

Full Length Research Paper

Lithological features and chemical characterization of metamorphosed carbonate rocks in Igue, Southwestern Nigeria

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This paper investigates and reports the lithological and compositional features of Igue marble deposit in southwestern Nigeria. The deposit occurs as low-lying heterogeneous units under a humus-laden dark brown tropical soil within Igarra Schist Belt on south eastern flank of basement complex of southwestern Nigeria. The marble deposit occurs as lenses sandwiched between quartz-biotite schist, calc-silicate gneiss and polygenetic metaconglomerate intercalated with mica schist and quartzite all resting on ancient migmatite gneiss. The three colour variants of the marble which are white, grey, and foliated have average SiO₂ contents of 2.92, 1.72 and 4.04% respectively. In the same order, average CaO contents are 60.76, 59.35 and 51.7%; MgO contents are 1.62, 1.42 and 2.57% indicating the marble is calcitic in nature. The oxides P₂O₅, TiO₂ and MnO altogether constitute 0.09, 0.11 and 0.41% of the bulk chemistry of the white, grey, and foliated marble, respectively. Average loss on ignition (LOI) in white marble (33.46%), grey marble (36.12%) and foliated marble (33.49%) are relatively high suggesting high volatile contents. Chemical features of the marble deposit are comparable to similar rock types in Obajana and Ososo areas in Southwestern Nigeria. The marble differs significantly from Igbeti marble deposit which is dolomitic in nature. Marble deposits from different parts of Nigeria basement exhibits variable geochemical features that are influenced by their protoliths, mode of formation and associated lithologies and forms the basis for various economic uses.

Key words: Igue marble, lithological and compositional features, Igarra Schist Belt, Nigeria, calcitic.

INTRODUCTION

Carbonate rocks occur as carbonatites, limestone, dolostone (dolomite) or marble. The first is related to igneous activities; the next two are sedimentary while marble is a metamorphic product of carbonaceous sediments subjected to high temperature and pressure. In the presence of chemically active fluids, sedimentary carbonates are progressively transformed into marble

through recrystallization starting at the grain boundaries. Under the influence of increased temperature and pressure, calcite in limestone changes to recrystallized interlocking minerals. The chemical composition of any marble deposit will depend on the original limestone from which it is formed and the physicochemical conditions during such transformations. Marble is a metamorphic

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rock that is composed primarily of recrystallized carbonate minerals, most commonly calcite (CaCO_3) and dolomite $\text{Ca,Mg}(\text{CO}_3)_2$. Marble may have colours ranging from pure white, grey, green, blue, or pink; it could also be foliated when its formation is accompanied by variable stress regimes. The nature of marble may depend on several factors dictated by the depositional environment, geochemical index prevailing during formation, degree of alteration or recrystallization, and composition of the original protolith. When it is formed from limestone with relatively few impurities, marble assumes a pure white colour. Marble could originate from contact metamorphism triggered by the thermal effects of magmatic activities on ancient limestone or dolostone. Most economic marble deposits in Nigeria are associated with the schist belts. The geology and occurrence of limestone and marble in Nigeria has been investigated (Odeyemi et al., 1997; Fatoye and Gideon, 2013). The industrial application of some viable marble deposits in Nigeria have also been reported (Okunlola et al., 2015; Dakus et al., 2017; Abdullateef et al., 2014; Adedoyin et al., 2017). Furthermore, recent publications on marble deposits around Igarra area include Obasi (2012); Egesi and Agomuo (2016); Oluwajana et al. (2018); Ogunleye et al. (2018); Ozegin (2019); Mohammed et al. (2019) among others. However, Elueze et al. (2015) believes many lately identified marble deposits in Nigeria are still in varying stages of geological appraisals and economic considerations. As revealed by scholars (Scott and Dunham, 1984; Ofulume, 1991; Emofurieta and Ekuajemi, 1995), marble find applications in architectural, pharmaceutical, and agricultural industries. In addition, marble is useful in the manufacture of cement. In Nigeria, marble come next to limestone as primary source of raw material for production of cement. Marble also find applications in the manufacture of steel, glass, and chemicals, while household applications include ceramics, insecticides, toothpastes, cosmetics, paints, and paper manufacture. However, all applications listed above for marble are directly related to lithologic and chemical properties. Hence, this research evaluates lithologic features and petrochemical characteristics of Igue marble that may be related to its petrogenesis.

Geological setting

Regional geology

The geographical location of Nigeria within Pan-African reactivated domain indicates it falls on eastern side of West African craton and directly south of the Tuareg shield (Figure 1). The reactivated Pan-African belt is a collision type orogen, its evolution during Mesoproterozoic was triggered by eastward dipping subduction zone. The vast N-S trending domain was activated by a series of crustal extension which precipitated rifting of the

continental block on eastern side of West African craton. This activity produced several graben-like structures vast enough to accommodate clastic and terrigenous sediments disaggregated from the crests and horsts of this rifted terrains into low-lying areas now representing present-day western Nigeria. These clastic units represent pelitic sedimentary sequences that are later metamorphosed to form components of the Nigeria schist belts (Elueze, 1992). The continuous westward drift of continental slab across the Benioff zone in overlapping tectonic cycles resulted in closure of an ocean located on eastern side of West African craton about 600 Ma. As the continental plate is consumed at deeper regions of the earth, the overflowing remnant of upper continental crust accumulated at the edge of the subduction zone causing thickening of continental mass around Ghana-Togo-Nigeria axis and subsequent warping of the sediments. The ancient pre-existing basement rocks were reactivated and later intruded by Pan-African granites (McCurry, 1976). Nigeria basement contain three lithological units. These are migmatite gneiss, schist belt and granitoids. The first is assortment of structurally complex and compositionally heterogenous migmatitic and gneissic units which forms the oldest, it is Archean-Paleoproterozoic in age. The second is assemblage of low-grade schistose rocks popularly referred to as schist belts of Mesoproterozoic age and finally, the granitoids of Pan-African (Neoproterozoic) age (Oyawoye 1965; Cooray, 1974; Elueze, 2000). The schist belts contain rocks of Mesoproterozoic-Neoproterozoic age that are deposited in intracratonic basins, 17 such belts occur in Nigeria (Ekwueme, 2003). Four out of these falls within south-western Nigeria, these are Iseyin-Oyan, Egbe Isanlu, Ife-Ilesha and Igarra schist belts (Rahaman, 1976). Emplacement of granitoids into ancient migmatite-gneisses and schistose assemblages is widespread throughout the Pan-African province (Odeyemi, 1977; Annor et al., 1996) (Figure 2). Many Nigeria schist belts host several economic minerals such as marble deposits and have been compared to the Archaean greenstone belts (Turner, 1983, Attoh and Ekwueme, 1997) which also host important metallic deposits. The Nigeria schist belts show distinctive petrological, structural and metallogenetic features (Okunlola, 2001; Elueze, 2002; Elueze and Okunlola, 2003). The Nigeria schist belts differ from Archean greenstone belts by being dominated by clastic sediments instead of volcanic (Turner, 1983). These belts were believed to represent relicts of a once widespread cover deposited in a single basin. However, Ajibade and Fitches (1988) refuted the single basin concept believing different lithological associations occurred within different basins. Elueze (2000) believed geochemical data have established that rocks in the Nigeria schist belts are pelites, semi-pelites and greywackes. The associated mafic rocks (now believed to be of igneous origin) are amphibolite with different tectonic settings ranging from Island arcs (Fitches et al.,

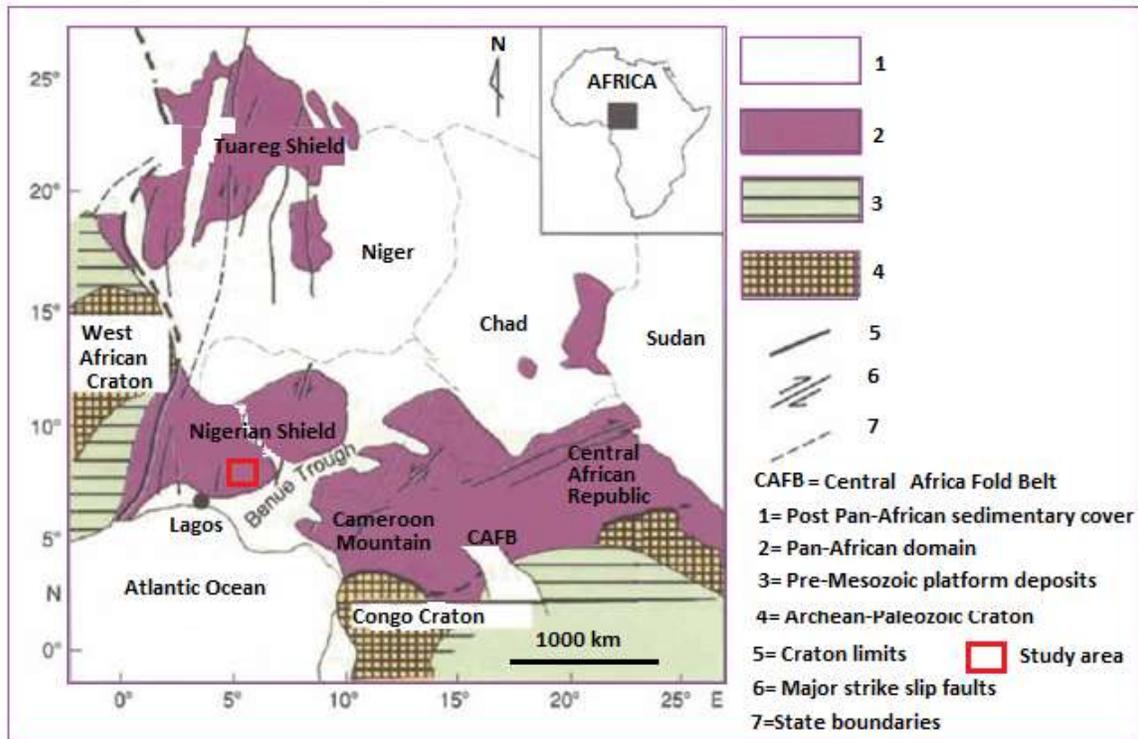


Figure 1. Map showing location of Nigeria within Pan-African reactivated domain on eastern side of West African craton, NW of Congo craton and south of the Tuareg shield. 1, Post-Pan African sedimentary cover; 2, Pan-African domains; 3, Pre-mesozoic platform deposits; 4, Archean to Paleozoic craton; 5, Craton limits; 6, major strike slip faults; 7, State boundaries; Modified after Turner (1983).

1985), Island arcs and ocean floor (Ekwueme, 2003), within-plate to mid-ocean ridge (Obiora, 2008). Rahaman (1988) had described the rocks of the schist belt as "metamorphosed pelitic to semi-pelitic rocks, granites, sandstones, polymict metaconglomerate, calcareous rocks, mafic to ultramafic rocks with minor amounts of greywacke and acid to intermediate volcanic rocks". Isotopic ages confirm the polycyclic nature of Nigeria basement, the crystalline rocks are Liberian (2700 ± 200 Ma), Eburnean (2000 ± 200 Ma), Kibaran (1100 ± 200 Ma), and Pan-African (600 ± 150 Ma) (Black et al., 1979; Caby et al., 1981). Specifically, the study area falls within the Igarr schist belt and hosts several metamorphosed carbonate rock units.

Lithologic relationship and field occurrence

Igue is located on coordinate N $07^{\circ} 08'30''$ and E $06^{\circ} 03' 20''$, it is about 10 km southwest of Igarr town and approximately 20 km northwest of Auch and on south eastern flank of the basement complex of southwestern Nigeria. Lithological successions in Igarr area include low grade, strongly deformed late Proterozoic meta-sediments (Odeyemi, 1990). The tectono-stratigraphic sequence of the metasedimentary assemblages as

described (Odeyemi, 1976, 1977) include quartz-biotite schist at the base, this is overlain by calc-silicate gneiss and marble, polygenetic (polymictic) metaconglomerate as well as mica schist and quartzite all resting on migmatite gneiss. The metasediments, together with their basement sub-structure were strongly deformed during the Pan-African orogeny when emplacement of Igarr, Ososo and Aroko granite plutons which occupy the core of the emergent folds took place (Odeyemi, 1990) (Figure 3). Igue marble is associated with calc-silicate gneiss and occurs as lenses above migmatized schist and below polymictic metaconglomerate. Igue marble occurs as low-lying heterogeneous bodies intersected at relatively shallow depth (between 3-8 m); it was overlain by humus-laden dark brown tropical soil. The marble stretches along east-west direction on Igue-Otuo axis but became evidently folded along the anticlinal structures representing regional trend of the basement gneiss. Igue marble is quite distinctive for having three varieties among which one has beautiful foliation exhibiting alternating patterns ranging from shades of white, brown, and sometimes grey which is well blended together in some parts of the deposit (Figure 4). Mining activities take place in open pits located beside Igue town where the marble appear closer to the surface (Figure 5); however, the carbonate body extends beyond these

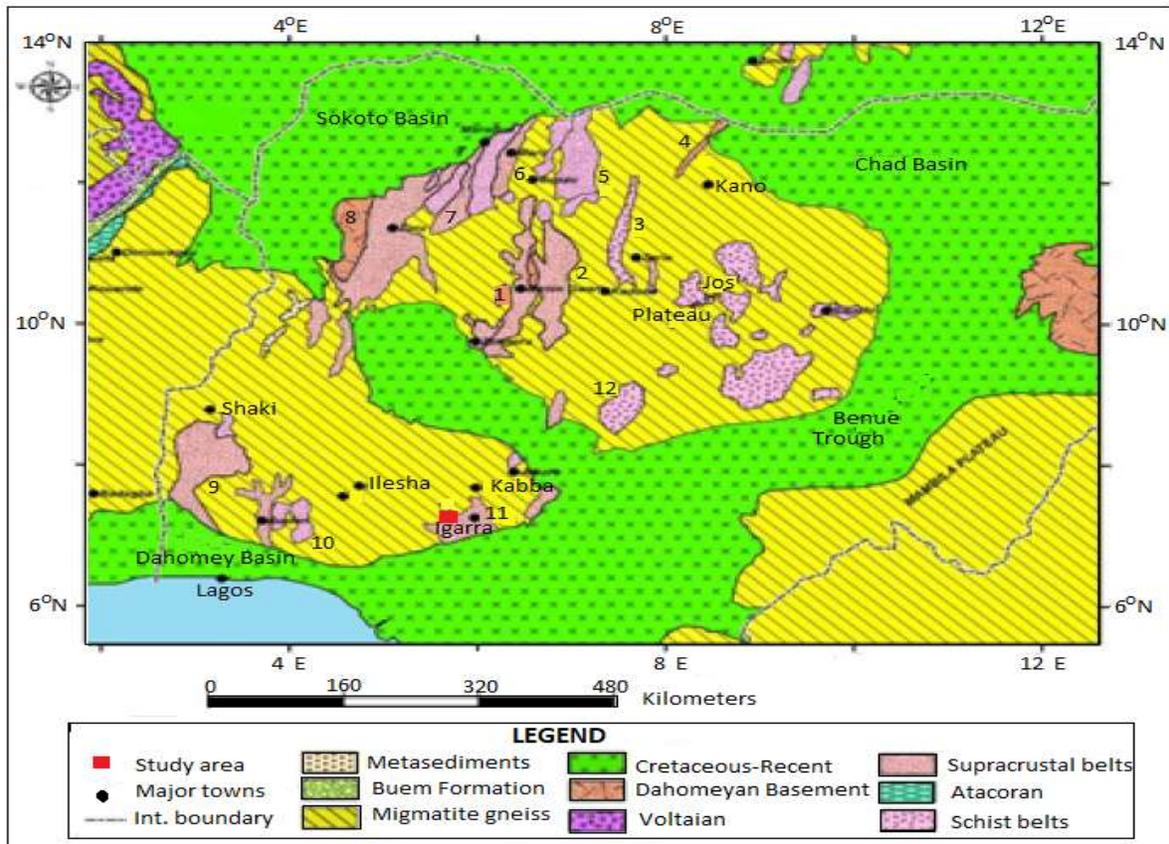


Figure 2. Geological map of Nigeria showing the study area and the schist belts (Modified after Turner, 1983, Elueze et al., 2015); 1, Zungeru-Birnin-Gwari; 2, Kushaka; 3, Karaukarau; 4, Kazaure; 5, Wonaka; 6, Maru; 7, Anka; 8, Zuru; 9, Iseyin-Oyan; 10, Ife-Ilesha; 11, Igarra

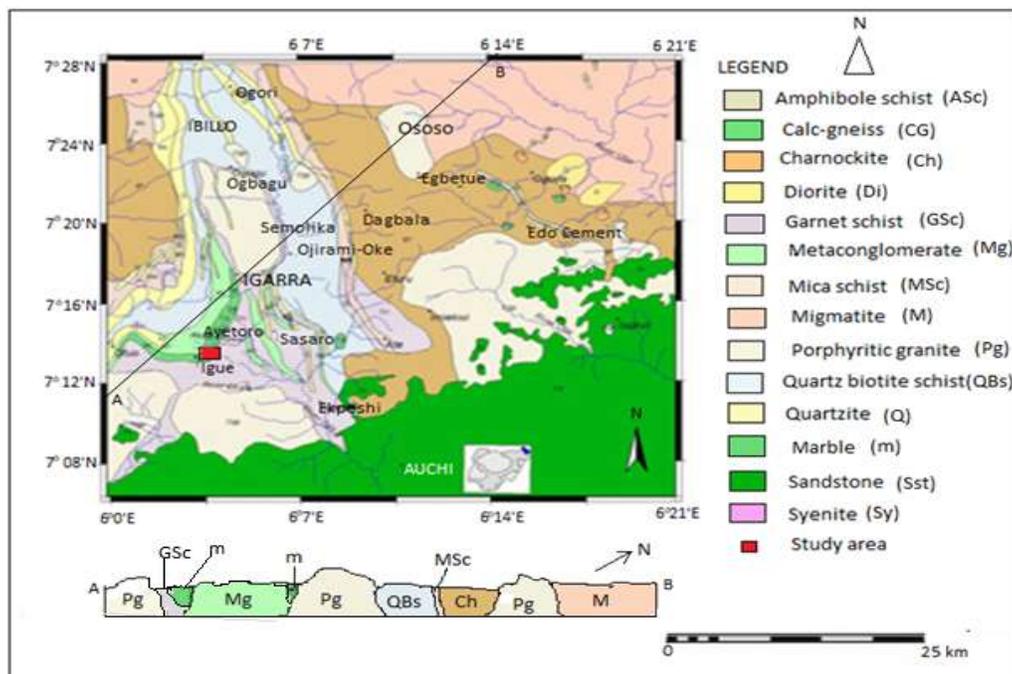


Figure 3. Geological map of Igarra area (modified after Odeyemi, 1990; Oyewole and Ofuyah, 2017).



Figure 4. Field exposure of the Igue foliated marble.



Figure 5. Exposure of the grey marble in the mines.

domains at the subsurface. The geological contacts between the marble and its associated lithologies are not exposed in most of the area. Mine workings do not reveal major lithologic contacts except for few dolerite dykes that cut through the marble bodies.

MATERIALS AND METHODS

Field investigation involves observing the marble deposit inside the mining pits in its *in-situ* position. In addition, the textural features and structural attributes of the marble units was described. Despite that the contact relationships of the marble and its associated

Table 1a. Analytical result of Igwe white marble.

Sample	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	Average
SiO ₂	3.05	2.85	2.52	2.50	3.58	3.47	3.06	2.71	2.44	3.01	2.92
Al ₂ O ₃	0.72	0.68	0.46	0.57	0.42	0.33	0.51	0.47	0.39	0.44	0.50
Fe ₂ O ₃	0.18	0.13	0.19	0.11	0.24	0.30	0.15	0.19	0.18	0.21	0.19
MgO	1.78	1.81	1.65	1.80	1.72	1.64	1.57	1.38	1.54	1.32	1.62
CaO	59.92	60.48	61.52	61.88	61.58	59.61	60.04	61.13	61.35	60.13	60.76
Na ₂ O	0.25	0.16	0.11	0.14	0.28	0.07	0.15	0.15	0.19	0.11	0.16
K ₂ O	0.27	0.23	0.05	0.19	0.74	0.05	0.46	0.31	0.51	0.27	0.31
P ₂ O ₅	0.08	0.05	0.05	0.04	0.09	0.05	0.05	0.05	0.05	0.05	0.06
TiO ₂	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MnO	0.03	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
LOI	33.71	33.59	33.42	32.75	31.33	34.45	33.98	33.58	33.33	34.43	33.46
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.01
Ba	457	393	251	380	216	179	204	115	272	319	278.6
Sr	3603	3012	2547	3019	1511	759	1268	784	1093	2086	1968.2
Rb	43	34	27	38	12	8	11	9	14	22	21.8

lithologies were not intercepted within the mining pits, several dolerite dyke intrusions which cut parallel to the strike direction of the foliated marble was observed. In two other pits located within same vicinity, the dyke intrusion is obliquely inclined to the regional strike direction of the host rock. Samples of the marble were collected as sizable lumps ranging between 3-5 kg from the mines. Even though the Igwe marble occurs at a relatively shallow depth, the thin gritty overburden has been scraped by a bulldozer to further expose the marble. As at the time of this investigation, the drill holes were about to be laced with blasting dynamite. Odeyemi (1990) produced the geological map of Igarra area, this map was very helpful as a guide. As part of the methodological approach, weathered samples were avoided as much as possible and all textural and colour variants of the marble are considered in the sampling procedure. Point sampling method was adopted, and samples are obtained following a random order. Thirty fresh samples (ten samples each for the three colours) were obtained from mine exposures and at different depths. Each sample was labelled appropriately before they are put inside sample bags. The samples were pulverized and subjected to geochemical analysis at Bureau Veritas, Vancouver Canada using Perkin-Elmer SCIEX (ELAN 6000) ICP-MS. This fully computer-controlled equipment utilizes a unique Auto-Lens ion optic system which allows Lens optimization for every element in a multi-element analysis to be determined at its optimum lens voltage while the quadrupole is scanned to achieve maximum ion signal with minimum matrix suspension. The preference for the equipment is the ICP-MS has simultaneous extended dynamic range detector, single scanning lens optimized for ICP-MS, compatibility with Windows NT software and improved detection through single-point hopping. The detector is a dual-stage discrete dynode electron multiplier while samples are introduced into the Hf-resistant crossflow nebulizer and Scott-type spray chamber. Accessories are autosampler and flow injection, the equipment has a Resolution of 0.3~3.0 amu, 3-stage vacuum system, a free-running ICP generator and Argon flow (L/min) = 16.

RESULTS

Analytical results of the marble deposit are presented in

Table 1. Comparison of compositional features of Igwe marble with other metamorphosed carbonate rocks from south-western Nigeria is shown in Table 2.

Interpretation of results

Analytical results of different units of Igwe marble deposit shows that the rock exhibits slightly varying geochemical characteristics. Average SiO₂ content in foliated marble (4.04%) is higher than white marble (2.92%) and grey marble (1.74%). Similarly, alumina contents in these units are respectively 3.49, 0.50 and 0.35%. Average magnesia content also exhibits similar trend for the three members with values of 2.57, 1.62 and 1.42% respectively. The significantly higher percentages of these oxides in foliated marble may have resulted from major Fe and Mg bearing rock forming mineral impurities which were deposited as clay materials within the geosyncline (basin) which now gives the unit zebra foliation appearance after metamorphism. Conversely, average calcium content follows a reverse trend with the white, grey, and foliated marble containing 60.76, 59.35 and 51.70% respectively (Figure 6). Na₂O and K₂O contents of white marble (0.16%, 0.31%) and grey marble (0.16 and 0.26%) does not show significant variations; however, the foliated marble (Na₂O, 1.11%; K₂O, 1.40%) have higher values. The unprecedented high values of these oxides may be attributed to Na and K bearing clay mineral impurities in the foliated marble. Oxides of Phosphorus, Titanium and Manganese altogether constitute 0.09, 0.11 and 0.41% of bulk chemistry of white, grey, and foliated marble, respectively. Average loss on ignition (LOI) values in all the marble types (White marble, 33.46%; Grey marble, 36.12%; and Foliated marble, 33.49%) are relatively high. Elevated average

Table 1b. Analytical result of Igue grey marble.

Sample	GG1	GG2	GG3	GG4	GG5	GG6	GG7	GG8	GG9	GG10	Average
SiO ₂	2.57	1.96	1.33	1.86	1.94	1.55	1.38	1.42	1.51	1.87	1.74
Al ₂ O ₃	0.33	0.43	0.26	0.41	0.41	0.36	0.29	0.21	0.33	0.46	0.35
Fe ₂ O ₃	0.36	0.28	0.47	0.62	0.71	0.59	0.42	0.65	0.38	0.51	0.5
MgO	1.79	1.18	1.0	1.52	1.39	1.45	1.78	1.26	1.21	1.62	1.42
CaO	58.42	59.84	59.48	60.56	58.45	59.11	58.71	59.44	59.41	60.03	59.35
Na ₂ O	0.51	0.12	0.06	0.08	0.13	0.09	0.11	0.11	0.26	0.15	0.16
K ₂ O	0.31	0.13	0.16	0.25	0.41	0.29	0.33	0.26	0.26	0.19	0.26
P ₂ O ₅	0.09	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.05
TiO ₂	0.14	0.14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04
MnO	0.02	0.03	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.02
LOI	35.46	35.84	37.15	34.62	36.47	36.49	36.91	36.58	36.57	35.12	36.12
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.01
Ba	504	612	486	218	355	261	111	83	401	387	341.8
Sr	4136	4883	2984	1880	2457	1950	874	562	2161	1509	2339.6
Rb	51	59	38	25	27	19	13	8	30	15	28.5

Table 1c. Analytical result of Igue foliated marble.

Sample	GF1	GF2	GF3	GF4	GF5	GF6	GF7	GF8	GF9	GF10	Average
SiO ₂	4.45	5.46	3.82	4.28	3.96	3.92	3.71	3.82	3.55	3.46	4.04
Al ₂ O ₃	2.57	2.06	3.01	2.11	4.36	4.72	5.36	2.98	4.25	3.44	3.49
Fe ₂ O ₃	2.13	1.89	2.38	2.05	1.36	1.55	1.36	2.01	1.58	1.51	1.78
MgO	2.98	1.79	3.38	2.08	2.71	2.83	2.71	2.45	2.26	2.52	2.57
CaO	50.97	51.53	51.43	51.80	51.03	52.51	51.03	52.14	52.67	51.93	51.7
Na ₂ O	1.36	0.31	1.52	1.16	0.89	1.22	0.89	1.04	1.32	1.41	1.11
K ₂ O	1.56	0.60	1.87	1.57	1.30	1.77	1.30	1.22	1.39	1.42	1.4
P ₂ O ₅	0.11	0.81	0.13	0.18	0.12	0.13	0.12	0.11	0.11	0.11	0.19
TiO ₂	0.15	0.08	0.13	0.11	0.23	0.29	0.23	0.23	0.27	0.18	0.19
MnO	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
LOI	33.7	35.45	32.32	34.64	34.01	31.03	33.26	33.97	32.57	33.99	33.49
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.99
Ba	205	114	106	313	157	84	41	132	98	239	148.9
Sr	1572	801	753	2568	660	459	300	582	496	1405	959.6
Rb	26	9	7	28	5	4	3	6	4	15	10.7

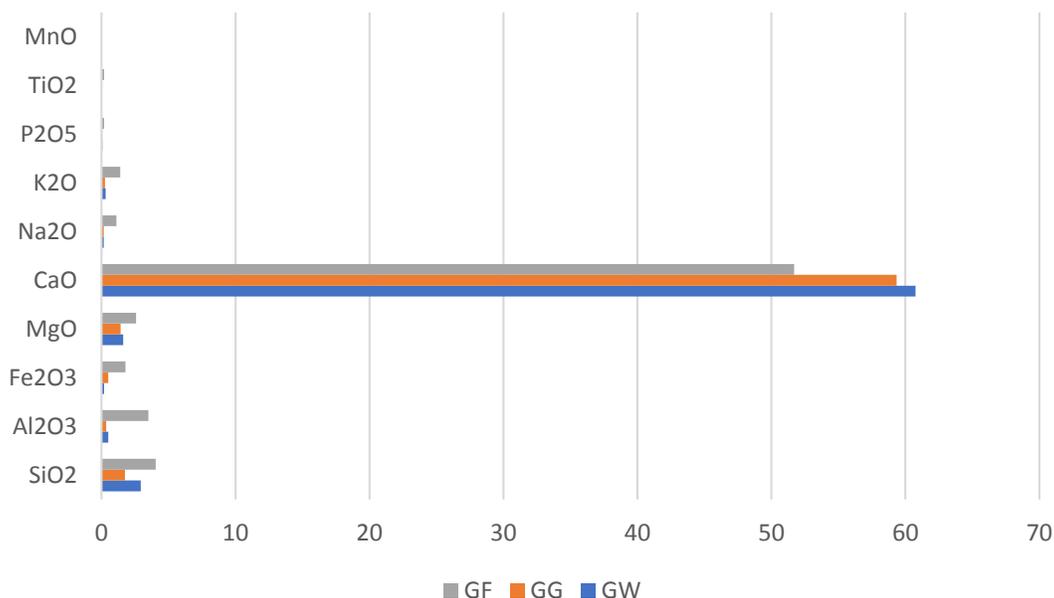
LOI values can be related to disintegration of CaCO₃ into CaO and CO₂ and the carbon dioxide was released as gaseous residue. Analytical result of rocks can trace chemical changes in terms of absolute and relative abundances of elements in materials such as soils, rocks, water, and atmosphere of the earth. It also can provide insights into evolution of the crust, oceans, or the primordial atmosphere. During metamorphism, the bulk composition of a given rock under a variable P-T-t regime results in the distribution of various elements in different phases that are in equilibrium with each other. These phases often assist in interpreting the various processes of rock origin. Geochemical characterization has always

been used as a guide in establishing the petrogenetic pathways for metasediments. According to (Elueze, 2002) compositional characteristic is a veritable tool in the appraisal of any geo-material, and it plays a significant role in tracing the transformation pathways of rocks. These also allow similar rocks from different regions to be compared. The geochemical characteristics of Igue marble (Tables 1a, b and c) in general indicate average SiO₂ content is low. However, the minor discrepancies in chemical parameters of shades of sample species obtained from the different mines may have resulted from slight mineralogical variations influenced by lithological association.

Table 2. Chemical composition of Igue Marble compared to other similar deposits in SW Nigeria.

Sample	A* (GW)	B* (GG)	C* (GF)	D (GBW)	E (GBG)	F (OBJ)	G (JKR)	H (BRM)	I (OSS)	J (KWK)	K (ELB)
SiO ₂	2.92	1.74	4.04	0.11	0.33	1.90	0.43	3.81	1.18	12.52	
Al ₂ O ₃	0.50	0.35	3.49	0.02	0.02	0.24	0.06	0.16	0.08	0.51	
Fe ₂ O ₃	0.19	0.5	1.78	0.02	0.03	0.114	0.02	0.15	0.07	0.27	
MgO	1.62	1.42	2.57	21.5	20.4	1.098	0.58	20.75	1.75	11.43	19.9
CaO	60.76	59.35	51.7	40.7	42.4	53.31	54.17	31.0	53.64	39.50	29.5
Na ₂ O	0.16	0.16	1.11	0.02	0.03	0.12	0.03	0.05	0.01	-	
K ₂ O	0.31	0.26	1.4	0.01	0.02	0.07	0.06	0.15	0.02	-	
P ₂ O ₅	0.06	0.05	0.19	-	-	0.058	-	0.03	-	0.03	
TiO ₂	0.01	0.04	0.19	-	-	0.029	0.01	0.17	-	-	
MnO	0.02	0.02	0.03	0.01	-	0.015	0.03	0.01	-	-	
LOI	33.46	36.12	33.49	37.6	36.5	42.18	43.81	43.56		35.63	44.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.9
Ba	278.6	341.8	148.9			67					
Sr	1968.2	2339.6	959.6			2740					
Rb	21.8	28.5	10.7			5.44					

A*, B*, C* Igue Marble (This study); D (Igbeti white marble); E (Igbeti grey marble) (Akinola and OlaOlorun, 2012); F (Obajana Marble)(Elueze et al. 2015); G (Jakura Marble) (Okunlola et al. 2003); H (Borum Marble) (Okunlola et al. 2003); I (Ososo Marble) (Emofurieta and Ekuajemi, 1995); J (Kwakuti Marble) (GSN Report No. 1192); K (Elebu Marble) (GSN Report No. 1192).

**Figure 6.** Major elements composition of Igue marble. GF, foliated; GG, grey; GW, white.

Average SiO₂ content of Igue white marble (2.92%) is higher than Igbetti white Marble (0.11%). Similarly, average Al₂O₃ and Fe₂O₃ content of Igue white marble (0.50 and 0.19%) are higher than Igbeti White marble (0.02 and 0.02%). These geochemical discrepancies could connote variation in the associated lithologies in these different localities. Average alkali contents of Igue white marble (Na₂O, 0.16%; K₂O, 0.31%) are marginally

higher than Igbeti white marble (0.02 and 0.01%) (Akinola and Olaolorun, 2012). Average chemical composition of Igue grey marble is significantly different from Igbeti grey marble. For instance, average SiO₂, Al₂O₃ and Fe₂O₃ contents of Igue grey marble (1.74, 0.35 and 0.5%) are respectively higher than similar rock from Igbeti (0.33, 0.02, and 0.03%) (Table 2). Despite these variations, both marbles have their highest components as CaO

(Igue white, 60.76%; Igue grey, 59.35%; Igue foliated 51.70%, Igbeti white 40.7%, Igbeti grey, 42.4% and Obajana marble 53.31%). Average magnesia contents of Igue marble and Obajana marbles show low values, while contrasting elevated magnesian contents indicate Igbetti marble is dolomitic. These chemical parameters reveal that marble bodies in the basement complex of southwestern Nigeria significantly depend on both nature of protoliths and lithological associations. The overall SiO₂ contents which range between 1.33-5.46% (average, 2.9%) in Igue marble is higher than Obajana Marble (average, 1.90%) (Elueze et al., 2015). Silica contents of Igue grey marble (1.74%) is marginally lower than Obajana marble (1.90%) (Table 2). MgO contents of Igbeti grey marble (20.4%), Igbetti white marble (21.5%) is comparable to Burum marble (20.75%) and marginally higher than Elebu marble (19.9%). MgO contents of Igue white marble (1.62%) is also marginally lower than Ososo marble (1.75%). Average MnO, Na₂O, K₂O, P₂O₅, and TiO₂ contents of all the marble deposits in SW Nigeria are generally low. Trace element geochemistry of Igue marble show enhancement in Sr and Ba against Rb. Average Sr contents of Igue white marble (1968.2 ppm), Igue grey marble (2339.6 ppm) is comparable to Obajana marble (2740 ppm). However, Ba contents of Igue white marble (range, 115-457 ppm; average, 278.6 ppm), Igue grey marble, (range, 83-612 ppm; average, 341.8 ppm) and Igue foliated marble, (range, 41-313 ppm; average, 148.9 ppm) are marginally higher than Obajana marble (range, 24-157 ppm; average 67 ppm). Around the world, most marble deposits form at destructive plate margins (subduction zones) where two plates boundaries approach each other and collide. Most times, such large expanse of Earth's crust is characterized by regional metamorphism in a compressional setting. The Igarra area forms part of regional polymetamorphic terrain of south-western Nigeria (Odeyemi, 1977), suggesting the marble could have resulted from regional metamorphism of these carbonaceous sediments. However, marble could also be formed when a hot magma intrudes into adjacent limestone or dolostone. Based on several previous works (Rahaman, 1988; Goodenough et al., 2014; Adetunji et al., 2016) which referred to Nigeria granite as post-collisional granitoids, suggested that Nigeria falls on eastern side of West African craton and most of the areas within this domain is located on an eastward dipping Benioff zone; meaning it has a subduction related tectonic setting. The vast area extending from Ghana across Nigeria into Cameroon towards east is equally an extensive polycyclic metamorphic terrain within the Pan-African domain. The Igarra schist belt, and particularly, Igarra town contains large granite plutons which intruded older rock assemblages which include calc-silicate gneiss and metaconglomerate. These units are carbonaceous (enriched in calcite), so, the injection of hot magmatic fluid into these host rocks could also be a plausible source of the marble. However, the occurrence of marble

in various segments of Igarra Schist Belt with specific examples from Ikpeshi, Igue and Okpella each closely associated with massive granitic intrusions may also not rule out the possibility of the Igue marble been a product of contact metamorphism. In as much as regionally formed marble cannot be distinguished from those formed through contact metamorphism on geochemical basis, a more exhaustive field geological mapping and structural analysis may be required to authenticate the genesis of these marble deposits.

Conclusion

The present investigation involves field study, lithologic description, and geochemical investigation of Igue marble in southwestern Nigeria. Field investigation revealed the marble deposit occurs as lenses in-between quartz-biotite schist, calc-silicate gneiss and polygenetic metaconglomerate intercalated with mica schist and quartzite. The marble exists in three colour varieties which are white, grey, and foliated. The three types are all fine-grained while the foliated type is distinctive for its beautiful alternating bands. The intermix of colours in the foliated type resulted from clay impurities that are deposited alongside the sedimentary limestone before it was metamorphosed and distorted by stress regime within the ancient geosyncline. Average CaO content of Igue white marble (60.76), grey marble (59.35%) and foliated marble (51.7 %) and the relatively low MgO 1.62, 1.42 and 2.57% respectively classifies Igue marble deposit as calcitic. The chemical composition of the marble deposit is comparable to Obajana marble in the basement complex of northcentral Nigeria but differ significantly from dolomitic marble in Igbeti area of southwestern Nigeria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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