Compositional Characteristics And Industrial Potential Of The Lateritic Clay Deposit In Ara-Ijero Ekiti Areas, Southwestern Nigeria.

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Abstract : Compositional features and industrial application of the residual clay deposit overlying the Precambrian basement complex in Ara-Ijero Ekiti; Southwestern Nigeria was investigated and it is hereby reported. Granulometric analysis indicates that the mean clay fraction in the deposit is 42.3%, the silt 14.0%, and sand fraction 42.2%. The mean liquid limit, plastic limit and the plasticity index are 47.8%, 26.4% and 21.5% respectively. Mineralogical analysis using X-ray diffraction method indicates the dominance of kaolinite, with illite occuring in subordinate amount while the non-clay impurity is mainly quartz. Assessment of the industrial potentials of the clay based on physical properties, consistency limits and plots of plasticity indices against liquid limits indicate that the clay is inorganic and plastic. It has a mean firing shrinkage value of 9.08%, water absorption capacity 6.1%, specific gravity 2.78, unconfined compressive strength of 3.87KN/m^2 and pH value of 5.8. Analytical result on twenty representative samples using Fussion method (FUS-XRF) from Activations laboratory indicates mean SiO_2 (48.50%), Al_2O_3 (28.82%) and Fe_2O_3 (9.84%) while other oxides (MnO, MgO, CaO, Na_2O and K_2O) altogether, constitute less than 5% of the bulk composition. The chemical compositions of the clay compares well with other notable clay deposits in Southwestern Nigeria. The geochemistry, thermal characteristics and water absorption capacities are within the ranges recommended for some industrial specifications. With appropriate treatment, the clay could serve as raw material for the manufacture of quality bricks, pottery, ceramics and structural wares.

Index Terms: Residual, Granulometric, Kaolinite, illite, Pottery, Ara-Ijero Ekiti

1.0 INTRODUCTION

Clay is a useful industrial raw material from which many domestic and commercial products can be manufactured. Residual clay spreads across the crystalline basement complex of Nigeria particularly the southwestern part. However, these clay deposits have been grossly underutilized considering the quality and quantity that occur in the country. Underutilization of these deposits may be attributable to insufficient geological information on the compositional features on one hand and inadequate knowledge of industrial suitability of the deposits on the other. The contributions these weathered products can make to the socio-economic development of the local communities in which they occur cannot be-overemphasized, most especially when several industries could depend on these locally sourced raw material that are available. Residual clay deposits are easily accessible due to their closeness to the surface [1]. The strategic location of the country within the tropics with a good climate characterized by alternating dry and wet seasons and coupled with a relatively high humidity encourages intensive weathering activities. The type of clay that formed is not only a function of the nature of parent rock but also the intensity of weathering and the length of time during which it occurred. One major precursor of clay deposits is feldspar, which is a common mineral in many granitic rocks like granite pegmatite. In addition, clay deposits are common in areas wherehydrothermal alteration leads to high level of kaolinization, which characterizes area where Pan-African magmatism is prevalent [1],[2]. The present study elucidates the compositional features of the residual clay deposit of Ara-Ijero Ekiti in Southwestern Nigeria, with a view to assessing its suitability as industrial raw material

2.0 LOCATION AND LITHOLOGICAL ASSOCIATION

Geologically, Nigeria is located within the Pan African mobile belt, specifically between the West African and Congo Cratons. The Nigeria sector of the belt is characterized by the occurrence of migmatite-gneiss complex, metasediments (supracrustal rocks) consisting of heterogeneous lithology of schistose assemblages known as the schist belts and the intruding Older Granite. The Younger Granite is Jurassic in age and occurs in Jos Plateau in the north central part of the country . The study area, considered an Archean to Proterozoic terrain [3], is located about 40km northwest of Ado-Ekiti, the Ekiti State capital and between latitudes 7^o 46^1N and 7^o 53^1N and longitudes 5^o 00^1E and 5^o 07^1E. Ara-Ekiti, within the Ijero-Ekiti area contains gneisses, schists, quartzite, epidiorite, granite and pegmatite (Fig.1).

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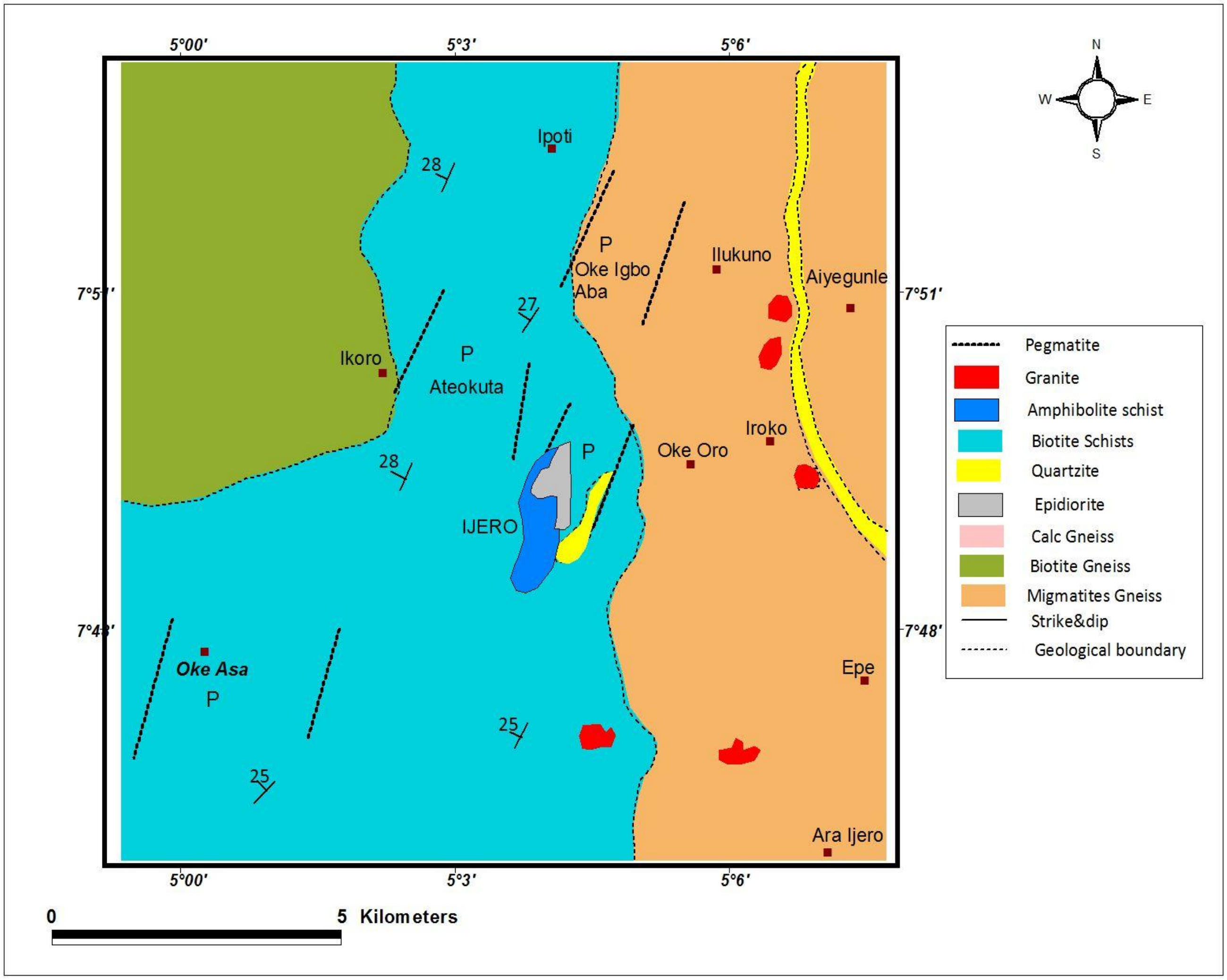

Fig. 1: Geological map of Ijero Ekiti area showing the location of Ara-Ekiti

Banded gneiss and migmatites covers about 80% of the study area. It is composed of well-defined mineralogical variations defined by closely spaced alternating bands of leucocratic minerals (quartz and feldspars) and melanocratic minerals indicated by the preponderance of biotite flakes. The banded gneiss marked by complex closely spaced antiformal and synformal structures contain folds ranging in geometry from simple symmetrical to asymmetrical folds to highly disharmonic ptygmatic folds. Quartzite occurs mainly as ridge following a north-south trend in the eastern part of the area. The quartzite grades into quartz schist where muscovite becomes a prominently associatedmineral towards the south. Other associated lithological unit includes pegmatite that forms a major topographic feature in the northwestern part of the study area. Ara clay deposit (Fig.2) occupies a shallow depression along the bank of river Amu that flows in a southwestern direction at the west end of Ara-Ijero Ekiti.

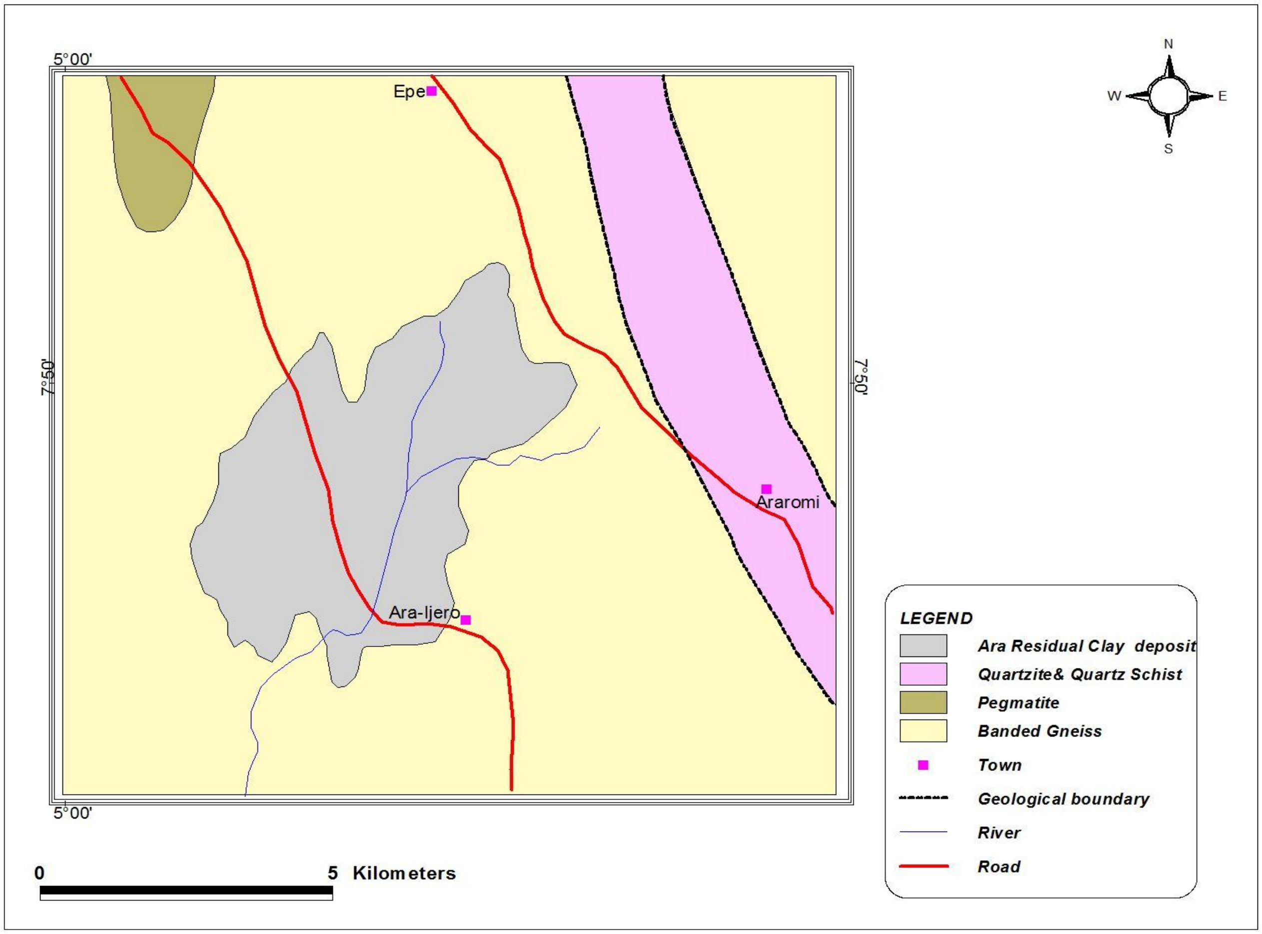

Fig.2: Geological map of Ara-Ijero Ekiti showing the Ara Residual clay deposit

The clay deposit occurs as weathered profile overlying an extensive low lying, highly denuded, basement of banded gneiss. A more detailed geology of the area could be found in the studies by [4],[5],[6],[7],[8],[9],[10] and [11].

3.0 MATERIALS AND METHODS

Twenty representative samples were collected from the clay deposit at ten meters interval along a horizontal profile in a northwest-southeast direction, adopting point sampling method. The samples were air-dried for two weeks due to damp weather to facilitate the sieving process. They were then subjected to the following tests: Grain size analysis, Consistency Limits, using the British Standard Specifications of [12] apparatus, water absorption capacity (WAC), Linear shrinkage limits (FSV), and firing test to determine thermal characteristics using Gallenkamp Muffle Furnace Model S 2. Other tests include unconfined compressive strength (CS), specific gravity (SG) and pH. All physical tests were undertaken at Trevi Foundations, Lagos. The powder of the clay samples were prepared for X-ray diffraction, by heating to a temperature of 600^{o}C and later subjected to cobalt k-alpha radiation 40kv, 20mA, chart sp = 1200mn/hc and count rate = 1x10^{3} cps using Phillips-PW1011 model diffractometer. X-ray diffraction curves were interpreted by comparing peaks of notable intensities with those of standard minerals established by [13]. Relative proportions of the identified minerals were calculated using the areal methods. Chemical analysis for major elements using X-ray Fussion (XRF) technique was undertaken at the Activation Laboratories, Canada.

Water absorption capacity was determined on fired sample pellets produced using standard press and heated in a furnace set at 1000^{o}C for about five hours. On cooling, pellets were immersed in water for 24 hours. Loss on Ignition was determined as weight difference between the dried and fired pellets while the linear shrinkage was determined as the percentage decrease in diameter after firing.

4.0 RESULTS

The particle size distribution curves were plotted (Fig.3) using percentage fines by weight against the particle diameter (mm).

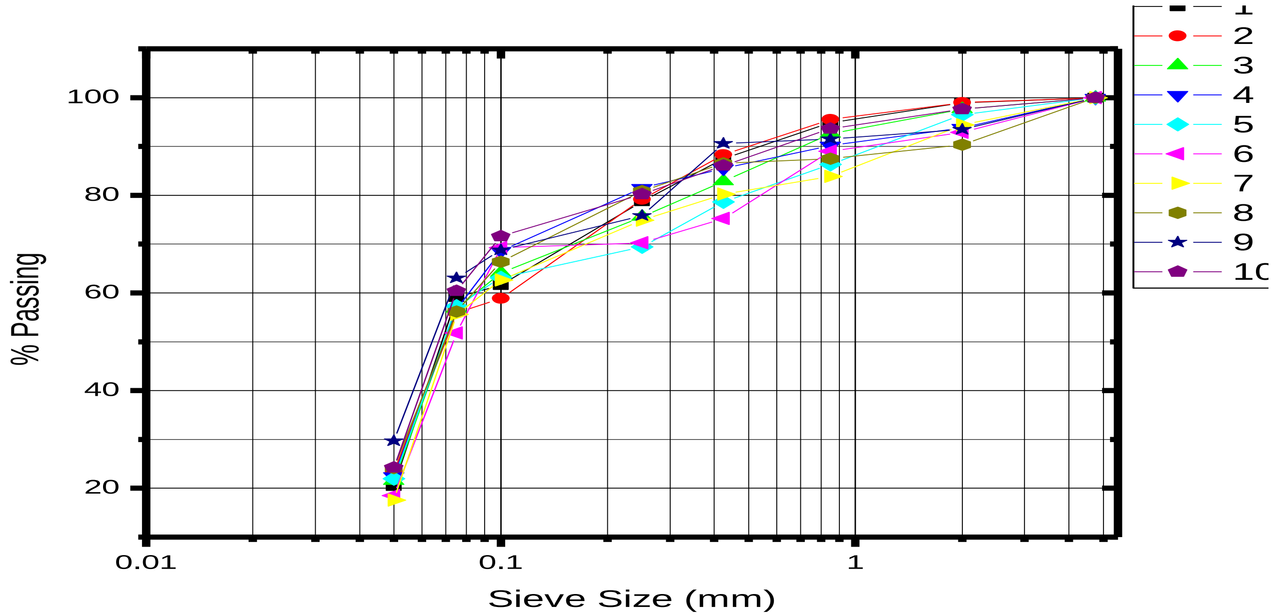

Fig. 3: Granulometric analysis curve of Ara clay

Table 1 is the analysis of the percentage distribution of the grain sizes.

Table 1: Percentage of grain sizes in Ara-Ijero clay

Sample No	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
A1	45.5	10.6	43.1	0.8
A2	51.4	6.5	41.1	1.0
A3	44.1	13.3	41.2	1.2
A4	40.5	13.4	44.0	2.1
A5	42.8	21.2	33.0	3.0
A6	41.3	14.8	42.1	1.8
A7	37.5	16.4	45.5	0.6
A8	44.7	11.3	41.8	2.2
A9	40.8	13.7	43.7	1.8
A10	34.2	18.3	46.1	1.4
Average	42.3	14.0	42.2	1.4

The chemical analysis method employs a lithium metaborate/ tetraborate fusion in analyzing oxides with 0.001% detection limit. The concentration of the major elements in weight percent SiO_2, Al_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, Cr_2O_5, total iron as Fe_2O_3 and Loss on ignition were determined. The result of the measurements as compared with notable references and specifications of some industrial clays are presented in Table 2. The consistency limits and other physical characteristics of the clay are presented in Table 4

Table 2: Mineralogical composition of Ara clay compared with notable clay deposits

Minerals %	Ara clay* (A)	Itakpe clay (B)	Ibadan Kaolinite (C)	Isan Brown clay (D)	Isan red clay (E)
Kaolinite	48.27	61.60	91	50	40
Quartz	47.05	31.30	6	40	48
K-Feldspar	-	4.10		8	10
Illite	4.68	2.30	3	2	2
Smectite		0.50			

Table 3: Chemical composition of Ara clay compared with similar clay and industrial specification

Oxide	Ara*	References						References (#)					
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
SiO_2	48.50	44.98	55.49	45.47	49.88	57.67	52.65	49.88	47.00	44.90	45.00	67.50	46.07
Al_2O_3	28.82	37.54	18.63	38.45	37.65	24.07	27.24	37.65	40.00	32.35	38.10	26.50	38.07
Fe_2O_3	9.84	2.35	9.67	0.75	0.88	3.23	3.01	0.88		0.43	0.60	0.50	0.33
MnO	0.03	0.01	0.04	-	-	-		-	-	Tr	-	1.20	
MgO	0.96	1.72	1.25	0.05	0.13	0.30	0.38	0.13	-	Tr	-	0.19	0.01
CaO	0.58	0.09	0.77	-	0.03	0.70	0.19	0.03	-	Tr	-	0.30	0.38
Na_2O	0.23	0.19	0.64	-	0.21	0.20	0.37	0.21	-	0.14	-	1.50	0.27
K_2O	2.49	1.01	1.84	0.06	0.60	0.50	1.44	1.60	-	0.28	-	3.10	0.43
TiO_2	1.02	1.42	-	0.10	0.09	-		0.09	-	1.80	1.70	-	0.50
P_2O_5	0.12	-	-	-	-	-		-	-	-	-	-	-
Cr_2O_3	0.02	-	-	-	-	-		-	-	-	-	-	-
LOI	14.16	12.60	10.18	-	12.45	10.50	13.80	12.45	13.00	14.20	14.70	12.51	13.47
Total	98.84	99.91	98.33	84.98	99.92	97.10	99.52	99.92					99.93

* This study (Average of 20 samples). A= Ibadan Kaolinite, [14] ; B= Isan brown clay, [9] ; C= Florida non active kaolinite, [15] ; D= China clay,[15] ; E= Plastic fire clay, St Louis, [15], F= Itakpe clay, [1]; G= Agricultural,[15]; H= Pharmaceutical,[17]; I= Rubber, [18]; J= Textile, [18]; K= Ceramics, [16]; L Fertilizer, [19].

DISCUSSION

X-Ray diffractogram (Fig.4) indicates that kaolinite is the dominant clay mineral in the clay sample, while quartz is the major non clay mineral. Kaolinite accounts for 48.27%, quartz, 47.05%, and illite component of Ara clay deposit is 4.68%.

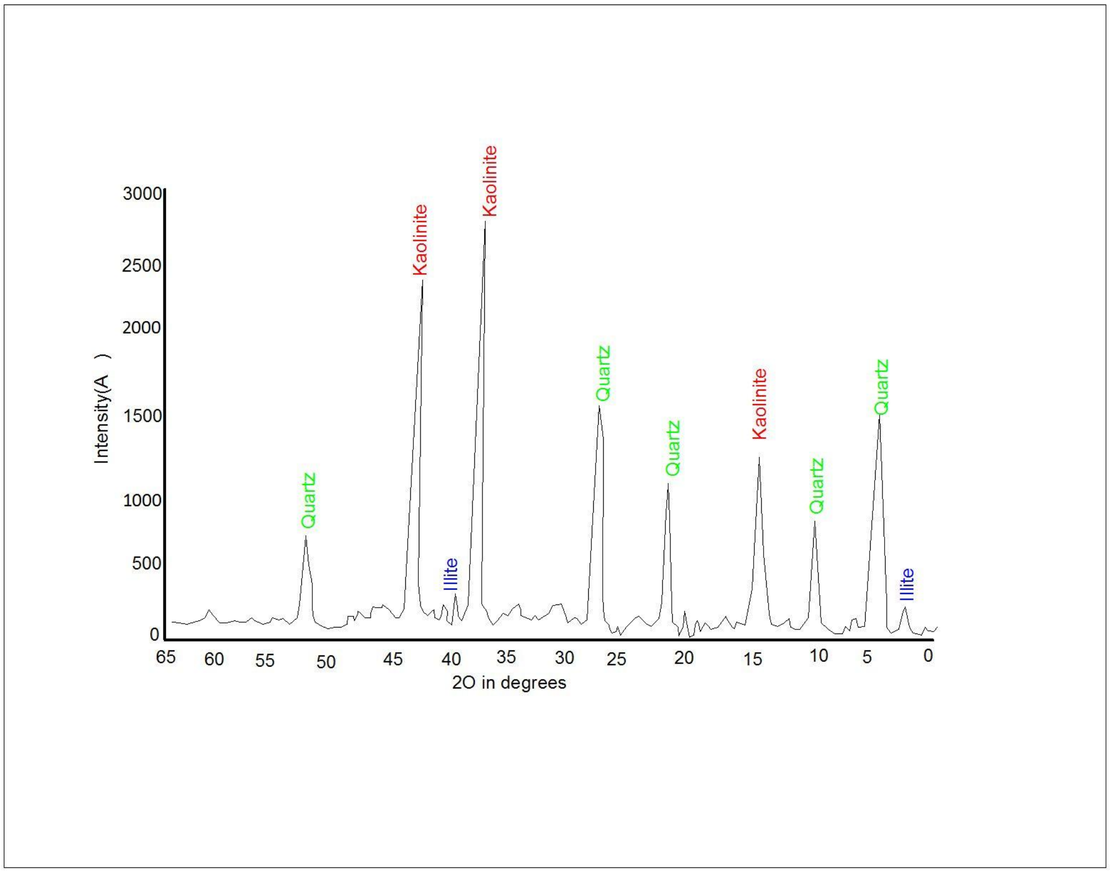

Fig. 4: X-Ray diffraction trace of Ara-Ijero Ekiti clay

A simple comparison of the mineralogical composition of Ara clay with other notable clay deposits (Table 4) indicates that the clay is similar to Isan brown and red clay deposits in southwestern Nigeria. The kaolinite content of Ara clay (48.27%) is less than that in Itakpe clay (61.60%), Ibadan clay (91%) and marginally lower than the Isan brown clay (50%), but higher than Isan red clay (40%) [9]. The quartz content of Ara clay (47.1%) is marginally lower than the Isan red clay (48%). Illite content of Ara clay (4.68%) is higher than that of Itakpe clay (2.3%) , Ibadan (3.0%) [14], Isan brown clay (2%) and Isan red clay (2%) [9]. Analytical result (Table 3) shows the dominance of SiO_2 and Al_2O_3 over all other oxides, as these alone constitute about 70% of the bulk composition of the clay. Average silica content of Ara clay (48.50%) is marginally lower than China clay (49.88%) (Huber, 1985) but higher than Ibadan Kaolinite (44.98%) [14] or Florida non active Kaolinite (45.47%) [15]. This mean value compares favourably with the industrial specification for rubber and textile industries (Keller, 1964) .

The mean Al_2O_3 content of Ara clay (28.8%) is marginally higher than that of Itakpe clay (27.24%) [1] and it meets up with the content recommended for use in the manufacture of ceramics (26.50%) [16]. However, the mean alumina content of Ara clay is lower than Ibadan Kaolinite (37.54%) [14], and China clay (37.65%) [15]. Average Fe_2O_3 content in Ara clay (9.8%) is comparable to Isan Brown clay (9.67%) [9]. The mean Fe_2O_3 value is much higher than Ilukuno clay (0.71%) and many residual clay deposits within Southwestern Nigeria. The high content of Fe_2O_3 in this clay may be attributable to possible breakdown of biotite, augite and other ferromagnesian minerals in the precursor banded gneissic rock of the underlying basement. Average K_2O content of Ara clay (2.5%) is slightly lower than the value recommended for industrial manufacturing of ceramics (3.10%) [16]. The average K_2O, Na_2O, CaO and TiO_2 are generally less than 3% and are within the limits for varied industrial applications for clays.

PHYSICAL AND MECHANICAL FEATURES

The economic use of clay is equally dependent on its physical properties. Industrial properties evaluated for the clays include thermal characteristics, specifically fired shrinkage value (FSV) and Loss on ignition (LOI). Others are water absorption capacity (WAC), compressive strength (CS), specific gravity (SG), atterberg limits (Liquid Limits, LL; plastic limits, PL; and plasticity index ,PI); and pH (Table 4).

Table 4: Physical properties of Ara clay compared with similar clays from other location

FSK (Fired shrinkage value); WAC (Water absorption capacity); SG (Specific gravity),; CS (Unconfined

	Range	Ara clay (P)	Isan brown clay (Q)	Isan red clay (R)	Itakpe clay (S)
FSV	8.61-10.00	9.08	2.79	3.39	0.95
WAC	5.42-8.45	6.14	11.25	12.46	13.58
SG	2.69-2.81	2.78	-	-	-
CS	3.51-4.39	3.87	2.64	3.27	-
LL	43.68-52.22	47.80	47.58	41.70	26.88
PL	24.31-28.14	26.42	23.74	22.10	15.51
PI	17.01-23.80	21.48	23.80	19.60	10.38
pH	5.6-6.0	5.8	6.50	6.40	

compressive strength), ;LL (Liquid limit), PL (Plastic limit), PI (Plasticity index), pH (Acidity/ alkalinity).
*Average of 10 samples, P (This study, Average of 20 samples), Q, R [9], S [1]

Average Loss on Ignition value of Ara clay (14.16%), is slightly higher than the average value for Isan brown clay (10.17%) and Isan red clay (9.12%) [9] is also higher than that of Itakpe clay (8.38%) [1]. Average shrinkage value for Ara clay (9.08%) is higher than the average for Itakpe clay [9]. The water absorption capacities varies from 5.35 to 8.45%, (ca. 6.14%) in Ara clay. This value is significantly lower than that of Itakpe clay (ca. 13.58%). The unconfined compressive strength of Ara clay (ca. 3.87N/mm^2) is slightly higher than that of Isan brown clay (2.64N/mm^2) and Isan red clay (3.27N/mm^2) [9]. Even though the specific gravity value of Ara clay (2.8) is comparable to other similar clay deposits, the relatively higher compressive strength is attributable to its higher plasticity. Sieve analysis result indicates that the average clay fractions for Ara clay is 42.3%, silt (14.0%), sand (42.2%) and gravel is 1.4%. This suggests that the Ara clay is well graded. Consistency limits determinations (Table 4), and the plot of plasticity indices against liquid limit values. [13] (Fig5) classifies Ara clay as inorganic clay of medium compressibility and toughness. It therefore demonstrates good moldability, hence , adequate workability.

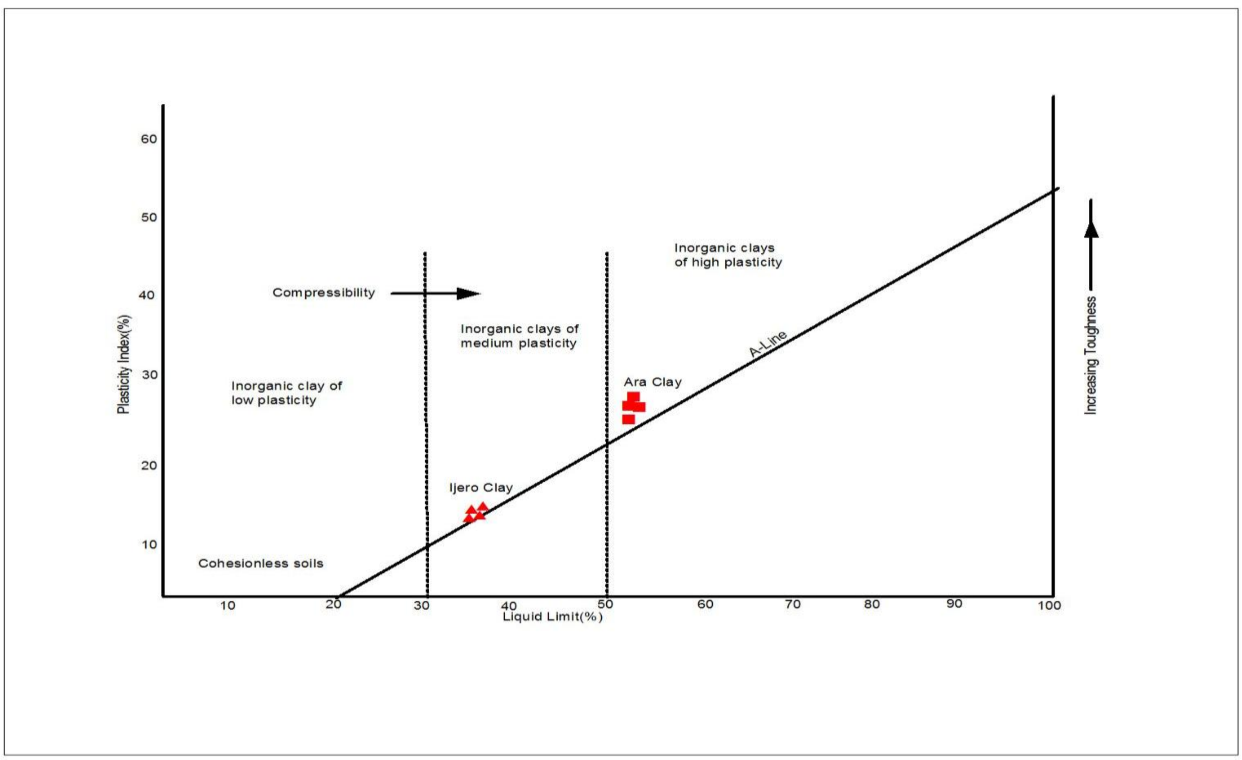

Fig.5: Plasticity Chart for the Classification of Ara-Ijero Clay deposit (Casagrande, 1948)

CONCLUSIONS

Geological appraisal indicates that the clay deposit developed over the basement rocks as a result of in situ weathering of quartzo-feldspartic rocks most especially pegmatite and gneissic basement rocks. Mineralogical composition based mainly on X-ray diffraction techniques confirms that the clay contains mostly kaolinite in composition. Illite occurs only in small amounts while the non clay mineral is quartz impurities. Generally, SiO_2, Al_2O_3 and Fe_2O_3 together represent approximately 70% of the bulk chemical composition of the clay deposit. High Fe_2O_3 content of Ara clay indicate a source from chemical decomposition of iron rich minerals like augite and other ferromagnesian minerals associated with the basement rocks. Ara clay deposit is mildly acidic (pH 5.8). Physical characteristics such as adequate plasticity and chemical characteristics that fall within certain industrial specifications, the residual clay is quite amenable to beneficiation. For instance, removal of the non-clay fractions and gritty content could upgrade the clay, while chemical treatment through leaching of the Fe_2O_3 and other impurities could similarly enhance the Al_2O_3 content. Ara-Ijero Ekiti clay is similar to some other clay deposits found within southwestern Nigeria most especially the Isan brown clay. When appropriately beneficiated, Ara clay could be a raw material for the manufacture of ceramic wares and refractory bricks.

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