Journal of Mining and Geology Vol. 60(1) 2024. pp. 45 - 55 0022-2763

www.nmgs-journal.org

Mineralogical, Geochemical, and Industrial Applications of Residual Clays in Ilero and Illua Town, Southwestern Nigeria

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Abstract
Mineralogical, geochemical and industrial characterization of eleven residual clays collected from 3 weathered profiles of biotite granite (A), porphyritic granite (B) and granite (C) at Ilero and environ, southwestern Nigeria. The samples were subjected to X-ray Diffraction (XRD) and Fusion-Inductively Coupled Plasma (FUS-ICP) analysis to determine their mineralogy and elemental composition. Physical tests such as grain size analysis, plasticity, thermal characteristics, water absorption capacity (WAC) and linear shrinkage were also carried out to determine their industrial applications. XRD showed that quartz (20-46 wt.%), K-feldspar (45-58 wt.%), plagioclase (3-5 wt.%) and kaolinite (4-8 wt.%) are the dominant minerals in the clays, however, illite (10%) and heamatite (1%) were determined only in profile B. Elemental composition showed the following averages for major oxides in the clays to be SiO_2 (60.73) > Al_2O_3 (16.63) > Fe_2O_3 (16.16) > K_2O (5.87) > TiO_2 (1.22) > MgO (0.83) > Na_2O (0.58) > CaO (0.37) > MnO (0.14) > P_2O_5 (0.06). the grain size results showed that the clays are well graded and can be texturally classified as sandy mud (Profile A and B) and mud (Profile C). The average plasticity indexes clays in Profiles A, B and C are 16.68%, 13.46%, and 23.82% respectively. WAC values are Profile A (avg. 3.71%), Profile B (avg. 4.45%) and Profile (avg. 5.8%). Linear shrinkage (%) ranged from 11% in clays from Profile A to 19.5% in Profile C. The compositional characteristics of clays from the study area show they can serve as suitable raw materials for building bricks and ceramic wares.

Keywords: *clay; granite; industrial minerals; petrology*

Introduction

Clay can help drive sustainability in the construction industry and the production of low-CO_2 and low-cost geopolymer binders (Ounissi et al., 2020). Clay minerals develop from the progressive chemical breakdown of silicate-rich rocks (Moore and Reynolds Jr, 1989). In-situ residual clay forms via the hydrothermal modification of rocks and subsequent leaching processes (Onyekuru et al., 2018). Clay minerals predominantly originate in environments where rocks interact with water, air, or steam (Velde, 1992). These scenarios encompass the weathering of boulders on slopes, Sea or lake bottom sediments, sediments buried deep underground that retain pore water, and rocks in contact with water that has been cooked by magma (Montana 2020). Clay minerals can develop under diverse conditions, including variations in pH, temperature, and pressure (Brown and Brindley, 1980). Clay-rich sediments can form by a variety of processes, including detrital material inheritance, solid-state modification, dissolution, and neo-formation (Zhou, Xiang, et al., 2018).

The occurrence of clay in different parts of Nigeria was discovered as early as the inception of the geological survey in Nigeria in 1905 (Idakwo, 2020). According to Jones and Hockey (1964), it was ascertained that basement rocks in the southwestern part of Nigeria have undergone extensive weathering processes, resulting in the formation of residual clays. Sustainable agricultural development and soil environmental quality management require a deep understanding of clay minerals' role in soil structure and function (Lal, 2004).

Clay minerals represent the most economical minerals, and their utilization hinges on their structure and chemistry (Murray, 2000). Clay minerals play a direct role in numerous industrial applications and are integral to our daily lives. Agwuet al. (2015) emphasized that certain clay deposits in Nigeria hold the potential for use as drilling mud. Adeola and Dada (2017) stated that the Kaolinite clay materials found in Awa-Oru Ijebu Nigeria have high plasticity and can be used for the purpose of manufacturing ceramics, paints, and as additives in the cement industry. The clay sample used in the manufacture of paper by Ounissi et al. (2020) was composed of illite and kaolinite as well as auxiliary minerals, and the properties are similar to the samples used for this study. The usage of clay mixtures and composites can reduce the energy cost involved in the production of tiles (Comin et al., 2021).

Clay materials should be subjected to evaluation for their physical properties, such as flexural strength, water absorption, and shrinkage during drying and fire to determine their suitability for industrial use (Kuru Mutlu 2022). In the field of biomedical science, kaolinite is one of the best materials for the adsorption of lipids, proteins, viruses, and bacteria (Carretero, 2002).

Bentonite has a strong swelling capacity and very grain size, it is therefore applied as a soil sealant and as an adhesive to join sand into malleable shapes for metallurgy (Patel, 2020). Additionally, Clay filters are efficient in the water purification process (Kang et al., 2022). It is used to clean water by getting rid of heavy metals, microorganisms, and other contaminants (Boruah et al 2023). The arrangement of the aluminosilicate films that make up clay minerals influences both their physical characteristics and chemistry (Velde, 1992). Despite its abundance and quality in various regions of the country, clay in Nigeria has not been fully utilized, particularly in areas like architecture ceramics, and decorative crafts. This could be attributed to the absence of comprehensive geological data regarding the evaluation of clay deposits and their specific applications in manufacturing. This study was carried out to assess the mineralogical, geochemical, and industrial uses of residual clay deposits in Ilero and its environs.

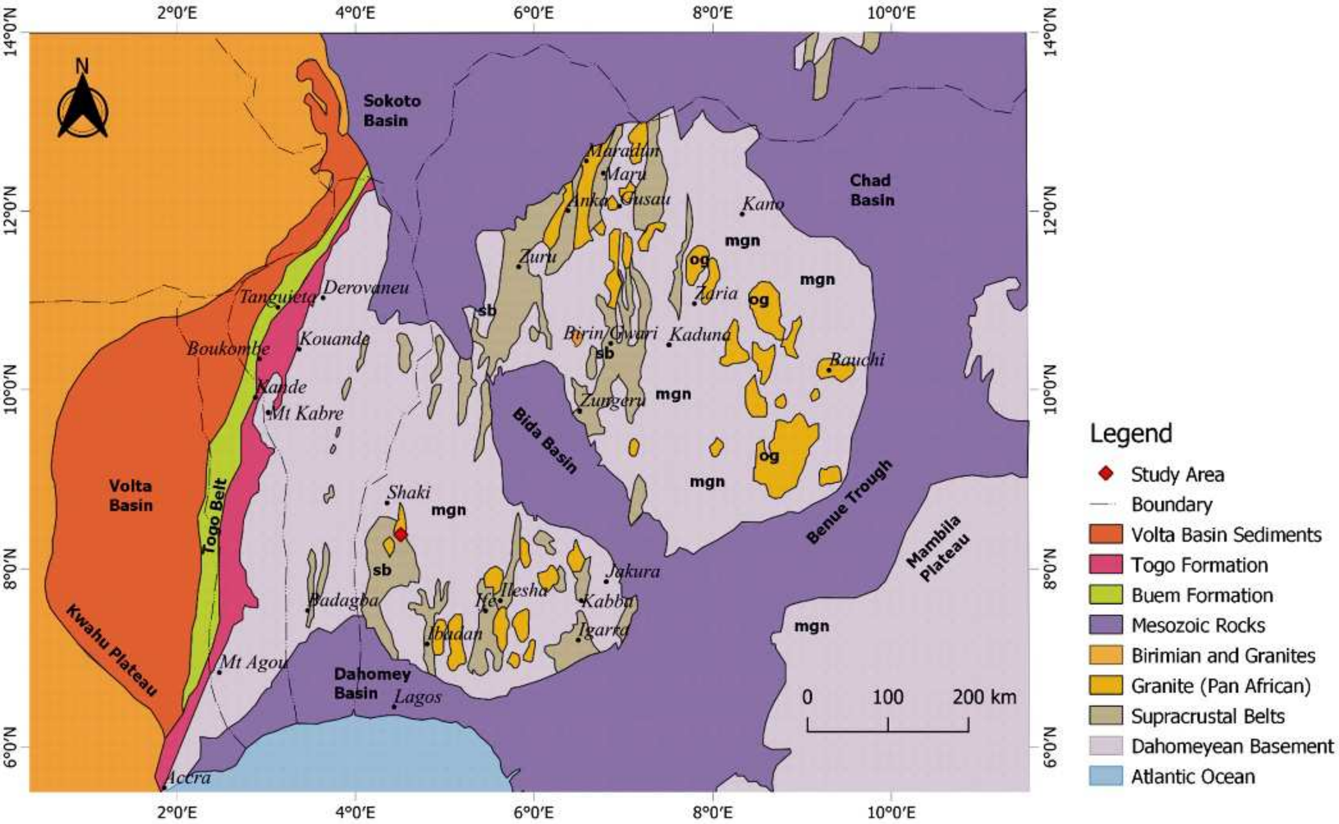

Fig. 1: Nigerian Basement Geology; mgn: Migmatite-Gneiss Complex, sb: Schist Belts, og: Older Granites (og) (Modified from Wright, 1985)

Geological Setting

Southwest Nigerian Precambrian Basement Complex

The western sector of the Nigerian Basement Complex (NBC) is situated west of Longitude 8°E (Figure 1). Prominent rock types in this sector include gneisses, migmatites, schists, psammitic rocks, pegmatites, intrusives, and related masses, such as ridges of Older Granite. In this sector, one can observe narrow schist belts that are predominantly sedimentary and characterized by low-grade metamorphism trending from North to South in the basement (predominantly migmatite-gneiss and older). Also, Pan-African granitoids, which were deposited within the migmatite-gneiss complex and the Schist belts, intrude on it. According to Elueze (1995), high relief in this sector is characterized by ridges and inselbergs predominantly made of rocks resistant to weathering such as gneiss and granite.

Geology of the Research Location

The predominant rock types in the studied location are granitic rocks, Porphyritic granite, quartzite and schisto-quartzite, while the minor rock type such as pegmatite and quartz are incursions in the main rock classifications (Figure 1) Granitic rocks occur mostly as a low-lying outcrop (Figure showing picture to support this). The granitic rocks consist of Granite, Biotite granite and syenite etc and are widely spread in the western part of area of study. They have a medium to coarse grained texture. Mineralogically, it is composed of mafic minerals and felsic minerals which include biotite, orthoclase feldspar, plagioclase feldspar, quartz and some accessory minerals (Photomicrograph to support this). Structurally, the granitic rocks have joints that cut across discordantly through the host rock and some mineralized joints as veins such as quartzo-feldspartic, quartz and dolerite veins (Figure showing picture to support this).

Porphyritic granites occur as a low-lying outcrop and was found along Ilero road around Kajola Local Government area, Oyo state. The rock type is grey colored and texturally porphyritic, having plagioclase feldspar as phenocrysts with the matrix of quartz and biotite (Figure showing picture to support this). The plagioclase feldspar grains are commonly euhedral shape with length ranging from 4-6 cm and width ranging from 1.2-2 cm (Figure showing picture to support this). Mineralogically it is composed of quartz, biotite and phenocrysts of plagioclase feldspar. Tensional joints and Quartz veins are the common structures in the porphyritic granite

Geological Location and Profile Description

The study area is Ilero and its surrounding regions in southwestern Nigeria, between latitudes 8°9'30" and 8°6'15"N and longitudes 3°19'40" and 3°25'30" E. The area is humid, densely vegetated and has a well-drained dendritic drainage pattern. The predominant rock types are granitic rocks, porphyritic granite, quartzite, schisto-quartzite, pegmatite, and quartz. Granitic rocks, including granite, biotite granite, and syenite, are widely distributed in the western part of the area. The coordinates and description of the profiles where clay samples were collected are presented in Table 1.

Granitic rocks occurred widely as low-lying outcrops in

Table 1: Sample location and coordinates

Profile		Location	Latitude	Longitude	Parent Rock
A	Illua Grey	Illua	8°1'30"N	3°23'28"E	Biotite Granite
B	Ilero Brown	Ilero	8°4'54.5"N	3°20'57.34"E	Porphyritic Granite
C	Ilero Grey	Ilero	8°4'42.579"N	3°20'57.879"E	Granite

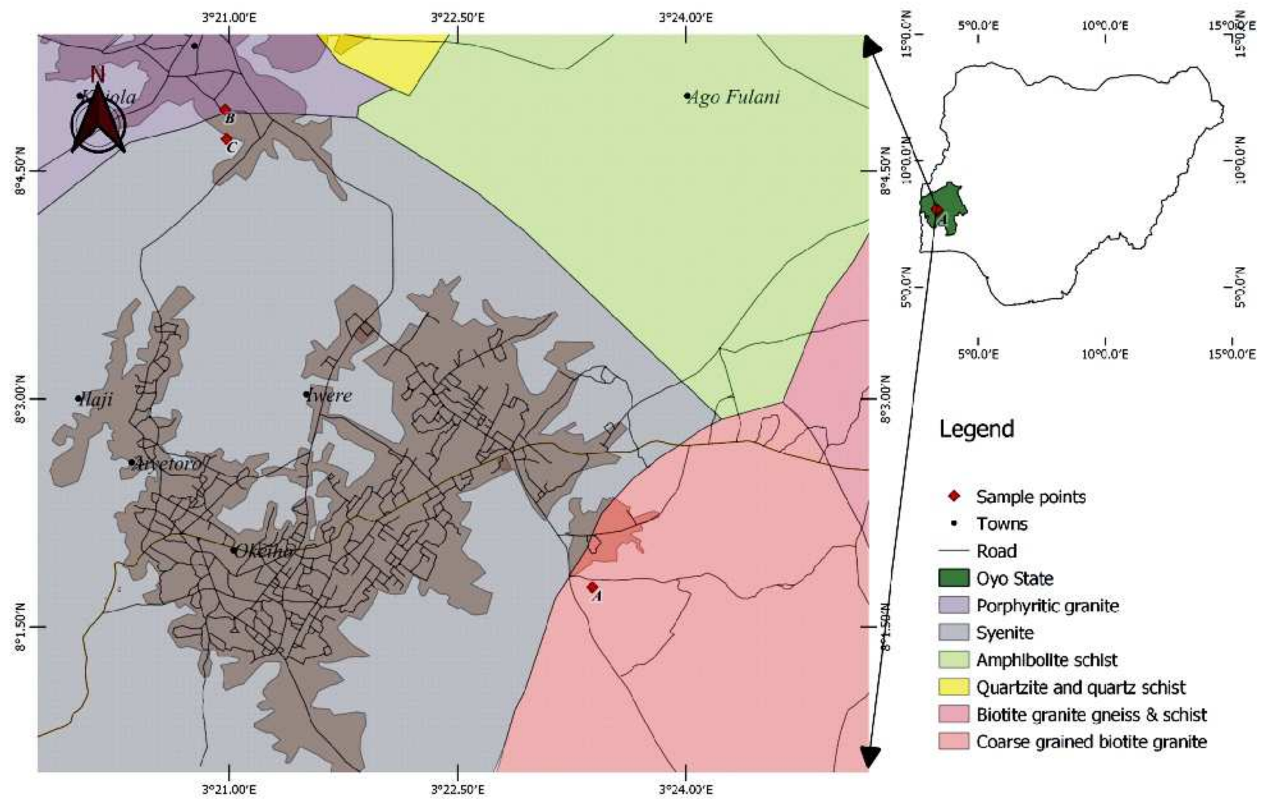

Fig. 2: Geologic map of the research area and environs

the westernmost region of the research area and they had medium to coarse-grained texture. The granitic rocks consisted of Granite, Biotite granite, and Syenite, etc. Mineralogically, the granitic rocks are composed of mafic and felsic minerals, which include biotite, orthoclase feldspar, plagioclase feldspar, quartz, and some accessory minerals (Figure to support this).

The mapping exercise was carried out in March 2020 using a topographic and geological map of Ilero southwest on a scale of 1:50,000. Samples of clay were gathered from three soil profiles situated in both the Ilero and Illua regions. Samples from Profile A were collected at Illua (8°1'30"N, 3°23' 28"E, and 327m elevation) from a weathering profile above Biotite granite and was labeled as L1. The clay deposit was grey with red spots and not more than 2.0 m thick, with a smooth grading of different horizons, implying residual nature (Fig. 2A). The second sample (labeled as L2) was collected from a weathering profile at Ilero (8° 4' 54.5"N, 3° 20' 57.34"E, and 290m elevation) and occurred above porphyritic granite. The deposit was greyish-brown and not more than 2.0m thick, overlain by lateritic soil and topsoil (Fig. 2B). The third sample (labeled as L3) were also collected at Ilero (8° 4' 42.579"N, 3° 20' 57.879"E, and 277m elevation) from a profile occurring above granite. The clay deposit was gray and not more than 2.0 m thick and was overlain by lateritic soil and the residual soils were developed over granite (Fig. 2C).

Methodology

Sample Collection

Eleven residual clay collected from weathering profiles at three different Profiles (A, B and C) in the study area (Figure 3) were used for the study. At Profile A in Illua (latitude 8° 1' 30"N, longitude 3° 23' 28"E, elevation 327m), four the clay samples labelled L1A, L1B, L1C, and L1D were collected above Biotite granite, the clay horizon has a thickness of approximately 2.0 m and overlain by topsoil. Profile B is located at Ilero (latitude 8° 4' 54.5"N, longitude 3° 20' 57.34"E, elevation 290m), four samples were collected from its clay horizon overlying porphyritic granite and labelled L2A, L2B, L3C, and L4D. At Profile C, also located in Ilero (latitude 8° 4' 42.579"N, longitude 3° 20' 57.879"E, elevation 277m), the residual clay horizon overlays weathered granite from which 3 samples labelled L3A, L3B, and L3C were collected.

Geochemistry

Eleven clay subsamples were prepared and analyzed to determine elemental composition using the Fusion-Inductively Coupled Plasma (FUS-ICP) at the Activation Laboratories in Ontario, Canada. the samples are mixed with flux of lithium metaborate and lithium tetraborate and fused in an induction furnace and the molten bead is quickly broken down in a mild nitric acid solution. The samples are then run for major oxides and trace elements using the ICP.

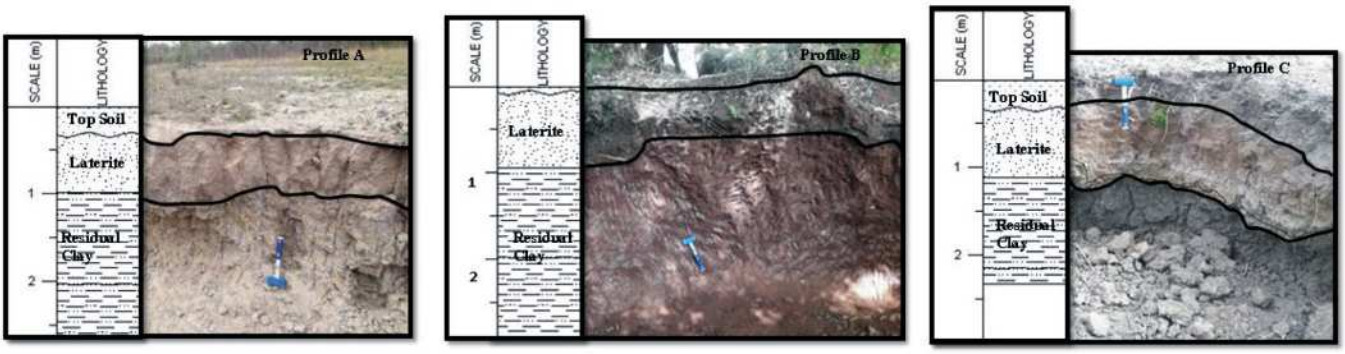

Fig. 3: Weathering profile of residual clays above granitic rock in Illua(Profile A), porphyritic granite in Ilero(Profile B) and granite in Ilero (Profile C).

Mineralogy

Composite samples of clays from the profiles were also sent to the laboratory to be subjected to mineralogical analyses using X-ray Diffraction (XRD), the analysis utilized a Bruker D8 Endeavour diffractometer with Cu X-ray source and settings as follows: 40 kV and 40 mA; step size of 0.02 degrees; interval between steps of 0.5 seconds; fixed divergence slit with an angle of 0.30; and sample rotation of 1 revolution per second. Mineral identification was conducted using the PDF4/Minerals ICDD database, with the Rietveld method employed for quantitative analysis of crystalline mineral phases. To evaluate industrial potential, physical analyses including thermal characteristics, grain size analysis, elasticity tests, density evaluations, linear compression, and water absorption tests were conducted. These analyses were performed using standardized methods and equipment at the Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife.

Physical Tests

The physical properties analysis of the clay samples was evaluated for grain-size distribution, moisture content, Atterberg limits (liquid limit, plastic limit, and plasticity index), shrinkage limit determination, specific gravity, firing characteristics, and water absorption. The samples were air-dried for two weeks before analysis to ensure reliability. Grain-size distribution was determined using both dry and wet sieving methods, with hydrometer tests conducted for the fine-grained fraction. Natural moisture content was measured using standard moisture cans and a dry oven. Atterberg limits were determined to assess soil consistency, with liquid and plastic limits calculated using prescribed methods (Cassagrande, 1932). Specific gravity was determined using a pycnometer, while firing characteristics, including colour change, water absorption, and loss on ignition, were assessed through firing samples at various temperatures and subsequent measurements. Linear shrinkage was determined by measuring sample dimensions before and after oven drying. These analyses provide crucial insights into the physical properties of the clay samples, essential for understanding their industrial applications.

Result and Discussion

Mineralogy

X-ray diffractograms and a summary of the clays' mineralogical compositions are provided in **Error! Reference source not found.** and Table 2 respectively. The table showed that the concentrations of kaolinite in clays from Profiles A, B and C are 4.2%, 7.8%, and 4.8% respectively. Only the clay deposit at Profile B has illite. The relative abundance of quartz compared with the other minerals could be due to its ultra stable nature in response to weathering, the concentration of quartz is highest in Profile A (45.8%) and Profile C (44.4%), while potassium feldspar is the most dominant mineral in Profile B clay (58.2%). Kaolinite and Illite are products of weathering of feldspars. The presence of plagioclase in the clay samples suggests low to moderate weathering. At the advanced stage, feldspars would have been completed and converted to clay minerals.

Table 2: Average mineralogical composition compared with standard industrial requirement

Mineralogy		Profiles		Reference	Sample
Wt%	A	B	C	(A)	(B)
Quartz	45.8	20	44.4	trace	4
K feldspar	45	58.2	47	_	3
Plagioclase	5	3	3.8	_	_
Kaolinite	4.2	7.8	4.8	85	85
Muscovite/Illite	n.d.	10	n.d.	15	-
Smectite	Y	n.d.	Y	-	-
Hematite	-	1	-	-	-

Note: n.d. = not detected; Y = present
(A)- Huber 1985 (B)- National Fertilizer Company of Nigeria (NAFCON, 1985) recommended values

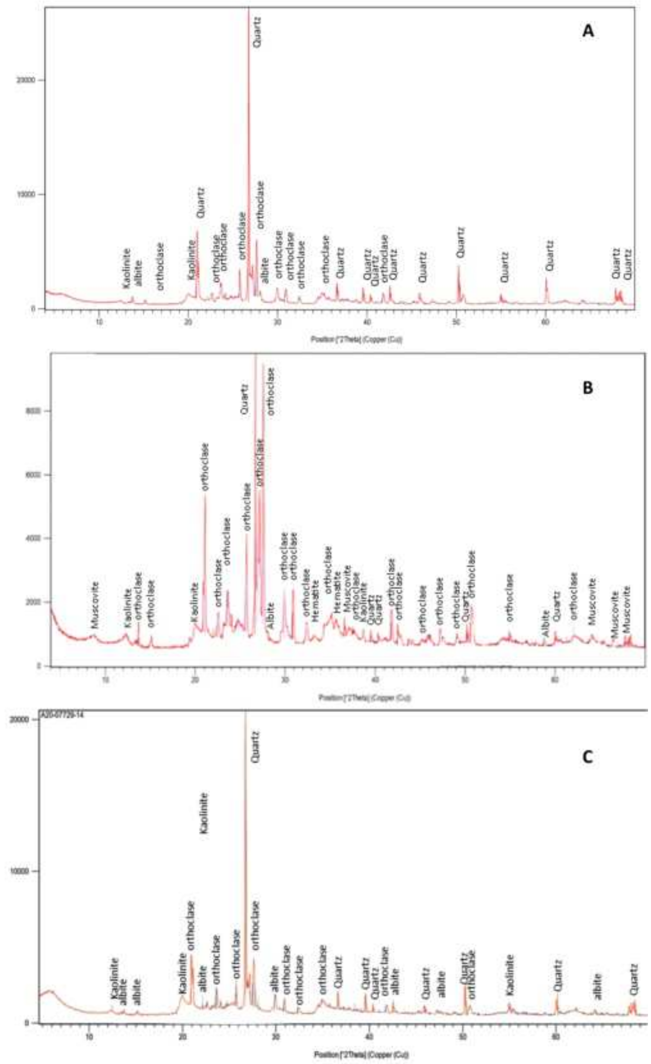

Fig. 1: X-ray Difractogram of composite clay samples from Profiles A, B and C

Geochemistry

Nine major elemental oxides (SiO_2, AL_2O_3, Fe_2O_3, MnO, CaO, Na_2O, K_2O, TIO_2 and P_2O_5) as well as seven trace elements (Ba, Sr, Y, Sc, Zr, Be and V) were determined in the samples and presented in Table 3. The average concentration of the oxides (wt.%) are in the following order SiO_2(60.73) > Al_2O_3(16.63) > Fe_2O_3(16.16) > K_2O(5.87) > TiO_2(1.22) > MgO(0.83) > Na_2O(0.58) > CaO(0.37) > MnO(0.14) > P2O5(0.06) . The average compositions of SiO_2, in Profile A, B and C clays are 68.16%, 54.59%, and 59.02% respectively showing that SiO_2 content is relatively higher in Profile A clay is relatively low when compared to Profile B which also has relative abundance of Al_2O, Fe_2O_3, K_2O and P_2O_5 when compared with clays from other profiles. Profile C overlies weathered porphyritic granite. The clay's X-ray diffractogram shows distinct quartz peaks, probably as a result of its comparatively elevated crystallinity (Brindley, 1961).

The concentration of Al_2O_3 ranges from 14.29% to 19.52%. The aluminum concentration in Profile B clay is the highest (19.52%) and the lowest value is recorded in Profile A clay (14.29%) (Table 4). The clays from the study area often have low levels of Fe_2O_3 (3.69% to 8.24%). The brownish color of Profile B clay can be linked to the abundance of hematite (1 wt.%) and Fe_2O_3 (avg. 8.2%). This observation can be supported by many hematite peaks on the X-ray diffractogram of Profile B clay (**Error! Reference source not found.**). The relative depletion of CaO, MnO, Na_2O, K_2O, P_2O_5, TiO_2, MgO, and LOI in the clays strongly suggest leaching. The average silica concentration of the clay samples is 60.49%, the average alumina content is 16.53%, and the average iron content is 6.21%, according to the results of the chemical analysis of the clay samples. The average calcium and sodium levels are 0.4% and 0.57%, respectively.

Table 2: Chemical composition of clays in the study area

Samples	Profile A Clay				Profile B clay				Ilero grey clay		
	L1A	L1B	L1C	L1D	L2A	L2B	L2C	L2D	L3A	L3B	L3C
Major Oxides											
SiO_2	68.12	67.38	67.32	69.81	54.2	54.19	55	54.98	58.41	60.18	58.47
Al_2O_3	14.38	14.57	14.42	13.8	19.03	19.18	19.85	20	15.84	15.98	15.92
Fe_2O_3	3.56	3.88	4.03	3.27	8.05	8.26	8.36	8.3	6.64	6.55	6.88
MnO	0.02	0.04	0.03	0.04	0.072	0.075	0.081	0.076	0.238	0.245	0.594
MgO	0.46	0.49	0.47	0.42	0.83	0.85	0.9	0.81	1.31	1.29	1.3
CaO	0.3	0.31	0.31	0.29	0.19	0.18	0.23	0.17	0.72	0.52	0.86
Na_2O	0.63	0.61	0.62	0.63	0.57	0.56	0.58	0.58	0.53	0.54	0.52
K_2O	5.56	5.41	5.36	5.5	7.26	7.15	7.32	7.73	4.34	4.5	4.45
TiO_2	0.99	1.05	1.03	0.95	1.214	1.257	1.263	1.189	1.484	1.513	1.497
$P2O_5$	0.03	0.04	0.04	0.04	0.08	0.08	0.08	0.08	0.06	0.06	0.06
LOI	6.07	6.45	6.11	4.76	6.51	6.63	6.65	6.06	9.1	9.07	9.11
Silica and Aluminum ratio											
SR	3.8	3.65	3.65	4.09	2	1.97	1.95	1.94	2.6	2.67	2.56
AR	4.04	3.76	3.58	4.22	2.36	2.32	2.37	2.41	2.39	2.44	2.31
MgO+CaO	0.76	0.8	0.78	0.71	1.02	1.03	1.13	0.98	2.03	1.81	2.16
$Na_2O + K_2O$	6.19	6.02	5.98	6.13	7.83	7.71	7.9	8.31	4.87	5.04	4.97
Trace elements (ppm)											
Ba	1691	1689	1652	1712	2452	2410	2500	2626	1413	1466	1991
Sr	364	353	354	360	518	514	533	562	249	258	258
Y	19	20	19	18	26	26	26	23	49	51	58
Sc	8	8	8	7	14	15	15	15	14	14	14
Zr	949	1057	968	1010	763	789	792	648	398	437	425
Be	2	3	2	2	3	3	3	3	6	6	6
V	68	75	73	67	131	132	135	135	112	110	119

Industrial Application

The clays in the research are contrasted with common industrial references in **Error! Reference source not found.** showing that Profile A clay, Profile B clay, and Ilero grey clay cannot be used for the production of paint because they fall short of the requirements for producing paint. However, for the production of ceramic, Profile A clay, Profile B clay, and Ilero grey clay can be improved to meet requirements for the production of ceramics. For refractory bricks development, Profile A clay, Profile B clay, and Ilero gray clay can be used for it. As observed in the table below, none of the clay specimens can be used to generate fertilizer, because of their low percentage of kaolinite compared to the standard. All the samples are poor in kaolin (Huber, 1985). Based on the standard for NAFCON, none of the clay samples meets the standard and cannot be used for fertilizer Although Profile B clay has the highest values, if beneficiated and used, it would yield low- and poor-quality products.

Table 4 showed that Ilero grey clays can be used as plastic fire clay (Ike et al., 2021). It satisfies the requirements for plastic fire clay. Profile B clay is very close to the standard, therefore it can be used for China clay. For Florida Active Kaolinite, Profile B clay is up to the standard. Some substances can seriously affect the quality of clay and its finished products if they are concentrated in it past a certain point. (Eyankware, 2021). It may be difficult to meld the clay if quartz, for example, is present in an excessive amount in a clay deposit (Adeseko and Bolarinwa, 2021; Osokpor, 2020).

Table 3: Comparison of the clay minerals with the Industrial specification for refractory bricks, paints, and ceramics

Oxides (%)	Profile A Mean (N=4)	Profile B Mean (N=4)	Profile C Mean (N=3)	Some (A)%	Industrial (B)%	Speciation (C)%
SiO_2	68.16	54.59	59.02	47.90-48.30	67.57	51.0-70.0
Al_2O_3	14.29	19.52	15.91	37.90-38.40	26.5	25.0-44.0
Fe_2O_3	3.69	8.24	6.69	13.40-13.80	0.50-1.20	0.2-0.7
MnO	0.04	0.08	0.36	-	-	-
MgO	0.46	0.85	1.3	0.20-0.30	0.10-0.19	0.2-0.7
CaO	0.3	0.19	0.7	0.03-0.25	0.18-0.30	0.1-0.2
Na_2O	0.62	0.57	0.53	0.20-0.35	0.20-1.50	0.8-3.5
K_2O	5.46	7.36	4.43	0.40-0.10	1.10-3.10	-
TiO_2	1	1.23	1.5	-	-	-
P_2O_5	0.04	0.08	0.06	0.02	-	-
LOI	5.85	6.46	9.09	-	-	-
Total	99.89	99.17	99.58			

Average values of 8 samples (A)- Paints (Payne, 1961) (B)- Ceramics (Singer and Sonija, 1971)
©- Refractory Bricks, (Parker, 1967).

In terms of industrial uses, a comparison of these clays' chemical compositions (Table 4) reveals that the two clay types from Ilero can be utilized to make refractory bricks (Parker, 1967) and building bricks (Murray, 1960). When compared to Florida active kaolinite and plastic fire clay, only Profile B clay is suitable for the production of paint (Payne, 1961). The chemical nature of Profile A clay is within the limit of industrial specifications for ceramic (Adegbuyi et al., 2015) and they could be used if further beneficiation for the production of paper.

Smectite (montrimonolite) is present in Profile A and Ilero grey clay as one of their minor minerals, and the modification of palygorskite through thermal activation can be applied for elimination of environmental toxins using adsorption (Biswas, et al., 2016). Profile B clay is composed of 10% illite, a mineral that improves the plasticity of clay, and plays a significant role in the creation of ceramics like bricks and roof tiles. (Dousova et al 2016). The presence of phyllosilicates such as smectites, Kaolinite, and Illite in the clay samples indicate that they could be useful in the enhancement of peloids for therapeutic purposes (Carretero, 2020). In the field of cosmetics, the utilization of clay is dependent on its chemical and mineralogical composition. Additionally, the high concentrations of Si in the clay samples imply that the clay can be employed for tissue hydration, skin tissue repair, and the reduction of potential inflammatory processes. The healing properties, pigment dispersion, hydration, and melanin adsorption of this metal are well recognized; these properties make it a very useful raw material for cosmetics applications. Clays with Si, Al, Fe, Ca, Ti, and K content can be used for antibacterial, regenerative, and antiseptic action that supports cell regeneration, impurity adsorption, vigor of tissues, and circulation activation. (da Silva Favero et al., 2019).

The color of clay is the most striking of all its physical properties and it varies from one source to another depending on presence of oxides and the horizon. One of the key characteristics considered when determining whether a clay is suitable for industrial use is color. Clay color is greatly influenced by the presence and relative amounts of iron and other elements, and the color is more defined when the clay sample is fired, the average firing characteristics of the samples are seen in Table . The distributions of clay minerals' grain sizes are shown in Table 5.

In general, the clay's flexibility and stability when employed as an industrial material depend on the particle size distribution. However, a high clay content boosts stability and plasticity. The research shown below demonstrates that clay content increases with depth in the clay profile, so the more weathering there is, the more clay is contained in the profile. The typical percentages for clay, silt and sand are 30 %, 35.5%, and 34% respectively in Profile A clay. Also, the typical percentages for clay, silt and sand are 23%, 34.5%, and 39% respectively in Profile B clay. typical percentages for clay, silt and sand are 36.5%, 55%, and 6.5% respectively in Ilero grey clay.

Table 5: Average firing characteristics of the clay samples

		Illua	Ilero reddish brown	Ilero dark grey
Weight before oven dry (g)	Mean	24.86	20.88	19.87
	Range	24.66 - 25.06	20.85-20.9	19.64-20.09
weight after oven dry (g)	Mean	20.53	17.72	17.24
	Range	19.92 - 21.13	17.1-18.33	17.21-17.27
weight after fired at 600°C (1hr) (g)	Mean	17.26	15.08	14.84
	Range	17.1-17.42	14.22-15.93	14.69-14.99
Loss on Ignition (LOI)%	Mean	18.9	17.66	16.19
	Range	16.49-21.3	15.07-20.25	14.81-17.56
specific gravity (s.g)	Mean	2.6	2.6	2.55
	Range	2.6	2.6	2.55
water absorption capacity (WAC)%	Mean	3.71	4.45	8.865
	Range	3.67-3.74	4.33-4.57	8.47-9.26
Linear Shrinkage (LS) %	Mean	11	16.5	19.5
	Range	11	16-17	19-20

Table 6: Average grain size distribution of all the clay samples

Grain size	Profile Aclay		Ilero reddish brown Clay		Ilero dark grey Clay	
	mean	range	mean	Range	Mean	Range
Gravel	0.5	0-1	3.5	4-Mar	2	2
Sand	34	34	39	38-40	6.5	6 – 7
Silt	35.5	35-36	34.5	34-35	55	54-56
Clay	30	29-31	23	22-24	36.5	36-37
Total	100		100		100	

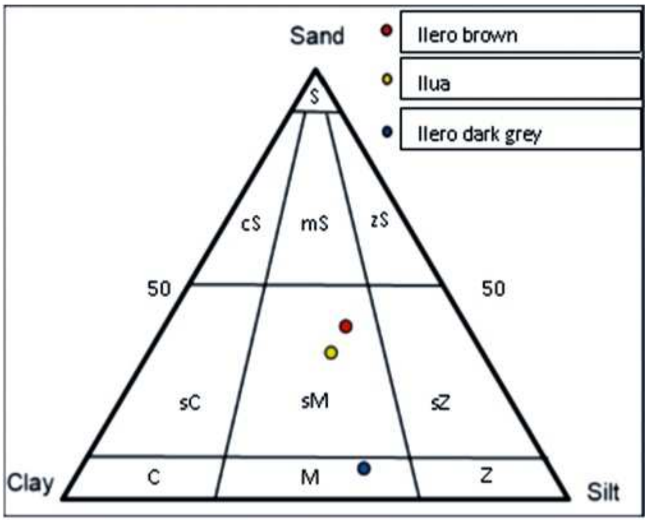

Fig. 2: Textural classification of Illua, Profile B and Ilero grey clays (After Folk, 1974) S: Sand, s:Sandy, Z: Silt,z:-Silty, M: Mud, m: Muddy, C: clay, c: Clayey, Ms: muddy sand, zS: silty sand, cS: clayey sand, sC: Sandy clay, sM: sandy mud, sZ: silty sand

The textural classification of clays in the study locations is described based on the amounts of clay, silt, and sand in each in Table 5.

Profile A and Profile B clays plots within the Sandy mud zone, while Ilero grey clay plots within the Mud zone. The result of the plasticity tests is presented in Table 8 show that Profile A clay has the lowest values of liquid limit (39.64%) and plastic limit (22.96%), followed by Profile B clay with liquid limit (40.32%) and plastic limit (26.86%). The clay from Ilero grey clay has the highest values of liquid limit (51.11%) and plastic limit (27.29%). This shows that Ilero grey clay is much more mature than Profile B and Profile A clay. It has been found that plasticity increases with clayey content percentage. Due to the significant sand percentage in this sample, clay from Profile A has the lowest liquid and plastic limit values. Ilero grey clay retained more water than the other clays, as seen by the liquid limit result, which reveals that Profile B and Profile A clays are less than 50% and Ilero grey clay is larger than 50%. Additionally, the plasticity results show that the samples are fairly elastic. Ilero grey clays are very poor in subgrade due to their high compressibility, whereas Profile B and Profile A clay samples are fair in sub-grade due to their clay of intermediate compressibility, according to Cassagrande's (1948) plasticity chart for the classification of clay.Since sand makes up a large portion of Profile A clay samples, their sub-grade is fair to poor.

Table 7: Average plasticity indices of the clay samples

Profile		A	B	C
LL%	Mean	39.64	40.32	51.11
	Range	39.02-40.25	39.43-41.20	50.03-52.18
PL%	Mean	22.96	26.86	27.29
	Range	22.86-23.06	26.35-27.37	27.49-27.08
PI%	Mean	16.68	13.46	23.82
	Range	16.16-17.19	13.08-13.83	24.69-22.95

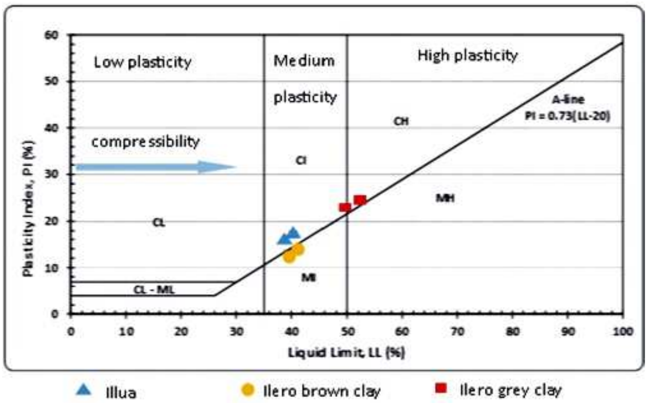

Fig. 3: A plasticity chart for classification of the clay deposits (After Cassagrande, 1948)

Conclusions

According to the analysis of the various available data, the clay could be used as ceramics, fertilizer in agriculture, for the production of paints, brick making, pharmaceuticals, refractory industries, and paper manufacturing. The clays could potentially be used to make bricks for construction. To achieve acceptable mouldability, the material must comprise 40% to 60% clay-silt particles. The three main clay minerals that are appropriate for making bricks are kaolinite, illite, and vermiculite. Additionally, they work in the manufacturing of pipes, sanitary ware, stoneware, roofing, wall and floor tiles. The clay-silt of the weathering profile in Profile A and Ilero (65.5% and 57.5%) meet the requirements. Hence, they can be used for the production of bricks and ceramics. Kaolinite clay that has been processed for use in paint is used as an inert extender or filler. $CaCO_3$ and clay are rivals. Filler materials include talc and gypsum. For filling purposes, fine-grained clay is required. It must be in the range of 80 to 90 for particles less than 2um. When compared to Profile A clay, which typically has finer particles than necessary and is therefore unsuitable for the creation of paints, the clay from the worn profile at Ilero can be utilized to make paint. Clay is used as filler and extender in paper production., this often involves the use of china clay, however, well-beneficiated clay could also be employed. For high-quality printing paper, it is also employed as a covering tint to provide a smoother, glossier surface. The clay that will be utilized needs to be white, fine-grained, and free of mica and iron oxide.

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Pictorial view of the new NMGS House under construction at Abuja.