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GEOCHEMICAL ASSESSMENTS OF OWA-KAJOLA MARBLE, SOUTH-WESTERN NIGERIA.

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ABSTRACT
Extensive deposit of dominantly calcitic marble occurs around Owa-Kajola, Sheet 224 (Osi) NW, south-western Nigeria. Geological field mapping on scale 1:10,000 showed that the marble is intercalated with variably migmatized gneisses, pelitic to semi-pelitic schists, amphibolite, and quartzite, all of which are intruded by late- to post- Pan African granite and pegmatites. Geochemical investigations of the marble were done with a view to ascertaining its industrial applications for national development. Results show that the marble, for which there is no published work, is white, with well-interlocked sub-hedral to euhedral crystals, and medium- to coarse-grained. The physical properties also indicate that it can be used in the production of scouring soap, glass, tooth paste, rubber, polished stones, and lime. The relatively low MgO content against CaO, Slica-Alumina Ratio, Silica Modulus, and the Total Alkali content make the deposit adequate for cement production. The combined high CaO and the low P (<0.1%) and S (<0.5%) make the deposit applicable in the steel industry but the low dolomite content may disqualify it for being used as refractory lining in metallurgical engineering. The amounts of the components of marble such as CaO, MgO, SiO_2, P_2O_5, Fe_2O_3, Na_2O and K_2O are within the tolerable limits for the production of Portland Cement while the low levels of P(0-0.1), Pb (<5ppm), U (<0.4ppm) and other deleterious elements make such an industrial venture environmental-friendly.

Keywords*: Marble, Owa-Kajola, geochemical, applications, cement.*

INTRODUCTION
Lenticular marble deposit occurs around Owa-Kajola, Southwestern Nigeria (Fig. 1). Geochemical assessment of the marble was carried out in order to determine its potential uses. Although marble occurs extensively in Nigeria, e.g. Oreke (Adedoyin *et al*, 2012), Jakura (Harzell, 1956), Igbetti (Emofurieta, 1984), Igarra (Folami and Ojo, 1991), Ososo (Emofurieta, 1995), etc., the uses to which they can be put differ. The differences are largely geochemical; hence, adequate knowledge of such characters will help immensely in making decisions on how they can be effectively applied in the manufacturing industries. Fieldwork, desk study, and geochemical assessment are expedient in considering limestone for industrial purposes (Harrison, 1996). The essence of this study is therefore to asses such characteristics of Owa-Kajola marble and compare its properties with standard specifications for industrial application. This is because the industrial application of marble requires certain limits of some impurities.

METHODOLOGY
Geological mapping was carried out on scale 1:10000 and rock samples were taken. In the field, the marble was assessed at outcrop and hand specimen levels. Big, fresh, representative samples were chipped by the use of hammer and chisel. Twenty four samples were taken across the deposit. About 0.5 – 1kg of samples were hammer- milled, divided and pulverised to ≤40μ at the Department of Geology and Mineral Sciences, University of Ilorin and analyzed through Inductively Coupled Plasma Spectrometry and Atomic Absorption Spectroscopy at Activation Laboratory Laboratories (ALTLABS) in Ontario, Canada; and the Laboratory of the Geological Survey Agency of Nigeria, respectively. The essence of the geochemical analysis was to determine the major oxide content as well as the trace elements in the marble sample. See Table 1 for the mineralogical composition of the marble samples.

FIELD CHARACTERISTICS
The marble (Fig. 2) occurs and is well exposed about two kilometres south of Owa-Kajola to the east of a major quartzite hill. It lies in a low but undulating terrain being bounded by Latitudes 08^0 13'53"- 08^0 23' 36"N and Longitudes 05^0 05' 11" $05^0$10'40"E. The area can be reached through Ilorin-Omu-Aran-Oro-Ago-Owa-Kajola and Lokoja-Kabba-Omu-Aran-Oro-Ago-Owa-Kajola roads.
The deposit is about 57km from Omu-Aran, 40km of which is paved. It is an elongate body which stretches northerly and run parallel to the quartzite body for over two kilometres before disappearing under the quartzite hills. It re-appears again as a major in-lier in the valley between two quartzite ridges. The deposit exhibits irregular width along strike. The marble occurs as a lenticular or podlike body with a general N-S strike length covering about $3.5km^2$. It occurs in association with other rock units with which it is inter banded. The dominant rock types include migmatitic gneiss of tonalitic percentage (Adedoyin et al, in prep) amphibolite, calc- silicate gneiss, mica schist, quartzite (member of the Omu-Aran-Dyon Hills) and pegmatite of Precambrian (>500 my) age. This area is part of the Oro formation (Oluyode et al, 1988) which is northern continuation of the Ilesha Schist Belt (Adedoyin et al, 2012), a component of the basement complex of SW Nigeria. The deposit is closely and structurally related to the Oreke dolomitic marble deposit (Adedoyin et al, op cit). Studies at outcrop and hand sample levels show that the marble vary in color from light grey to white. Sometimes, bands of the two varieties are seen together. The grey color is due to contamination from organic materials. The grain size is medium- to coarse-grained, with occasional sugary textures in the coarse varieties. Muscovite, graphite, tremolite and sulphide are accessory minerals identified in

the marble. The marble, like its Oreke counterpart, is strongly folded and jointed but the F_2 fold that is present in Oreke marble was not identified in the latter. The jointing and its low hardness (H=3) makes blasting easier.

RESULTS AND DISCUSSION

The marble samples show variable crystal sizes but the color is generally white (Fig. 3). In hand specimens some samples show streaks of graphite, depicting mineral elongation lineation under tectono-thermal deformation. Under the microscope, calcite ($CaCO_3$) is the dominant mineral constituent (Fig. 3), constituting more than 71% in all the samples while dolomite ($CaMgCO_3$) is about 22%. Quartz (SiO_2) varies between 2.5 and 5%. Tremolite-actinolite and muscovite are about 1.5% while sulphide (probably chalcopyrite) is about 0.5%. The crystals are dominantly subhedral. Quartz occurrs as tiny anhedral crystals, which are embedded between the carbonate crystals. Under the microscope, it is strongly pleochroic from colourless to light blue.

Muscovite is only prominent in areas with close proximity to the pegmatite. Occurrence of graphite depicts a sedimentary protolith for the marble. The elongate geomorphology of the body points to deposition in a N-S trending ancient inter-cratonic basin while the disappearance of marble exposure under the quartzite body, only to reappear as a major inlier in a major valley within the quartzite to the west signifies that the marble is overlain by the quartzite.

The geochemical result (Table 2) shows that the marble deposit is highly calcitic with calcium oxide ranging between 47.2% and 53.6%. This shows that the $CaCO_3$ content of the marble is high, in the border of 80%. High-grade limestones possess approximately 56% CaO. The silica content varies between 2.61 and 5.5% while the iron oxide is between 0.21 and 0.42%. The high loss on ignition attests to the high $CaCO_3$ and that corroborates the high calcite content over dolomite. All the samples show that CaO content is greater than 75%. The MgO content is low (0.44%-1.72%) while the average Na_2O and K_2O contents are 0.21 and 0.25, respectively.

INDUSTRIAL APPLICATIONS

For cement production, $CaCO_3$ content must not be less than 75% while silica should be equal or less than 4% only 30% of the sample show silica in excess of the acceptable standard but this is made up for by the much lower silica content of the remaining 70%. The average silica content for the marble deposit are within a tolerable limit (average=3.51%). Total alkali is 0.46% which is much lower than the acceptable maximum level of 0.84%. Average Fe_2O_3 is much less than 2.5%, the maximum required for cement production. Total average MgO and P_2O_5 are lower than the required maximum of 5% and 1% respectively (See Table 3). High MgO content increases the grinding cost of marble (Andrew and Vast, 1993). Consideration of the marble for cement production is further enhanced by certain factors such as the Silica Modulus (Table 4), proximity (approximately 7km) to paved roads and low-relief, relatively flat, expansive land, upon which a cement factory can be built. The exposure of the marble on the surface indicates that the overburden is zero to shallow. The overburden ratio is therefore less than the 1:3 standards required for cement manufacture.

Owa-Kajola marble is also appropriate for use as flux in the steel industry. This is because the stipulated CaO content is high enough; the phosphorous is less than 0.1% and sulphur is less than 0.5%. These are the requirements desired for marble to be used as flux in the steel industry. However, the low dolomite content may disqualify the marble from being used in metallurgical engineering especially as refractory lining in the high temperature furnace. On the other hand, the MgO content is also low enough for the marble to be used in the production of carbide.

The brilliant lustre, especially of the white variety will make the rock yield beautiful polished stone for table tops and other accessories, but presence of pyrite may cause tarnish on exposure to weather. The marble will also find uses as raw material in the production of toothpaste, soap, paint, scouring powder, animal feeds and rubber. Investing in the marble industry will be enhanced by the availability, easy accessibility to power supply an existing dam, perennial rivers and co-operation from the host communities. Investment in the marble deposits will not only be of financial gain to government but will also reduce the high rate of joblessness s and invariably reduce the increasing rate of anti-social vices among the youths.

CONCLUSIONS

Results of field and laboratory work carried out on Owa-Kajola marble deposit show that it is hosted by gneisses and metasediments, extensive, easily accessible and possesses qualities which make it usable in a vast number of industrial applications, especially in the production of Portland cement, for which other neighbouring deposits cannot be used. Good accessibility and availability of other factors of industrialization also support investing in the marble deposit, for which there is cheap labour as well as local and international markets.

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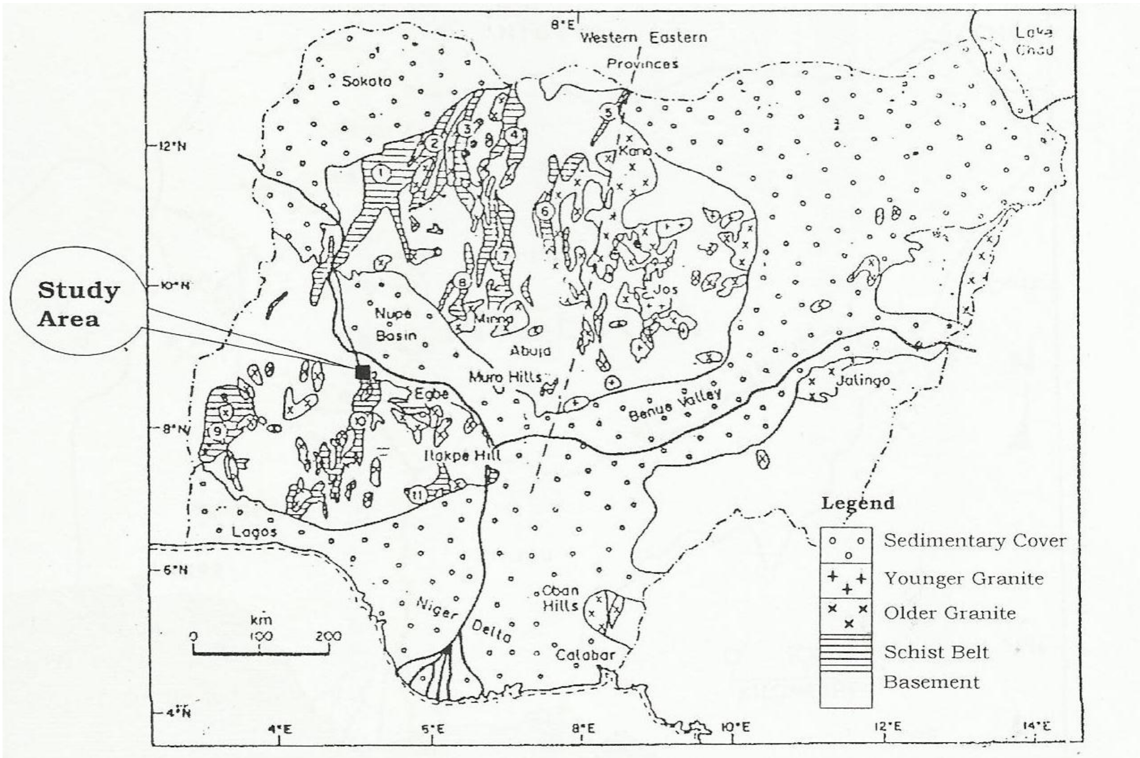

Fig.1: Location of the study area within the Schist belt terrain of Nigeria.

Fig. 2: Geological Map of the study area

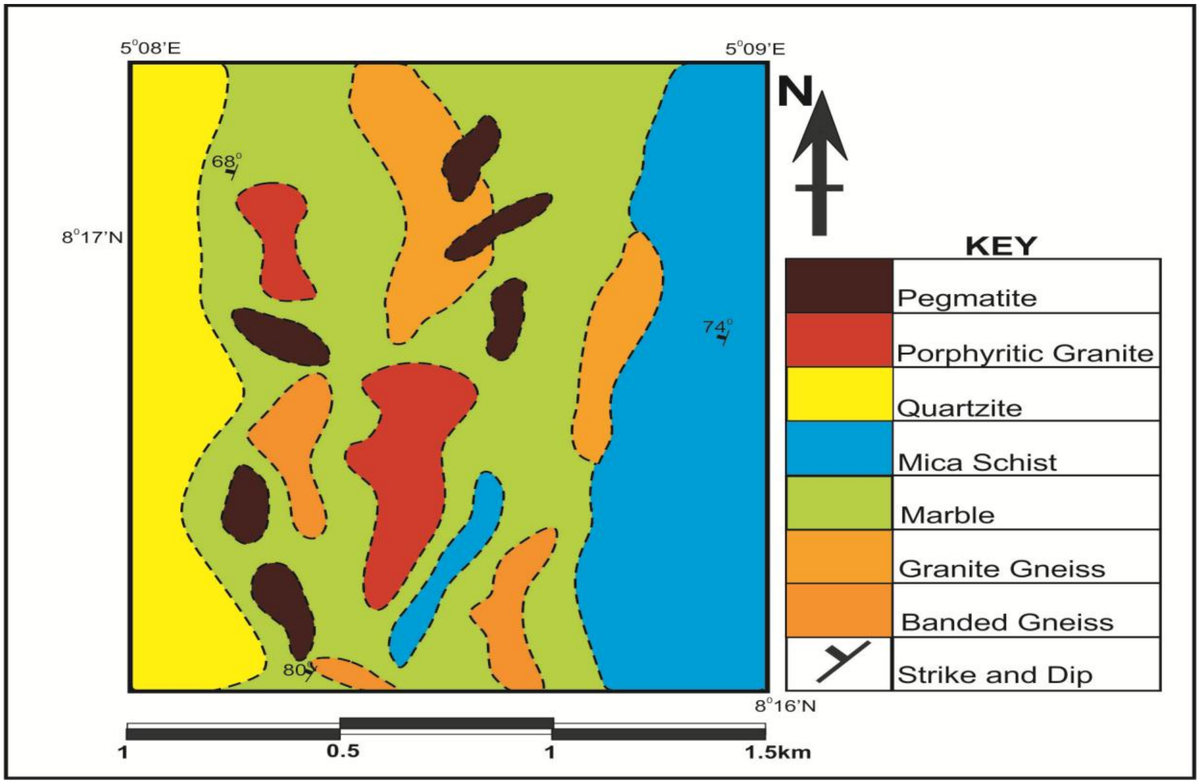

Fig. 3: Sparkling white marble lumps ready for haulage.

Table 1: Mineralogical Composition

Mineral	Average (%)
Calcite	71
Dolomite	22
Quartz	3.5
Tremolite	0.5
Muscovite	1
Sulphide	0.5
Graphite	1.5

Table 2: Major Oxide Geochemical Result

Sample	SiO_2	Al_2O3	Fe_2O_3	CaO	MgO	P_2O_5	TiO_2	K_2O	Na_2O_3	MnO
Oki	2.61	2.40	0.35	52.16	1.72	0.15	0.03	0.06	0.08	0.01
OKii	2.15	0.47	0.21	53.3	0.46	0.04	0.02	0.12	0.06	0.01
OKiii	1.80	1.26	0.31	50.96	2.22	0.16	0.04	0.22	0.10	0.01
OKiv	3.16	0.52	0.28	48.1	1.58	0.07	0.03	0.08	0.04	0.01
OKv	5.36	0.98	0.42	49.7	0.72	0.22	0.02	0.18	0.06	ND
OKvi	2.18	1.24	0.34	51.6	1.55	0.18	0.02	0.06	0.12	ND7
OKvii	4.6	2.421	0.28	50.7	5.68	0.20	0.04	0.20	0.06	0.01
OKviii	1.80	0.48	0.27	49.3	3.26	0.18	0.04	0.1	1.11	0.01
OKix	4.20	0.66	0.34	47.2	0.48	0.15	0.02	0.07	0.04	ND
OKx	5.5	1.28	0.24	52.3	1.46	0.12	0.03	0.04	0.13	ND
OKxi	2.38	2.38	0.33	51.6	2.52	0.16	0.2	1.21	0.14	0.01
OKxii	3.66	1.37	0.22	53.6	3.44	0.07	0.03	0.11	0.12	0.01

Table 3: Standard components of Portland cement

Components	Acceptable Limits	Obtained Values
CaO_3	≥75%	84.3-95.7%
SiO_2	≤4%	3.51%
MgO	≤5%	0.44-0.72%
$Fe_2\ O_3$	2.5%	0.21-0.35
$P_2\ O_5$	≤1%	0.04-0.22%
Total Alkali	≤0.8%	0.29%
Silica Modulus	1.5-4%	2.46%
Alumina-Iron Ratio	1.4-3.5	5.1

Table 4: Silica Modulus

Sample	SiO_2	$Al_2\ O_3$	$Fe_2\ O_3$	Silica Modulus
Oki	2.61	2.40	0.35	0.95
Okii	2.15	0.47	0.21	3.16
Okiii	1.80	1.26	0.31	1.15
Okiv	3.16	0.52	0.28	3.95
Okv	5.36	0.98	0.42	3.83
Okvi	2.18	1.24	0.34	1.38
Okvii	4.6	2.421	0.28	1.70
Okviii	1.80	0.48	0.27	2.40
Okix	4.20	0.66	0.34	4.20
Okx	5.5	1.28	0.24	3.62
Okxi	2.38	2.38	0.33	0.87
Okxii	3.66	1.37	0.22	2.30