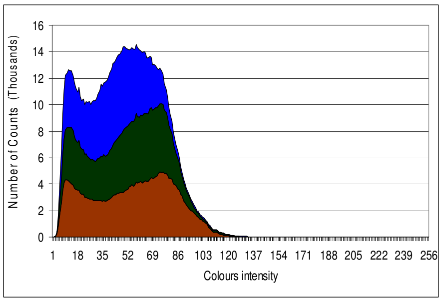
Rock Name	Ewu (Green)	Ore (Pink)	Awo (Black)	Ikere (Gold)	Supare (Ivory White)	Ikole (Zebra)
Quartz	< 20%	30% (Pool of Q2 in alkaline feldspar)	35% (<1mm in groundmass)	25%	37%	45% (strained,undulose extinction)
K-feldspar	40% (Minor alteration to sericite)	35%	5%	32% (2 – 3% alteration to sericite)	20% (20% alteration to sericite)	8%
Plagioclase	25% (Minor alteration to sericite)	10%	25% (Strained rare 3mm phenocryst)	35% (1 – 2% alteration to sericite)	40% (Altered up to 40% in places usually <10)	40%
Biotite	5% (In some area altered to green chlorite)	14% (Dark-Brown in colour)	15% (Dark-Brown turns to Light-Brown)	8%	2% (Light Dark-Brown)	6%
Amphibole	10% (Greenish in colour)	8%	15% (1-3mm Phenocryst and <1mm in groundmass)	Not identified	Not identified	1%
Titanite	Not identified	1%	Not identified	Not identified	Not identified	1%
Apatite	Not identified	Not identified	Not identified	Not identified	Not identified	1%
Monazite	Not identified	Not identified	Not identified	Not identified	Not identified	Not identified
Opaque	< 1.2%	1%	5%	Not identified	1%	Not identified

The Ore granite exhibits multi-colour (pink-black). From mineralogical analysis of this sample, the ground mass is predominantly black feldspar impregnated with abundant pink alkaline feldspar. The Awo granite exhibits black colour as a result of the presence of amphibole and biotite in largest percentage in the composition, while the Ikole granite is rich in quartz; plagioclase feldspar with biotite rich bond which gives it Zebra colour. The Supare granite is rich in plagioclase feldspar. As a result of unaltered nature of these minerals, the colour of the granite is Ivory white. Conversely, the Ikere granite has the same mineralogical composition as Supare granite, but Ikere granite has been altered to give Gold colour.

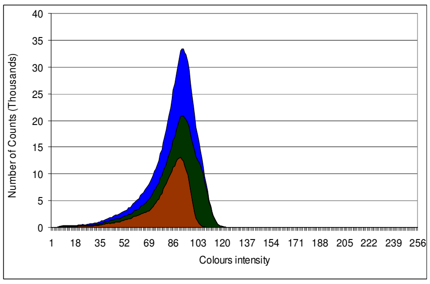
Colour identification using colour spectrum identified Ewu (Green), Awo (Black), Supare (Ivory-White) and Ikole (Zebra) as one coloured granites because of one noticeable peak in the colour spectrum while Ore (Pink-Black) is classified as multicoloured as a result of two peaks observed in the colour spectrum. Ikere (Gold) is not classified as multi-coloured based on the resultant spectrum because the second observed peak is as a result of the presence of some black mica in the sample which appears negligible. The colour spectrum is shown in Fig. 3. (a)-(f).



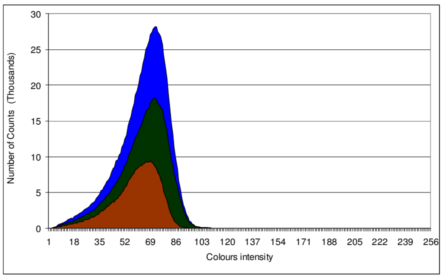
(a) Ikere (Gold)



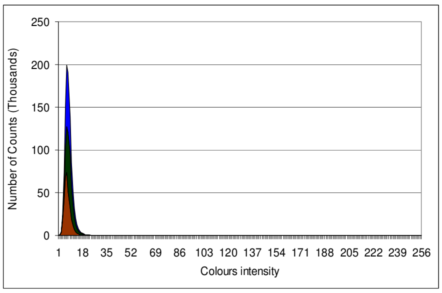
(b) Ore (Pink)



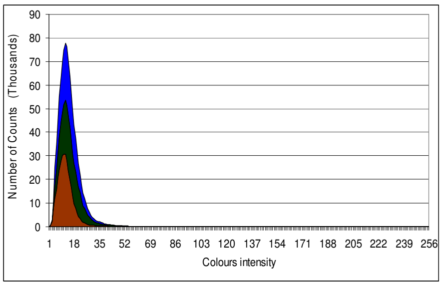
(c) Supare (Ivory-White)



(d) Ikole (Zebra)



(e) Awo (Black)



(f) Ewu (Green)

Fig. 3. Spectrum Showing the Colour Composition of Granite Outcrops in S/W Nigeria.

5. Conclusions

The aesthetic properties of granites are observed to be a significant factor controlling the marketability of rock for dimension stone production. From the observations made, it can be concluded that the granite rock types studied are ideal for dimension stone production based on colour, texture and mineralogical analyses.

From the detailed analysis conducted on the samples of the rock, the following conclusions were reached:

- five of the granites investigated are one coloured granite while only one is multi-coloured.
- the textures of the granite are either porphyritic or equi-granular.

- the mineralogical analyses conducted so far indicated that the rocks composed of some trace minerals like Zircon, Monazite and cassiterite that will add to the beauty of the stone after polishing.
- of all the granites analysed, the Awo granite is the only one that contains a little trace of sulphide, which thus limits its applications.

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