Field Occurrence, Chemical Composition and Industrial Application of Ekinrin-Adde Marble Deposit, Kogi State, North Central Nigeria

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ABSTRACT
Field occurrence, chemical composition and industrial application of the Ekinrin – Adde marble deposit of Kogi State, north central Nigeria has been studied. Field occurrence of the marble deposit has been determined by traversing on foot along closely spaced horizontal traverses of 10 meters interval. The major element composition of twenty representative samples of the marble deposit was determined using the Minipal-4 EDS X – Ray Flourescence Spectrometer. The field occurrence shows that the marble deposit occurs as a lensoid body within a granite gneiss host rock. The marble is whitish in colour, coarse grained in texture and is overlain in some places by a sandy clay overburden of 2 – 3m thickness. The major element composition of the marble deposit shows it is a calcitic marble with a mean chemical composition of CaO (51.08 %), MgO (1.56 %), SiO2 (3.60%), K2O (0.15%), Na2O (0.19%), Al2O3 (1.02%), Fe2O3 (0.57%), and Loss on Ignition – L.O.I (41.66%). On the basis of chemical composition only, the marble deposit in Ekinrin –Adde is suitable for the manufacture of cement, production of sodium alkalis (sodium carbonate, bicarbonate and hydroxide), pesticide, poultry feed, calcium ammonium nitrate fertilizer and as a refractory lime.

Keywords: marble, deposit, chemical, composition, Industrial

Introduction
Marble, a crystalline metamorphic rock formed from limestone (carbonate of lime) due to the action of heat and or pressure, has wide applications in industry depending on the purity and character. Marble and its lime product are used in many industrial chemical processes e.g., the manufacture of bleaching powder, calcium carbide, glass, soap, paper, paints e.t.c. Enormous quantities of marble are used in the manufacture of cement. Marble is also used in the construction industry as building and ornamental stones, as a flux in smelting, in agriculture as grit in the preparation of poultry feeds and as lime fertilizer in dressing soils.

The need to diversify the economy of Nigeria from its over dependence on the petroleum and natural gas sector and to create job opportunities for its growing unemployed population has created the necessity to develop the solid mineral resources of Nigeria including marble which have been described in most of the Schist belt des Nigeria. Detailed geological and geophysical studies have been carried out on the Jakura marble deposit in Kogi State (Okunloa, 2001, Jatau & Bajeh, 2008), Ikpeshi marble deposit in Edo State (Odeyemi et al 1997, Obasi & Anike, 2012); Muro-Toto marble deposit in Nasarawa State (Tegure, 1989; Age, 2008; Moumouni et al, 2016), Itobe marble (Onimisi, 2014), Igbeti marble in Oyo State (Emofurieta & Ekuajemi, 1990), Kwakutu marble in Niger State (Danladi, 1993), Nsofang marble in Cross River State (Bassey, 2011), Burum - Takalafia marble deposit (Ojo et al, 2003; Davou and Ashano, 2009) and the Elebu marble in Kwara State (Odewumi et al, 2012).

Very little is known of the marble deposit in Ekinrin – Adde, Kogi State, north central Nigeria. The deposit occurs in the Isanlu – Egbe Schist belt described by Oloibaniyi, 1997; Oloibaniyi & Annor et al, 2003. The study area lies between latitudes N07 53’ 30” and N07 55’ 15” north of the Equator and longitudes E 005 50’ 00” and E005 52’ 30” east of the Greenwich. This present study seeks to determine the field occurrence, major element composition and industrial application of the Ekinrin – Adde marble deposit.

Materials and methods
The field occurrence of the marble and the associated rocks was studied by the traverse method involving horizontal traverses of 10 meters interval along pre - determined oriented compass routes, streams and bush
paths, and locating rock outcrops, identifying the rocks on the field and taking measurements of strike and dip (using the Bruto Compass-Clinometer) of rock outcrops and structures observed on them. Mapping was done using a 1:25,000 topographic map sheet (prepared from 1:100000 topographic map sheet – Ikole NE sheet 245), and measurements/observations made on rock outcrops were plotted on the topographic map. Fresh representative samples of the marble deposit exposed in the area were obtained using a sledge hammer. Sampling pattern was designed to reveal any significant geochemical variation within the marble body. Sampling of the marble deposit was done at intervals along the surface of the deposit and at intervals of 1m within the open pit quarry. In all, a total of (20) marble samples were collected and analyzed for major element composition. Analysis was done at the geochemical laboratory of Obajana Cement Company in Kogi State, central Nigeria using the Minipal - 4 EDS X- Ray Fluorescence (XRF) Spectrometry.

Results
Field Occurrence
The Ekinrin-Adde marble deposit occurs as a lensoid body in a host rock of granite gneiss having a foliation trend in the NE-SW direction. A quartz –vein about 15cm wide cuts through the marble deposit at River Oyi which flows through the study area (Fig. 1). The marble deposit is well exposed in the river valley, the bank of the river and in the open pit quarry created by artisanal miners. The marble is whitish in colour with a coarse grained saccharoidal texture. An exposed thickness of about 8 metres of marble and a sandy clay overburden of 2m to 3m thickness has been estimated in the quarry site of the marble deposit. A dolerite sill (3cm wide) occurring at a depth of 5m from the surface has been observed within the marble deposit in the open pit quarry.

Fig.1 Field geologic map of the Ekinrin – Adde marble deposit (Inset is map of Nigeria)
Major Element Composition

The results of the major element analysis of twenty samples of the marble deposit and the calculated values of CaCO₃ and Ca²⁺/Mg²⁺ ratio are presented in Table 1 below. The calculated mean and standard deviation of the data are also presented in the table.

Table 1. The Mean and Standard Deviation of the Wt % of the Major Element Oxides and the calculated values of CaCO₃ and Ca²⁺/Mg²⁺ ratio of the Ekinrin Adde Marble

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>LOI</th>
<th>Total</th>
<th>CaCO₃</th>
<th>Ca²⁺/Mg²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.15</td>
<td>0.62</td>
<td>0.61</td>
<td>51.73</td>
<td>1.56</td>
<td>0.16</td>
<td>0.17</td>
<td>43.01</td>
<td>100.01</td>
<td>92.39</td>
<td>33.16</td>
</tr>
<tr>
<td>2</td>
<td>2.34</td>
<td>0.33</td>
<td>0.5</td>
<td>50.99</td>
<td>1.62</td>
<td>0.15</td>
<td>0.19</td>
<td>43.52</td>
<td>99.64</td>
<td>91.07</td>
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</tr>
<tr>
<td>3</td>
<td>18.57</td>
<td>3.59</td>
<td>1.18</td>
<td>40.23</td>
<td>1.64</td>
<td>0.23</td>
<td>0.27</td>
<td>33.87</td>
<td>99.58</td>
<td>71.85</td>
<td>24.53</td>
</tr>
<tr>
<td>4</td>
<td>1.02</td>
<td>0.63</td>
<td>0.46</td>
<td>52.72</td>
<td>1.53</td>
<td>0.15</td>
<td>0.21</td>
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<td>0.57</td>
<td>51.36</td>
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<td>0.15</td>
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<td>99.88</td>
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<td>0.47</td>
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<td>1.54</td>
<td>0.15</td>
<td>0.19</td>
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<td>99.95</td>
<td>89.94</td>
<td>32.7</td>
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<td>8</td>
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<td>0.44</td>
<td>53.54</td>
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<td>0.14</td>
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<td>99.61</td>
<td>95.62</td>
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<tr>
<td>9</td>
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<td>0.44</td>
<td>0.46</td>
<td>53.08</td>
<td>1.52</td>
<td>0.15</td>
<td>0.18</td>
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<td>0.15</td>
<td>0.18</td>
<td>40.27</td>
<td>99.54</td>
<td>93.18</td>
<td>33.44</td>
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<td>0.14</td>
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<td>0.46</td>
<td>53.51</td>
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<td>0.14</td>
<td>0.18</td>
<td>43.36</td>
<td>100.02</td>
<td>95.57</td>
<td>35.67</td>
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<tr>
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<td>0.36</td>
<td>0.59</td>
<td>51.08</td>
<td>1.52</td>
<td>0.13</td>
<td>0.16</td>
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<td>99.76</td>
<td>91.23</td>
<td>33.6</td>
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<td>53.01</td>
<td>1.56</td>
<td>0.16</td>
<td>0.19</td>
<td>42.72</td>
<td>100.04</td>
<td>94.68</td>
<td>33.98</td>
</tr>
<tr>
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<td>1.25</td>
<td>0.48</td>
<td>51.97</td>
<td>1.61</td>
<td>0.13</td>
<td>0.17</td>
<td>42.01</td>
<td>99.96</td>
<td>92.82</td>
<td>32.28</td>
</tr>
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<td>0.54</td>
<td>52.16</td>
<td>1.57</td>
<td>0.13</td>
<td>0.16</td>
<td>42.01</td>
<td>99.91</td>
<td>93.16</td>
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<td>0.4</td>
<td>52.57</td>
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<td>0.15</td>
<td>0.18</td>
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<td>0.13</td>
<td>0.19</td>
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<td>99.98</td>
<td>92.6</td>
<td>32.82</td>
</tr>
<tr>
<td>Mean</td>
<td>3.60</td>
<td>1.02</td>
<td>0.57</td>
<td>51.08</td>
<td>1.56</td>
<td>0.15</td>
<td>0.19</td>
<td>41.66</td>
<td>99.83</td>
<td>91.23</td>
<td>32.90</td>
</tr>
</tbody>
</table>

Discussion

CaO/MgO content

CaO and MgO are the most important elemental oxides in metamorphosed carbonates (Marble). In calcitic marble, CaO is usually in the order 50 – 54% while MgO is < 15%. Dolomitic marble on the other hand, have CaO values generally in the range of 28 – 31% and MgO values in the range of 15 – 21% (Goldschmidt et al., 1955). The Ca²⁺/Mg ratio has been generally accepted as a classification criteria for carbonates; those with Ca²⁺/Mg ratio of the order of 1.0 - 1.5 are dolomitic while those of the order of 8 -10 are calcitic (Talbor, 1990). On the basis of the criteria above, the Ekinrin - Adde marble is a typical calcitic marble. A comparison of the chemical composition of the Ekinrin - Adde marble with typical calcitic and dolomitic marbles in Nigeria and other parts of the world (Table 2), shows that the marble is comparable to those of typical calcitic marbles.
Table 2. A comparison of the chemical composition of Ekinrin-Adde marble with typical calcitic and dolomitic marbles

<table>
<thead>
<tr>
<th>Major Element Oxides (Wt %)</th>
<th>Group A (Typical calcitic marbles)</th>
<th>Ekinrin-Adde marble (This study)</th>
<th>Group C (Typical dolomitic marbles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.71</td>
<td>0.9</td>
<td>1.18</td>
</tr>
<tr>
<td>TiO₂</td>
<td>n.d.</td>
<td>0.02</td>
<td>n.d.</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.52</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>(Fe₂O₃)₉</td>
<td>0.34</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>MnO</td>
<td>-</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>MgO</td>
<td>0.35</td>
<td>0.42</td>
<td>1.75</td>
</tr>
<tr>
<td>CaO</td>
<td>54.75</td>
<td>54.01</td>
<td>53.6</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.01</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
</tr>
<tr>
<td>SO₃</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>97.71</td>
<td>-</td>
<td>95.7</td>
</tr>
<tr>
<td>MgCO₃</td>
<td>0.78</td>
<td>-</td>
<td>3.67</td>
</tr>
<tr>
<td>L. O. I</td>
<td>42.01</td>
<td>43.72</td>
<td>-</td>
</tr>
</tbody>
</table>

n.d – not detected
Tr – Trace amount
1. Shapfell marble (Dowrie et al., 1982)
2. Jakura marble (Okunlola, 2001)
3. Ososo marble (Emuforieta et al., 1990)
4. Mfamosing limestone (Dada, 1990)
5. Zambezi belt marble (Munyanyiwa and Hanson, 1988)
7. Mfamosing Limestone, SE, Nigeria (Ofulume, 2008)
8. Ekinrin-Adde marble (This study)
9. Igbeti marble (Emuforieta et al., 1990)
10. FCT, Abuja marble (Davou and Ashano, 2009)
11. Zambezi belt marble (Munyanyiwa and Hanson, 1988)

**CaCO₃ content**

Pure carbonate rocks have a total carbonate (CaCO₃ or CaMg (CO₃)₂) of 70% and above while impure carbonate rocks have between 40 – 70% (Lipmann, 1973). The percentage of CaCO₃ in marble is obtained by multiplying the percentage weight of the CaO by 1.78. Similarly the percentage of MgCO₃ in marble is obtained by multiplying the percentage weight of the MgO by 2.09. The average CaCO₃ and MgCO₃ content of the Ekinrin – Adde marble are 91.24% and 3.26 % respectively (Table1). The total carbonate (CaCO₃ and MgCO₃) content of Ekinrin – Adde marble is 94.5%. Thus the Ekinrin Adde marble deposit is a pure carbonate rock.
SiO₂ content
SiO₂ in carbonate rocks comes from both silicate minerals and chert nodules resulting from the influx of near shore silici-clastic materials into the basin of the original limestone deposit which was metamorphosed into marble (Brownflow, 1996). The silica content (3.60%) of the Ekinrin - Adde marble deposit is relatively high when compared with similar marble deposits (Table 2) and this indicates that the basin of deposition of the pre - metamorphic limestone protolith is near to the shore.

Alkali (K₂O/Na₂O) content
The concentration of alkali (K₂O + Na₂O) in the Ekinrin-Adde marble deposit is very low (less than 0.35 %). This value is similar to the alkali content of typical marble deposits (Table 2). Alkali content in carbonate rocks decrease with increase in salinity and increase with depth (Clarke, 1924). The very low alkali content (0.34%) in the marble deposit is therefore indicative of a shallow, saline environment of deposition of the limestone protolith.

Al₂O₃ and Fe₂O₃ content
The Alumina content (1.02%) and total iron oxide content – Fe₂O₃ (0.57%) in Ekinrin-Adde marble deposit are generally low and these may be indicative of minor presence of aluminosilicate minerals in the marble

Loss on Ignition (L.O.I) content
Loss on Ignition (L.O.I) content in marble reflects the content of volatiles (CO₂, H₂O e.t.c) in the marble. The average L.O.I content in the Ekinrin-Adde marble deposit is high (41.73%). This indicates high volatile content in the marble deposit and by implication high carbonate content as heating to a temperature of 900°C results in the evolvement of CO₂ (Olatunji, 1989).

Industrial Application of Ekinrin- Ade Marble
Marble generally has high economic value. Scott and Durham (1984) identified about 204 end uses of raw marble and lime (the calcined form of marble). The specification for the use of marble as an industrial raw material varies considerably with the different end use of the marble. The economic values of marble can however be broadly classified into six main groups namely, construction, chemical, environmental, refractory, agriculture and metallurgical, (Boynton, 1979). Each of these groups requires some chemical specifications for the marble to be useful. The industrial applications of the Ekinrin - Adde marble deposit based on chemical composition only using the BCI specification (cement production) and the Industrial Specification of India -ISI (Bhargava, 1978) are discussed below:

Construction Use (Cement):
The range of CaO and CaCO₃ expected in limestone/marble used for the manufacture of cement are 46.65 - 52.46% and 83.50 - 93.90% respectively, and the upper tolerable limits for MgO required for the manufacture of cement is 2% (Table3). Higher MgO values result in the formation of periclase in the clinker which combines with water to form Mg(OH)₂. The consequential volume contrast between the initial MgO and Mg(OH)₂ causes structural in equilibrium which results in expansion often experienced with low quality cement (Talbot, 1982)
Table 3: Average Chemical Composition of the Ekinrin-Adde Marble and those of some Limestone used for Cement Production

<table>
<thead>
<tr>
<th>% Oxides</th>
<th>Ekonrin-Adde Marble Samples</th>
<th>Reference Samples of Marble/Limestone used for Cement Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>3.60</td>
<td>3.76</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>P$_2$O$_5$</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>1.02</td>
<td>1.10</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>0.57</td>
<td>0.66</td>
</tr>
<tr>
<td>MgO</td>
<td>1.56</td>
<td>1.23</td>
</tr>
<tr>
<td>CaO</td>
<td>51.08</td>
<td>52.46</td>
</tr>
<tr>
<td>Na$_2$O</td>
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<tr>
<td>K$_2$O</td>
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<td>0.18</td>
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<tr>
<td>LOI</td>
<td>41.73</td>
<td>40.38</td>
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<tr>
<td>CaCO$_3$</td>
<td>91.24</td>
<td>93.90</td>
</tr>
<tr>
<td>MgCO$_3$</td>
<td>3.26</td>
<td>2.57</td>
</tr>
<tr>
<td>TC</td>
<td>94.50</td>
<td>96.47</td>
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<tr>
<td>S/R</td>
<td>2.26</td>
<td>2.14</td>
</tr>
<tr>
<td>A/R</td>
<td>1.79</td>
<td>1.67</td>
</tr>
<tr>
<td>LSF (%)</td>
<td>437</td>
<td>417</td>
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<tr>
<td>SO$_3$</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Reference limestone samples I - IV are from Cement Data book. Reference limestone samples V - VI are from Cement Technology Course Volume (after blue circle industries Ltd., 1978).
Reference limestone sample (vii) = Typical cement feed (after Blue Circle Industries Ltd., 1978).

To produce a satisfactory cement clinker, a 'raw mix' of the correct chemical composition is required. Three chemical ratios: Silica Ratio, S.R., Alumina Ratio, A.R., and Lime Saturation Factor, L.S.F., are used to monitor the composition of the 'raw mix' and the clinker. They are calculated using the contents of the oxides CaO, SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$.

The standard Silica Ratio (S.R.), Alumina Ratio (A.R.) and Lime Saturation Factor (L.S.F.) of a typical cement kiln feed are calculated as follows:

\[
\text{S.R.} = \frac{\text{SiO}_2}{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3} = \frac{3.60}{1.02 + 0.57} = 2.26
\]

\[
\text{A.R.} = \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3} = \frac{1.02}{0.57} = 1.79
\]

\[
\text{L.S.F.} = \frac{100 \, (\text{CaO})}{2.8 \, (\text{SiO}_2 \%)+ 1.2 \, (\text{Al}_2\text{O}_3 \%)+ 0.65 \, (\text{Fe}_2\text{O}_3 \%)} = \frac{100 \times 51.08}{2.8 \times 3.60 + 1.2 \times 1.02 + 0.65 \times 0.57} = 437
\]
The recommended S.R., A.R and L.S.F. ranges in marble used in cement production are (1.9 - 3.2), (1.5 - 2.5) and (242- 417) respectively. The calculated S.R., A.R. and L.S.F. for the marble deposit in Ekinrin-Adde are 2.26, 1.79 and 437 respectively. The S.R. and A.R. values of the Ekinrin - Adde marble fall within the recommended range used in cement production. The L.S. F of the Ekinrin -Adde marble (437) is higher than the recommended upper limit (417) used in cement production (Table 3). However, the L.S.F value of the marble can be adjusted to fall within the recommended range required for a typical cement kiln by blending the marble with suitable proportions of clay and laterite to supply SiO₂ and Al₂O₃; and Fe₂O₃ respectively (Panda, 2016)

The alkalis (Na and K) can substitute for calcium and can lead to setting of cement in air if stored in humid conditions. The alkalis also react with active silica in some aggregates and cause disintegration of some concretes (Talbot, 1982). Therefore total alkalis must be sufficiently low in marble used for cement manufacture. The total alkali value in Ekinrin – Adde marble is sufficiently low (0.34%) as compared to the upper tolerable limit of 0.35% (Talbot, 1982) allowed for cement production. Al₂O₃, Fe₂O₃ and SiO₂ values in Ekinrin-Adde marble are 1.02%, 0.57% and 3.60% respectively. These values also fall within the recommended values for cement production (Table 3). Sulphur and Phosphorus, regarded as most undesirable impurities in the manufacture of cement when present in more than 1% (Talbot, 1982) slows down the setting of Portland cement. Sulphur and Phosphorus were not detected in the Ekinrin - Adde marble deposit.

**Chemical Use**

**Manufacture of Sodium Alkalis**

One of the largest uses of raw marble and their lime products is in the manufacture of sodium alkalis i.e. sodium carbonate, bicarbonate and hydroxide by Solvay (or ammonium soda) process. The basic requirement is a total carbonate (CaCO₃, MgCO₃) content > 70%. This specification is met by the Ekinrin – Adde marble which has total carbonate content of 94.5%.

**Manufacture of Calcium Carbide**

In the manufacture of calcium carbide, an important source of acetylene, quicklime (CaO) is mixed with coke and heated in an electric furnace to 2000°C. Molten carbide is removed from the furnace and crushed upon solidifying. It is then ground for use. For the manufacture of calcium carbide, the chemical specifications are: High calcium lime (CaO > 90%), SiO₂ < 3%, low P (< 0.02%), MgO < 0.5%. Based on these specifications, the Ekinrin – Adde marble does not meet the requirements for the manufacture of calcium carbide as it contains SiO₂ > 3% and MgO > 0.5% (Table 1).

**Manufacture of Bleaching Powder**

Bleaching powder is prepared by absorption of chlorine by dry hydrated lime. The hydrated lime should not contain more than 2% of excess water. Iron and manganese lead to unsuitability of the product as iron oxides tend to discolor the bleached material. For the manufacture of bleaching powder, the specification is lime (CaO > 95%, total Fe₂O₃ + Al₂O₃ + MnO₂ < 2%, MgO < 2%, SiO₂ < 1.5%). Silica impedes solution and settling of bleaching powder. Based on these specifications, the Ekinrin – Adde marble is unsuitable for the manufacture of bleaching powder as it contains CaO < 95% and SiO₂ > 1.5%.

**Pesticide Production**

In pesticide production (calcium arsenate), arsenic acid is reacted with a milk of lime forming calcium arsenate. Lime of CaO > 65% is required. Based on this specification, the Ekinrin –Adde marble is suitable for the manufacture of Pesticide as it contains lime of CaO > 65%.

**Glass Use**

Glass industry requires high calcium marble (CaCO₃ > 94.5%). Iron and other colouring matter like carbon are regarded as objectionable. Fe₂O₃ should not be more than 0.2%. For colourless glass, marble should contain > 98.5% CaCO₃; Fe₂O₃ should not be more than 0.04%. Based on the above specification, the Ekinrin – Adde marble is not suitable for the manufacture of glass as it contains < 94.5% CaCO₃ > 0.2% Fe₂O₃ and > 2.5% SiO₂.

**Sugar Use**

In the sugar industry, lime is used for clarification of juice from cane. Milk of lime 1% in volume of cane juice is added to pre-heated juice. The Industrial Specification of India (ISI: 3204 - 1978) stipulated the following
specifications of marble for use in the preparation of sugar: CaO > 50 %, silica < 2%, MgO content should be less than 1%, Al₂O₃ + Fe₂O₃ < 1.5%. The presence of iron must be negligible or absent as iron tends to colour the finished product. On the basis of this specification, the Ekinrin-Adde marble deposit is unsuitable for the preparation of sugar as it contains > 2% silica, > 1% MgO, and > 1.5% Al₂O₃ + Fe₂O₃

**Metallurgical Use**

There are numerous applications of raw marble and their lime products in the metallurgical industry. However, the largest specific application is for fluxing steel. Eighty-five percent of total lime produced worldwide is used as steel flux (O’Drascoll, 1988). In steel manufacture, marble is used first to lower the temperature of melting and second to form calcium silicate by combining with silica of the iron ore which comes out as slag. Specifications for metallurgical lime include CaO > 65%, SiO₂, 1-1.5%, SO₃, 0.05 – 1%. Another metallurgical application of lime is as refractory lime. It is used for lining open hearth. The specification for this use is similar to those of fluxes except that the silica requirement is less stringent (2-4%).

Based on the above specifications, the Ekinrin - Adde marble is unsuitable for use as steel flux as the SiO₂ content in it is higher than the recommended upper tolerable limit of 1.5%. However, the marble meets the specification for use as refractory lime as its silica content (3.14%) falls within the accepted range of 2-4% required for refractory lime.

**Environmental Use**

Raw marble and their lime products have found wide applications for environmental purposes (Boynton, 1980). This includes water treatment and neutralization of sewage.

**Water Treatment**

For water treatment purposes, lime is very important, especially in water softening and pH adjustment. It also prevents the dissolution of undesirable materials from the piping system. In this case, lime removes the temporary bicarbonate hardness. In water purification, lime is added to water in retention tanks for 24 - 48 hours. High pH (about 11+), produced by lime kills most types of bacteria (Boynton and Gutshick, 1975). The major requirements of lime for water softening and purification include CaCO₃ > 80%, MgO < 2%, SiO₂ < 0.01%. Based on these specifications, Ekinrin - Adde marble is not suitable for water treatment as it contains SiO₂ > 0.01%

**Neutralization of Sewage**

Lime is also useful in sewage treatment, neutralization of acid water, silica and phosphate removal from sewage effluents. The specifications are similar to that for water softening and purification. Marble is also used in water treatment as filtering gravel in which case CaCO₃ > 95%, CaO > 53.2%, SiO₂ < 1%. The Ekinrin-Adde marble does not meet the specifications above as it has CaCO₃ < 95%, CaO < 53.2% and SiO₂ greater than 1%

**Agricultural Use**

Soil liming is one of the oldest uses of raw or calcined marble (Ojo et al, 1998). The marble or lime function as a neutralizer of acid soils and plant nutrient enhancer. The requirement is low grittiness. Marble is also used as grit in the manufacture of poultry feed. For this purpose, the degree of purity of the marble is insignificant but alumina content must be < 1.5%. Based on this specification, Ekinrin-Adde marble is suitable for use as grit in the manufacture of poultry feed as it contains 1.02% Al₂O₃.

A more recent use of limestone/marble is in the manufacture of calcium ammonium nitrate fertilizer. For this purpose, the marble should contain CaCO₃ > 85%, CaO > 47.6 %, SiO₂ < 5%. On the basis of this specification, the Ekinrin - Adde marble is suitable for the manufacture of fertilizer as it contains CaCO₃ (91. 24 %), CaO (51.08%), SiO₂ (3.60%)

**Filler/Extender Use**

Marble is useful as Fillers/extenders in the manufacture of paint, rubber, plastics, pulp and paper, animal feed, tooth paste and pharmaceuticals. The general specification for this use is CaO > 52 %, Al₂O₃ < 0.2 %, Fe₂O₃ < 0.2 %, MgO and SiO₂ must be lower (< 3 %), SO₃ < 0.2%, P₂O₅ < 0.15%). Based on this specification, the Ekinrin - Adde marble is unsuitable for use as fillers/extenders as it contains < 52 % CaO, > 0.2 % Al₂O₃, > 0.2 % Fe₂O₃, and > 3% SiO₂.
Conclusion and Recommendation
The marble deposit in Ekinrin – Adde, Kogi State, north central Nigeria based on its chemical composition is a pure carbonate and a typical calcitic-type marble. On the basis of it’s chemical composition and the Industrial Specification of India (ISI), the marble deposit can be used for the manufacture of cement (although it may have to be blended with appropriate quantity of clay and laterite to lower the L.S.F from the relatively high value of 437 to fall within the recommended range of 213 – 417 required for a typical cement kiln feed). The marble deposit also satisfies the chemical requirements for the production of sodium alkalis (sodium carbonate, bicarbonate and hydroxide), pesticide, poultry feed, calcium ammonium nitrate fertilizer and as a refractory lime.

Further uses may be found for the marble deposit if physical and geotechnical properties of the marble are determined. It is recommended that geophysical exploration and drilling be employed in delineating accurately the extent of the marble deposit and subsequently determine the reserve of the deposit.

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