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Geochemical analysis of the Jakura- Obajana marble, Kogi State, North Central Nigeria: Implication for Industrial uses

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Abstract

Geochemical analysis of the Jakura-Obajana marble deposit in Kogi State, North Central Nigeria was investigated. The paper seeks to put into perspective the diverse uses of marble which hinges on its geochemical characterization. Beside the popular use of marble for cement production, the research tends to elucidate other uses of marble predicated on predefined specifications. This will trigger optimal benefit of the Jakura-Obajana marble deposit. To achieve this, fieldwork was carried out to map the rock units underlying the area. Representative marble samples were randomly collected for laboratory analysis using XRF at the Nigerian Geological survey Agency, Kaduna. The result of the fieldwork reveals that the Jakura-Obajana marble was found occurred with limestone, quartzite and schist. It was also found that marble are the most dominant rock type in the study area. The colour varies from white to grey and the grain sizes range from fine to medium. The Geochemical result reveals that CaO and MgO have the average content of 32.37 wt% and 19.57 wt% respectively. The average content of the oxides is 99.43wt% and the average loss of ignition (LOI) is 43.01 wt%. The average $CaCO_3$ and $MgCO_3$ content of the Jakura-Obajana marble are 58.33 wt% and 41.08 wt% respectively. The percentages indicate that $CaCO_3$ higher than $MgCO_3$. This implies that, the Jakura marble is calcitic in origin. The total carbonate content in the marble is 99.41 %. This makes it suitable for fertilizer production, cement production, and in the production of useful industrial chemical such as sodium carbonate, bicarbonate and hydroxide. It is concluded that the investigated marble deposits have other potential areas of application in addition to usage for cement production, except for animal feeds production and usage as fluxes in steel production.

Keywords: geochemical analysis, marble, Industrial uses, Jakura-Obajana

1. Introduction

Marble is one of the industrial minerals present in commercial quantity in some parts of Nigeria (Ako *et al.*, 2012; Godwin, 2006). Several of these marble deposits are currently being exploited for cement (Ukpilla and Obajana) and decorative stone (Jakura, Kwakuti and Igbetti) with some production of ground rock for industrial use (Felix and Yomi, 2013). In the Nigerian basement complex, marble deposits are found in Burun- Takalafiya in the Federal Capital Territory (FCT) Abuja, Itobe, Ajaokuta, and Jakura in Kogi State, Ukpella in Edo State and Elaba in Kwara State (Oluyide and Okunlola, (1995); Emofurieta and Ekuajemi (1995); Ofulume (1993); Ako, (2006). It is one of the industrial rocks that gain prominence in the manufacturing sector of the Nigerian economy (Romanus and Fredrick, 2012). Marble is a metamorphosed limestone (recrystallization) and occurs within the migmatite-gneiss, schist-quartzite complexes as relicts of sedimentary carbonate rocks (Felix and Yomi, 2013). They are used mostly for one purpose – the production of building and constructional materials. Many cement factories have been built by government and even individuals to utilize the limestone and marble deposits at various locations nationwide where they occurred (Felix and Yomi, 2013). Besides domestic construction, marble can also be used in lime, drugs, toothpaste, and paper and paint production. It is also important in the production of livestock feeds, electrical insulators, flooring tiles and terrazzo chips (Romanus and Fredrick, 2012). Romans and Fredrick (2012) worked extensively on the geochemistry and economic potential of marble of Ikpeshi, southwestern Nigeria. They reported that SiO_2 (Silica) values are low. This was because the values ranged from 0.44% to 7.96%. As result of the low silica content they concluded that, the marble cannot be used for cement production. The carbonates analyses are very critical for the assessment of the presence or absence of calcite or dolomite. Bathrust in his work in (1975) pointed out that an MgO value whose $MgCO_3$ equivalent exceeds 2% indicates the presence of mineral dolomite. In a similar study, Greensmith (1978) suggested that carbonate rocks that contain less than 8% of $MgCO_3$ have isolated crystals of dolomite. Despite the large occurrence (deposit) of the marble in Jakura-Obajana area of Kogi State (Oluyide and Okunlola 1995; Emofurieta and Ekuajemi 1995, Ofulume, 1993,) very little data are available on its geochemical characteristics. This research tends to fill that gap by focusing on the preliminary assessment of the geochemical analysis of the marble. The result from this study will help in appraising the economic potentials and industrial applications of the Jakura-Obajana marble deposits. This research will contribute to the growth and the development of solid mineral sector in Nigeria, and thus, give future investment direction to government, private sectors and other stakeholders.

2. Geology of the Study Area

The Jakura-Obajana is part southwestern quadrant of the Sheet 62. The rock units of the area belong to Kabba- Jakura formations. These include: Obajana gneiss member, schist, Garnetiferous biotite gneiss, quartzite and Marble (Falconer, 1911).

2.1 Obajana Gneiss Member

There are two main varieties of the Obajana gneiss member one is rich in biotite and hornblende (which is leucocratic) and the other is rich in basic and ultrabasic rocks. The biotite and hornblende rich gneiss occurs in most of the outcrop to the south of the Kabba-Lokoja road. It tends to be rather schistose when compared with the gneiss in the migmatite gneiss complex and displayed a marked variation in the amount of feldspathic banding. The second type of gneiss is granitic coarse grained and leucocratic in which schitosity and banding are lacking. However, the rock displays good foliation locally.

2.2 The Schist

The schist of the Kabba-Jakura formation includes both quartzite schist and mica schist. Biotite schist is known to occur as intercalation with the Obajana gneiss member. They contain scattered pebbles and was originally referred to by Falconer (1911) as pebbly muscovite. They are usually of bluish quartz and contain a larger amount of iron and some iron rich green tourmaline.

2.3 Garnetiferous Biotite Gneiss

The outcrop of the rock type occurs east of Kabba town. Along the Lokoja road, these gneisses are well exposed. They are dark coloured, coarse grained and schistose lenses of quartz and feldspar crystals, which up to 1km across, occur as porphyroblastics in the matrix.

2.4 Quartzite

The quartzite in Kabba-Jakura formation occurs as intercalations in quartz muscovite schist. In the eastern part of the outcrop formation, the intercalation is frequent but too small to be noticed. They are massive especially the thicker bands. The composition of the quartzite is essentially almost interlocking quartz with grains size ranging from coarse to fine. There is small amount of iron ore, garnet and iron rich epitode.

2.5 Marble

The large marble deposit occurs northward of the northeastern quadrant of Sheet 62 at Jakura but a part of its southern extension outcrops over a strike width of 180 m -275 m in the bed of River Mimi about 275 m south of the northern boundary of the sheet. The marble is generally white and coarse grained, although, grey and fined-grained varieties may also occur. No sign of distinguishable calc-gneiss is seen in the Jakura marble.

3. Materials and Methods

The method adopted for this study consists of fieldwork in which the various rock units in the area were mapped and marble samples were collected, and field observations made to determine the physical appearance (colour), grain size (texture) of the marble in hand specimen. Laboratory works were also carried out on six samples collected from the field and were analysed for their oxides, loss of ignition (LOI) and respective trace element contents.

3.1 Fieldwork

The research method involved field mapping, which lasted for one week. The mapping technique employed was a conventional method of traverse along the major road, minor road, and footpath. During the fieldwork, each exposure encountered was observed and described using mineralogy, grain size, colour, structural elements and mode of occurrence. Rock samples were collected using a geological hammer.

3.2 Laboratory Analyses

Chemical analyses are useful and important for comparing rocks and deposits, and also indicate the degree of variation within the rock units in the study area. Fresh samples each weighing about 4g from different visited locations were obtained from exposure during the fieldwork. A total of six (6) representative samples were selected and analysed. About 3g of each sample was crushed in a jaw crusher, the product was screened and any other size material was returned to the jaw crusher and finally, the powdered form was obtained. The powdered samples were analyzed for major, minor and trace elements using X-ray Fluorescence (XRF) machine, at the National Geo-science Research Laboratory (NGRL) of Nigerian Geological Survey Agency (NGSA), Kaduna.

4. Results and Discussion

4.1 Fieldwork Results

The field relation revealed that the Jakura-Obajana marble occurred with limestone, quartzite and schist. The marble is well exposed at the Jakura and Dangote quarry sites (Figure 1A and 1B).

Figure 1: Exposed marble deposits at the (a) Jakura and (a) Dangote quarry sites.

The marble is the most dominant rock type in the study area. The marble generally shows white and grey varieties. The field relation also showed that there is no well-defined contact between the marble, quartzite, granitic gneiss, limestone and the schist (Figure 2). The limestone occurs in the north eastern part of the study area.

The investigated samples are to a greater extent white in coloration. The observed marble texture ranges from medium to coarse. The samples generally and instantaneously effervesce in cold dilute hydrochloric acid (HCl) which point to the fact that calcite content the marble is high.

Schist was found in the study area, however, there were no identifiable boundaries between it and the marble (Figure 3).

The schist is generally low-lying, light coloured with characteristic medium to coarse grained texture. Mineral components of the rock consist of quartz, feldspar and mica. The schist is slightly weathered and foliated. The foliation is manifested by displacement of schistocity. The rock generally trends in NW-SE direction and generally dips between 30° - 40° NW.

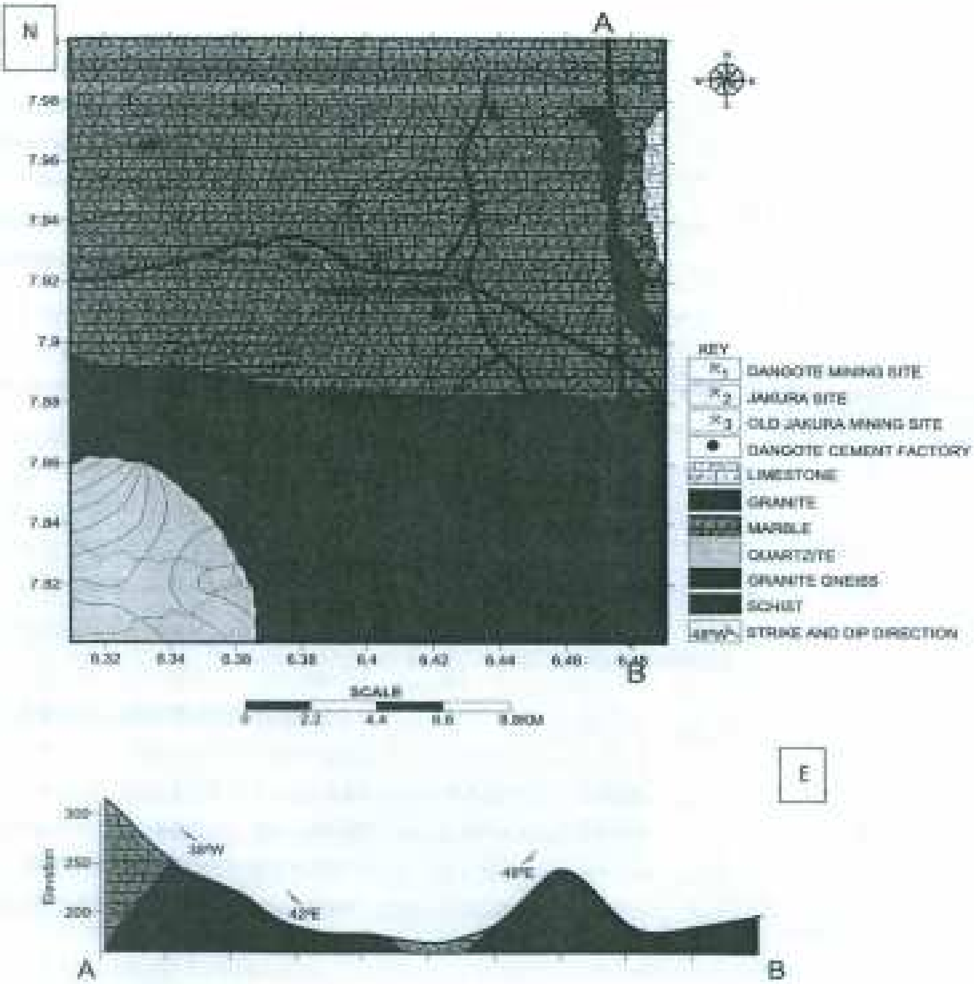

Figure 2: Geological map and cross-section showing different lithological units underlying the study area of the study area.

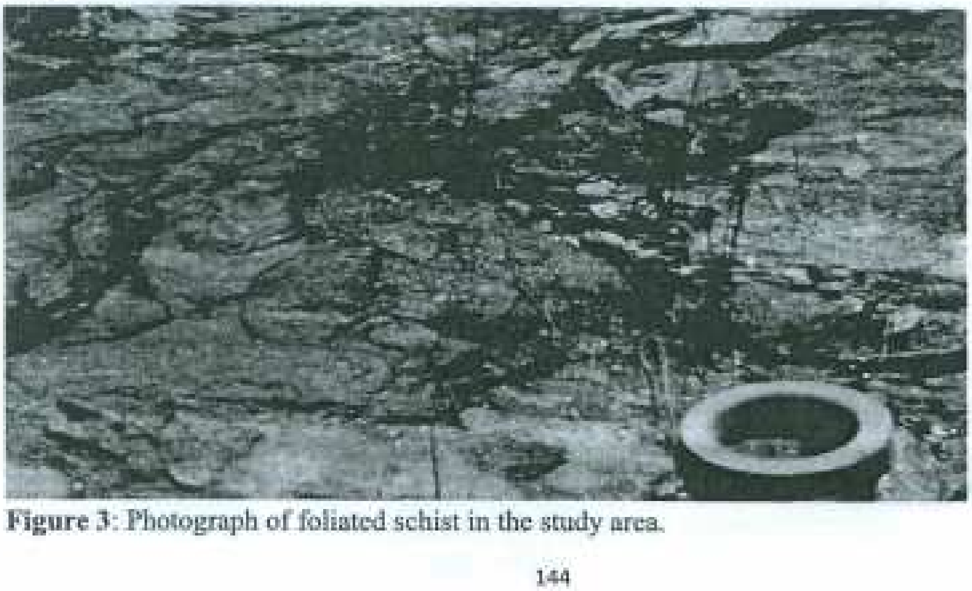

Figure 3: Photograph of foliated schist in the study area.

4.2 Geochemical Analysis Result (wt. %)

Table 1 shows the chemical composition of the Jakura marble and the results reveal that CaO and MgO have the average contents of 32.00 wt% and 19.57wt% respectively. The total content of the Carbonate is 99.43wt% and the average loss of ignition (LOI) is 43.01wt%. The average $CaCO_3$ and $MgCO_3$ content of the Jakura marble are 58.33w% and 41.08w% respectively. The percentages indicate that $CaCO_3$ has a greater value than $MgCO_3$. This implies that, the Jakura marble is calcitic in origin. This was also observed in the bar chart (figure5). The total carbonate content in the marble is 99.41%.

Table 1: Geochemical analysis result of Jakura – Obajana marble (wt.%)

Oxides	Samples						
	1	2	3	4	5	6	Average
SiO_2	3.64	3.60	3.21	3.20	3.56	3.50	3.45
Al_2O_3	0.90	0.89	0.90	0.91	0.80	0.85	0.88
Fe_2O_3	0.11	0.12	0.11	0.10	0.20	0.15	0.15
MnO	0.02	0.02	0.021	0.02	0.04	0.22	0.021
MgO	19.63	19.65	20.15	20.20	18.98	18.80	19.57
CaO	32.00	31.60	33.20	30.50	32.60	31.90	32.00
Na_2O	0.004	0.004	0.003	0.004	0.007	0.006	0.0047
TiO_2	0.03	0.03	0.02	0.03	0.02	0.03	0.027
LOI	42.68	42.50	42.72	42.60	44.37	43.21	43.01
Total	**99.98**	**98.71**	**99.99**	**99.95**	**99.95**	**98.28**	**99.43**
$CaCO_3$	58.85	58.70	58.64	58.16	57.08	58.02	58.33
$MgCO_3$	41.05	42.14	41.07	42.01	39.69	40.40	41.08

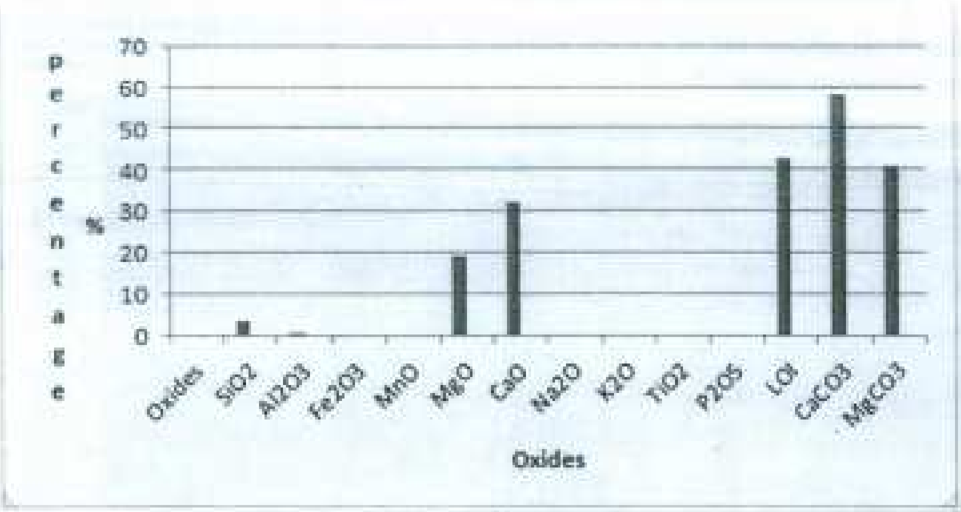

Figure 5: Percentage of the oxides and carbonates present in the Jakura marble.

The implication of the high calcite (or carbonate) content in the analysed Jakura-Obajana marble is that the marble is calcitic in origin. This therefore suffices to add that the marble may have been formed from the metamorphism of the initial limestone in the area. In addition, the calcitic nature of the marble is responsible for the higher concentrations of the calcium and magnesium carbonate found in the marble. Furthermore, the marble can be put into various industrial applications based on the chemical compositions and this is the subject for the next section

4.3 Specifications and possible Uses of Jakura Marble

4.3.1 Uses for Agricultural Purposes

Marble is basically used in agriculture as lime CaO, slake lime Ca(OH) or as a conditioner for mixed fertilizer. They are used as a source of Mg and Ca to increase plant nutrients. They are also used for poultry grid and animal feed supplements. The specifications for $CaCO_3$ used for animal feeds must be within the range of 98% - 98.5% (Brown, 2007). Using this criterion, the Jakura marble with the maximum $CaCO_3$ content of 58.66% could not be utilized for animal feeds since it did not meet the basic requirement. Some fertilizer industries uses marble containing $MgCO_3$ + $CaCO_3$ content of 85% (min), SiO_2 (5%max). This implies that Jakura marble (99.41 %. Of carbonates) is suitable for fertilizer production.

4.3.2 Cement Production

The production of cement required the total carbonate content of at least 97%, $MgCO_3$ 6-7%, MgO 3-3wt%, CaO 43wt% and a silica content of less than 5wt% (Boynton and Gutschick, 1983). The Jakura marble deposit has a total carbonate content of 99.41%, MgO (19.57wt %) CaO (43wt %) and $MgCO_3$ (41.08wt %). This implies that Jakura marble is suitable for cement production. The presence of Dangote Cement Company in the study area validates the result.

4.3.3 Chemical Production

Marble can be used in the production of chemicals like sodium carbonate, bicarbonate and hydroxide via a process otherwise referred to as the solvary or ammonium soda process. For this condition to be met, the total carbonate ($MgCO_3$, $CaCO_3$) content of at least 70wt% is required. From the results on Table 1, the Jakura marble meets this specification with total carbonate content of 99.41wt%. Furthermore, in the paper, paints and plastic industries, grounded marble is used as filler or extender. The requirements for this are that the Al_2O_3, Fe_2O_3 and P_2O_5 content of the marble must be less than 1wt% each coupled with high colour purity, smoothness and lack of grits in the final crushing quality. The marble deposit in Jakura has Al_2O_3 of 0.88wt%, Fe_2O_3 of 0.13wt %) and P_2O_5 (not determined). This implies that the Marble deposit has certified the conditions for these uses.

4.3.4 Metallurgy

Metallurgical industry uses raw marble for fluxing steal (Ofulume, 1993). Requirements for metallurgical lime include Ca, MgO or CaO greater than 65%, high reactivity, LOI of 1-2wt% and SiO_2, 1-2wt%. From the result of the chemical analysis of Jakura marble, for lime product, it does not meet the requirements for use as fluxes in steels production. The Jakura marble (43.01wt %) is more than the required (1-1.5wt %) for use as fluxes in steel production. Finally, the SiO_2 content of the Jakura marble (3.45wt %) is higher than the recommended SiO_2 content of 1-1.5wt%. Hence, the marble cannot also be used as fluxes.

5. Conclusions

Marble deposits occurring in Jakura-Obajana area of Kogi State has been classified as calcitic in origin, based on the geochemical analysis carried out on the marble. The chemical analysis of the marble reveals oxides with less than 1 wt% content, except for SiO_2 with 3.45 wt%, LOI with 43.01 wt%, MgO with 19.57 wt% and CaO with 32.37 wt%. The deposits also contain high total carbonate content ($CaCO3$ and $MgCO_3$) of 99.41 wt%. This makes it suitable for fertilizer and cement production and other uses in chemical industries for production of sodium carbonate, bicarbonate and hydroxide by the solvary process. However, the Jakura marble deposits are found to be unsuitable for animal feeds production as well as for fluxes in steel production. This study has shown that Jakura marble has many other areas of application in addition to its current usage for cement production.

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