Preliminary appraisal of compositional and industrial properties of clay deposits in Udubu area, northeastern Nigeria

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Abstract

Preliminary compositional and geotechnical studies have been undertaken to appraise the industrial qualities of clay deposits at Tumfure, Rukwu and Tashar Garba in Udubu area, northeastern Nigeria.

Mineralogical studies indicate that the bodies are mainly composed of kaolinite, while quartz and feldspar are accessory constituents. Chemical analysis of samples indicates that the dominant oxides are SiO₂ and Al₂O₃, with average values of 47.7% and 36.0%, respectively. Minor oxides are MgO, Fe₂O₃, K₂O, Na₂O, TiO₂, and CaO with average values of 1.92%, 1.63%, 0.56%, 0.15%, 0.34% and 0.13%, respectively. Geotechnical evaluation shows that the clays have liquid limits range of 29.0% to 29.6%, plastic limit range of 11.1% to 14.0% and linear shrinkage limit of 5.9-6.0%. The composition and geotechnical properties of Udubu clays indicate that they are potentially suitable for paint, ceramic and refractory production.

Introduction

Udubu area is located within longitudes 10°30' and 11°00' E and latitudes 11°30' and 11°45'N on the Udubu sheet 85 and lies on the western flank of Chad Basin in the north western end of the Upper Benue trench.

Studies of the evolution, stratigraphy, biostratigraphy and palaeogeography of the Upper Benue Trough have been undertaken (Furon 1963, Adegoke et al. 1986, Benkhelil 1989, Dike 1995). The Continental Kerri-Kerri Formation overlies the basement in this part of the Upper Benue trough (Ako and Osondu, 1986; Dike 1990, 1993). Elsewhere in the Upper Benue trough, the Bima sandstone deposited during the Cretaceous overlies the Paleozoic basement. The Kerri-Kerri Formation varies in thickness from 40m to 320m and consists of intercalations of clay, sandstone and ironstone (Adegoke et al., 1986 and Dike, 1995). The sediments were deposited unconformably on the Paleozoic basement during the Paleocene. Lacustrine sediments of the Chad Formation deposited during the Pleistocene-Pliocene overlie the Kerri-Kerri Formation in the Chad Basin (Adegoke et al., 1986 and Dike, 1995). The Udubu area has however not been studied.

This paper reports the mineralogical, chemical and geotechnical properties of clay deposits in Udubu area, compares these with properties of clay deposits elsewhere and known industrial standards with a view to determining their industrial potentials.

Geology of the area

The southern part of Udubu area is underlain by sediments of the continental Kerri-Kerri Formation. This is overlain by sediments of the Chad Formation in the north. The Kerri-Kerri Formation in the study area consists of clay, sandstone and ironstone (Fig. 1). Clay occurs as large deposits exposed at the surface in the Tumfure, Rukwu and Tashar Garba areas and as sub-surface members of the Kerri-Kerri Formation in the Udubu sheet 85 (Fig. 1). Field studies indicate that the sub-surface occurrences are exposed in pits, wells and boreholes and that clay is extensive and covers several kilometers. At Tumfure, for example, clay...
is exposed at the surface sometimes with thin sedimentary cover of about 2.2m below the surface (Fig. 2). At Danbam, the overburden varies from 2.0 to 2.8m. Examination of logs and fresh wells indicate that the clay deposit varies in thickness from > 50m in the south to < 3.8m in the north in Udubo site. The basement was not encountered in any of the pits, wells and bore holes indicating thick sedimentary sequence in the Udubo area. At the contact between clay and the overlying sandstone is clayey sand. Oolitic and massive limestone overlie clayey sand. In the north of the study area, sandstone and sand of the Chad Formation overlie the Kerri-Kerri Formation (Fig. 1). The lithostratigraphy is similar to those of Lanzai area in the Upper Benue Trough where Dike (1995) has reported clay deposits of about 53m thick. Correlation between the two locations is however uncertain.

![Diagram](image)

**Fig. 2. Composite well sections across selected sites (W-E) showing depth to Kaduna deposit in the southern part of Udubo area.**

**Sampling and analytical methods**

Samples of clay horizons in wells at Tumfure, Rukwu, and Tashar Garba were collected at the time of drilling for detailed examination. Three representative samples from each location, selected based on their position in the stratigraphic column, texture and mineralogy, were pulverized and dried on a sand bath at constant temperature of 300°C and divided into portions for mineralogical study at the National Steel Council in Kaduna, wet chemical analysis at the GSN laboratory in Kaduna, and geotechnical analysis at the Soil science laboratory, Ahmadu Bello University, Zaria.

Mineralogical analysis was carried out using Philips X-ray diffractometer model 1800 fitted with a copper anode set at a scanning rate of 2°/2θ/minute following the procedure of Brown (1951). X-ray diffraction patterns were obtained for the clay samples and interpreted using standard interpretation method of Carrol (1971) while their approximate abundance was calculated using area method (IJCPs, 1980). Samples used for firing test were kept in a furnace at a temperature of 1000°C for 24 hours. Liquid and plastic limits were determined using the USA model CL 404 geotechnical apparatus while Casagrande (1984) method was used to determine plasticity and hence the compressibility of the clays.

**Physical properties**

Physical characteristics such as grain size, density and plasticity were determined using standard methods and specifications. Values have been compared with known industrial standards and reference samples.

The percentage of particles passing the finest sieve, BS 230 (aperture 63 μm) ranges from 68.37 for Tashar Garba, 96.17 for Rukwu to 98.75 for Tumfure (Table 1). The clays also have high density: 1482.3 kg/m³ for Rukwu, 1370.5 kg/m³ for Tashar Garba, and 1465 kg/m³ for Tumfure clays indicating that there is a small range in the density of clays in these localities. The Clays possess average plasticity index of 14.94% while the average liquid limit value is 29.5%. Plots of the plasticity limits of the clays on the Casagrande (1984) scale show that they are of medium plasticity and compressibility (Fig. 3).

**Mineralogical characteristics**

Petrographic examination of Udubo clay samples shows that they contain over 80% of opaque clay aggregates and small amount of quartz and feldspars. The quartz particles are anhedral to subhedral in shape. X-ray diffractometer patterns (Figs. 4-6) indicate that kaolinite is the dominant clay mineral in all the samples. Prominent kaolinite peaks are recorded at 2θ values of 12.4° and 25°. Minor peaks are recorded at 36.0°, and 43° to 47° in some samples. Calcite, smectite and pyrophyllite are recorded only for Tumfure clays. Quartz is the major non-clay constituent in all the samples. It is particularly prominent in the sample from Tashar Garba. K-feldspar is an accessory mineral in all the samples.
Chemical compositions

The major oxides in Udubo clay are SiO₂, Al₂O₃, and Fe₂O₃. Minor oxides include MnO, MgO, TiO₂, K₂O, Na₂O and CaO (Table 2). Among the three locations, Rukwu clay has lowest concentration of SiO₂ (43.72%) compared to the Tumfur and Tashar Garba clays with 44.88% and 54.34%, respectively. Fe₂O₃ concentration is generally low, varying from 1.6% in Rukwu clay to 2.3% in Tumfur clay. The Rukwu clay however has the highest concentrations of Al₂O₃, TiO₂, K₂O and CaO compared to Tumfur and Tashar Garba clays.

Table 1. Some physical properties of Udubo Clay samples

<table>
<thead>
<tr>
<th></th>
<th>Tumfur</th>
<th>Rukwu</th>
<th>Tashar Garba</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour of sample</td>
<td>Buff white</td>
<td>White</td>
<td>Yellowish white</td>
</tr>
<tr>
<td>Clay minerals (%)</td>
<td>Kaolinite (98%)</td>
<td>Kaolinite (97%)</td>
<td>Kaolinite (67%)</td>
</tr>
<tr>
<td></td>
<td>Smectite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phylilitie (7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non clay minerals (%)</td>
<td>Calcite (1%)</td>
<td>Quartz (3%)</td>
<td>Feldspar (5%)</td>
</tr>
<tr>
<td>Clay-sized fractions</td>
<td>98.75</td>
<td>96.17</td>
<td>68.37</td>
</tr>
<tr>
<td>(63 μm)</td>
<td>1483</td>
<td>1493</td>
<td>1371</td>
</tr>
<tr>
<td>Density (Kg/m³)</td>
<td>29.0</td>
<td>29.6</td>
<td>29.5</td>
</tr>
<tr>
<td>Liquid limit (%)</td>
<td>14.9</td>
<td>16.4</td>
<td>15.0</td>
</tr>
<tr>
<td>Plasticity Index (%)</td>
<td>10.3</td>
<td>8.2</td>
<td>9.7</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Colour of fired pellets</td>
<td>Ash white</td>
<td>Ash white</td>
<td>Red brown</td>
</tr>
</tbody>
</table>

(Data given are average values of three samples from each location)

Fig. 3. Plot of Udubo clay deposits on the Casagrande plasticity chart (1984).
### Table 2. Chemical composition of Udubu clays compared with reference samples and industrial specifications

<table>
<thead>
<tr>
<th></th>
<th><em>Tumfure</em></th>
<th><em>Rukwu</em></th>
<th><em>Tashar Garbu</em></th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>44.88</td>
<td>43.73</td>
<td>54.34</td>
<td>57.67</td>
<td>46.66</td>
<td>46.88</td>
<td>46.6</td>
<td>51.0-70.0</td>
<td>67.50</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.94</td>
<td>0.13</td>
<td>0.80</td>
<td>-</td>
<td>0.66</td>
<td>-</td>
<td>7.00</td>
<td>-</td>
<td>0.50-1.20</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.30</td>
<td>1.60</td>
<td>1.65</td>
<td>3.32</td>
<td>4.21</td>
<td>0.88</td>
<td>-</td>
<td>0.5-24</td>
<td>26.50</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>39.01</td>
<td>46.24</td>
<td>32.81</td>
<td>24.00</td>
<td>34.04</td>
<td>37.65</td>
<td>2.70</td>
<td>25.0-44</td>
<td>-</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.35</td>
<td>0.16</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MnO</td>
<td>2.3</td>
<td>1.54</td>
<td>1.60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.45</td>
<td>-</td>
<td>0.11-0.12</td>
</tr>
<tr>
<td>MgO</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.30</td>
<td>0.25</td>
<td>0.13</td>
<td>-</td>
<td>0.2-0.7</td>
<td>0.01-3.0</td>
</tr>
<tr>
<td>CaO</td>
<td>0.10</td>
<td>0.25</td>
<td>0.13</td>
<td>0.70</td>
<td>0.03</td>
<td>8.50</td>
<td>0.1-0.2</td>
<td>12.0-12.5</td>
<td></td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>11.28</td>
<td>8.22</td>
<td>9.66</td>
<td>10.50</td>
<td>12.25</td>
<td>15.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>100.25</td>
<td>101.99</td>
<td>101.35</td>
<td>97.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(*Data given are average values of three samples from each location, this study)

(A) Plastic fire clay, St Louis (Huber, 1985)
(B) Ibot clay (Nnuka et al., 1997)
(C) Chitas Clay Huber, 1985
(1) Brick Clay (Murray, 1960)
(2) Refractory bricks (Parker, 1967)
(3) Ceramic (Singer and Sonja, 1971)

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Sample ident: TK 1

X-ray diffractogram of Tumfure clay

**Kn**: Kaolin  
**Sm**: Smeectite  
**Py**: Pyrophyllite  
**Ca**: Calcite

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Fig. 4. X-ray diffractogram of Tumfure clay
Fig. 5. X-ray diffractogram of Tarsha Garha clay

Fig. 6. X-ray diffractogram of BugweI clay
On average the Uduboo clays contain lower SiO₂ but higher Al₂O₃ than those of refractory bricks (Parker, 1967) and Inu clays (Elueze et al., 1999). The compositions however compare well with Irot Igwe clays (Nnuka et al., 1997) and China clays (Huber, 1985).

**Industrial potential**

Grain size, density, mineralogical composition, chemical composition and plasticity are some of the parameters used in assessing clay materials for characteristics required for various industrial applications. Grain size studies of the Uduboo clays show that they contain a high percentage of ash-white clay fraction of 96-98%. The high percentage of fine materials in clays indicates small amount of silt content evidenced by the low SiO₂. It also makes them industrially useful as fillers and coating materials in paint, rubber, cosmetic and paper industries. Among the three locations studied in the Uduboo area, the Tumfure and Rukwung clays have close variation of values suggesting a uniform gradation for the clays. This texture compares with those of clays from Mbak in Iru area, which have been recommended for the paint and cosmetic production (e.g. Elueze et al., 1999).

Use of the Uduboo clays for painting is already gaining recognition among the set lers in Rukwung and Tumfure who are using the unprocessed clay for painting.

XRD analysis of Uduboo clays indicates that the main clay mineral is kaolinite and that quartz and feldspar are the main non clay minerals. With a plasticity index value of 15.5% and shrinkage value of 6%, the clay deposits of this study have medium compressibility.

The chemical composition of clays in this study falls within the values given by Grimsdull (1975) for clays with good refractory material. The low SiO₂ and high Al₂O₃ contents of the clays in this study compare well with the industrial specifications for refractory and ceramic clays (Table 2) and indicate that they are good materials for the industry. The low alkali metal content of the kaolinite in Uduboo area further supports the suitability of the clays in the refractory (Parker, 1967) and ceramic industries (Singer and Songa, 1971). The low LOI (8.0 - 10.0%) indicates that the clays have low porosity and that the finished products from Uduboo clays would show no cracks or damages on firing, thus making them suitable for ceramic wares.

**Conclusions**

Field studies indicate that extensive clay deposits covering several kilometers occur in Uduboo area on the surface, and in pits and wells with thin overburden. Studies of wells indicate that the clay deposits vary in thickness from > 35m in the south to < 3.8m in the north of the study area. The clay changes in texture and composition at the contact with the overlying sandstone.

A preliminary appraisal of the physical, mineralogical and chemical properties of Uduboo clay deposits show that the clay is essentially kaolinitic with quartz and feldspar as the non-clay minerals. The clay is fine textured, has high density and contains low SiO₂ and high Al₂O₃. Uduboo clay deposits at Tumfure and Rukwung are suitable for use in the refractory, ceramic, paint, cosmetics and paper industries. The clay can be milled through open cast on a large scale.

**Acknowledgements**

The authors are grateful to the Director, Geological Survey Agency of Nigeria for financial support of the project. The work of the laboratory staff of the Agency and the National Steel Council, Kaduna is also gratefully acknowledged.

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NNUKA, F.E., UTIN, T., and ADEGOYE, M.B. 1997. Compositional Characteristics and industrial potentials of Ikot Igwe - Okon


Received 31 August, 2005; Revision accepted 8 February, 2007
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