Full Length Research Paper

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

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Received 25 July, 2020; Accepted 8 October, 2020

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 SiO$_2$ 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 P$_2$O$_5$, TiO$_2$ 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
rock that is composed primarily of recrystallized carbonate minerals, most commonly calcite (CaCO₃) and dolomite Ca,Mg(CO₃)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; Abdullah et al., 2014; Adeyoyin et al., 2017). Furthermore, recent publications on marble deposits around Igarra area include Obasi (2012); Egesi and Agomu (2016); Oluwajana et al. (2018); Ogunleye et al. (2018); Ozegi (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 Tuarag 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 heterogeneous 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, Ile-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 Archaean 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.,
1985), Island arcs and ocean floor (Ekwue me, 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 Igarra schist belt and hosts several metamorphosed carbonate rock units.

**Lithologic relationship and field occurrence**

Igue is located on coordinate N 07° 08’30” and E 06° 03’ 20”, it is about 10 km southwest of Igarra town and approximately 20 km northwest of Auchi and on south eastern flank of the basement complex of southwestern Nigeria. Lithological successions in Igarra area include low grade, strongly deformed late Proterozoic metasediments (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 migmatised gneiss. The metasediments, together with their basement sub-structure were strongly deformed during the Pan-African orogeny when emplacement of Igarra, 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 migmatised 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 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, Archaean to Paleozoic craton; 5, Craton limits; 6, major strike slip faults; 7, State boundaries; Modified after Turner (1983).
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, Ile-Ilesa; 11, Igarra.

Figure 3. Geological map of Igarra area (modified after Odeyemi, 1990; Oyewole and Ofuyah, 2017).
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
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 Igue 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
suppression. 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 1a. Analytical result of Igue white marble. |
| Sample | GW1 | GW2 | GW3 | GW4 | GW5 | GW6 | GW7 | GW8 | GW9 | GW10 | Average |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|---------|
| SiO₂   | 3.05| 2.85| 2.52| 2.50| 3.58| 3.47| 3.06| 2.71| 2.44| 3.01| 2.92    |
| Al₂O₃  | 0.72| 0.68| 0.46| 0.57| 0.42| 0.33| 0.51| 0.47| 0.39| 0.44| 0.50    |
| Fe₂O₃  | 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| 1.81| 1.80| 1.80| 1.72| 1.64| 1.57| 1.38| 1.54| 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  |
| Na₂O   | 0.25| 0.16| 0.11| 0.14| 0.28| 0.07| 0.15| 0.15| 0.19| 0.11| 0.16    |
| K₂O    | 0.27| 0.23| 0.05| 0.19| 0.74| 0.05| 0.46| 0.31| 0.51| 0.27| 0.31    |
| P₂O₅   | 0.08| 0.05| 0.05| 0.04| 0.09| 0.05| 0.05| 0.05| 0.05| 0.05| 0.06    |
| TiO₂   | 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| 0.02| 0.02| 0.01| 0.01| 0.02| 0.02| 0.02| 0.02| 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| 100.0   |
| 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  |

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

**Interpretation of results**

Analytical results of different units of Igue 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 |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|---------|
| SiO₂   | 2.57| 1.96| 1.33| 1.86| 1.94| 1.55| 1.38| 1.42| 1.51| 1.87 | 1.74    |
| Al₂O₃  | 0.33| 0.43| 0.26| 0.41| 0.41| 0.36| 0.29| 0.21| 0.33| 0.46 | 0.35    |
| Fe₂O₃  | 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   |
| Na₂O   | 0.51| 0.12| 0.06| 0.08| 0.13| 0.09| 0.11| 0.11| 0.26| 0.15 | 0.16    |
| K₂O    | 0.31| 0.13| 0.16| 0.25| 0.41| 0.29| 0.33| 0.26| 0.26| 0.19 | 0.26    |
| P₂O₅   | 0.09| 0.05| 0.06| 0.05| 0.05| 0.05| 0.05| 0.05| 0.05| 0.03 | 0.05    |
| TiO₂   | 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| 0.03| 0.03| 0.03| 0.03| 0.03| 0.03| 0.03 | 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 |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|---------|
| SiO₂   | 4.45| 5.46| 3.82| 4.28| 3.96| 3.92| 3.71| 3.82| 3.55| 3.46 | 4.04    |
| Al₂O₃  | 2.57| 2.06| 3.01| 2.11| 4.36| 4.72| 5.36| 2.98| 4.25| 3.44 | 3.49    |
| Fe₂O₃  | 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    |
| Na₂O   | 1.36| 0.31| 1.52| 1.16| 0.89| 1.22| 0.89| 1.04| 1.32| 1.41 | 1.11    |
| K₂O    | 1.56| 0.60| 1.87| 1.57| 1.30| 1.77| 1.30| 1.22| 1.39| 1.42 | 1.4     |
| P₂O₅   | 0.11| 0.81| 0.13| 0.18| 0.12| 0.13| 0.12| 0.11| 0.11| 0.11 | 0.19    |
| TiO₂   | 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 (Èlúeze, 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) |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| SiO₂   | 2.92    | 1.74    | 4.04    | 0.11    | 0.33    | 1.90    | 0.43    | 3.81    | 1.18    | 12.52   |         |
| Al₂O₃  | 0.50    | 0.35    | 3.49    | 0.02    | 0.02    | 0.24    | 0.06    | 0.16    | 0.08    | 0.51    |         |
| Fe₂O₃  | 0.19    | 0.5     | 1.78    | 0.02    | 0.03    | 0.14    | 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    |
| Na₂O   | 0.16    | 0.16    | 1.11    | 0.02    | 0.03    | 0.12    | 0.03    | 0.05    | 0.01    |         |         |
| K₂O    | 0.31    | 0.26    | 1.4     | 0.01    | 0.02    | 0.07    | 0.06    | 0.15    | 0.02    |         |         |
| P₂O₅   | 0.06    | 0.05    | 0.19    | -       | -       | 0.058   | -       | 0.03    | -       | 0.03    |         |
| TiO₂   | 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   | 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 (Burum 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 Igbetti 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.
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 (51.72 %) 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.

ACKNOWLEDGEMENTS

The authors wish to appreciate students of the Department of Geology, Ekiti State University who helped during the fieldwork and data gathering. All anonymous reviewers whose suggestions improved the manuscript are gratefully acknowledged.

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