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Quality of Kuba Clay Minerals in Bokkos, North Central Nigeria.

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ABSTRACT

The study area lies in the Jos Plateau of North Central Nigeria. Clay minerals such as kaolinite, montmorillonite, chlorite, micas are main components of raw materials of clay and formed in presence of water. The particle size of clay minerals is <2microns which can be present in form of plastic in presence of water and solidified when dried. The small size and their distinctive crystal structure make clay minerals very special with their unique properties including high cation exchange capacity, swelling behavior, specific surface area, and adsorption capacity. Due to all these unique properties, clay minerals are gaining interest in different fields. Clay minerals has industrial applications in the ceramic, paint, rubber, plastics, powder, electrical industries as well as in drilling muds and as a plasticizer in moulding sands, paper industry and others. Montmorillonite group of clays are used in the powder, paints, rubber, Chemical analyses of three clay samples reveals that the total alteration of calcium and fast leaching of other alkaline elements such as Mg^{2+}, Na^{+}, K^{+} favour the formation of kaolinite in the area with Si:Al ratio of about 1:1. Also, one of the clay samples was discovered to be montmorillonite which has a ratio of Si:Al about 2:1.The pie charts indicate that sample C of the clay have the highest percentage of silica composition than that of the primary rocks. The reason being that montmorillonite has large ion-exchange capacity, therefore, sample C is montmorillonite. This paper seeks to look at the quality of the Kuba clay minerals and its usefulness in some industries in Nigeria.

Key words: Clays, quality, industries, Kuba, Bokkos, Nigeria.

I. INTRODUCTION

Clay minerals are hydrous aluminium phyllosilicates, sometimes with variable amount of iron, magnesium, alkali metals, alkaline earths, and other cations. Clay minerals are very common fine grained sedimentary rocks such as shale, mudstone, and siltstone in fine grained metamorphic slate and phyllite. 1:1 clay would consist of one tetrahedral sheet and one octahedral sheet and example is kaolinite. A 2:1 clay consists of an octahedral sheet sandwiched between two tetrahedral sheets and example is montmorillonite.

Montmorillonite is a major active component of bentonite and a multifunctional clay mineral with unique properties, such as swelling and adsorption. These characteristics, have allowed montmorillonite to be widely used in medical and industrial applications (Eisenhour and Brown 2009; Carretero and Pozo 2010). Moreover, it has been applied to develop diverse drug delivery systems to overcome the pharmaceutical disadvantages of drugs, including low solubility and poor pharmacokinetic properties (low bioavailability and short biological half-life), McNerny et al. 2010; Savjani et al. 2012; Griffin et al. 2013; Mould et al. 2015.Activated montmorillonites are used to catalyse various chemical reactions. The activation process is similar to that used for the bleaching clays. An early example of their use was for the catalytic cracking of petroleum. This process, which is used for increasing the yield and quality of gasoline from petroleum, involves splitting the heavier molecular weight hydrocarbons into lighter ones with lower boiling points. The catalyst used must promote rupture of the carbon to carbon bond near the middle of the hydrocarbon chain. The first cracking catalysts were montmorillonite but synthetic catalysts have now mainly replaced them. Present uses of activated clays are as alkylation catalysts, particularly for the alkylation of phenols. These alkylated phenols have many uses and are intermediaries in the formation of detergents. Clays are also used to promote polymerization, dehydration and various other chemical reactions. In addition, the activated clays are used as delicate pH adjusters where the last traces of alkalinity have to be removed from organic liquids. The natural clay is similarly used for the removal of traces of acidity for the past several centuries, clays have been used for a variety of applications (Lin, et al, 2002, Joshi et al., 2009).

With the recent introduction of montmorillonite clay as a functional filler in thermoplastic and thermoset polymers, the clay minerals, or montmorillonite, have been studied for various applications and performance including the use as a catalyst in organic synthesis as a food additive for health and stamina, for antibacterial activity against tooth and gum decay, for the assessment of frictional and sliding behaviour or the study of mineralogical attributes and as a sorbent for non-ionic, anionic, and cationic dyes. More recently the interest and volume in the investigation of the use of clay minerals, particularly montmorillonite clays, have significantly increased. The research has concentrated on the development of nanoclays through modifications in physical and chemical structures and on the study of the effects of nanoclays on the thermal-mechanical properties of polymers (Bhadane et al, 2018).

The kaolinite group of clay mineral has industrial applications in the ceramic, paint, rubber, plastics and the largest use is in the paper industry. Montmorillonite group of clays are used in the powder, paints, rubber, electrical industries as well as in drilling muds and as a plasticizer in moulding sands and other materials (Kwar, 2002). Daspan et al (2009) and Kwar (2002) have worked on kaolinite in Kuba and its industrial application without determining if there are other clay minerals present in the study area.

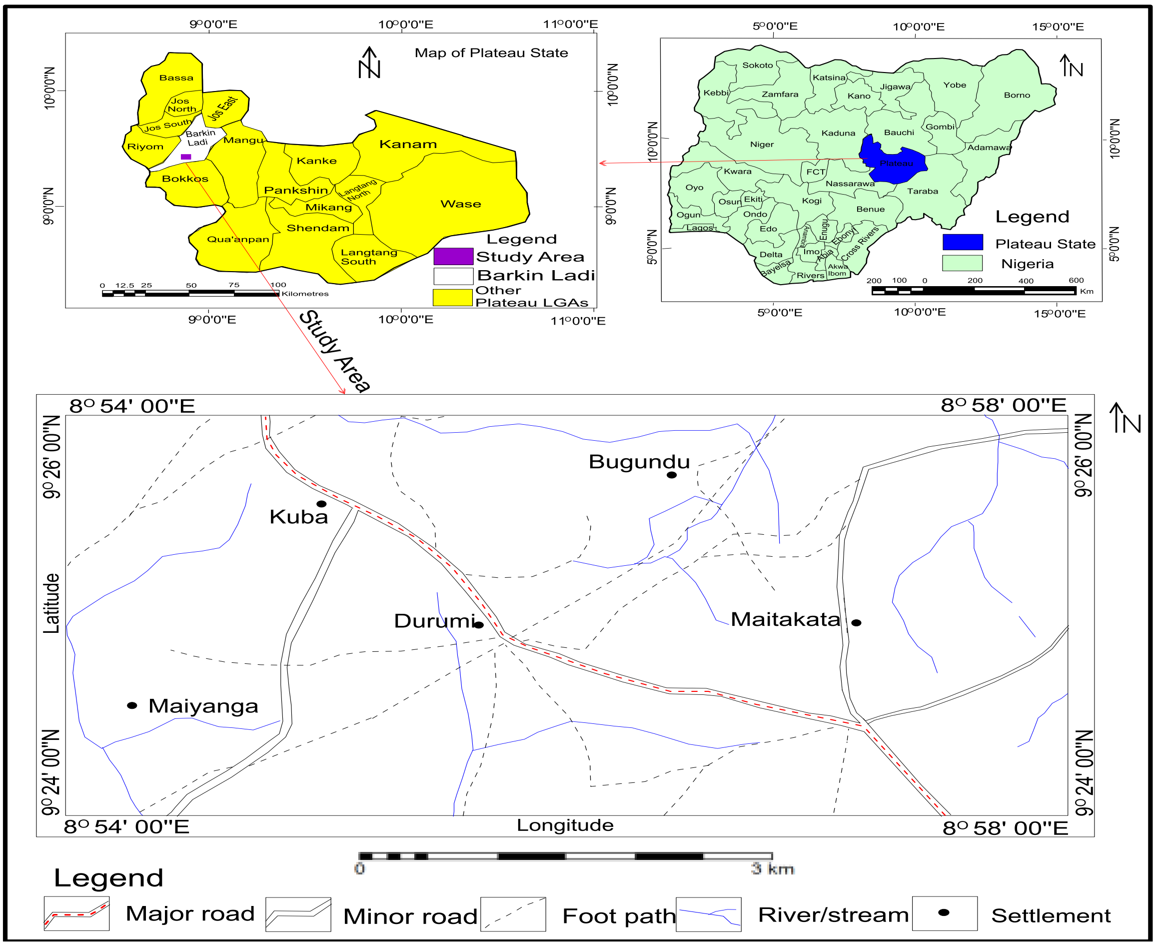

Figure 1: Location map of the study area

Geological Setting

The study area lies on longitudes 8°54' 00" - 8° 58' 00" and latitudes 9° 24' 00" - 9° 26' 00", Plateau North Central Nigeria. It is underlain by Precambrian basement rocks that have been intruded by the Jurassic Younger Granites. Also volcanic intrusion belonging to Older Basalts origin which is Tertiary in age forms part of the rock in the area laterite formed by the weathering of the Older Basalts covered part of the basement rock.The granite –gneiss covered about 30% of the

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study area.They are banded and weakly foliated, caused by segregation of quartz and felsdpars.

Biotite hornblende-granite belonging to the Younger Granites series intruded the basement on the northwestern and the southwestern part of the study area. The biotite hornblende-granite covers about 45% of the study area and is composed of quartz, feldspar, biotite and hornblende, it is medium grained in texture. The Older Basalt is generally completely decomposed, usually to a creamy coloured plastic clay-like material which is responsible for kaolin formation. They have been preserved from complete erosion by the presence of hard laterite capping formed during the weathering of the iron rich basalt rock. It covered about 15% of the study area and is located south east of the area and very little in the north east.

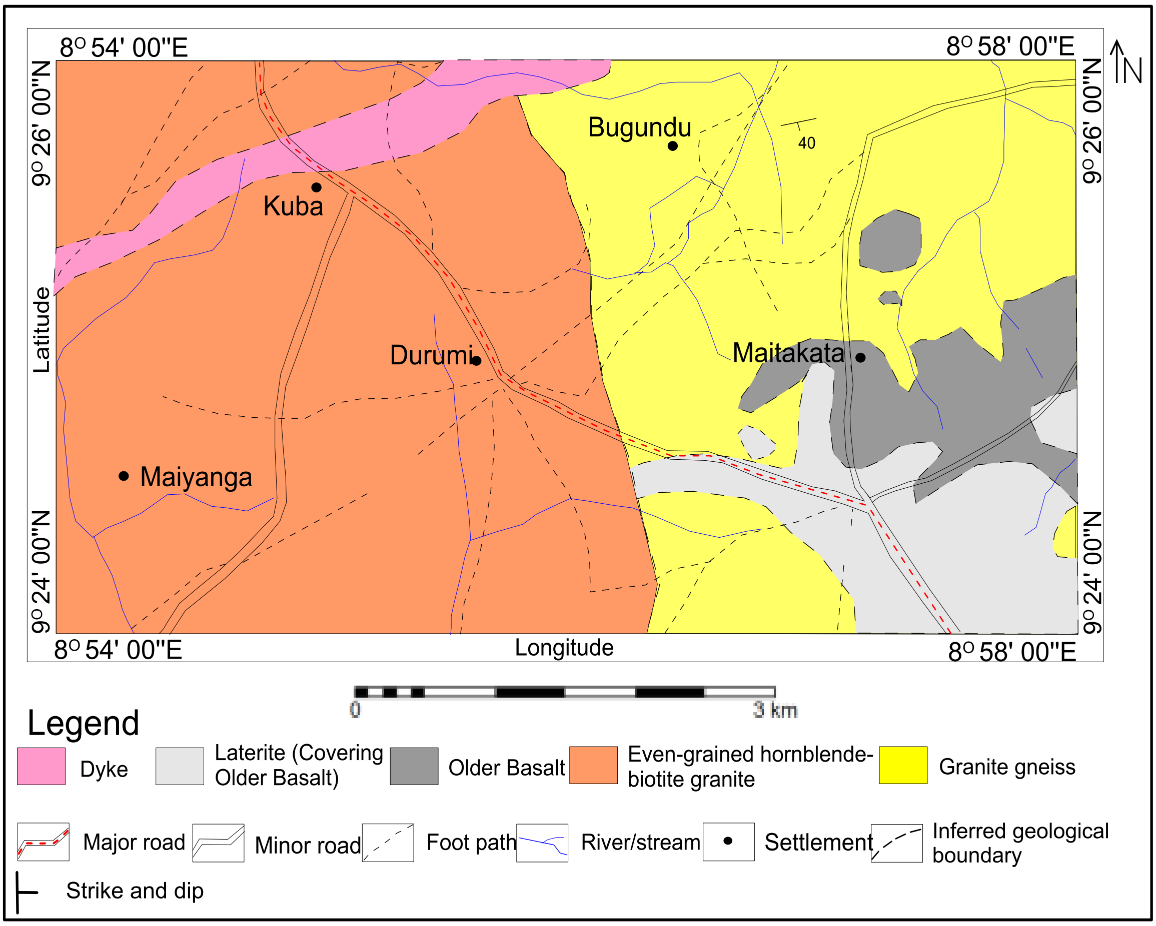

Figure 2: Geological map of the study area

II. METHODOLOGY

A detailed mapping of the study area was carried out with emphases placed on the different rock types of the study area. The clays were grounded with agate mortar and a pestle, before admitting any sample for grinding, the agate mortar and pestle was washed and dried.

A 60µm mesh sieve size was used to ensure that the powered particle are in the same size. The sieve was made of nylon as iron steel sieve can introduce Zn, Pb, and Cu impurities into the samples during sieving.Titration method was used tocarry out the analyses at the National Metallurgical Development Centre (NMDC) in Jos, Plateau State.

Presentation of Results

The analyses results in weight percent is in Table 1, comparism with other clay minerals in Table 2. And 3.

Comparism of Kuba clay minerals with other clay minerals in Nigeria

Table 2 above showed the chemical analyses of clays from weathered rocks of the study area (A, B, C), while columns DL_1 and DL_2 are chemical analyses of clay deposits at Dembori of

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Kirfi District, Alkaleri area of Bauchi State (Kwar, 2002). When calcium is present in an environment the formation of kaolinite is retarded. This is because calcium is formed in a basic environment under high temperature (Kwar, 2002). Therefore, from the results in Table 2, and Figure 6, calcium is not detected (N.D) in the Kuba clays of the study area. This is an indication that the formation of kaolinite in the study area is faster than in the sedimentary clays, because calcium was found in small amount in the sedimentary clay. Clay from the sedimentary origin tends to have low percentage of SiO_2 which is about 43% for both samples. This percentage is lower than actual composition of 46.51% for SiO_2. The Al_2O_3 percentage of sedimentary clay is very close to the actual composition of kaolinite (i.e. actual composition=39.53% while sedimentary clay have DL_1=39.89% and DL_2=39.53%) respectively. Clay samples from sedimentary environment tend to be finer because they have undergone long distance of transportation, thereby, reducing their particles to smaller sizes. Kuba clays range from finer to coarse grain sizes. Sample A clay is finer (SiO_2=43.94%) because it has undergone high degree of leaching with Al_2O_3 31%. Sample B clay is very close to the actual composition of standard kaolin with SiO_2 49.59% and $Al_2O_3$30.88%. This is an indication of purer kaolin than that of the sedimentary kaolin. Due to the fine grain size of sedimentary clay and sample A clay of the study area, they can serve as seal in reservoir rocks or in aquifers.

From Table 3 above, Kuba is an average of sample A, B, and C clays from the study area. Kuba clay sample has a chemical composition close to those of Kankara, and Abeokuta clay samples. The differences in the three clay samples is that Kuba clay has low percentage of Al_2O_3 which is 28.9%, while those of Kankara and Abeokuta are about 34%. The percentage of SiO_2 in the Kuba clay sample is slightly higher than those of Kankara and Abeokuta. Kuba clay does not have anything in common with the Ozubulu clay (Figure 5). High alumina contents are associated with clays rich in kaolinite. Therefore, Kankara and Abeokuta clays can be considered as the best kaolinite because their Si: Al ratios are 1:1 and they have the high alumina content. Kuba clay on the other hand has its Si:Al ratio as almost 2:1 with lower content of aluminium when compared with those of Kankara and Abeokuta clays. This is an indication that the average of Kuba clay is more of montmorillonite than kaolinite. Azubulu clay did not fall under kaolinite or montmorillonite, therefore, it belong to a different class of clay mineral.

Table 1: chemical composition of clay minerals in weight percent

% Oxide	**X**	**A**	**B**	**C**
SiO_2	50.85	43.94	48.59	58.3
TIO_2	2.03	N.D	N.D	N.D
Al_2O_3	14.07	31.00	30.88	24.69
$Fe2O_3$	2.88	1.80	1.03	0.84
FeO	9.06	N.D	N.D	N.D
MnO	0.18	N.D	N.D	N.D
MgO	6.34	0.7	0.7	0.8
CaO	10.42	N.D	N.D	N.D
Na_2O	2.23	0.01	0.05	0.07
K_2O	0.82	0.5	0.60	0.70

N.D = Not detected
Column X gives the results of analyses of sample of a fresh older basaltic rock (Nockolds, 1954). Column A, B, and C give the results of the analyses of clay minerals in the study area.

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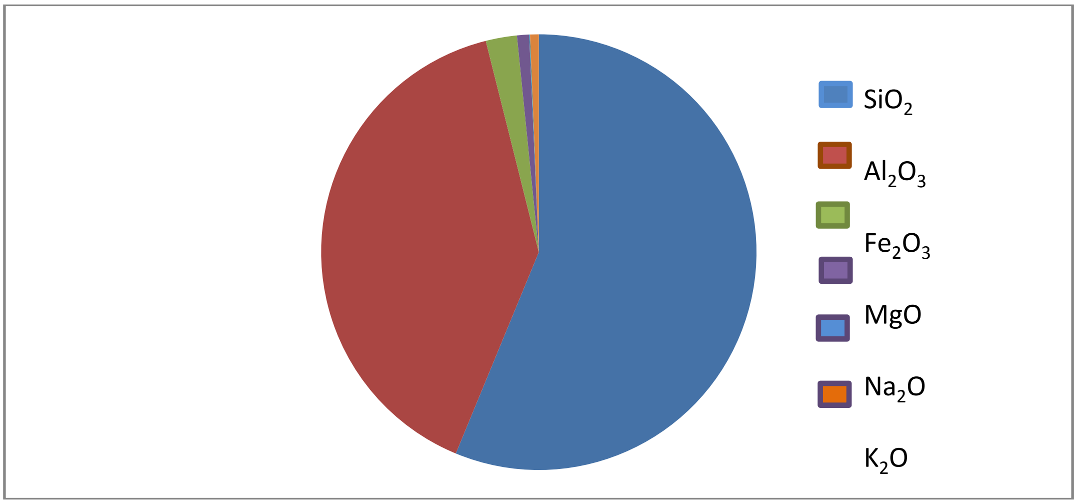

Figure 3: Pie chart of clay sample A

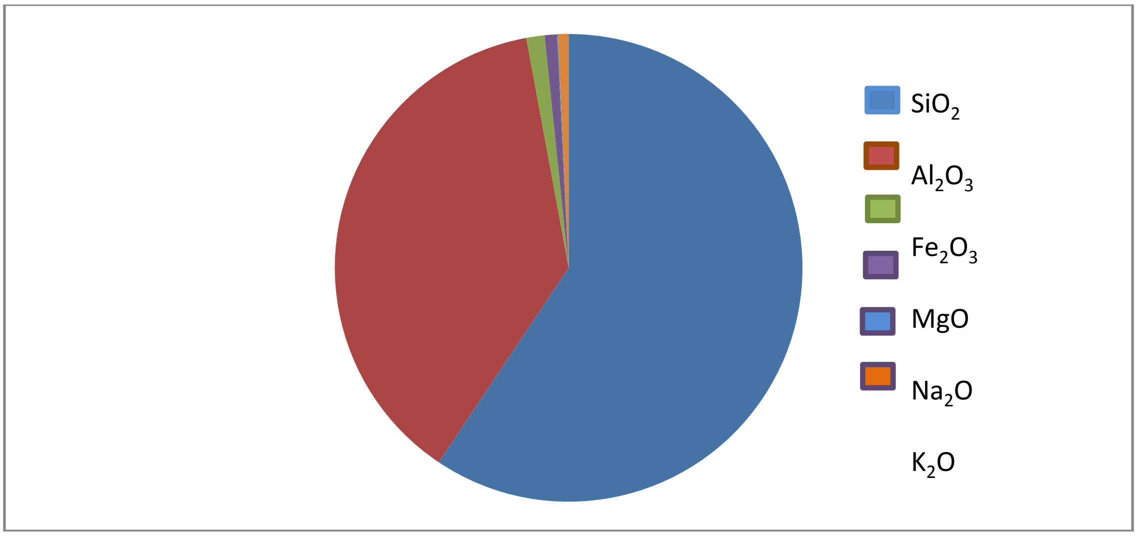

Figure 4: Pie chart of clay sample B

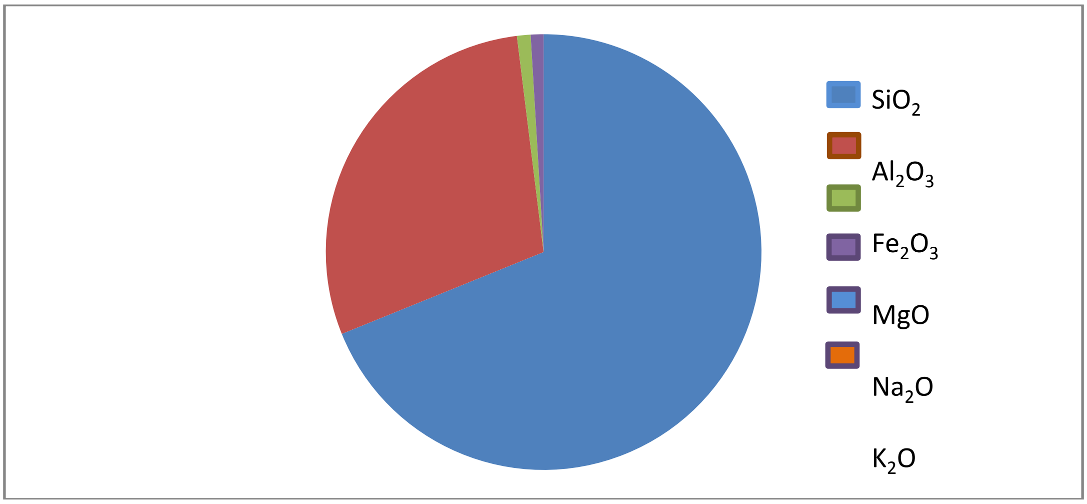

Figure 5: Pie chart of clay sample C

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Table 2: ComparismbetweenKuba clays and Alkaleri Sedimentary clay in Bauchi State

% Oxide	A	B	C	DL1	DL2
SiO_2	43.94	48.59	58.3	43.30	43.60
Al_2O_3	31.00	30.88	24.69	39.89	39.00
Fe_2O_3	1.80	1.03	0.84	0.92	1.11
MgO	0.7	0.7	0.8	0.02	0.03
CaO	N.D	N.D	N.D	0.50	0.25
Na_2O	0.01	0.05	0.07	0.12	0.13
K_2O	0.5	0.60	0.70	0.17	0.12

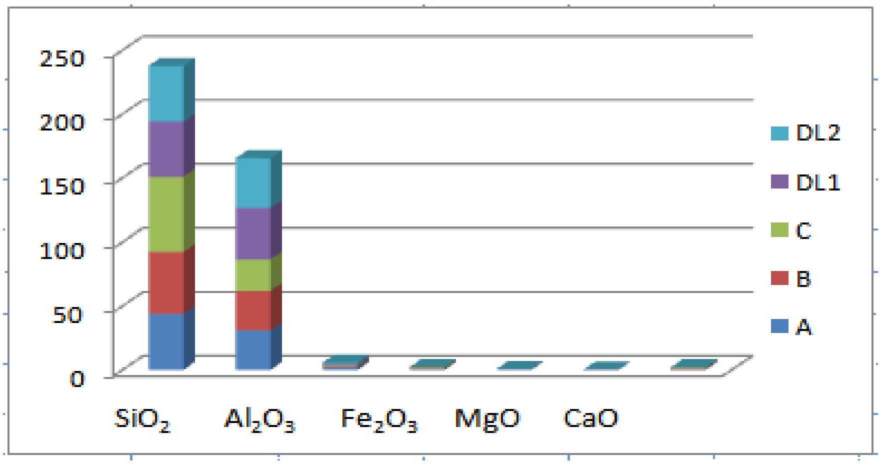

Figure 6: Comparism between Kubaclays and Alkaleri sedimentary clay in Bauchi State

Table 3: Comparism betweenKuba clays (average) with other clay from Kankara, Ozubulu and Abeokuta

% Oxide	Kuba	Kankara	Ozubulu	Abeokuta
SiO_2	50.00	48.73	62.00	48.30
Al_2O_3	**28.90**	34.70	23.20	34.00
Fe_2O_3	**1.22**	2.11	2.12	2.30
MgO	N.D	0.25	0.13	0.16
CaO	0.73	0.31	0.06	0.08
Na_2O	0.60	1.05	0.13	0.39
K_2O	0.04	0.05	0.01	0.01

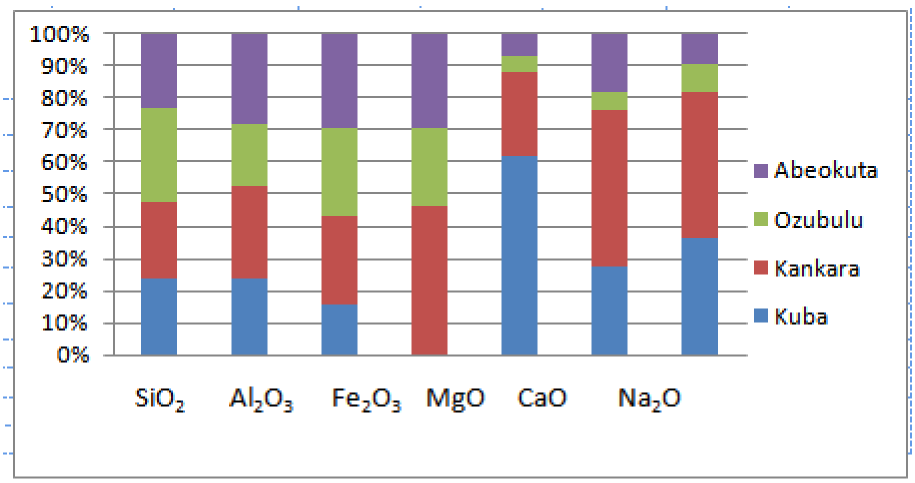

Figure 7:Comparism between Kuba clays (average) with other clay from Kankara, Ozubulu and Abeokuta

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Table 4: Comparism of the chemical composition of analysed Kuba clay (A= kaolin)with chemical specification of industrial kaolin for plastic (b),cracking catalyst (c), rubber (d), textile (e).

% Oxide	A	b	c	d	e
SiO_2	43.94	45.78	44.90	44.90	45.00
Al_2O_3	31.00	36.4	38.35	32.35	38.10
Fe_2O_3	1.80	0.28	0.13	0.43	0.60
MgO	0.7	0.50	Trace	Trace	Trace
CaO	N.D	0.04	Trace	Trace	Trace
Na_2O	0.01	0.25	Trace	0.14	Trace
K_2O	0.5	0.25	Trace	0.28	Trace

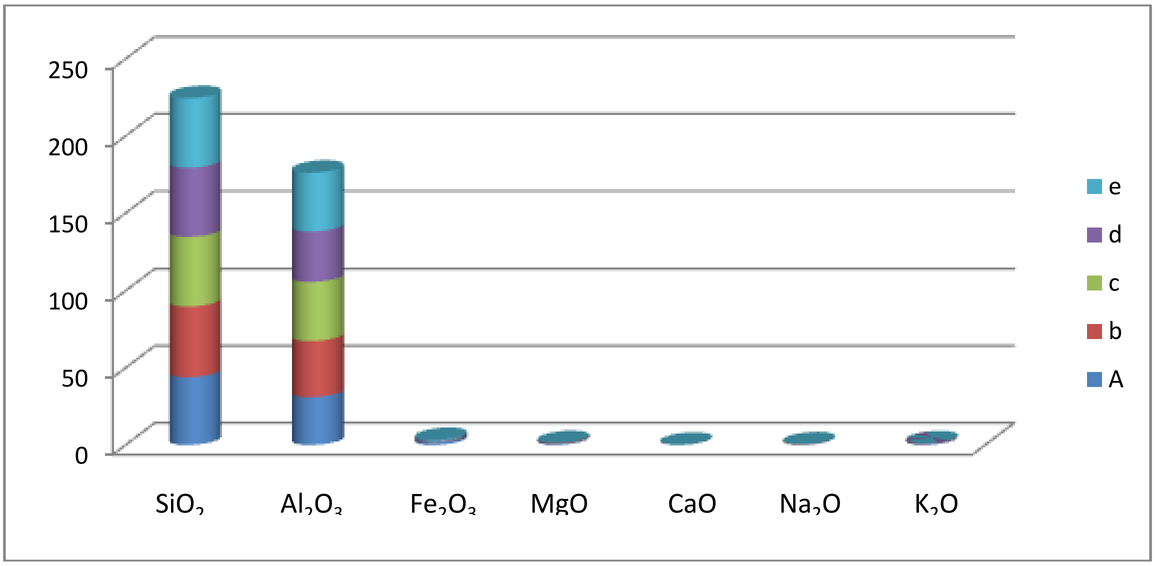

Figure 8: Comparism of the chemical composition of analysed Kuba clay (A= kaolin)with chemical specification of industrial kaolin for plastic (b),cracking catalyst (c), rubber (d), textile (e).

Table 5: Comparism of the chemical composition of analysed Kuba clay (B= kaolin)with chemical specification of industrial kaolin for paper industry as (f) as coating agent, paper industry as filling agent (g), pharmaceutical (h), ceramic (i), industries

% Oxide	B	F	g	h	i
SiO_2	48.59	47.80	47.80	48.00	48.00
Al_2O_3	30.88	37.00	36.00	40.00	37.00
Fe_2O_3	1.03	0.58	0.82	0.10	0.60
MgO	0.7	0.40	0.60	0.01	0.10
CaO	N.D	0.16	0.25	0.20	0.30
Na_2O	0.05	0.10	0.10	0.10	0.10
K_2O	0.60	1.10	2.10	1.10	1.60

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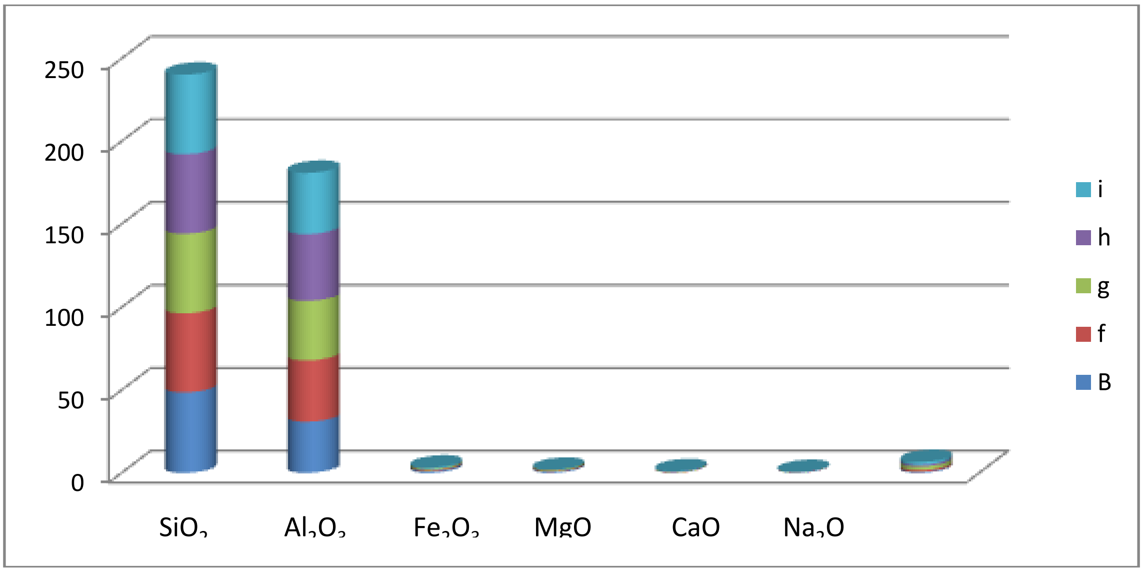

Figure 9: Comparism of the chemical composition of analysed Kuba clay (B= kaolin)with chemical specification of industrial kaolin for paper industry as (f) as coating agent, paper industry as filling agent (g), pharmaceutical (h), ceramic (i), industries.

Table 6: Comparism of the chemical composition of analysed Kubaclay (C= Montmorillonite)with chemical specification of industrial clay for plastic fire clay (j) and refractory bricks (k).

% Oxide	**C**	**j**	**k**
SiO_2	58.3	57.67	51.0-70.00
Al_2O_3	24.69	24.00	25.0-44.0
Fe_2O_3	0.84	3.32	0.5-2.4
MgO	0.8	0.30	0.2-0.7
CaO	N.D	0.70	0.1-0.2
Na_2O	0.07	0.20	0.8-3.5
K_2O	0.70	0.50	Trace

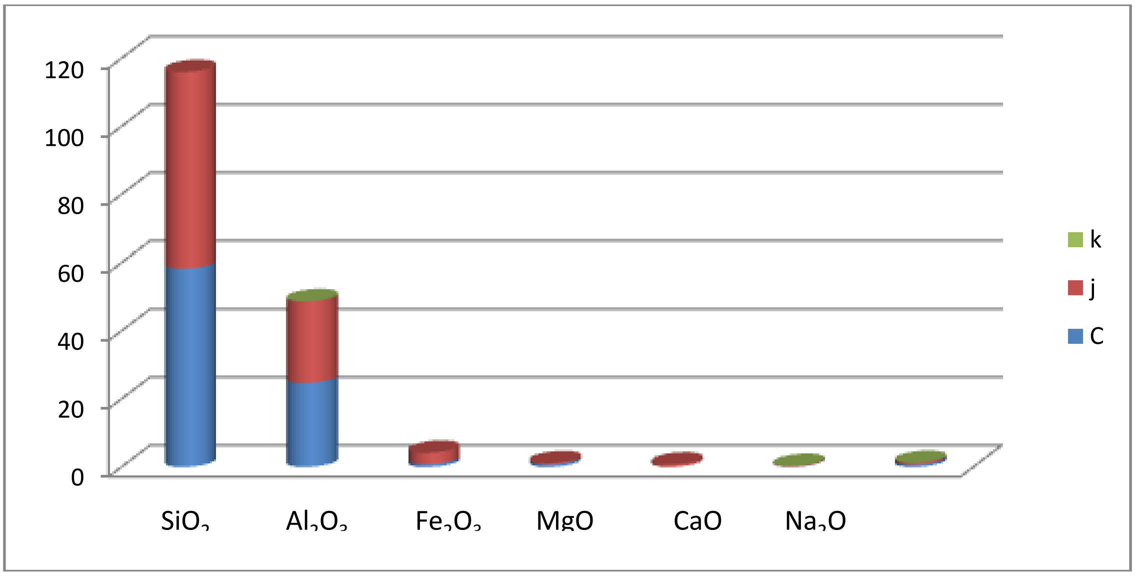

Figure 10: Comparism of the chemical composition of analysed Kuba clay (C= Montmorillonite)with chemical specification of industrial clay for plastic fire clay (j) and refractory bricks (k).

III. DISCUSSION OF RESULTS

The theoretical composition of clay substances or kaolinite is $Al_2O_3.2SiO_2.2H_2O$ which corresponds to a percentage composition of:

SiO_2	46.51%
$Al2O_3$	39.53%
H_2O	13.96%

In fact, this exact composition is not found in nature, although some clays approach it closely. This extent of deviation from this ideal composition gives an indication of the type and extent of impurity present in the clay (Elueze and Bolarinwa, 2001).From the result in Table 1, clay sample B is slightly leached because its SiO_2 is very close to the parent materialand clay sample A is highly leached, there is a difference between it and the SiO_2 composition of the fresh basaltic rock and its composition.Kaolinite has a Si:Al ratio of 1:1 (Elueze and Bolarinwa, 2001). From Table 1 samples A and B have Si:Al ratio of about 1:1 (Figures 3 and 4) and this an indication that these two samples are likely to be kaolinite. On the other hand, montmorillonite has a Si: Al ratio of 2:1, and other cations such as magnesium and iron are probably essential to its formation. Sample C is likely to be montmorillonite because it has a chemical composition that meets this condition (Figure 5).

The Major Oxides Geochemistry of the Kuba Clay Minerals and their Industrial Applications

From Table 4 above, and Figure 6, clay sample A of the study area has a chemical composition which is close to the chemical specification for plastic industry. The different between the two is that the percentage of SiO_2 and $Al_2O_3$are slightly below the required chemical specification standard. Also, Fe_2O_3 and MgOare slightly above the chemical specification standard. The differences are not much therefore, clay sample A can be used in the plastic industry.Also from Table 4 above, and Figure 6, clay sample A has a chemical composition which is very close to that of the industrial specification for used as cracking catalyst except for Al_2O_3 whose composition is slightly lower than that of the industrial specification for used as cracking catalyst. This is an indication that clay sample A is good for use as cracking catalyst.In the same Table 4,and Figure 6, the chemical composition of clay sample A is extremely close to that to that of industrial specification of kaolin for rubber industry. This is an indication that clay sample A is very suitable for use in the rubber industry. From Table 4 aboveand Figure 6, the differences between clay sample A from the study area with the industrial specification for textile industry is only in Al_2O_3 composition which is not much. Therefore, clay sample A is good material for textile industry.

In Table 5 above, and Figure 7, the chemical composition of clay sample B met the industrial requirements for paper industry as coating agent, paper industry as filling agent, pharmaceutical industry, and for ceramic industry. Only that the Al_2O_3 chemical composition is slightly below the industrial specification standard, but the values of the other elements are similar to that of the industrial specifications. The differences in theAl_2O_3 is not much therefore, it can be neglected. From Table 6 above, and Figure 8, the chemical composition of clay sample C in the study area is similar to the industrial specification for plastic fire clay. The only difference is that the Fe_2O_3 is slightly lower than the required standard.In the same Table 6, and Figure 8, the chemical composition of clay sample C in the study area is very perfect for the refractory brick industry. All the chemical compositions of all the elements fall within the range of the industrial specification.

IV. CONCLUSION

The results from the chemical analyses of the three clay samples from the study area revealed two types of clays: kaolinite and montmorillonite. All the three clay samples collected from the study area are of great importance to the Nigeria industries because they met the industrial specification standards for most Nigeria industries. The Clay sample A (kaolinite) from the study area can be used in the plastic, rubber and textile industries. The same clay can also be used as a cracking catalyst in industries. Clay sample B (kaolinite) can be used in the paper, pharmaceutical, and ceramic industries. Likewise, clay sample C (montmorillonite) can be used as plastic fire clay and also in the making of refractory bricks.

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