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Research Paper

ASSESSMENT OF INDUSTRIAL POTENTIAL OF KAOLINITE CLAYS FROM BAUCHI, NE NIGERIA

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Clays around Bauchi North-Eastern Nigeria, were investigated in order to determine their suitable in different industries. Minerological, chemical and geotechnical compositions were determined in order to ascertain their quality. This was achieved by using X-Ray Diffraction (XRD), X-Ray Fluorescence (X-RF) and atterberg limits using the (BS 1377) method. Based on plasticity classification chart, the clays were classified as silty clays with medium plasticity, X-RD reveals that the clays are kaolinite (48.35-90.37wt%) with minor quartz, anatase, muscovite, microcline and hematite, while XRF shows predominance of SiO_2 (47.60-56.20%) and Al_2O_3 (23.60-36.4%) which also support the kaolinite nature of the samples, and also shows they are aluminosilicates. Based on the different qualities, the clays are said to be useful in different industries like ceramics, paper, paints and bricks.

Keywords: Minerological, Chemical, Kaolinite, Bauchi

INTRODUCTION

Clay is a name given to a fine grained, earthy material that is tenacious and plastic when moist, and become hard when fired or baked. Clay is a product of chemical weathering of pre-existing granitic rocks or feldspar minerals, usually in warm tropical and sub-tropical regions or from hydrothermal alteration of granitic rocks. Chemically, they are hydrous aluminum silicates, with some impurities like, potassium, sodium, calcium, magnesium, or iron and have characteristics of sheet silicate structure of composite layers that are stacked along the C-axis (Grim, 1968). Clay has a wide range of occurrences globally, in Nigeria clays are widely distributed in almost every part of the country. Clay serves as a major raw material in numerous industries which include ceramic, paint, paper, refractory, fertilizer and pharmaceuticals (Abel *et al.*). Clays from Kutigi Bida Basin have wide range of uses which include ceramics, refractory bricks, paper, paint and fertilizer (Akhirevbulu, 2010). Nigerian clays were assessed by Mark *et al.* (2009) and found out that the clays have the potential to serve as raw material in ceramic, paper, paint, fertilizer and pharmaceutical if beneficiated. This paper is aimed at determining the industrial potentials of some of the clays found

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within Bauchi State. The area lies within latitudes 9°30’ E to 11°50’ N and longitudes 9°50’ E to 11°30’ E, and has huge deposits of kaolinite which are mostly mined by local illegal miners.

GEOLOGIC SETTING

The study area is underlain by the Kerri-Kerri Formation which is the youngest Formation within the Gongola Basin in Nigeria. The sequence is characterized by clays, silts and sandstones. (Maigari *et al.*, 2005). The deposit is a secondary deposit formed as a result of in-situ alteration of igneous rocks (Eze, 2015). It represent Early Tertiary sediments in the Gongola Basin, Nigeria (Dike, 1993).

MATERIALS AND METHODS

Representative clay samples were collected from different clay rich areas within Bauchi State (Figure 2). The samples were pulverized to 0.07 mm size and packed for XRF and XRD analyses at University of Pretoria, South Africa.

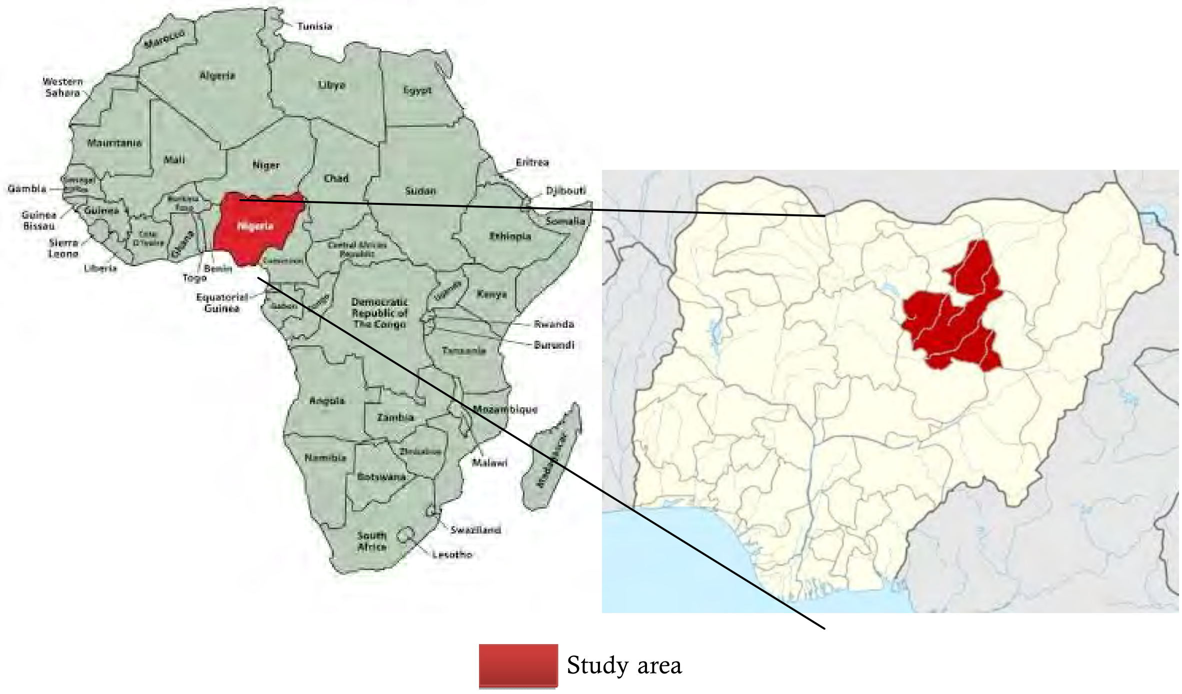
Chemical Analysis

The samples were dried at 100°C and roasted at 1000 °C to determine Loss on Ignition (LOI) values. 1 g sample was mixed with 6g Lithiumteraborate flux and fused at 1050 °C to make a stable fused glass bead. For trace element analyses the sample was mixed with PVA binder and pressed in an aluminium cup at 10 tons. The Thermo Fisher ARL Perform’X Sequential XRF with OXSAS software was used for the analysis.

Mineralogical Analysis

The samples were analyzed using a Panalytical X’Pert Pro powder diffractometer in θ–θ configuration with an X’Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Ká radiation (λ = 1.789Å). The

Figure 1: Location Map of the Study Area



phases were identified using X'Pert High score plus software.

The relative phase amounts (weight %) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3 sigma level in the column to the right of the amount.

Physical Analysis

Atterberg limits (Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) were determined for all the twelve samples using the British method of testing (BS) 1377: Part 2: 1990) at Soil laboratory Civil Engineering Department of the Abubakar Tafawa Balewa University Bauchi.

RESULTS AND DISCUSSION

Mineral Constituents

The mineralogical analyses as shown in Table 1 and Figures 3, 4 and 5 shows that the clays are predominantly kaolinite, with Papa clays containing 87.34%, Gabarin 46.23%, Alkaleri 81.84%, Kirfi 90.37%, while quartz is the dominant non-clay mineral detected, other non-clay minerals detected include anatase, microcline, muscovite and hematite. When compared with other clays within Nigeria in Table 2, the mineralogy is similar which all have kaolinite as the dominant clay mineral.

Figure 2: Geological Map of the Study Area (Modified from Dike, 1993)

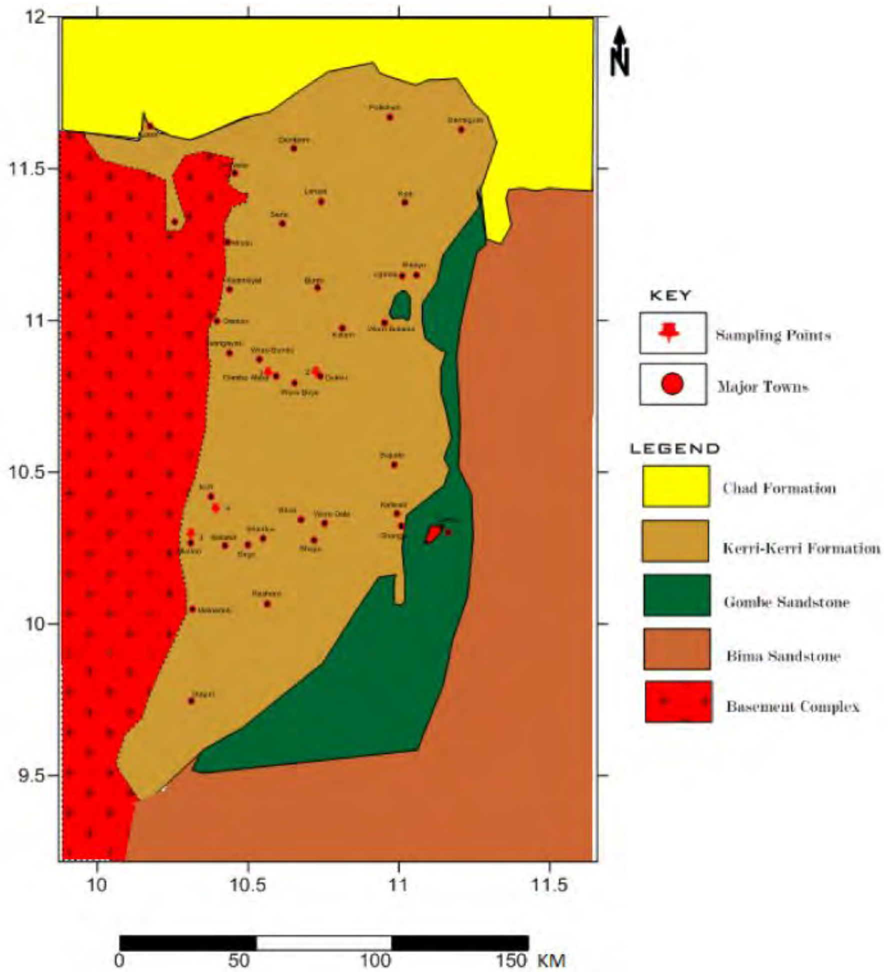


Table 1: Mineral Composition of Samples from Bauchi

Mineral	Papa	Gabarin	Alkaleri	Kirfi
Kaolinite	87.34	48.35	81.84	90.37
Quartz	10.93	37.2	4.75	6.29
Anatase	1.73	-	2.8	3.35
Muscovite	-	-	10.61	-
Microcline	-	6.91	-	-
Hematite	-	7.00	-	-

These clays are therefore kaolinite clays and can be used in different industries which include agriculture, painting, textile, pharmaceuticals, ceramics, refractory bricks, after beneficiation in order to reduce the amount of impurities like quartz.

Chemical Composition

The chemical compositions of the analyzed clays as show n in Table 3, indicates that silica (SiO_2) is the major oxide with value ranging between 47.60% to 49.10%, these range of values are similar when compared with other clays within Nigeria and around the world in Table 4, the high SiO_2 content indicates quartz content, Bain *et al.* shows that quartz occurs as fine crystal particles in kaolinite, if the quartz is in excess of 50%, then quartz is the main constituent of the clay sample. From the analyzed samples all SiO_2 content is

Table 2: Mineral Composition of Samples from Bauchi Compared with Nigerian Clays

Mineral	Papa	Gabarin	Alkaleri	Kirfi	1	2	3
Kaolinite	87.34	46.35	81.84	90.37	72	63	50
Quartz	10.93	37.2	4.75	6.29	16	21	36
Anatase	1.73	-	2.8	3.35	-	-	-
Muscovite	-	-	10.61	-	7	-	3
Microcline	-	6.91	-	-	-	-	5
Hematite	-	7.00	-	-	-	-	-

Note: 1. Asaba (Okunlola *et al.*, 2014), 2. Ibadan (Okunlola *et al.*, 2014) and 3. Benin (Okunlola *et al.*, 2014).

Figure 3: Mineralogical Compositions Plot

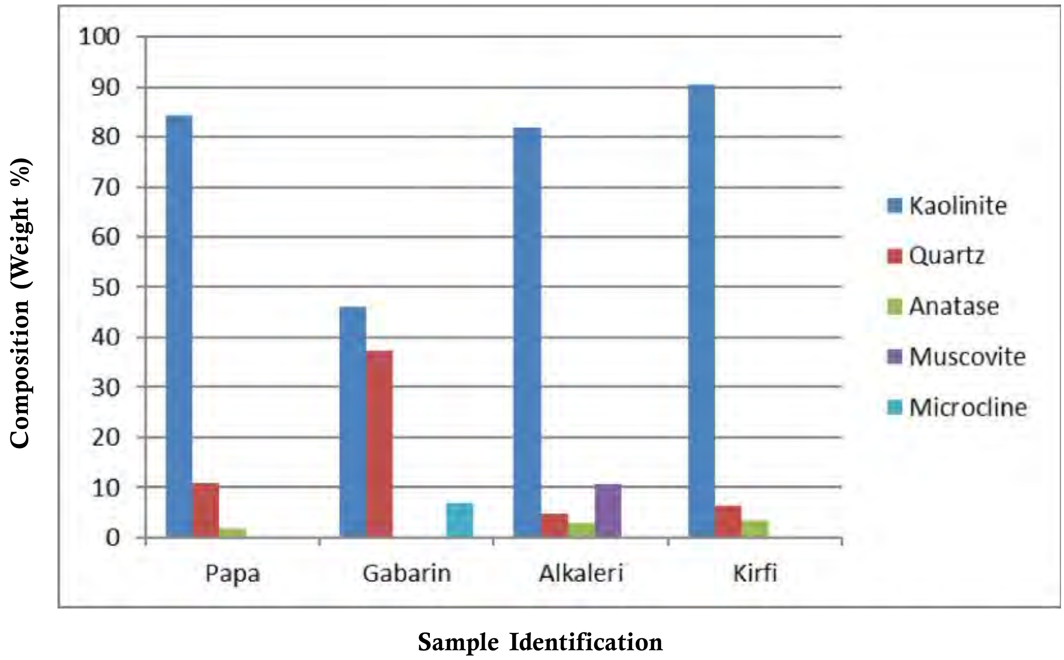


Figure 4: X-Ray Diffraction of Alkaleri Sample

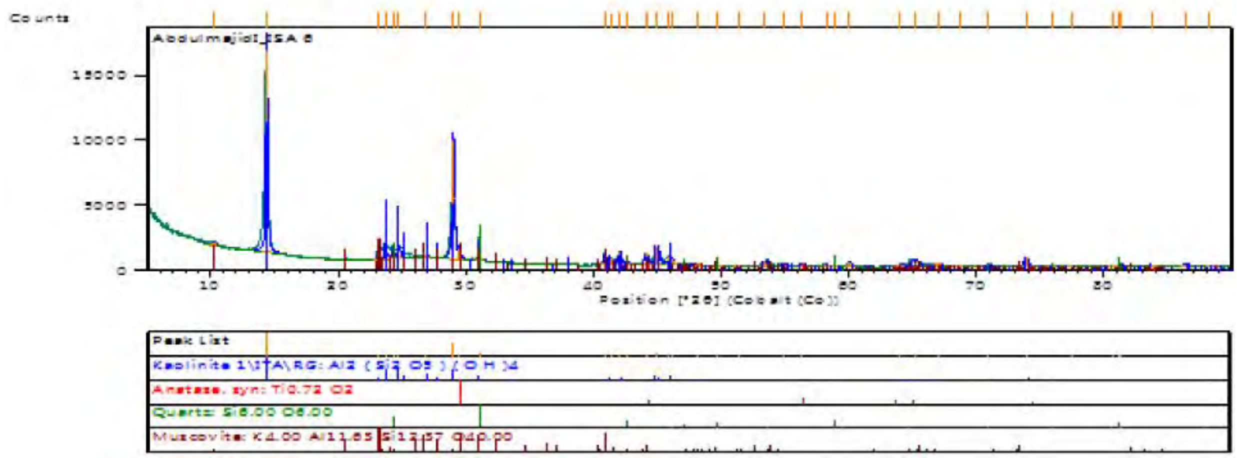
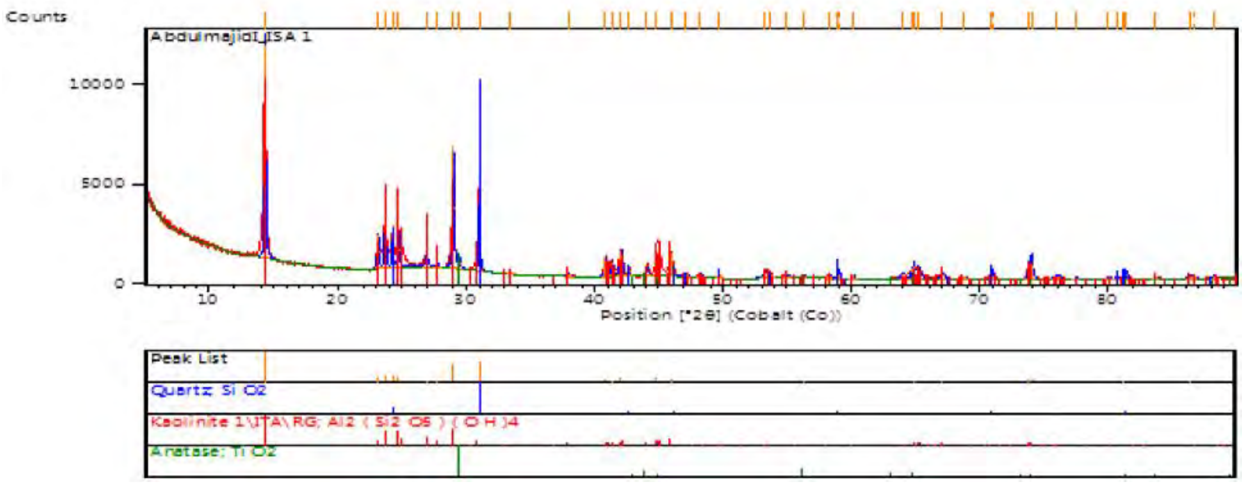


Figure 5: X-Ray Diffraction of Papa Sample



below 50% except sample from Gabarin which has SiO_2 content of 56.20%. Also the alumina (Al_2O_3) content ranges between 31.6% to 36.4% which also comparable with other clays within Nigeria and around the world in Table 3. According to Ekosse *et al.*, Al_2O_3 increases as kaolinization increases and also hydrated clay minerals are formed like kaolinite, from the data sample D from Kirfi has the highest alumina content and the highest kaolinite content while sample B from Gabarin has the lowest alumina content and hence the lowest kaolinite content as shown in Ttable 1. The presence of Fe_2O_3 indicates presence of hematite, Fe_2O_3 content is very low except for sample from Gabarin which has 1.42%, this can also be seen from the XRD analysis, it is the only sample that show the presence of hematite.

The results shows that Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, TiO are in minor amounts and similarly compared with clays within Nigeria and around the world. The low CaO, MgO, K_2O

Table 3: Chemical Composition of Bauchi Kaolinite

Oxides (%)	A	B	C	D	E
SiO_2	48.9	56.2	47.6	49.1	48.78
TiO_2	2.88	2.2	1.72	1.97	2.19
Al_2O_3	34.3	23.6	35.4	36.4	34.43
Fe_2O_3	0.99	1.42	0.7	0.35	0.78
MnO	0.01	0.01	0.01	0.01	0.01
MgO	0.03	0.05	0.01	0.01	0.03
CaO	0.01	0.04	0.03	0.03	0.03
Na_2O	0.01	0.01	0.01	0.01	0.01
K_2O	0.06	0.19	0.16	0.06	0.12
P_2O_5	0.07	0.09	0.06	0.02	0.06
LOI	12.6	8.25	13.1	12.8	11.69

Note: A. Papa, B. Gabarin, C. Alkaleri, D. Kirfi and E. Average.

Table 4: Average Chemical Composition of Bauchi Kaolinite Compared with Previous Research Works

Oxides (%)	A	B	C	D	E	F	G	H
SiO_2	48.8	44.98	58.69	49.88	45.47	46.77	46.55	48.78
Al_2O_3	34.4	37.54	21.89	37.65	38.45	37.79	39.49	34.43
Fe_2O_3	0.78	2.35	2.74	0.88	0.75	0.36	-	1.53
MnO	0.01	0.007	-	-	-	-	-	0.01
MgO	0.03	1.72	0.22	0.13	0.05	0.24	-	0.03
CaO	0.03	0.92	1.51	0.03	-	0.13	-	0.03
Na_2O	0.01	0.19	0.66	0.21	-	0.05	-	0.01
K_2O	0.12	1.01	0.79	1.6	0.06	1.49	-	0.12
T_iO_2	2.19	1.42	0.92	0.09	0.1	0.02	-	2.19
P_2O_5	0.06	-	-	-	-	-	-	0.06

Note: A = Bauchi kaolin (this study), B = Ibadan kaolin (Emofurieta), C = Ilorin (Olusola *et al.*, 2014), D = China clay (Huber, 1985), E = Florida Non-active kaolinite (Huber, 1985), F = UK kaolin (Aref and Lei, 2009), G = Ideal kaolin (Aref and Lei, 2009).

and Na_2O shows that the clays are not expansive.Also when compared with other industrial specifications in Table 5, all the clays can be used for agricultural purposes, ceramic industry and textile industry, while the kaolinite clays are not favorable for use in pharmaceuticals and refractory bricks, because of high amount of impurities. However, these impurities can be removed by using various techniques of

Table 5: Chemical Composition of Bauchi Kaolinite Compared with Some Industrial Specifications

Oxides (%)	I	II	III	IV	V	VI	VII	VIII
SiO_2	48.78	49.88	48.67	67.5	47	51.7	45	46.07
Al_2O_3	34.43	37.65	19.45	26.5	40	25-44	38.1	38.07
Fe_2O_3	0.78	0.88	2.7	0.50-1.20	-	0.5-1.20	0.6	0.33
MnO	0.01	-	-	-	-	-	-	-
MgO	0.03	0.13	8.5	0.10-0.19	-	0.2-0.7	-	0.13
CaO	0.03	0.03	15.85	0.18-0.30	-	0.1-0.2	-	0.03
Na_2O	0.01	0.21	2.76	1.20-1.50	-	0.8-3.5	-	0.27
K_2O	0.12	1.6	2.76	1.10-3.10	-	-	-	0.43
TiO	2.19	0.09	-	-	-	-	1.7	0.5
P_2O_5	0.06	-	-	-	-	-	-	-

Note: I. Bauchi clays (This study), II. Agriculture (Huber, 1985), III. Brick clay (Murry, 1963), IV. Ceramic (Singer and Sonja, 1971), V. Pharmaceutical (Todd, 1973), VI. Refractory Brick (Parker, 1967), VII. Textile and VIII. Fertilizer (NAFCON, 1985).

Figure 6: Plasticity Classification Chart (After Casagrande, 1932)

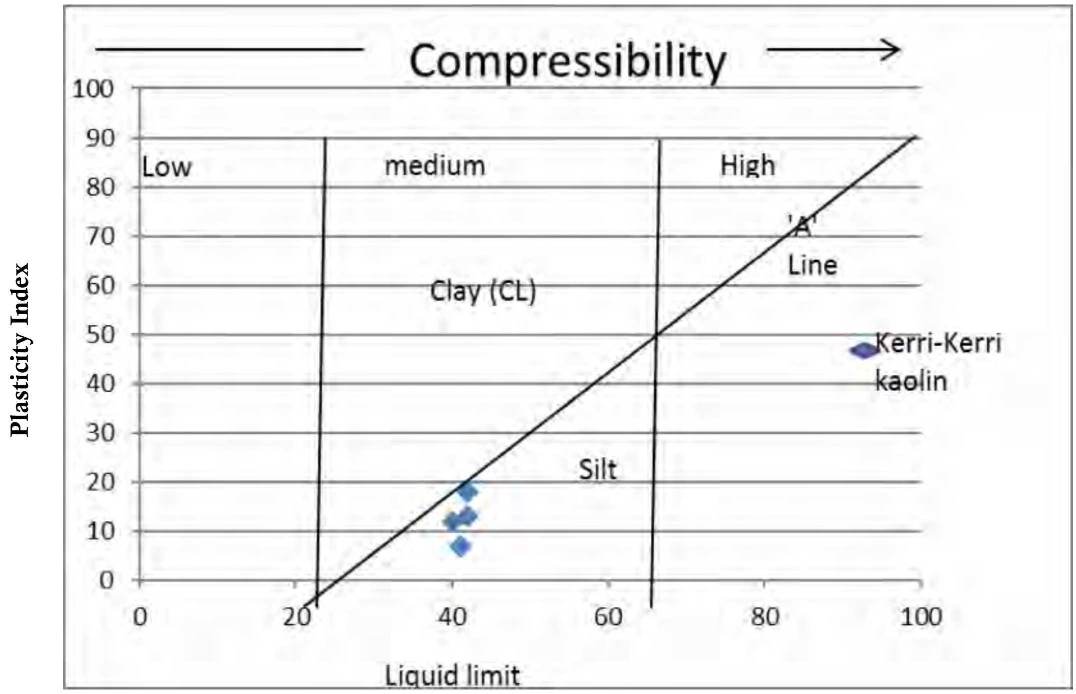


Table 6: The Atterberg Limits and Linear Shrinkage of Kerri-Kerri Kaolin

Sample Number	Plasticity (%)			Linear Shrinkage (%)
	LL	PL	PI	
Alkaleri	42	24	18	95
Kirfi	40	28	12	95.7
Papa	42	29	13	95
Gabarin	41	34	7	22.6

beneficiation, like sieving, leaching and magnetic separation.

Physical Properties

The liquid limit is the moisture content in which clay begins to behave as liquid and start flowing. According to Dondiet *et al.* (2008) ceramic kaolin should have at least 49.4% liquid limit. From Table 6 all the samples have liquid limit between 40-42%, which is within the range of ceramic application. High liquid limit indicate high clay content, which is a good characteristic for ceramic kaolin. Plastic limit is the minimum moisture content in which clay starts crumbling when rolled into a thin thread. The plastic limit ranges between 24-34%, this is within the range plastic limit of ceramic application. Plasticity index is the range of moisture content in which clay behaves plastically. It shows how clay changes it shape without rupturing when water is added. From the plasticity classification chart in figure 6 all the samples fall within medium plasticity and below the A line, this indicate the samples are clays with high silt content which can be reduced by beneficiation.

CONCLUSION

The mineralogical, chemical composition and physical properties of Bauchi clays was evaluated in order to find their possible application in various industries. It was determined that the clays are kaolinitic with quartz as the dominant non clay mineral, the clays also have high SiO_2 and Al_2O_3 with low Ca, Mg, Na and K. After comparison with various industrial standards, the abundance of kaolinite, low Fe_2O_3 and TiO_2 the kaolinite clays of Bauchi were found to be useful in agriculture, painting, brick making, ceramics and paper industry with beneficiation were necessary.

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