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Geochemistry, Mineralogy and Reserve Estimate of Clay Occurrence in Kutigi, Northwestern Nigeria.

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Abstract

Kutigi village in Niger State of Nigeria lies within longitude $5^{0}35^{l}E$ and $5^{0}36^{l}E$ and latitudes $9^{o}11^{l}N$ and $9^{o}13^{l}N$ and falls within the sedimentary basin of Nigeria known as Bida basin. Stratigraphy of the northern part of the basin consists of Bida sandstone, Sakpe ironstone, Enagi siltstone and Batati ironstone respectively. Field observations revealed that the clay occur beneath Oolitic ironstone and lateritic soil of about 2.5 meters. Mineralogical and geochemical investigation indicated that the clays are of kaolinitic and are formed from acid rock insitu. Geophysical investigations of the occurrences revealed varying thicknesses of 3 meters, 13 meters and 12 meters of clay. Reserve estimate of 279,760 tones suggested that the clay can be exploitable. Open cast method is applicable due to thin overburden.

KEY WORDS: Geochemistry, mineralogy and reserve estimation.

Introduction

Bida Basin is located within the tropical area which enhances the formation of clay either by chemical weathering of pre-exiting sedimentary rocks rich in feldspathic material or as a result of hydrothermal alteration of sand stone rich in feldspathic material. Clay formation could be inheritance, neoformation or transformation. The nature and characteristics of the clay deposit are inferred by the chemical chrematistics of the parent materials, climatic conditions and the processes by which the clay was formed, (Maurice, 2001).

Depending on its chemical and physical characteristics, clay has found varying uses in a number of industries, like the ceramics, chemical, paint, paper, rubber and pharmaceutical industries among others, (Parker, 1967). Clay is therefore an important raw material for many industries. With increase in population, there is need for raw materials to meet industries demand. Therefore, there is need to investigate clays within the sedimentary basin of Bida basin of northwestern Nigeria. The results of detailed occurring within the sedimentary basin (Kuitgi) in this paper will be of immense contribution to the economic potential of Bida basin.

Location and Geology of the Study Area

Kutigi falls within the central sedimentary basin of Bida Northwestern Nigeria (fig 1). The Bida basin extends from Kontagora in Niger State to Dekina in Kogi State where it merges with the Anambra basin. The total length of the Bida basin was estimated at 400km with a maximum width of about 160km (S.P Brade, 1992). The basin is bounded to the north and south by the precambrain basement rocks. The most important distributaries are River Niger, River Kaduna (Wuya) and River Gurara. The belt of mesas is discontinuous and covers about 10% of the basin. Geophysical evidence of Adeniyi (1985;1986) suggest the sedimentary pile in the basin is about 3.5km thick. The age of the sediments is Maestrichtain as determined by Jan du Chene et al, (1978) from pollens in Lokoja formation to the south, which Adeleye. (1971, 1978) considered to be

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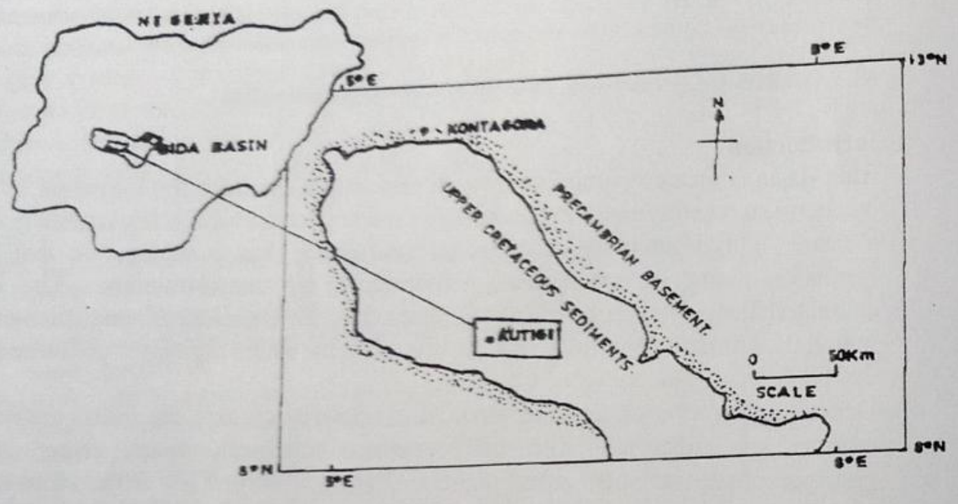
lateral equivalent of the Bida sandstone. A rift origin for the Bida basin has been postulated by Kogbe et al, (1981), Whilst Whiteman, (1982) suggested the basin to have been formed from a simple cratonic sag. Also, Ojo and Ajakaiye, (1989) thought the basin to be of local subsidence.

The northern Bida basin has been stratigraphically subdivided into:

i. – Batati Ironstone ii. – Enagi Siltstone
iii. – Sakpe Ironstone iv. – Bida Sandstone

Kutigi falls between Batati Ironstone/Sakpe Ironstone and Enagi siltstone. It is about 15kms from Sakpe and Enagi and about 25kms from Batati by main road. The area is occupied by about 20% Mesas. Maximum thickness of about 2 meters of ironstone caped the Mesas with variable thin layers of laterite under the ironstone. The siltstone of pale yellow to purplish brown of about 8 meters is exposed east of Enagi.



(Fig. 1). The location map of the study area within Nigeria and the Bida basin itself

Field Occurrence of Clay

An area of 55km^2 was mapped covering Kutigi village and its environs, two rock types of sandstone and oolitic ironstone occurred in the area. Clay was encountered in two locations, all which fall within Kutigi Village (Fig 2). Indicator test was carried out on the clay samples in the field by slowly adding water to a powdered and perfectly dry sample in a plastic bowel and uniformly mixed, the sample gradually assumed first forming lumps and eventually reached a plastic stage at which it was rolled out in long, unbroken thread upon a solid surface of wood. This confirms the material under investigation is clay.

Two hills were confirmed to contain clay. The first hill located beside the Ministry of Works NW of Kutigi Village, is about 36meters high 250 meters long and a maximum

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width of about 300 meters. Two clay beds of varying thickness occurred beneath thin lateritic overburden and ironstone forming the base of the hill.

The second hill located behind Hill side Hotel NE of Kutigi Village is about 30 meters high, forming a continuous ridge and of maximum width of 220 meters. One clay bed is poorly exposed beneath lateritic overburden.

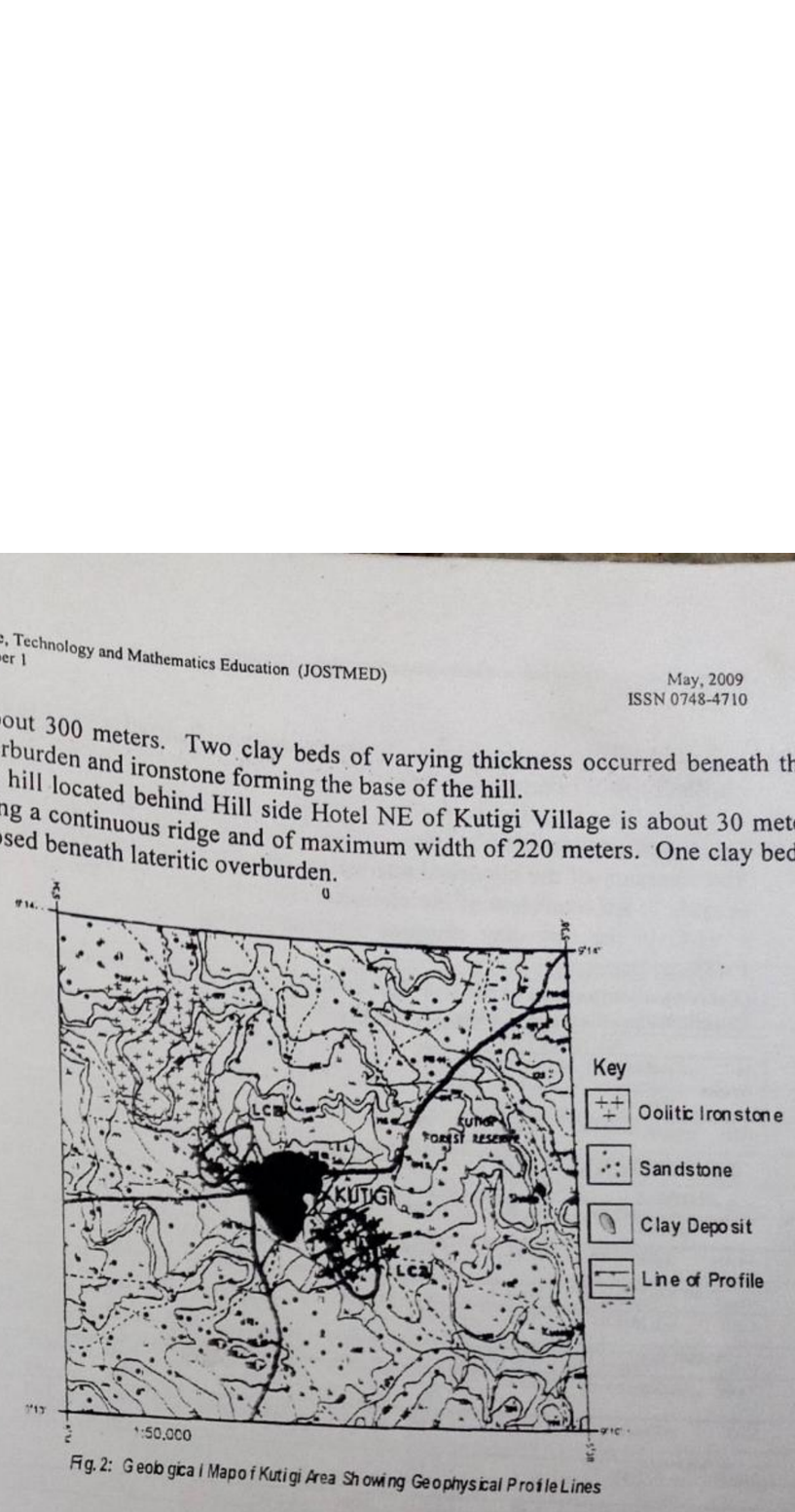


Fig. 2: Geological Map of Kutigi Area Showing Geophysical Profile Lines

Method of Investigation

Twelve representative spot samples were collected at different vertical section of the clay 1.000° bodies (Fig. 5a and 5b). Sieve analysis was carried out to obtain clean clay fraction for analysis.

Mineralogical Analysis.

Powdered samples of the clay were analyzed using Philip PW 1800 model X-ray diffractometer. It was scan using Cu tube anode in a courteous scanning process at an angle of and 70.000$^0\phi$2 using a 55MA/40KV power supply at National Steel Raw National Exploration Agency Kaduna. The diffractograms were interpreted by comparing peaks obtained with those of standard minerals established by the Joint Committee on Powder Diffraction Standard (JCPD, 1974). The relative proportions of the minerals were calculated by using area method described by (Carol, 1971).

Geochemical Analysis

The chemical analysis was by Atomic Absorption Spectrophotometric (AAS) method. Ten Oxides were determined. These include SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, P_2O_5, Na_2O, K_2O and MgO. The intergranular water (H_2O) was determined as percentage loss in weight of the sample after frying in an oven at 110°c for four hours. The structural

water (H_2O^+) was determined at loss on ignition (L.I) after heating the dried sample in muffle for four hours at 1100°c.

Geochemical Analysis

The summary of the chemical analysis result of ten representative samples is represented in table 1. An overview of the chemical analysis shows that the average of $SiO_2 + Al_2O_3$ + H_2O in the raw clay samples constitutes about 95.46%. Other oxides range from 1.45% to trace

(Table 1). Comparison of the Average Chemical Compositions of the Kutigi Kaolin Clays with the Chemical Specification of some Industrial Clay in Percentage.

	KUTIGI CLAY		SOME INDUSTRIAL SPECIFICATION							
% Oxides	Range of 10 Clays %	Average of 10 clays %	i %	ii %	iii %	iv %	v %	vi %	Vii %	viii %
SiO_2	66.1-66.00	66.00	49-88	47.00	45.78	44.90	45.90 – 45.80	45.90 – 45.80	67.50	51.00 – 70.00
Al_2O_3	26.85-26.89	26.87	37.65	40.00	36.46	32.35	33.50 – 36.10	33.50 – 36.10	26.50	25.44
TiO_2	1.36-1.54	1.45	0.09	-	-	1.80	0.00 – 1.70	0.00 – 1.70	0.10 – 1.00	1.00 – 2.80
Fe_2O_3	0.88-0.89	0.88	0.88	-	0.28	0.43	0.30 – 0.60	0.30 – 0.60	0.50 – 1.20	0.50 – 2.40
MnO	Trace-0.03	0.03	-	-	-	-	-	-	-	-
CaO	1.28-1.24	1.25	0.03	-	0.50	Tr	0.00 – 0.50	0.00 – 0.50	0.18 – 0.30	0.1 – 0.2
P_2O_5	Trace-0.39	0.39	-	-	-	-	-	-	-	-
NaO_2	Trace-0.02	0.02	0.21	-	0.25	0.14	0.00 – 1.60	0.00 – 1.60	0.20 – 1.50	0.80 – 3.50
K_2O	Trace	Trace	1.60	-	0.25	0.28	0.00 – 1.60	0.00 – 0.60	1.1 – 3.10	-
MgO	0.15-0.19	0.17	0.13	-	0.04	Tr	-	-	0.10 – 0.19	0.20 – 0.70
H_2O	2.35-2.59	2.59	12.43	10.00	13.40	14.20	14.20	14.20	12.00	-
Total		99.65								

i. *Agricultural (Huber. 1985)*
ii. *Pharmaceutical (Todd. 1973)*
iii. *Paints (Paynes. 1961)*
iv. *Plastic (frados. 1965)*
v. *Rubber (Keller. 1964)*
vi. *Paper (Keller. 1964)*
vii. *Ceramics (Singer and Sonja. 1971)*
viii. *Refractory Bricks (Parker. 1964)*

Geophysical Investigation

Electric resistivity method was adopted using ABEM 303 machine of which it operative physical property is electric conductivity. This is to determine the thickness and area extent of the clay occurrence at each location. A total of twenty six (26) profiles were run covering all the area to be investigated. Electric Resistivity Profile (ERP) was adopted first using Werner array configuration, this provide means of studying lateral variation in the resistivity of the ground. A spacing of 10 meters was chosen for electrical resistivity profiling.

The Vertical Electrical Sounding (VES) was adopted nest; this provides means of studying horizontal resistivity variation of the ground. This involved the schlumberger array configuration with electrode spacing, AB/2, varying from 1 meter to 100 meters.

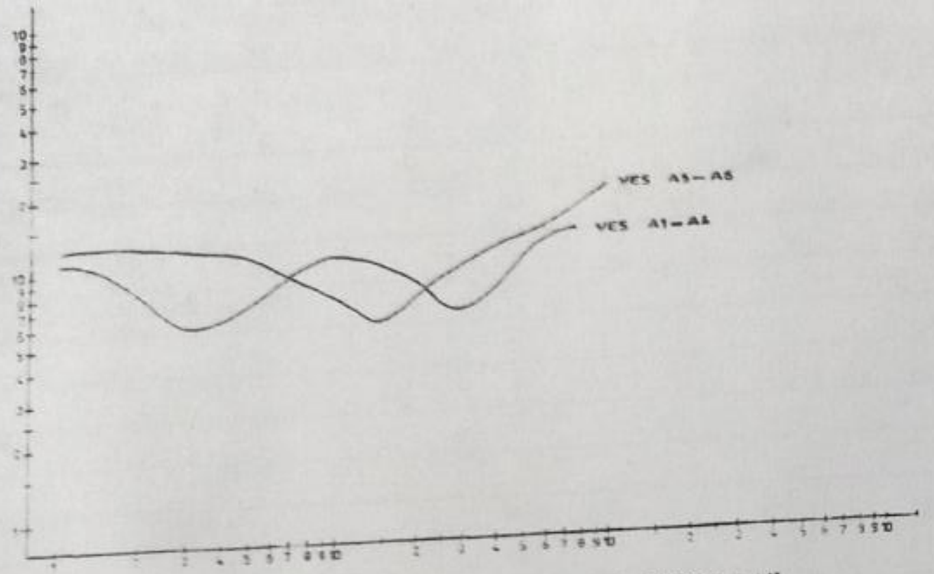
A general observation of VES curves show two turning point curve for location A and are within electrode separation $^{AB}/_2$ of 3.5 meters and 6 meters for the first turning point and 30 meters to 50 meters for the second turning point ($VES_1 – VES_4$, for $VES_5 – VES_6$), there is only one toning point with electrode spacing $^{AB}/_2$ of 10 meters and 25 meters

(Fig 3a). One turning point curve was observed on VES curve for location B which is within electrode separation $^{AB}/_2$ of 8 meters and 25meters (Fig 3b; $VES_5 – VES_6$). Quantitative interpretation for VSE data was performed using the conventional partial curve matching method. The results and interpretation of VES group stations is shown in table 1.

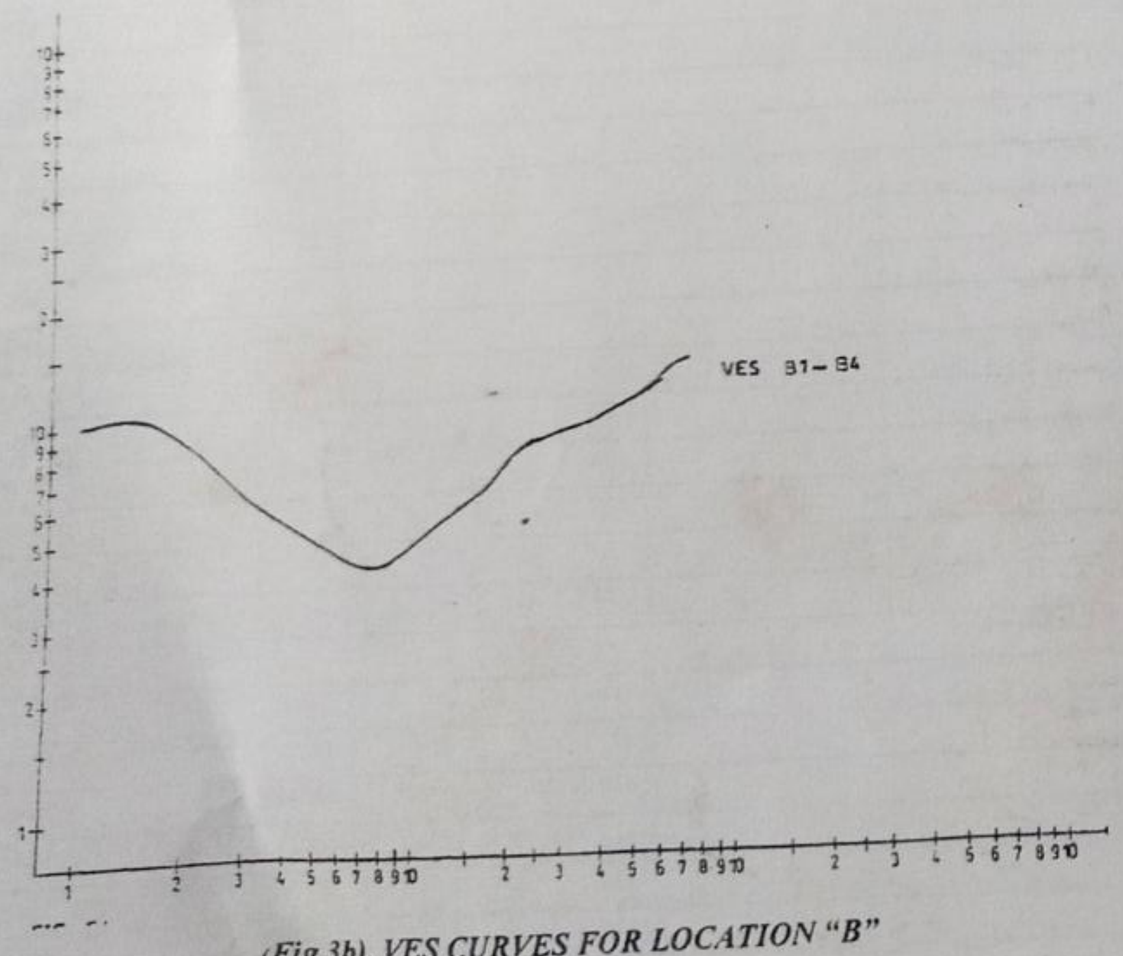
(Tab. 2) VES RESULTS AT KUTIGI GROUP STATIONS

Station Numbers	Layer Number	Average Resistivity (Ohm m)	Layer Thickness (m)	Lithology Observed Diagnostic Soil
Location A				
1	1	120	2.5	Laterite
	2	66	13	Clay
	3	106	16	Laterite
	4	170	13	Clay
	5	129	Infinity	Sandstone
2	1	112	2.7	Laterite
	2	65	3.5	Clay
	3	105	17	Laterite
	4	69	12.5	Clay
	5	130	Infinity	Sandstone
3	1	106	2.4	Laterite
	2	62.5	3.1	Clay
	3	98	15.5	Laterite
	4	71	12.8	Clay
	5	123	Infinity	Sandstone
4	1	92	2.6	Laterite
	2	63.5	3.0	Clay
	3	96	15	Laterite
	4	70	13.5	Clay
	5	115	Infinity	Sandtstone
5	1	120	7.3	Laterite
	2	70.5	10.5	Clay
	3	108	Infinity	Sandstone
6	1	118	7.6	Laterite
	2	71	10.2	Clay
	3	138	Infinity	Sandstone
Location B				
1	1	106	2.3	Laterite
	2	47	10.5	Clay
	3	420	Infinity	Sandtstone
2	1	112	2.5	Laterite
	2	45	10	Clay
	3	115	Infinity	Sandtstone
3	1	120	2.4	Laterite

	2	41	10.5	Clay
	3	140	Infinity	Sandtstone
4	1	108	2.4	Laterite
	2	46	10	Clay
	3	110	Infinity	Sandstone



(Fig 3a). VES CURVES FOR LOCATION "A"



(Fig 3b). VES CURVES FOR LOCATION "B"

Specific Gravity Investigation

Density bottle method was used to determine specific gravity of clay samples.

First of all the density bottles were washed, dried, cooled to 20°c and weighed (w_1) to avoid contamination of clay samples and hence an error of free reading. The clay samples were then dried at low temperature over night.

50g of clay sample which was passed through 2mm sieve was obtained and was divided into three equal half and placed in to three different density bottles. Each of the bottles was weighed (w_2). Distilled water was slowly poured into each of the bottles from the side of the bottle to avoid entrapping of air and the disturbance of the clay sample. To attain even saturation, the bottle was stirred and shaken. More distilled water was added till the bottle was half filled. Bottling method was used so as to remove air from the bottle using a water bath. The bottles were there after placed in the refrigerator, at a temperature of 20°c the bottles were weighed (w_3) after cooling. Separate bottles were cleaned and filled completely with de-aired distilled water by boiling, refrigerated and weighed at 20°c (w_4).

The specific gravity (Gs) of the clay samples was obtained using the formula below.

$$Gs = \frac{(w_2 - w_1)\, G_1}{(w_4 - w_1) - (w_3 - w_2)}$$

Where :- Gs= Specific gravity of liquid used at constant temperature (Gs= assumed to be equal to 1.0 for distilled water).

w_1 = Mass of density bottle (g)
w_2= Mass of density bottle + dry soil
w_3= Mass of bottle + soil + liquid (g)
w_4= Mass of bottle + liquid (g)

Mineralogical investigation

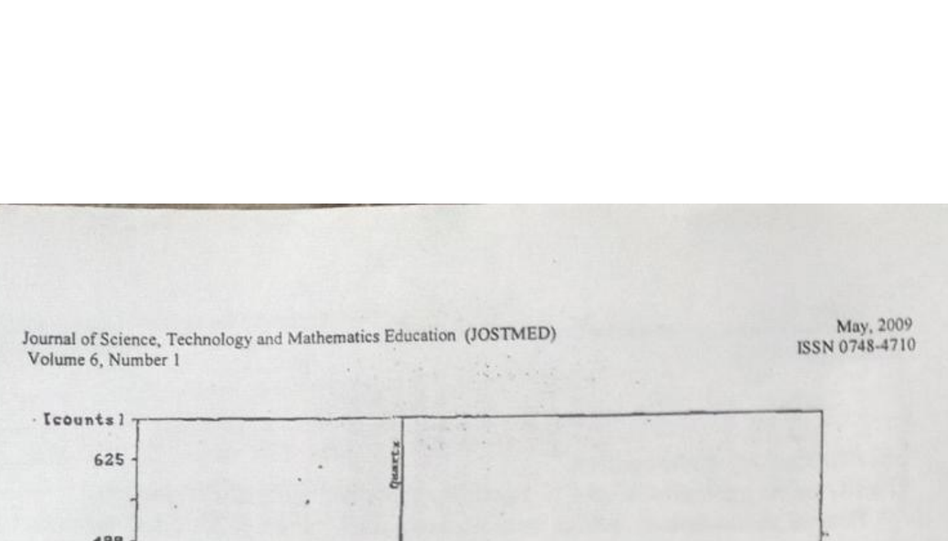
Result of Mineralogical analysis is presented in Table 3. show that the mineralogical assemblages of all samples are similar and mineral present have been indicated against their diagnostic major peaks, distinctive kaolinite peaks is the dominant clay minerals in the sample at d = 7.32 Å and d = 3.61 Å. Quartz and feldspar are the non-clay constituent that exhibits notable intensities in the diffractograms(Fig 4a and 4b).

(Table3). Average mineralogical composition (%) of Kutigi kaolin compare with well-known kaolin deposits.

Mineral %	Kutigi Clay	Well known Kaolin deposits		
	Average (10) Samples	I	ii	Iii
Kaolinite	85	91	96	85
Quartz	13	6	2	Tr
Illite	-	3	3	15
K-feldspar	Tr	-	-	-
Others	-	-	-	-

i. *Average mineralogical composition of the Ibandan kaolin (Emofurieta, 1988)*
ii. *Average mineralogical composition of the Kaduna (Kankara) Koaline (Emofurieta, 1988)*
iii. *Average mineralogical composition of the China-Clay (Huber, 1985)*

(Fig. 4a). Diffraction of the studied clay fraction



(Fig. 4b). Diffractograms of the studied clay fractio

Results.

Field Observation.

A generalized lithologic distribution of clay shows that the lithology of the area displayed intercalation of laterite and clay soil of varying thicknesses, the clay varies from white to reddish brown in color as a result of stain from overburden oolitic ironstone. The top thin Oolitic ironstone and lateritic soil is conformable to the clay soil below (Fig.5a and 5b). The sandstone that dominant rock type in the area is of typical Bida sadstone.

(Fig. 5a). Geological section of Kutigi clay (location A) from geo-physical datas

(Fig. 5b). Geological section of Kutigi clay (location B) from geo-physical datas

Geophysical investigations and manual tape measurements taking in the filed from abadoned pits and exposures, revealed three clay beds of average thickness of 3m, 10m and 13 meters on location A and 2 meters on location B.

Reserve estimation calculation

Location A
Thickness of clay = 16m
Surface area of clay = 250 x 26
Specific gravity = 2.6
= 16 x 250 x 26 x 2.6
= 270,400 tone

Location B
Thickness of clay = 12
Surface area of clay = 30 x 10
Specific gravity = 2.6
= 12 x 30 x 10 x 2.6
= 9,360 tone

Total = 279,760 tones

Discussion and Conclusion

Field observation indicate that the contact zone of the clay and the overlying oolitic ironstone and laterite is mottled reddish brown due to the leaching of Fe from the overlying oolitic ironstone and laterite by percolating water. Also, the clays are gritty in between fingers. This suggested that the clays are formed insitu.

Mineralogy analysis revealed that the clays are essentially Kaolinitic in nature with quartz and feldspar occurring as impurities.

Comparisons of kutigi Kaolin with well-known kaolin deposits indicate that Kutigi kaolin is similar to the Ibadan kaolin.

Geochemically, major element abundance shows that the kaolin have SiO_2 66%, Al_2O_3 26.87%, TiO_2 1.45%, Fe_2O_3 0.99%, other elements range between 0.39% to trace. This implies that the parent rock forming the kaolin is acidic in nature. Comparison of the average chemical composition of Kutigi kaolin with the chemical specification of some industrial clays revealed that Kutigi kaolin can find use in ceramic and refractory brick industries, (Emofurieta 1988). Reserve estimation of 279,760 tones can serve medium scale industry. These clay occurrences can be mined by opened cast method. Also, effective beneficiation of these clays will increase the kaolinite content that can fit other industrial uses.

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