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Geological setting, compositional features and economic evaluation of marble deposits around Alaguntan, southwestern Nigeria

Geološka lega, značilnosti sestave in gospodarska ocena nahajališč marmorja v okolici Alaguntana v jugozahodni Nigeriji

Olugbenga Okunlola[1,*] and Hafsat Muritala[1]
[1]University of Ibadan, Department of Geology, Nigeria
*Corresponding author. E-mail: gbengaokunlola@yahoo.co.uk

Abstract

Marble, occurring up to 5 000 m long and up to 30 m thick lenses within gneisses and other metasediments in Alaguntan area, southwest Nigeria, have been studied with the aim of investigating their compositional and industrial characteristics .

From X-ray Diffraction studies, the marble is composed dominantly of dolomite (95.67 %) with minor amount (up to 1.95 %) of calcite, tremolite, quartz, and actinolite. Chemical analytical results using Inductive Coupled Plasma Mass Spectrometry (ICPMS) confirm the mineralogical dolomitic nature with Ca^{++} /Mg^{++} (1 : 1.39) and average $CaMg(CO_3)_2$ content of 95.69 %.

Physical and mechanical tests reveal that the marble samples have effective porosity between 0.51 % and 0.76 %, hardness according to Mohs's scale is 3.0, compressive strength is between 87.53 MPa and 92.72 MPa, confirming their suitability for construction purposes. Further chemical and agronomic tests show the milled marble samples are useful in soil acidity neutralizations and in metallurgy for production of refractory lime and chemicals, manufacture for production of chemicals.

Key words: Nigeria, marble, composition, industrial use, deposits

Izvleček

Marmor, ki ga najdemo v lečah, dolgih do 5 000 m in debelih do 30 m v gnajsih in drugih metasedimentnih kamninah na območju Alaguntana v jugozahodni Nigeriji, smo preučevali za oceno značilnosti njegove sestave in industrijske uporabnosti.

Preiskava z rentgensko difrakcijo pokaže, da sestoji marmor pretežno iz dolomita (95,67 %) z majhno količino (do 1,95 %) kalcita, tremolita, kremena in aktinolita. Rezultati kemične analize z induktivno vezano plazemsko masno spektrometrijo (ICPMS) potrjujejo mineraloško ugotovljeno dolomitno naravo kamnine z razmerjem Ca^{++}/Mg^{++} 1 : 1,39 in povprečno vsebnostjo $CaMg(CO_3)_2$ 95,69 %.

Fizikalni in mehanični preizkusi kažejo v vzorcih marmorja efektivno poroznost med 0,51 % in 0,76 %, trdoto 3,0 po Mohsovi lestvici in stisljivo trdnost med 87,53 MPa in 92,72 MPa, kar potrjuje njihovo primernost za uporabo v gradbeništvu. Nadaljnje kemične in pedološke preiskave pričajo o uporabnosti mletega marmorja za nevtralizacijo kislosti tal, v metalurgiji za proizvodnjo ognjevzdržnih snovi in za proizvodnjo kemikalij.

Ključne besede: Nigerija, marmor, sestava, industrijska uporabnost, nahajališča

Introduction

Marble deposits globally, have attracted reasonable economic interest and have been classified under six main general areas of applications based on application in industry namely: metallurgical, chemical, environmental, constructional, and agricultural [1, 2].

Metamorphosed carbonate deposits (marbles) in Nigeria generally are found within the eastern margin of the Nigerian Schist belts. (Figure 1) The Schist belts occupy generally N-S trending troughs infolded into the migmatite-gneiss-complex and are best developed in western half of the country [2, 3]. Recently, we have identified some metamorphosed carbonate deposits (marble) in Alaguntan area in the southwest of Nigeria. The deposits are being studied to unravel the geologic setting, mineralogical variation and chemical quality with a view to find the potential industrial application of the marble. Marble occurs as lensoidal body similar to other prominent marble deposits in the eastern margins of the Nigerian Schist belt around Igarra, Kwakuti, Ubo, Igbetti, Osara, Jakura and Burum[4].

Materials and methods

Field sampling and sample preparation

About 25 fresh representative rock chips of white and grey marble samples and the selected representative host rocks were collected from

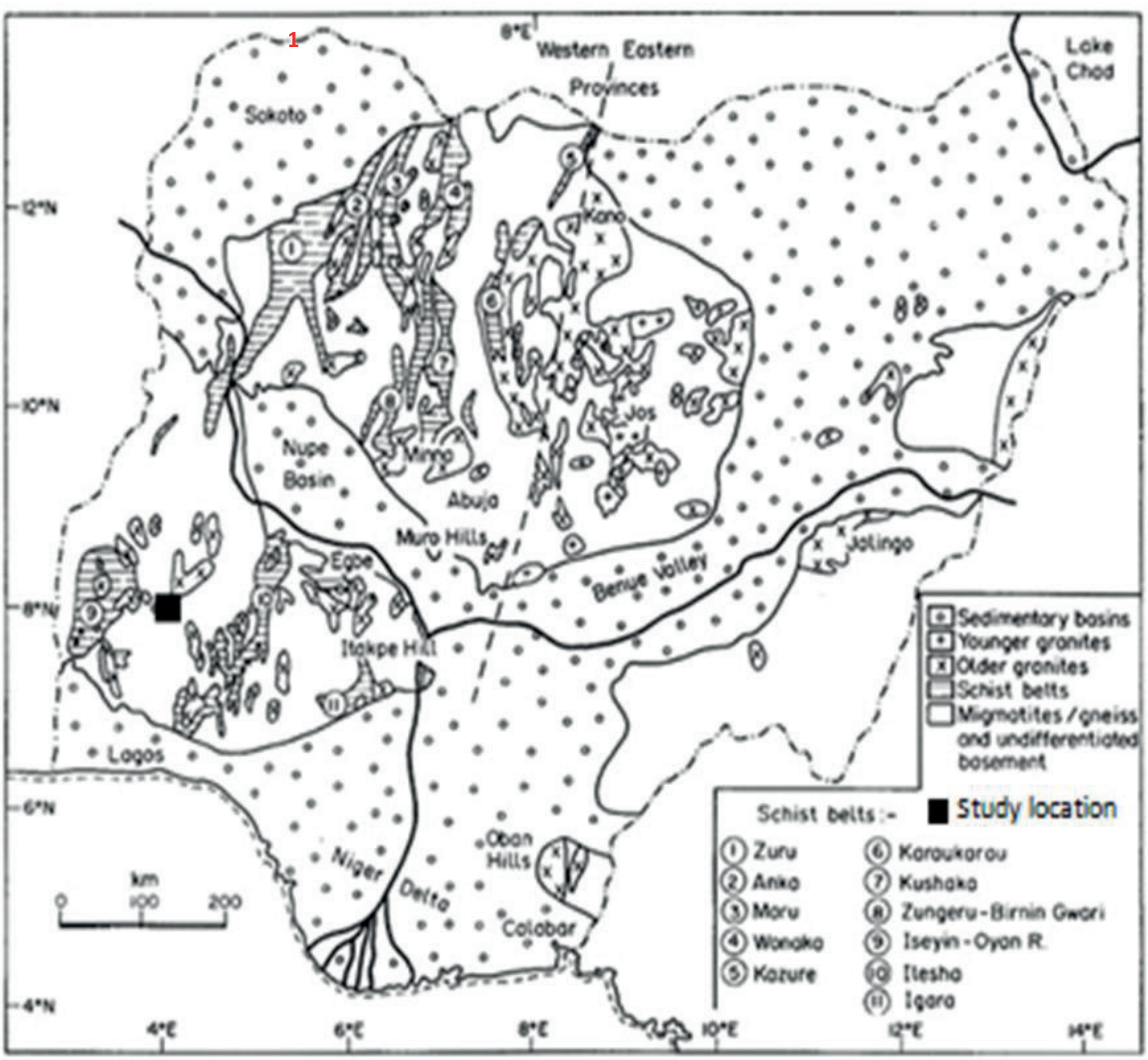

Figure 1: *Geological map of Nigeria showing the Schist belts (after Turner 1983).*

different portion of the mapped area around Alaguntan. For sample preparation, 100 g from each of the representative marble sample were pulverised below 100 µm for the mineralogical, chemical and agronomical studies.

Thin sections of representative samples of associated host rocks were studied microscopically. Mineralogical analyses were also carried out using X-ray diffraction (XRD) and chemical analyses by Inductive Coupled Plasma Mass Spectrometry (ICPMS) analytical techniques. Both analyses were carried out in Acme Analytical Laboratories Vancouver, Canada. The XRD was done using Siemens D500 diffractometer.

Effective porosity and bulk density were determined by immersing an oven dried sample with the mass about 200 g in water for 24 h, till it attains a constant mass. This was re-dried after removal and weight again. The fraction increase in mass relative to the original mass of sample was determined. The ratio of the original sample mass and water volume change was calculated as the Bulk density.

Loss on ignition was determined by heating the weighted samples in a furnace and the temperature set at 1 000 °C and fired for an hour. After an hour, the furnace was switched off for 30 min, after which the samples were packed from the furnace into a dessicator, covered to air tight and then allowed to cool in the dessicator for an hour, another measurement was taken to get the mass loss. All the physical and geotechnical tests on the marbles were carried out in the Department of Geology, Federal University of Technology, Akure, Nigeria.

Agronomical characteristics/parameters determination was done at the Institute of Agricultural Research and Training, Ibadan, by mixing 50 g of acidic soil samples of pH (5.9) collected within the University of Ibadan, Ibadan, premises with 20 g of 90-mesh Alaguntan marble samples and 50 ml of distilled water added for a period of 8 weeks. Major and minor soil nutrient were determined using Atomic Absorption Spectrometry (AAS) and Flame Photometry. Organic matter content, Cation Exchange Capacity, Conductivity, Base saturation were further assessed. The tests were carried out at the soil laboratory, Department of Agronomy, University of Ibadan.

Results and Discussion

Geological setting

The Alaguntan marbles and associated gneisses are part of the Precambrian basement rocks of Nigeria, which is situated in the pre-drift mobile belt that separate West Africa and Congo Cratons [5]**.** On the basis of structural, lithostratigraphic and geochemical data, and available geochronology data, the Precambrian basement complex of Nigeria have indicated polycyclic nature with multi orogenic events. The rocks of Nigeria have been regionally classified into three major groups namely: Migmatite Gneiss Complex, Metasedimentary and Metavolcanic rocks (Schist belts), and Pan African Granitoids / Older Granites [2] (Figure 1).

The schist belts show distinctive petrological, structural and metallogenic features. The schist belt is dominated by low grade metasediments, remnants of reworked supracrustal cover during the Pan African Orogeny. The schists belt in the southwest include those of the Iseyin, Igara, Egbe-Isanlu, Ife-Ilesha areas [2, 5, 6,]. The centrally located ones include the Lokoja-Jakura, and Toto-Gadabuike belts [4, 7, 8]). Some of the belts have also been identified in the southeastern parts of the country though not shown in Figure 1 [9, 10].

In the area of study, outcropping rocks include: Hornblende biotite gneiss, Granite gneiss, Quartzite, Calc silicate gneiss, Marble and Quartz veins (Figure 2). The marble outcrops are positioned within the granite gneiss (Figure 2).

Hornblende biotite Gneiss is the most common rock type mapped, it covers the northern and northeastern parts of the studied area. The extensive outcrops occur as low lying unit, well foliated with preferred orientation of the platy biotite and prismatic hornblende. Thin section studies show the samples are made up of quartz (20 %), biotite 17 %, plagioclase 30 %, hornblende 20 %, and minor amount of muscovite 3 %.

The Granite gneisses occupy the southern and southwestern part of the studied area. It is found as low lying outcrops at Aloba not far away to Alaguntan village. It is medium grained in texture with irregular bands rich in biotite and hornblende and are found to alternate with thicker bands richer in felsic minerals. The mineral assemblages includes: quartz 40 %, biotite 20 %, microcline 17 %, plagioclase feldspar 10 %, and muscovite 10 %.

Quartzite outcrops occur sub parallel to the calc-silicate rock and marble bodies. They occur as elongated lensoidal bodies up to 30 m thick and about 1.5 km long parallel to the calc-silicate rock with a displacement along shear zones between the marble bodies. The contact with the marble is tectonic and is marked by the development of silicified mylonites. Mineral composition is dominantly quartz with accessory muscovite mica

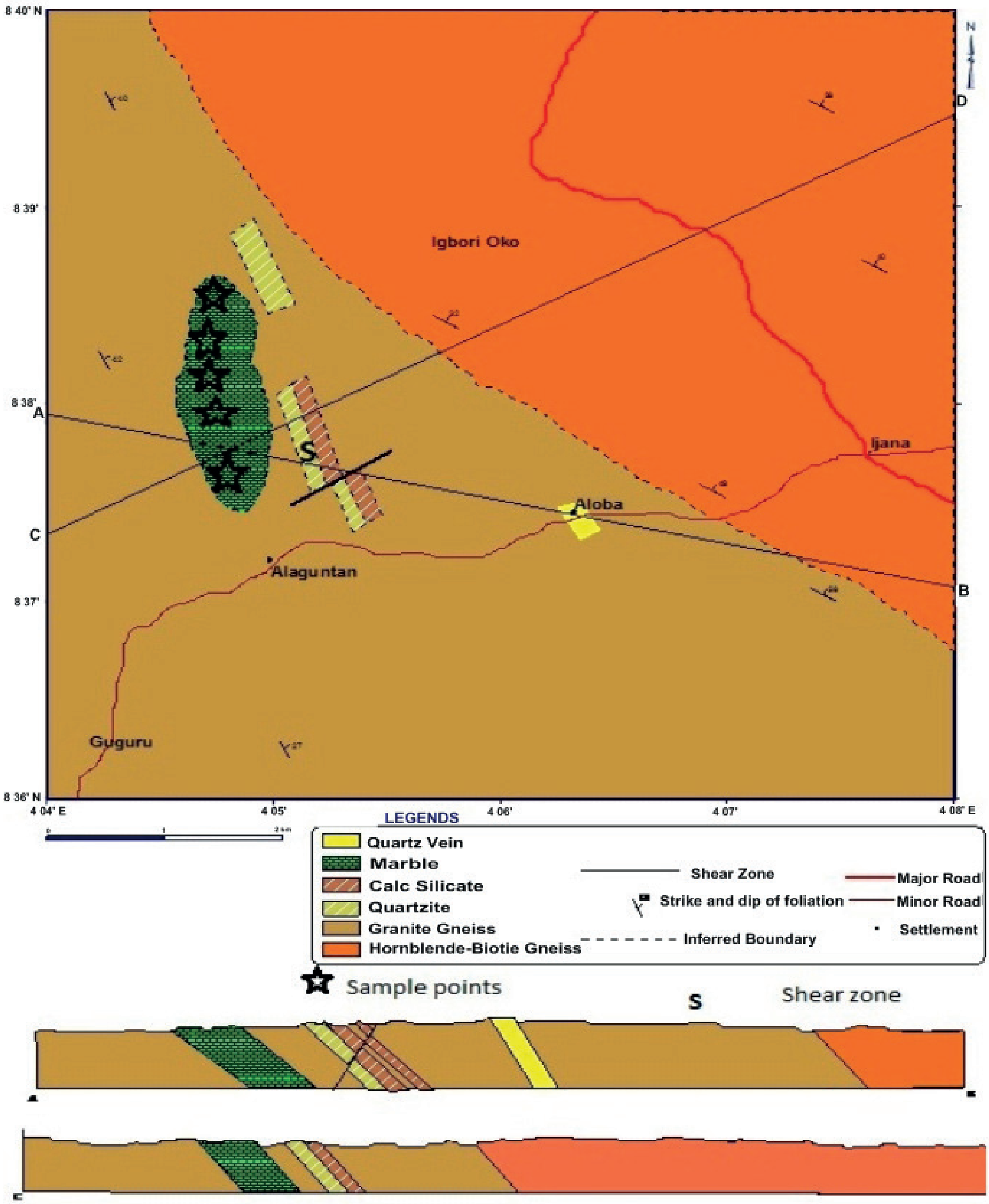

Figure 2: *Geological map of Alaguntan area.*

Calc-silicate gneiss occurs parallel to the marble bodies and quartzite.They are Dark grey in colour, medium grained and foliated.

Mineralogical constituent from XRD indicates it is composed mainly of dolomite (50 %), tremolite (26 %), quartz (2 %), calcite (10 %) with minor amounts of magnesian spinel and graphite 2 % (Figures 3, 4, Table 1).

The marble occurs in the western part of the study area. It occurs as lensoid bodies up to 2 000 m along the strike, 500 m wide and it crops out about 500 m wide around Alaguntan village. Color varieties ranges from pure white found at the southern part (Figure 5) and light to grey colour which occurs in the northern part of the occurrence. The colour variation may be due to the presence of tremolite and the magnesian spinel in places. The grain sizes vary from fine grain to medium grained (1–2 mm). From XRD analysis, the marble is dominantly dolomite (95.4 %) with minor amount (below 3 %) of quartz, calcite and tremolite, while magnesian spinel, as trace mineral is less than 1 % (Table 1).

The association of marble with 'S' type granitoids and gneisses of metasediments (greywacke) origin suggests that the gneisses were reworked from ancient sedimentary sequences, as earlier suggested by [11] for the Burum marble in central Nigeria. The location of the marble at the eastern fringe of Iseyin – Oyan belt suggests that they are relict inliers of carbonate rich and epicontinental transgressive, silicic, arenaceous sequences. These were metamorphosed during a later tectono-metamorphic cycle and accompanied by shearing/mylonitisation probably in the Pan African, resulting in the final formation of carbonate sequences.

The mineralogical composition shows that the marble is mainly dolomite (average 95.4 % up to 96.5 %) with minor amount (below 3 %) of calcite, colemanite, tremolite, actinolite, and quartz while the calc silicate associated with the marble contains dolomite (50 %), calcite (2.5 %), tremolite (19 %), quartz (25 %) magnesian spinel (1.8 %) and graphite 1.5 %) (Table 1).

Samples of marble contain average MgO 23.08 % and CaO 32.01 %. Average silica (SiO_2) content is 2.81 %. The average of alkalis: NaO, K_2O and Al_2O_3 are all lower than 0.1 % while Fe_2O_3 content is slightly greater than 0.1 % but not more than 0.4 % (Table 2). TiO_2, $P_2 0_5$ and Cr_2O_5 were not detected in any of the samples. Ti, P and Cr oxides have staining influences (Ofulume, 1993), and the absence in the samples account for relatively high whiteness of the marble. These analytical results are comparable to values for other Precambrian marbles of Nigeria [2, 12, 13] and those for Shapfell, United Kingdom [14] (Tables 3, 4, 5). Trace element Pb, Zn, Ni, As, all have the average values: (3, 14, 3, 3) × 10^{-6} respectively. Sr value though significant at 41 × 10^{-6} is not considered high enough for sample coloration influences [4]. For economic and industrial raw material consideration purposes, these trace elements values are below deleterious levels.

The plot of Molar ratio Mg^{2+}/Ca^{2+} against temperature [15] Figure 6, reveals that the temperature of dolomitising solution in Alaguntan marbles may have been around 70 °C revealing a dolomitisation at shallow depth with low formational pressure. Plot of salinity against molar ratio Mg^{2+}/Ca^{2+} also show salinity of formation water at 20 000 × 10^{-6} (Figure 7). This is much higher than fresh water average of 1 000 × 10^{-6}, but less than average sea water (35 000 × 10^{-6}) suggesting dolomitisation was facilitated by mixture of sea and fresh water. This agrees with the earlier suggestion of [15] that dolomitisation can occur at admixtures of 30–40 % sea water and 60–70 % fresh water.

Carbon and Oxygen isotope content determination of 4 marble samples carried out at the act labs in Ontario, Canada reveal that $\delta^{13}C$ values range from –0.8–3.9 ‰ while $\delta^{18}0$ range from 0.8 ‰ to –8.2 ‰. These values suggest diagenetic equilibration with meteoric water and it is consistent with the fact that the formation water have dilution of sea by fresh water [16]. These stable isotope values are also consistent with values for Burum marble of the same lithologic position and presumably the same genetic environment [2, 4] and Saxone basin carbonates, Germany [17]. These values are also comparable with values for carbonates that have undergone appreciable diagenesis in the presence of oxidizing organic matter and release of CO_2 [16].

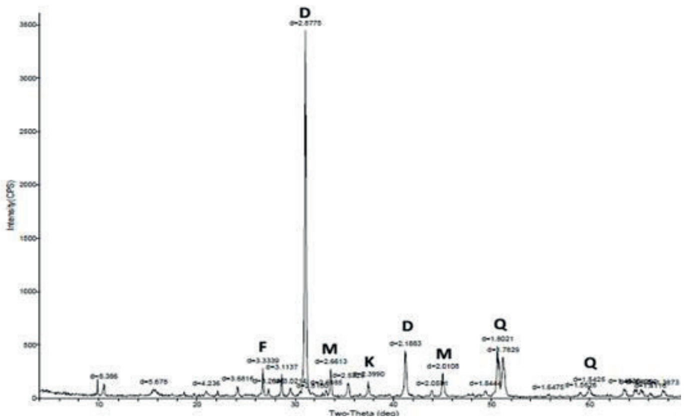

Figure 3: *XRD dIffractometer pattern of Alaguntan marble (Sample 1).*

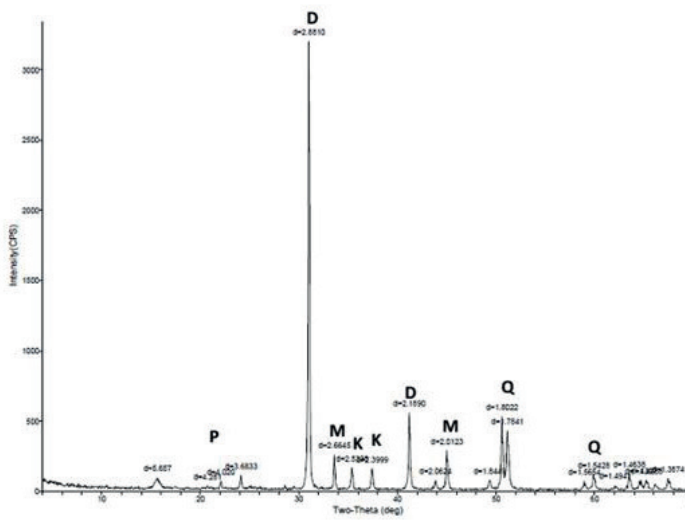

Figure 4: *XRD diffractogram pattern of Alaguntan marble (Sample 2).*

Table 1: *Mineralogical composition of Alaguntan marble from XRD results*

Mineral, w/%	1	2	3
Dolomite	94.24	96.91	95.92
Calcite	1.20	–	–
Quartz	–	0.54	0.35
Colemanite	1.20	2.55	2.59
Tremolite	1.35	–	1.14

Figure 5: *Showing the Alaguntan white marble.*

Marble Usefulness evaluation

Economic and industrial raw material usefulness was carried out in relation to such industries as agriculture (agronomic), metallurgy, construction, chemicals and environmental, materials (like fillers and extenders).

Construction:

Marble is one of the oldest building materials and is only predated by mud and stone [18]. It is presently widely used in aggregates for soil stabilisation, mansory and as ornamental stones where it is polished into decorative slabs.

General requirements are $w(CaO + MgO)$ content above 95 % and $w(CO_2) < 50$ %, compressive strength > 20 MPa, tensile strength > 7 MPa [19]. In term of finess, it must leave a residue not more than 5 % of 75 µm. Alaguntan marble meets these specifications and could thus be used as road stabilisers, ornamental

Table 2: *Chemical analytical results of the major oxides of Alaguntan raw marbles samples*

Oxides, w/%	1	2	3	4	5	6	7	8	9	10	Range	Average
SiO_2	1.56	1.58	2.93	5.56	1.89	4.69	2.74	2.52	1.51	3.15	1.51–3.15	2.81
Al_2O_3	0.10	0.05	0.10	0.04	0.07	0.07	0.03	0.13	0.04	0.02	0.03–0.13	0.07
Fe_2O_3	0.13	0.10	0.11	0.21	0.24	0.24	0.19	0.07	0.10	0.16	0.10–0.24	0.15
MgO	23.50	23.50	23.14	22.74	23.15	22.99	22.98	23.25	23.22	22.53	22.37–23.50	23.20
CaO	33.12	32.96	31.83	21.17	31.52	31.52	32.12	32.43	32.36	32.24	30.79–33.12	32.16
Na_2O	0.03	0.04	0.02	0.04	0.01	0.08	0.01	0.02	0.04	0.04	0.01–0.08	0.03
K_2O	0.03	0.02	0.01	0.01	ND	0.02	ND	0.02	0.02	ND	0.01–0.03	0.02
MnO	0.01	0.01	0.04	0.03	0.04	0.03	0.03	ND	0.01	0.04	0.01–0.04	0..03
LOI	41.1	41.1	41.4	39.8	42.5	39.9	41.5	41.2	42.3	35.9	35.9–41.5	41.15
Sum (%)	99.61	99.61	99.60	99.61	99.61	99.60	99.60	99.62	99.61	99.59	99.60–99.62	99.61

Table 3: *Chemical analytical results of the trace element of Alaguntan raw marble samples*

Trace element ($\times 10^{-6}$)	1	2	3	4	5	6	7	8	9	10	Range	Average
Ba	10	5	3	2	3	4	3	3	5	3	2–10	4.1
Sr	40.5	40.4	34.9	48.5	41.7	50.1	54.6	28.2	30.1	42.6	28.2–54.6	41.26
U	0.2	0.2	0.4	0.4	0.3	0.4	0.6	0.4	0.2	0.3	0.2–0.6	0.34
Zr	1.3	1.9	1.6	0.6	1.2	1.3	1.3	1.1	1.1	0.5	0.5–1.9	1.19
Y	0.5	0.5	0.6	0.4	0.7	0.5	0.5	0.2	0.2	0.3	0.2–0.7	0.44
La	0.3	0.4	0.8	0.5	0.8	0.5	0.3	0.2	0.8	0.3	0.2–0.8	0.49
Ce	0.6	0.5	1.4	0.6	1.0	1.0	0.6	0.5	0.6	0.3	0.4–1.0	0.71
Pr	0.09	0.05	0.12	0.06	0.10	0.07	0.04	0.04	0.03	0.02	0.03–0.12	0.06
Pb	1.6	2.0	5.7	3.5	4.6	3.7	3.2	2.5	2.9	5.5	1.6–5.7	3.41
Zn	2	3	6	29	7	19	40	5	7	21	2–40	13.9
Ni	2.0	2.3	5.0	2.5	3.5	3.4	3.0	1.9	2.2	2.3	1.9–5.9	2.81

Table 4: *Average chemical analytical results of Alaguntan marble and some marble deposit and lime products in Nigeria and the world.*

Oxides w/%	1	2	3	4	5	6	7	8	9	10	11
$Si0_2$	2.81	0.49	Tr	3.81	3.51	0.43	1.45	3.47	1.18	1.94	3.5
Al_20_3	0.07	0.02	0.02	0.16	0.03	0.06	0.02	1.00	0.08	0.21	0.11
Fe_20_3	0.15	0.06	0.06	0.15	0.05	0.02	0.05	0.21	0.07	0.12	0.04
Mn0	0.03	0.03	0.03	0.01	0.03	0.03	0.03	N. a.	0.03	0.01	N. a.
Mg0	**23.20**	**20.70**	**26.85**	**20.75**	**33.25**	**0.58**	**0.85**	**2.23**	**1.75**	**2.20**	**2.18**
Ca0	**32.16**	**28.94**	**38.29**	**31.03**	**59.17**	**54.17**	**95.35**	**51.29**	**53.64**	**52.5**	**51.69**
Na_20	0.03	0.01	0.01	0.05	N. a.	0.03	0.03	N. a.	0.01	0.02	0.92
K_20	0.02	0.01	0.01	0.12	N. a.	0.06	0.03	N. a.	0.02	0.17	0.26
$Ti0_2$	ND	ND	ND	0.17	0.03	0.01	0.03	N. a.	N. a.	0.06	N. a.
P_20_5	ND			0.03				0.03		0.05	1.63
LOI	41.15		34.73	43.56		43.81	2.12	41.53		41.6	41.97
Total	99.61			99.88		99.87				99.16	

1. Alaguntan marble | 2. Igbetti marble (Emofurieta et al, 1995) | 3. Igbetti lime (Emofurieta et al, 1995) | 4. Burum marble (Elueze and Okunlola, 2003) | 5. Burum lime (Elueze and Okunlola, 2003) | 6 . Jakura marble (Elueze and Okunlola, 2003) | 7. Jakura lime (Elueze and Okunlola, 2003) | 8. Ukpilla marble (GSN Report No 1192) | 9. Ososo marble (Emofurieta, 1995) | 10. Shapfell marble (Dowrie et al, 1982) | 11. South Korean marble (DPR) | ND Not detected | Tr Traces

Table 5: *Chemical analytical results of the calc silicate gneiss*

Oxides, w/%	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	NaO	K_2O	TiO_2	MnO	P_2O_5	LOI	Sum
	10.34	0.03	0.16	22.27	30.79	0.02	0.01	ND	0.04	0.02	35.9	99.64
Element ($\times 10^{-6}$)	Ba	Sr	U	Zr	Y	La	Ce	Pr	Pb	Zn	Ni	As
	6	30.9	0.2	0.1	0.2	0.3	0.4	0.04	5.5	4	2.3	3.0

Table 6: *Physical properties of the Alaguntan raw marble samples*

Effective porosity	$n = 10$ 0.51–0.76	$n = 10$ 0.64
Hardness (Mohs scale)	3.0	3.0
Bulk density g/cm³	2.65–2.67	2.66
Specific gravity	2.85–2.86	2.86
Compressive strength (MPa)	87.53–92.72	90.12
Shear strength (MPa)	13.62–15.10	14.36
pH	8.4–8.6	8.5

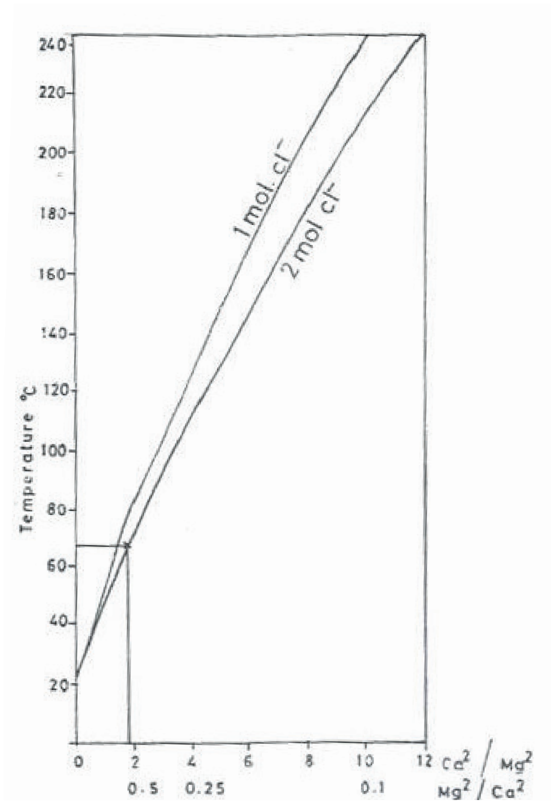

Figure 6: *Molar ratio of calcium and magnesium required for dolomitisation of calcite as a function of temperature (Modified after Hardie [15]).*

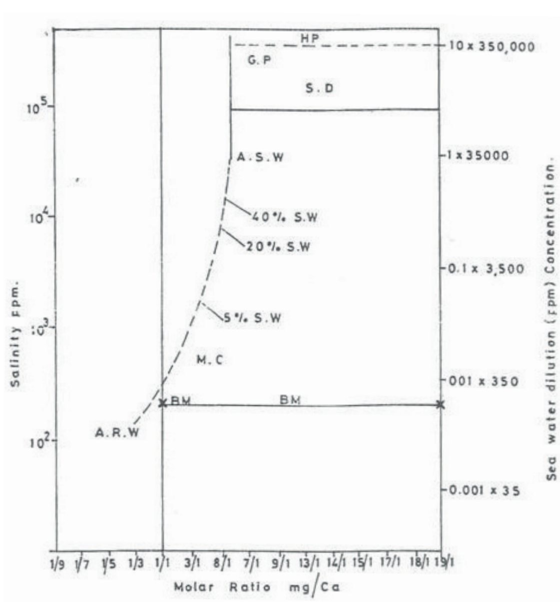

Figure 7: *Relationship between total salinity, Mg/Ca ratio and origin of dolomite. (After [15]). Alaguntan Marble plots at* 200 ppm *salinity (0.008 × 300 dilution of sea water).*

stones and building blocks considering the values of the compressive strength, (90.12 MPa) and shear strength of 14.36 MPa (Table 6, 7).

Agricultural (soil acidity neutralizer):
Results of agronomic tests (Table 8) have shown that the addition of the pulverised (below xμm) marble samples to an acid soil samples at intervals for 8 weeks reduced the soil acidity (Table 8) pH of interstitial water rose from 5.9 to 7.5 after 8 weeks. Organic matter content also increased to 12.31 from 11.70, base saturation show slight increase, while the available nutrient of N, P, K, Na, Ca, Mg, Fe, Mn, Zn, Cu, all show relative increases in their values from the original sample values.
Alaguntan marble thus has the potential of being useful in ameliorating soil acidity.

Metallurgy:
Raw marble and their lime products have been found to be very useful in the metallurgy industry. The largest application is for fluxing steel [19, 20]. Requirement for metallurgical lime include (Ca,Mg)O, or $w(CaO) > 50$ %, high reactivity, low $w(SiO_2)$ (1–1.5 %), and low $w(SO_3)$ (0.05–1 %). Also, $(Ca,Mg)CO_3$ or $w(CaCO_3) >$ 95 %.
Alaguntan marble meets these specifications and therefore is useful as steel fluxes. Another metallurgical application of lime is production of refractory lime. This is used for lining open hearths. The requirements are similar to those of fluxes except for the less stringent SiO_2 requirement (2–4 %). Alaguntan marble can thus also be useful for production of refractory lime as seen from the chemical analytical results.

Chemicals production manufacture:
Among the largest uses of raw marble and their lime products is the production of sodium compounds such as sodium carbonate, sodium hydrogen carbonate, and sodium hydroxide by the Solvay (or ammonium soda) process. The basic requirement is a total carbonate $w(CaCO_3 + MgCO_3)$ content greater than 70 % or lime/dolomite (CaO,/CaMgO content of > 80 %. Alaguntan deposit also meet these requirements. In the manufacture of calcium carbide, an important source of acetylene, quicklime is

Table 7: *Physical properties of Alaguntan marble compared with other marble samples*

	1	2	3	4	5	6	7	8	9	10
Effective porosity	0.69	0.65	0.68	0.62		0.68	0.65	0.67	n. a.	0.64
Hardness (Mohs scale)	3.0	3.0	3.0	3.0	3.0	3.0	n. a.	3.0	n. a.	3.0
Bulk density	2.76	2.65	2.67	2.65	2.65		2.65		2.61	2.66
Specific gravity	2.73	2.70	2.70	2.71	2.73	2.68	2.71	2.73	2.75	2.86
Compression strength	90.48	95.52	92.83	n. a.	90.81	n. a.	90.5	88.2	n. a.	90.12
Tensile strength	3.87	3.92	3.81	n. a.	3.21	n. a.	6.5	4.52	n. a.	n. a.
pH	8.38	8.5	8.3	8.1	8.35	n. a.	8.11	8.5	8.6	8.6
Oil absorption (ml/100)	n. a.	18.0	18.0	19.20	18.40	18.71	n. a.	20.15	n. a.	n. a.
Colour	n. a.	82.0	83.0	80.0	80.0	92.8	n. a.	91.7	n. a.	n. a.

1. Igbetti | 2. Jakura | 3. Burum | 4. Shapfell | 5. Cheetor | 6. British whiting | 7. Muro marble | 8. Indiana marble | 9. Ososo marble | 10. Alaguntan marble
Source 1–9: (Elueze and Okunlola, 2003)

Table 8: *Agronomical properties of Alaguntan marble*

Treatment	pH	Organic matter g/kg	CEC	Base saturation %	N g/kg	P mg/kg	K ←	Na cmol/kg	Ca	Mg →	Fe	Mn mg/kg	Zn mg/kg	Cu
OS	5.9	11.70	4.64	95.69	1.21	3.38	0.77	1.31	1.40	0.96	116.00	140.00	6.50	2.35
SA	5.9	11.70	4.64	95.69	1.21	3.38	0.77	1.31	1.40	0.96	116.00	140.00	6.50	2.35
A1	7.3	12.10	5.81	95.70	1.27	3.79	0.83	1.53	2.16	1.04	117.50	142.0	6.93	2.41
A2	7.5	12.31	6.88	95.74	1.34	3.86	0.98	1.71	2.36	1.53	119.00	144.00	6.94	2.41

OS = Original soil sample | SA = Soil + Alaguntan marble | A1 = Soil + Alaguntan marble after 4 weeks | A2 = Soil + Alaguntan marble after 8 weeks | CEC = Cation Exchange Capacity

mixed with coke and heated in electric furnaces to 2 000 °C. Molten carbide is removed from the furnaces and crushed upon solidifying. It is then ground for use. High calcium lime (w(CaO) = 90 %) / low w(P) (< 0.02 %) and w(Mg) < 0.5 % are required. Marble samples from the study area do not meet this requirement because of higher than acceptable MgO content. Also, in the production of cement, the major requirement are w(MgO) < 3 %, lime saturation factor (L. S. F.) 66–102 %, and hydraulic modulus (H. M.) 1.7–2.0 %. The marble deposit is not suitable because of too high w(MgO) content of 23.20 %.

Environmental:
Crushed and milled marble and their lime products have found application for environmental purposes [1]. This can be used for waste water treatment and water softening. Lime reduces bicarbonate hardness. The requirement include w(CaO) > 65 %, high alkalinity which makes it free from acid insolubles and toxic heavy metals like Cd, Pb, Ag, Zn and Cr thereby having pH > 10, w(MgO) < 2 %, $w(SiO_2)$ < 0.01 and absence of Co. Alaguntan marble has high w(MgO) and $w(SiO_2)$ > 0.01, therefore cannot be used as a calcite lime but meets the specification for dolime manufacture.

Table 9: *Summary of usefulness potentials and specification for Alaguntan marble.*

Industry	General requirements	Suitability
1. Metallurgy		
a. Fluxes in steel	(Ca, Mg)CO_3 or $w(CaCO_3)$ > 95 % $w(SiO_2)$ = (1–1.5) % $w(SiO_3)$ = (0.05–1) %	Alaguntan marble is suitable because of its high silica content.
b. Refractory lime	Same as in fluxes but SiO_2 allowed 2–4 %	Alaguntan marble is suitable.
2. Construction	Compressive strength > 20 MPa Shear strength > 7 % (ASTM, 1976)	The deposit is suitable.
3. Chemicals		
a. Sodium compounds	CaO, (Ca,Mg) w(O) > 70 % w(CaO) > 90 %, w(P) < 0.02 %	The deposits is suitable.
b. Calcium carbide	w(Mg) < 0,5 % w(SiO) < 1.2 %	Not suitable due to high magnesium content.
c. Pesticides	$w(Fe_20_3)$ < 0.5 % $w(CaCO_3)$ > 90 %	Suitable.
d. Bleaches	w(CaO) > 80 %, $w(SiO_2)$ < 2 %	Not suitable due to high magnesium content.
4. Agriculture		
a. Soil liming	pH > 8, $w(SO_3)$ = 2 %	Agronomical test carried out revealed its suitability.

Fillers and extenders:

Mineral filler are inert materials incorporated into different compounds to accomplish a variety of final result such as modification of physical characteristics, colour, opacity hardness, impact strength, surface texture, viscosity, heat conductivity, reduction in cost of production and many other applications. Extender pigment is necessary in all types of coating in paint industry. This keeps the relatively more expensive pigment material volume to a minimum without affecting paint performance. For suitability for paint, requirement is $w(CaCO_3)$ > 95 %, $w(MgCO_3)$ = 2 %, $w(SiO_2)$ = 0.5 %, $w(Fe_2O_3)$ = 0.05 %, $w(Al_2O_3)$ = 0.30 % while for rubber is $w(CaCO_3)$ > 95 %, CaO, free CO_2, w(MgO) = 0.02 %, Fe_2O_3, Al_2O_3, SiO_2 must be in traces only. Alaguntan marble does not meet the above purposes because it has higher $MgCO_3$ content.

Conclusions

The Alaguntan lensoidal marble body which occur for about 2.5 km along the strike within granite gneiss, subparallel to quartzite and calc silicates in Alaguntan village, southwestern, Nigeria, is of the dolomitic mineral composition with Mg/Ca 0.72). The SiO_2 content is low compared to similar marble bodies in Nigeria and elsewhere. K_2O, Na_2O, MnO_2, Al_2O_3 are all low, Fe_2O_3 marginally high while TiO_2 is undetectable like some other marble deposit. Physical and mechanical test for the raw marble samples such as effective porosity, specific gravity, compressive and tensile strength in combination with chemical composition revealed their suitability as raw material in metallurgical, construction, chemical and agricultural industries, Table 9.

Recommendations

The study has been able to unravel the geological setting, compositional features and usefulness of the marble. Appropriate drilling programme should be designed and carried should be applied in order to quantify the reserve. Also, further work should be done on the calcined product of the marble.

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