



GEOCHEMICAL AND MINERALOGICAL CHARACTERISTICS OF CLAY DEPOSITS AT IJESHA-IJEBU AND ITS ENVIRONS, SOUTH-WESTERN NIGERIA

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ABSTRACT

Two residual clay deposits and one transported clay deposit in Ijesha-Ijebu area were investigated for their mineralogical, chemical and industrial properties. The investigation was to evaluate their industrial applications and economic importance. The mineralogy of the clay samples was determined using X-ray Diffraction (XRD). The chemical composition of the clay samples was determined using Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). Physical tests which include; thermal properties, plasticity tests, density measurement, linear shrinkage and water absorption capacity were determined to determine their industrial potentials. The clay within the weathered profiles above banded gneiss and pegmatite at Ijesha-Ijebu is brownish with red spots, while the clays derived from sedimentary terrain is chocolate in colour. The X-ray diffraction results showed that kaolinite is the dominant mineral, while quartz, albite and muscovite are the major non clay minerals. Chemical data showed that the values of SiO₂, Al₂O₃ and Fe₂O₃ are 66.11%, 20.53% and 3.07%, respectively in weathered banded gneiss, in sedimentary the values of SiO₂, Al₂O₃ and Fe₂O₃ are 42.12%, 34.43% and 7.37%. In weathered pegmatite, the values of SiO₂, Al₂O₃ and Fe₂O₃ are 53.17%, 32.7%, 1.44%, respectively. The average percentage of clay in the banded gneiss, pegmatite and sedimentary samples are 50%, 56% and 47% respectively. The clay mouldability ranged between moderate to high. Evaluation of the clay properties and characteristics shows the industrial application of the clay like production of ceramic, building bricks and other structural wares.

KEYWORDS: Clay, Mineralogy, Chemistry, Ceramics, Building bricks.

1.0 INTRODUCTION

The use of clay in pottery making antedates recorded human history, and pottery remains provide a record of past civilizations. As building materials, bricks (baked and as adobe) have been used in construction since earliest time. Impure clays may be used to make bricks, tile, and the cruder types of pottery while china clay is required for the finer grades of ceramic materials. Another major use of clay is as paper coating and filler; it gives the paper a gloss and increases the opacity. Refractory materials, including fire brick, chemical ware, and melting pots for glass, also make use of kaolin together with other materials that increase resistance to heat. Fuller's earth clays have long been used in wool scouring, and rubber compounding, the addition of clay increases resistance to wear and helps eliminate molding troubles.

Clay minerals are the most important industrial minerals whose application is dependent on its physical, mineralogical and chemical composition. Clay bodies are widely distributed on the Precambrian basement complex of Nigeria (Ajayi and Agagu, 1981; Emofurieta and Salami, 1988, Bolarinwa 2005, Elueze 2014, Adegbuyi, 2015, Adeola and Dada 2016, Adeola et al. 2017). The southwestern part of Nigeria is noted for two main categories of clay occurrences comprising of residual and sedimentary clays (Elueze and Bolarinwa, 2001). These clays are generally consumed as industrial raw materials in the cement, ceramic; paper, pesticide, fertilizer, refractory and pharmaceutical industries. In the Southwestern Nigeria, the geology the sedimentary and residual clays have been investigated to determine their physical, chemical, mineralogical composition and firing properties. The industrial applications of these clays were investigated extensively

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by Elueze 2001 and Ajayi 1981. In Nigeria, clay deposits have not been utilized adequately considering the qualities of this type of industrial mineral that occurs in the country. This may be due to lack of geological information on the assessment of the clay deposits and what they can be used to manufacture. It is very pertinent that the physical and chemical properties of any clay deposit should be ascertained for industrial uses. The present investigation is intended to study the physical, chemical, mineralogical and industrial characteristics of the clay and appraise the economic potentials of the clay at Ijsha-Ijebu and its environs. This obviously will complement previous studies that were mainly concentrated on geochemistry of weathered profiles above basement rocks in the area.

DESCRIPTION OF THE STUDY AREA

The study area is located in Ijebu North East Local Government Area of Ogun State. It lies within longitude

$6^{\circ} 54' N$ and $6^{\circ} 59' N$ and latitude $3^{\circ} 46' E$ and $3^{\circ} 54' E$ with an area expanse of 141 km^2 . Ago-Iwoye and Ilishan-Remo are the closest major towns to the study area. The study area is well drained by River Ona, Omi and other numerous branches flowing south. The vegetation of the study area is of the tropical rain forest and the climate can be characterized by distinct wet and dry seasons. The study area is situated within the Transitional contact between the Precambrian basement of Nigeria and Ise Formation within the Dahomey Basin. The basin is a sedimentary basin on the continental margin of the Gulf of Guinea, it extends from the Volta region of Ghana in the west to the Okitipupa ridge on the western flank of the Niger Delta (Jones and Hockey 1964; Omatsola and Adegoke, 1981). The geological map of Dahomey basin is presented in Figure 1. Banded gneiss is the most predominant rock type in the study area. The rock is part of the Precambrian rocks of Nigeria and a product of high grade metamorphism

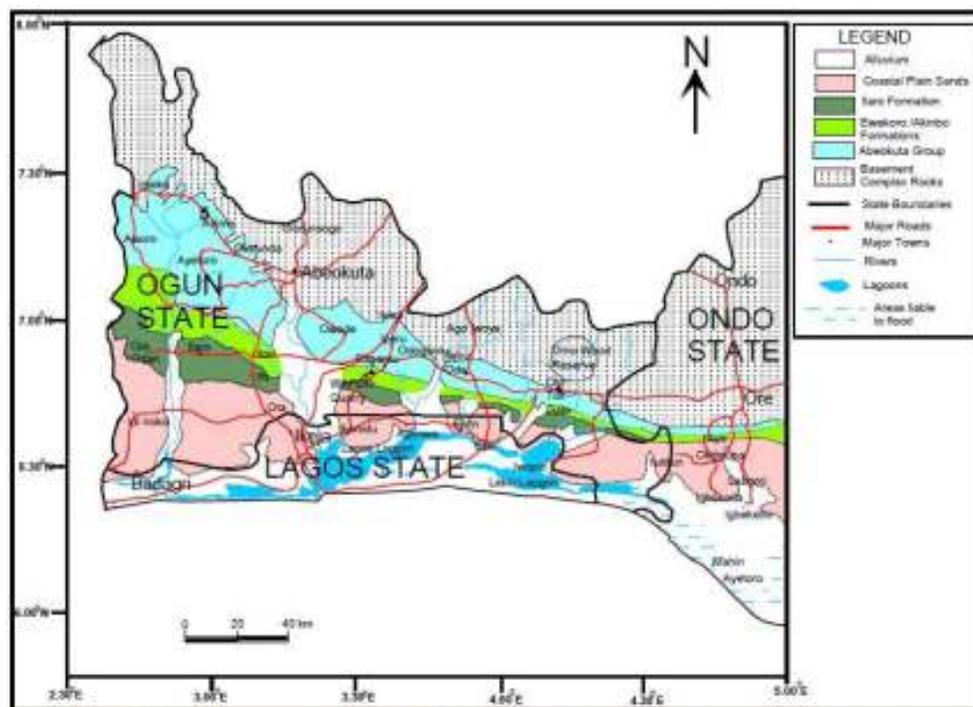


Figure 1: Geological map Dahomey Basin (after Olabode and Mohammed, 2016)

2.0 METHODOLOGY

Detailed field mapping of the area was carried out to delineate the contact between the basement and sedimentary terrain. The method of investigation was compass traversing method, rock outcrops, road cuts and river channels were mapped. Profiles on both road cut and river channels were developed to show the variation in horizons. Clay samples from the profiles were collected, described, appropriately labelled and sent to the laboratory for further investigations.

Twenty four samples from the three clay types were subjected to chemical and mineralogical analyses. Clay mineralogy was determined using X-ray Diffraction (XRD) at Activation Laboratory in Canada. The X-ray diffraction analysis was performed on a Panalytical X'Pert Pro diffractometer, equipped with a Cu X-ray

following conditions: voltage - 40 kV; current - 40 mA; range - $5-80^{\circ}$, 2θ ; step size: 0.017° , 2θ ; time per step: 50s; divergence slit: fixed, angle 0.5° . The crystalline mineral phases were identified by X'Pert HighScore Plus software using the PDF-4 ICDD database. The quantities of the crystalline minerals were determined using the Rietveld method. The Rietveld method is based on the calculation of the full diffraction pattern from crystal structure information. Elemental compositions of the rocks and clay samples were determined using Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) at Activation Laboratory, Canada. For ICP-MS, microwave high pressure/temperature decomposition of samples ($230^{\circ}C$, 7.0MPa; Paar Physical Multiwave sample preparation system) using Merck Suprapurs grade

measurements were made on a Sciex/Perkin-Elmer ELAR 6000 ICP-MS.

Firing characteristics

The characteristics of clay are affected when it is fired are; colors, shrinkage, porosity and loss on ignition. Color is one of the important properties used in assessing the suitability of clay for industrial use. The presence and the relative amount of iron and other constituents have great influence on clay's color. Generally, a desired color may be acquired by firing at different temperatures. Firing procedure was carried out with collecting four subsamples of 50g each from the residual clay over banded gneiss, residual clays over pegmatite and from the sedimentary clays in the study area. The subsamples were pulverized and made into pellets. The diameters of the pellet were measured before placing them in a furnace for firing at temperatures ranging from 100°C - 870°C for two hours. The clay pellets were allowed to cool down at room temperature in desiccators to determine their firing properties such as color change, shrinkage, moisture content and loss on ignition

Water Absorption: The fired pellets of clay were placed in a furnace at 1100°C and allowed to cool in desiccators, weighed and completely immersed in a

beaker of water at room temperature. The soaked pellets were cleaned with a damp cloth and reweighed. The difference between the weights gives the water absorption capacity of the clay sample. Water absorption is calculated as percentage of the original weight of the pellets.

Loss on Ignition (LOI)

Loss on ignition (LOI) was measured as the loss in weight after the clay was heated and it was expressed as percentage of the original weight. The pellets were weighed accurately before and after firing. Loss on ignition (LOI) was derived from the loss of weight and the difference gave the loss of ignition. The loss of ignition was calculated at a temperature of 1100°C.

Linear Shrinkage (LSK)

The pulverized clay samples were mixed with water to form paste and transferred into a shrinkage mould. The pastes were leveled into the rim of the mould and the surface smoothed. After oven-drying for twenty-four hours, the width of the resulting cast which had shrunk considerably was measured against that of the shrinkage mould using a Venier caliper. The difference was calculated as thus;

$$\text{Linear shrinkage} = \frac{128\text{mm} - X\text{mm} * 100}{128\text{mm}} \#(1)$$

*Length of shrinkage mould = 128mm

*Length of sample after oven drying = Xmm

2.0 RESULTS AND DISCUSSION

FIELD OBSERVATIONS AND MACRO-PETROGRAPHY.

The geology map of the study area was developed and presented in Figure 2. Seven rock types were identified in the study area namely, banded gneiss, porphyroblastic gneiss, schist, quartzite, granite, pegmatite and sedimentary suites (conglomerate, sandstone and clay). Banded gneiss is most predominant rock type in the study area covering about 60% map, it is bounded in the southwestern part by the Ise Formation of the eastern Dahomey basin and the other rocks especially the intrusive (granites and pegmatites) are embedded in it as pockets.

Three clay types were identified in the study area namely, residual clays over banded gneiss, residual clay over pegmatite and the sedimentary derived clays. The geological profiles of the clay horizons were developed. The first clay occurrence (Profile 1) lies on latitude N06° 55' 04.2" and longitude E03° 47' 27.2." with a thickness of about 5m and it is located on a roadcut exposure along Ilishan – Ago Iwoye road (

Figure 3a). The occurrence was observed as a residual clay over banded gneiss. The profile is within the contact between the basement and the Tertiary Ise Formation of the eastern Dahomey Basin, Nigeria. The presence of

relic structures from the banded gneiss and angular quartz grains in the profile strongly supported its insitu nature. Three distinct layers were identified based on colour, texture, and relic structure. The upper horizon is composed of the topsoil which is brownish in color and is about 0.5m thick. It is also characterized by the presence of rootlet of plants organic matter (humus) and quartz pebbles. Below the topsoil is the lateritic layer with little organic content. This unit is light brown with a thickness of about 1.8m. The lateritic layer grades gradually into the underlying clayey horizon. Underlying the laterite layer is the clayey layer. It is reddish brown in colour and has a thickness of about 2.6m. The clay layer is characterized by the presence of quartz and Iron-oxide which is responsible for the red color. The Iron-oxide suggests they are sourced from the ferromagnesian minerals in the banded gneiss.

The second clay occurrence in the study area (Profile 2) is located on latitude N 6° 55' 4" and longitude E 3° 47' 27" and has a thickness ranges between 3 to 6.5m with varied depths (

Figure 3b). The colour of this clay ranges from beige to yellow and with grits of quartz. The clay horizon was observed to have been formed as a result of the chemical decomposition of pegmatite intrusions across the banded gneiss.

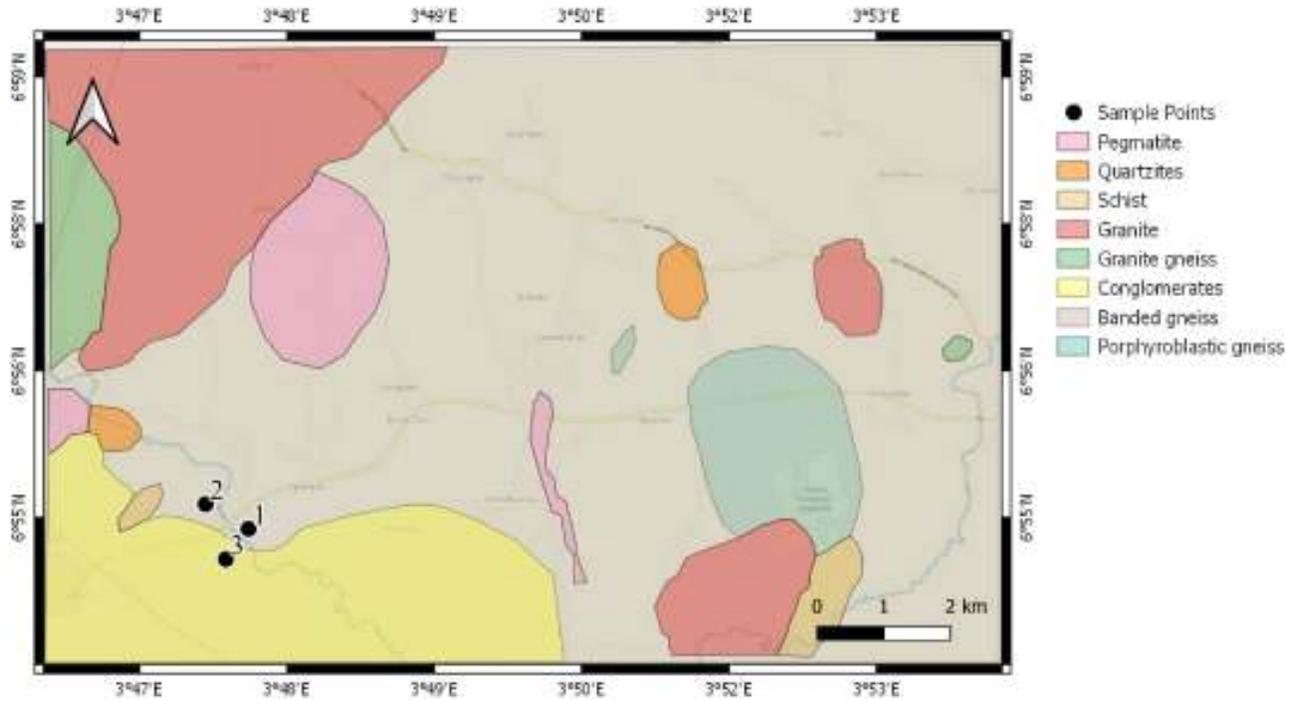


Figure 2: Geologic map of the study area showing the study profiles

The third clay occurrence in the study area (Profile 3) is located on latitude N6° 55' 4.3" and longitude E3° 47' 2" and has a thickness of 7m thick (

Figure 3c). The clay is sedimentary in origin, it is whitish in color, overlaid by an intercalation of sandstones and conglomerates and embedded with clay balls.

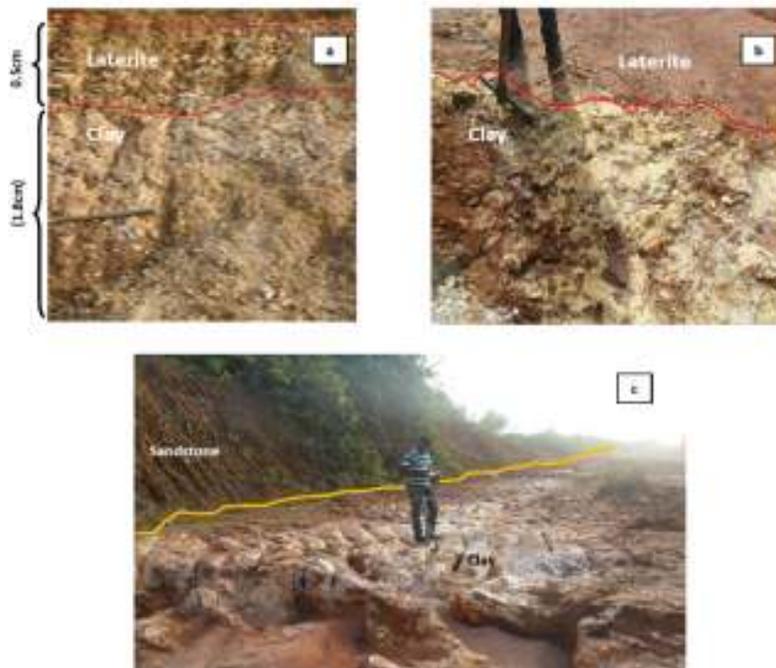


Figure 3: Profiles of exposures of clay deposits in the study area (a) - residual clay profile over banded gneiss (b) - residual clay deposit over Pegmatite (c) - sedimentary clay profile

MINERALOGICAL ANALYSIS

X-ray diffractograms of residual clays over banded gneiss, pegmatite and sedimentary clays are presented in Figure 4. The XRD of the clay horizon above banded gneiss (

Figure 4a) shows a mineralogical assemblage of kaolinite, quartz, and albite. Kaolinite was observed as the dominant mineral closely followed by quartz as indicated by the high intensity of its numerous peaks in the X-ray diffractogram. The presence of kaolinite suggests the chemical decomposition of the iron-bearing ferromagnesian minerals such as biotite and feldspar. The X-ray diffractogram of residual clay from weathered pegmatite (

Figure 4b) from the prominent peaks shows a mineralogical assemblage of kaolinite and quartz. The presence of kaolinite suggests the chemical decomposition of feldspar which is a predominant mineral in pegmatite. The XRD of the sedimentary clay (

Figure 4c) shows a mineralogical assemblage of kaolin, quartz and muscovite. The presence of muscovite is an indication that the weathering process is still at the incipient stage. Decomposition of muscovite to kaolinite at an advanced stage of weathering has been reported in several weathering profiles in tropical regions, notable among which is on the decomposition of some granite in India (Shama and Rajamani, 2000). The X-ray diffractograms of the sedimentary clay shows that the clay is predominantly made up of kaolinite.

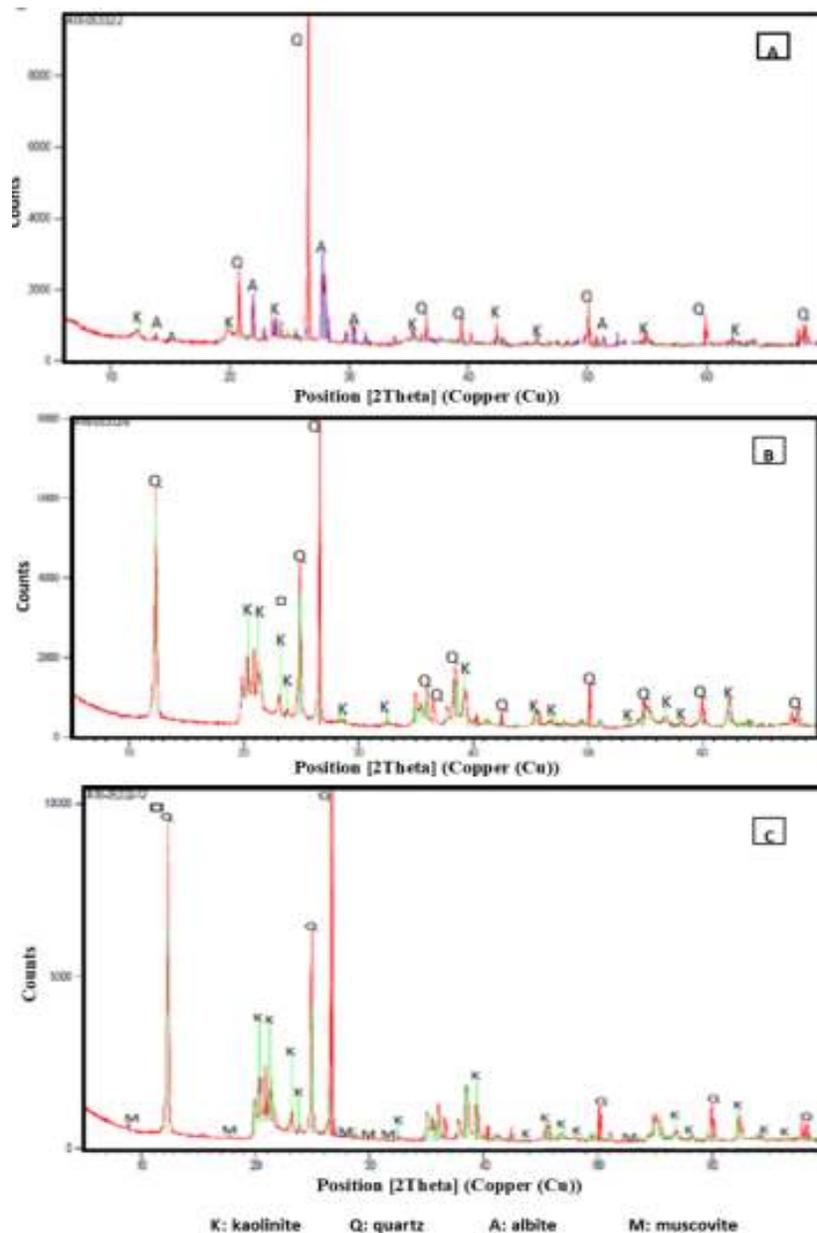


Figure 4: X-ray diffractograms (A: Residual clay on banded gneiss, B: sedimentary clay, C: residual clay on pegmatite)

MAJOR AND TRACE ELEMENT GEOCHEMISTRY

The summary of the composition of elemental oxides of major elements (%) determined specifically, Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, and P as well as other trace elements (ppm) in the clay are presented in Table 1. SiO₂ was the most abundant major oxide in the clays varying between 63.22 - 67.90% (avg. 66.11%) in banded gneiss derived clay, 51.91-55.46% (avg. 53.17%) in pegmatite derived clay and 38.6-46.03% (avg. 42.12%) in sedimentary clay. Al₂O₃ was observed as the second most abundant major oxide in the clay samples with contents varying between 18.14-23.23% (avg. 20.53%) in banded gneiss derived clay, 31.13-33.95 (avg. 32.70%) in pegmatite derived clay and 31.57-37.77% (avg. 34.43%) in sedimentary clay. Silica content was observed to be lowest in the sedimentary clay and relatively higher in the residual clay overlying the banded gneiss (avg. 66.11%).

The concentration of silica in clay over banded gneiss could have been enhanced by the relative depletion of other major oxides such as MnO, MgO, CaO, Na₂O, K₂O in the horizon. The high silica content suggest that the quartz is of secondary origin. The dissolution and weathering of these silicate minerals consequently led to the enrichment of SiO₂ and Fe₂O₃ in the topsoil. The X-ray diffractogram of the clays show prominent peaks of quartz probably due to their relative crystallinity (Brindly 1961). The mean concentration of Al₂O₃ in banded

gneiss, pegmatite and sedimentary clays are 20.53%, 32.70% and 34.43%, respectively. This shows that the Al₂O₃ content in Sedimentary clay profile is enriched. The lowest value is recorded in banded gneiss. The abundance of Fe₂O₃ (range from 3.07% to 7.37%) is generally low in the observed clays. The concentration average values of CaO are 1.07%, 0.03%, and 0.02%, Na₂O are 1.28%, 0.05% and 0.03% and P₂O₅ are 0.023%, 0.08%, and 0.09% in weathered Banded gneiss, Sedimentary and Pegmatite respectively. TiO₂ is relatively low in all clays 0.29%, 1.06% and 0.09%. The trace element Ba is relatively high in clay from weathered Banded gneiss (315.5 ppm), clay from weathered Pegmatite (138.2 ppm) but low in clay from Sedimentary (68.66 ppm). Sr is relatively high in clay from Banded gneiss with average value of (244 ppm), clay from weathered Pegmatite (150.75 ppm) but relatively low in clay from Sedimentary (69.33 ppm). Zr are 134.25, 435, 39.5 ppm in weathered Banded gneiss, Sedimentary and Pegmatite, respectively. The average concentration of V in the clays derived from banded gneiss, Pegmatite and Sedimentary origin are 35.75 ppm, 41 ppm and 138.66 ppm. Sc and Be are relatively low in residual clays. Some Trace elements such as Zr, V, Sc, Y were observed to be enriched more in the sedimentary clays while than the residual clays are enriched in Ba and Sr.

Table 1 Average concentrations of major and trace elements in the ljesha-ljebu clays

Oxides (%)	Banded Gneiss clay		Pegmatite clay		Sedimentary clay	
	Mean	Range	Mean	Range	Mean	Range
SiO ₂	66.11	63.22-67.90	53.17	51.91-55.46	42.12	38.6-46.03
Al ₂ O ₃	20.53	18.14-23.23	32.7	31.13-33.95	34.43	31.57-37.77
Fe ₂ O ₃ (τ)	3.08	1.02-5.79	1.44	1.06-2.01	7.37	1.19-14.09
MnO	0.011	0.04-0.24	0.03	0.03-0.04	0.05	0.03-0.09
MgO	0.23	0.03-0.46	0.03	0.02-0.04	0.043	0.02-0.07
CaO	1.08	0.03-2.22	0.025	0.02-0.03	0.036	0.02-0.06
Na ₂ O	1.28	0.03-2.72	0.032	0.02-0.04	0.056	0.02-0.09
K ₂ O	0.31	0.07-0.57	0.14	0.05-0.24	0.066	0.03-0.09
TiO ₂	0.29	0.03-0.58	0.095	0.04-0.25	1.069	0.66-1.33
P ₂ O ₅	0.02	0.01-0.04	0.09	0.03-0.13	0.08	0.05-0.10
LOI	7.62	5.64-8.63	12.19	11.69-12.48	14.68	14.29-14.96
Total	100.57		99.93		99.98	
Trace Elements (ppm)						
Ba	315.5	4-660	138.25	21-199	68.66	21-132
Sr	244	4-519	150.75	39-227	69.33	20-98
Y	8.75	2-16	8	6-10	11.33	4-19
Sc	4.5	4-6	5.5	4-7	13.33	5-20
Zr	134.25	12-310	39.5	18-76	435	192-657
Be	2.5	2-3	5.25	4-6	3	1-5
V	35.75	7-68	41	10-127	138.66	71-203

The result of both Silica and Alumina Ratio of the clay samples is presented in Table 2. Silica Ratio (S.R) was observed to be relatively higher in the residual clay over the banded gneiss with values ranging between 2.62 and 2.91 with an average of 2.79. The SR of residual clay over the pegmatite varies between 1.48 and 1.67 with an average value of 1.55. Sedimentary clays relatively have the lowest SR with the ratio varying between when with an average value is 1.02% whereas, the Alumina Ratio (A.R) is low in weathered Banded

gneiss with an average value is 12.85% and high in Pegmatite (24.63%) and clay from Sedimentary (12.97). The percentage of Na₂O + K₂O is high in weathered Banded gneiss with an average value of 1.59%, followed by clay from Sedimentary (0.12%) and the lowest is clay from Pegmatite (0.12%). The high percentage of CaO + MgO is clay from weathered Banded gneiss (1.30%) compared to Sedimentary (0.08%) and Pegmatite (0.05%).

Table 2 Silica and Alumina Ratio

	Banded gneiss clay		Pegmatite clay		Sedimentary clay	
	mean	range	mean	Range	mean	Range
SR	2.79	2.62-2.91	1.55	1.48-1.67	1.016	0.84-1.18
AR	12.84	3.16-22.77	24.63	15.48-32.02	12.97	2.24-31.73
MgO + CaO	1.3	0.06-2.62	0.05	0.05-0.06	0.08	0.05-0.1
Na ₂ O + K ₂ O	1.59	0.1-3.27	0.11	0.07-0.28	0.12	0.09-0.18

A comparison of the geochemistry of clays in the study area with other industrial references is presented in Table 3.

The residual clay derived from banded gneiss and pegmatite together with the sedimentary clay in the study area cannot be used for the production of paint because their silica content does not meet the specification for paint production. For the production of ceramic, clay derived from weathered banded gneiss can be beneficiated to meet the standard for required for production of ceramics. For the production of refractory

bricks, clay derived from weathered banded gneiss and weathered pegmatite can be used for it because the silica content falls within the specification of Refractory bricks. The silica content of the clays falls within the range of the Florida Active Kaolinite (53.17 and 50.11 wt.%) as proposed by Huber (1985). The SiO₂ and Al₂O₃ content of the clays did not meet up to the standard for China clay (Huber 1985). For Plastic Fire clay, clay derived from weathered pegmatite can be beneficiated so as to meet the standard.

Table 3 Comparison of Ijesha-Ijebu clays with some industrial chemical specifications and references

Oxides (%)	*B.Gneiss	*Peg	*Sed	Other industrial specifications and references					
				A	B	C	D	E	F
SiO ₂	66.11	53.17	42.12	47.90-48.30	67.57	51.0-70.0	52.92	57.67	46.88
Al ₂ O ₃	20.53	32.7	34.46	37.90-38.40	26.5	25.0-44.0	9.42	24	37.65
Fe ₂ O ₃	3.07	1.44	7.37	13.40-13.80	0.50-1.20	0.2-0.7	3.65	3.23	0.88
MgO	0.23	0.03	0.43	0.20-0.30	0.10-0.19	0.2-0.7	0.08	0.3	0.13
CaO	1.07	0.03	0.04	0.03-0.25	0.18-0.30	0.1-0.2	1.91	0.7	0.03
Na ₂ O	1.28	0.03	0.06	0.20-0.35	0.20-1.50	0.8-3.5	0.03		0.21
K ₂ O	0.32	0.14	0.07	0.40-0.10	1.10-3.10	-	0.98	0.5	1.6
P ₂ O ₅	0.02	0.09	0.08	0.02	-	-	0.02	-	-
MnO	0.02	0.03	0.01	-	-	-	-	-	-
LOI	7.63	12.19	14.68	-	-	-	10.19	10.5	12.45
TOTAL	100.27	99.83	99.33	-	-	-	79.2	97.1	99.83

* Average values for 5 samples

* **B.Gneiss:** Residual clay over Banded gneiss

* **Peg:** Residual clay over Pegmatite

* **Sed:** Sedimentary clay

(A) - Paints (Payne, 1961)

(B) - Ceramics (Singer and Sonja, 1971)

(C) - Refractory Bricks, (Parker, 1967)

(D) - Florida Active Kaolinite (Huber, 1985)

(E) - Plastic Fire Clay, St Louis (Huber, 1985)

(F) - China Clay (Huber, 1985)

PHYSICAL PROPERTIES

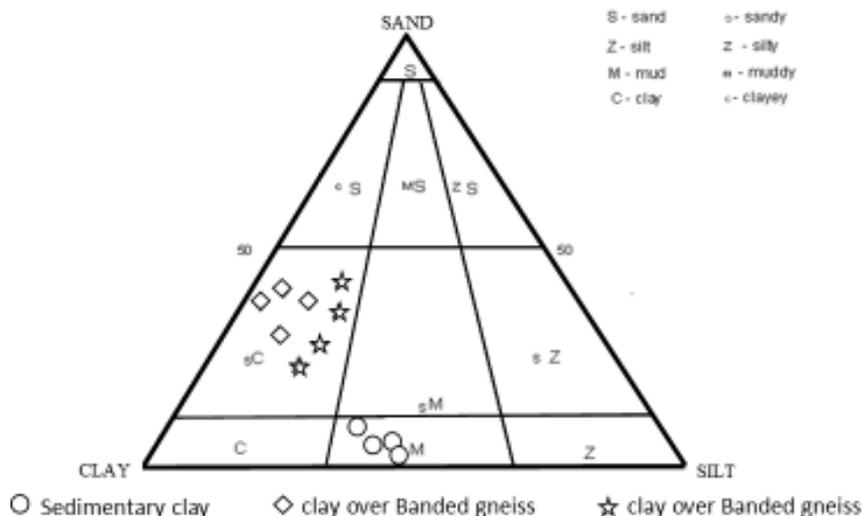
GRAIN SIZE DISTRIBUTION

The grain size distributions of the clay samples collected at Ijesha-Ijebu from weathered Banded gneiss, sedimentary and weathered pegmatite are shown in Table 4. Generally, grain size distribution affects stability and plasticity of the clay to be used as industrial mineral; however, higher clay constituent increases the stability and plasticity. According to Table 4, the average percentage of silt and clay size materials in the sedimentary clay is higher than the residual clays over banded gneiss and pegmatites. This is because the clay sediments were well sorted during the process of

deposition by the transporting medium (water) whereas the percentage of larger grain sizes (silt, sand and gravel) of minerals resistant to chemical weathering in residuals clays increases as the finer material leaches away. Based on the percentage of clay, silt and sand, the textural classification of clays in the study areas are shown in Figure 7. Residual clays derived from band gneiss and pegmatite were classified as Sandy-clay while the sedimentary derived clays were classified as Mudstone.

Table 4: Range and average of clay, silt, sand and gravel contents of clays from weathered Banded gneiss, Sedimentary, Pegmatite in Ijesha-Ijebu.

Parent rock	Clay%		Silt%		Sand%		Gravel%	
	Range	Average	Range	Average	Range	Average	Range	Average
B. gneiss	27-69	50.00	3 - 33	16.00	4 – 45	27.00	0-7	3.00
Pegmatite	39-52	47.00	4- 12	11.00	15-35	23.00	4376.00	8.00
Sedimentary	51-62	56.00	31-47	40.00	2 – 7	6.00	0-1	1.00

Figure 5: Textural classification of Ijesha-Ijebu Clays (After Folk. 1974).**COLOUR OF THE CLAY**

Clay colour is one of its most striking physical properties and it depends on factors such as the nature of the parent rock, the horizon and the presence of oxides. Colour is one of the important properties used in assessing the suitability of clay for industrial use. The presence and the relative amount of iron and other constituents have huge influence on clay colour. A desired colour may be acquired by firing at different temperatures. Colour and other physical properties of clays namely, shrinkage, loss on ignition and porosity are affected when clays are fired. Raw pulverized unfired clay samples range from buff white to light brown in colour due to the presence of other minerals that contain iron.

Montmorillonite and kaolinite are usually white when fired. However, on firing clay changes colour ranging from brown through yellow and to white due to the oxidation of iron as shown in Figure 6.

FIRING CHARACTERISTICS

The results of the fired clay pellets are shown in Table 5. Linear shrinkage is due to the re-crystallization of the crystalline amorphous constituents in the various clay samples. These results in the surface tension of the vitrified pellets at higher temperatures of 1100° C. The highest average values of loss on ignition are recorded in clay from sedimentary origin. It has an average value of 15% and ranges from 14.42% -15.90%. This could be due to the presence of a lot of pore spaces in

sedimentary clay which equally accommodates capillary water. This is then followed by clay from Pegmatite with average value of 13%. While clay from Banded gneiss exhibit lower loss of ignition with average value of 11.15%. The water absorption capacity, which is an estimation of the porosity of the clay, decreases with increase in temperature. Clay from Pegmatite is generally high in water absorption capacity compared

with clay from Sedimentary and Banded gneiss. Clay from Pegmatite has the highest water absorption capacity which ranges between 18.34% -32.64% with average of 26%. This is closely followed by sedimentary clay which ranges between 16.24% to 18.52% with average of 17%. Clay from Banded gneiss has the lowest water absorption capacity which ranges from 6.37% to 20.47% with average of 15.57%.

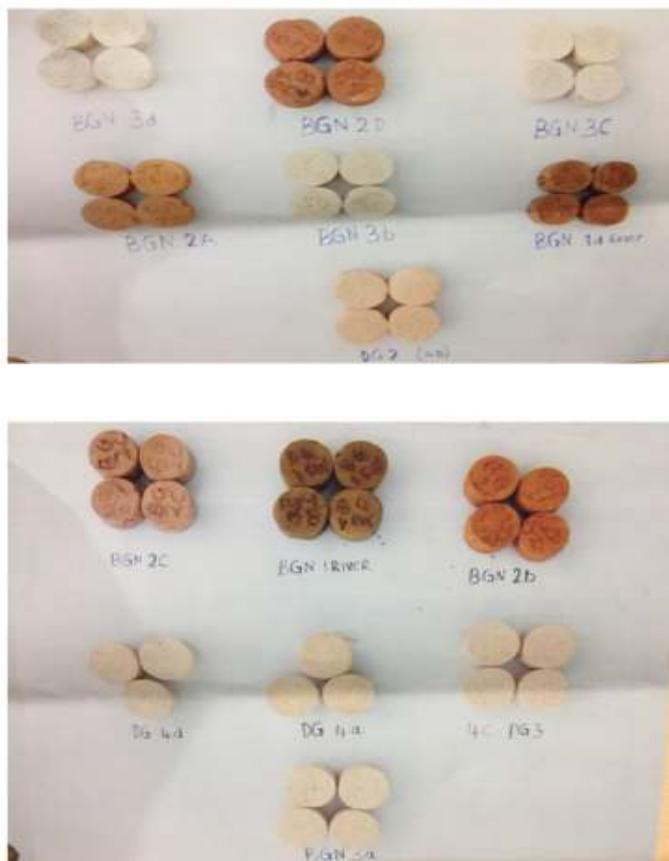


Figure 6: Colour of the fired clays

LIQUID AND PLASTIC LIMITS

The result of plasticity tests are shown in the Table 5, the result shows that the residual clays from weathered Banded gneiss has the highest values of liquid limit (58.00%) and plastic limit (33.92%), followed by clay from sedimentary with liquid limit (56.65%) and plastic limit (33.27%) and then the least which is clay from Pegmatite with liquid limit (51.45%) and plastic limit (31.81%). This suggests that clay from Banded gneiss is highly weathered compared to Sedimentary and Pegmatite. It is observed that the higher the percentage of clayey content, the higher the plasticity. Clay from Pegmatite has the lowest values of liquid limit (51.45%) and plastic limit (31.81%). This may be due to high sand content in this sample. The result of the liquid limit shows that clay from Banded gneiss retained more water than clay from Sedimentary and Pegmatite. Also the result of the plastic limit of the clay samples reveals that they are moderately plastic. The plasticity indices of the clay samples range from 31% to 33%.

PLASTICITY INDEX

The plasticity index is a range of moisture in which a soil remains in a plastic state while passing from a semisolid

limit and plastic limit of a soil ($PI = LL - PL$) using test method TEX-106-E.

Plasticity index is directly related to all the clay size in the deposit that is the increase in clay size will increase the plasticity of the clay (Parker, 1967). If the percentage of the clay content is more clayey then it would increase the percentage of plastic index and vice versa. Clay are characteristically plastic nature, Atterberg limit is the best classification of soil because it gives the accurate basis for the classification of clayey soil.

The clay in Ijesha-Ijebu is likely good for constructional purpose especially for mixing cement in construction of bridges base on the texture. Plasticity is the measure of affinity for water of a soil. Plastic characteristics of a clay soil are evaluated from the Atterberg limit tests that are liquid limit, plastic limit, and linear shrinkage. Gidigas (1976) noted that the higher the degree of laterization and leaching, the less the influence of the amount of clay size content on plasticity index due to reduction in surface activity of clay particles caused by sesquioxide coating from the result. The liquid limit is greater than the plastic limit (Table 5). When the value of plastic limit is not close to that of liquid limit, the soil is said to be

limit, the soil is said to be non-plastic. From this result, the plasticity of the clay from weathered Banded gneiss, Sedimentary and Pegmatite ranges from non-plastic to plastic.

Topography, chemical composition, parent rock material, nature of exchangeable cations, degree of laterization, nature of soil clay content, organic matter content are the factors affecting plasticity. The plasticity chart shows that the clay bodies are both organic and inorganic with medium plasticity (Figure 8). Clay derived from weathered pegmatite plots within Inorganic clays. The clays derived from weathered banded gneiss and

sedimentary also plots within inorganic silts and organic clays.

It must be noted that the shrinkage and mouldability of the clays, which largely determine the industrial suitability are affected by the grain size distribution and mineralogy of the clay. Clay derived from weathered banded gneiss and sedimentary plots within moderate shrinkage. Clay derived from weathered pegmatite plots on low shrinkage (Fig 7). This means that clay from derived weathered pegmatite have low swelling potential.

Table 5: Physical and firing properties of residual and sedimentary clays in the study area

Parent rock	Sample No	Clay size (%)	Atterberg limit		PI (%)	LOI (%)	LSK (%)	WAC (%)	SG	Colour
			LL (%)	PL (%)						
Banded gneiss	BGN 1	51	38.45	20	18.45	9.15	8	6.37	2.6	Dark brown
	BGN 2	45	35.01	17.38	17.63	8.24	11	9.91	2.6	Dark grey
	BGN 3	48	36.54	18.85	17.69	12.66	11	19.38	2.63	White
	BGN 4	69	56	31.8	24.2	16.28	11	19.66	2.5	White
	BGN 5	62	58	33.92	24.08	15.15	9	20.47	2.5	White
	BGN 6	27	24.5	17.59	6.71	5.42	11	17.63	2.7	Reddish brown
Pegmatite	PG 1	52	51.45	31.81	19.64	16.14	9	32.64	2.55	Brown
	PG 2	39	36.02	19.07	16.95	13.98	9	29.45	2.65	Light yellow
	PG 3	49	39.03	20.53	18.5	14.7	11	18.34	2.6	Light yellow
	PG 4	46	35.02	17.81	17.21	7.25	9	21.79	2.62	White
Sedimentary	SS 1	57	53.5	30.83	22.67	14.42	8	18.52	2.5	White
	SS 2	62	56.65	33.27	23.38	15.37	9	16.24	2.5	Reddish brown
	SS 3	55	54.06	29.59	24.47	15.9	10	17.29	2.5	Light brown
	SS 4	51	50.02	29.6	20.42	15.25	8.5	17.3	2.5	White grey

*LL- Liquid limit, *PL-Plastic limit, *PI- Plasticity index, *LOI- Loss on ignition, *LSK- Linear shrinkage, * WAC- Water absorption capacity, *SG- Specific gravity

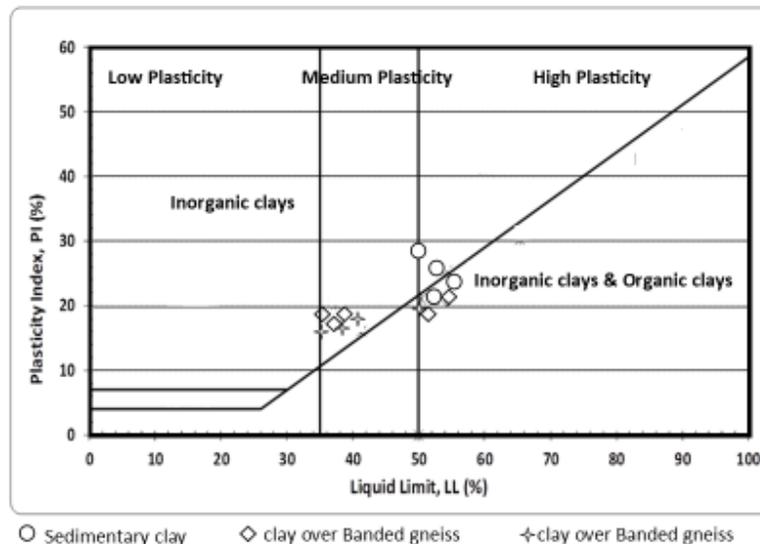


Figure 7: Plasticity chart for classification of Cohesive Soils (after Casagrande, 1948)

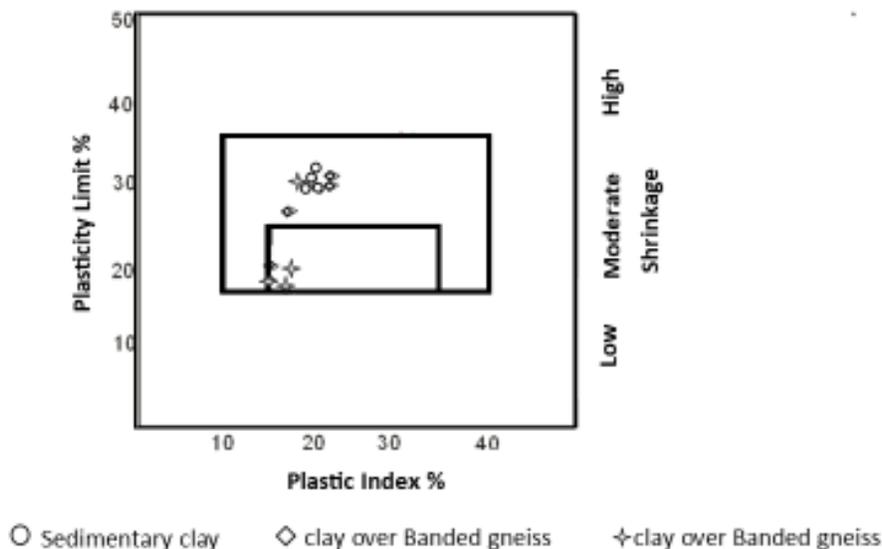


Figure 8: Mouldability chart for the clays of Ijesha Ijebu Area (After Bain 1971).

CONCLUSION

The residual clays derived from banded gneiss, pegmatite and sedimentary terrain cannot be used for the production of paint because their silica content does not meet the specification for paint production. The chemical compositions also show that all the clay samples contain more than 40% SiO₂ thus, these clays area are suitable for production of heavy ceramic

products. Kaolinite which is the most abundant mineral in all clay samples can be used for the production of toothpaste, cosmetics, ceramics and pharmaceuticals. For the production of refractory bricks, clay derived from weathered banded gneiss and weathered pegmatite can be used for it because the silica content falls within the specification of Refractory bricks. Texturally, Ijesha-Ijebu clays would serve as good constructional materials.

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