



PHYSICO-CHEMICAL AND MINERALOGICAL PROPERTIES OF CERAMIC CLAY DEPOSITS IN ERUSU AKOKO, SOUTHWESTERN NIGERIA.

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Abstract

Physico-chemical and mineralogical analysis of ceramic clay deposits was carried out in Erusu Akoko with the aim of determining the dominant type of clay mineral in the study area as well as assessing the quality of this abundant geologic earth material and its suitability as raw material for the ceramic industry. Clay is a mineral with wide technological applications in industry as it is used in the production of fibre glass, paper, rubber, tiles, ceramics, cements, latex, paint, printing inks, catalyst for petroleum refining, medicines, water treatment, cosmetics and others. Field and laboratory study methods were adopted in this study as clay materials were pre-treated and subjected to analysis involving Multi - Collector High Resolution Inductively Coupled Plasma Mass Spectrometry (MC-ICPMS) for the major, trace and rare earth elements. From the result, Erusu clay exhibited decompositional water loss of 13.23% and 13.14% in air and Argon respectively at 100°C. The X-Ray Diffraction (XRD), California Bearing Ratio (CBR) and Infrared Spectroscopy (IR) analyses confirmed the presence of Quartz. Samples were collected to obtain baseline geochemical information about the area. From the analysed clay deposits in Erusu Akoko, it is observed that the major clay deposit is the quartz rich which accounts for 19.6% of their bulk compositions. Other clay minerals in the study area include Rutile (14.75%), Haematite (11.47%), Kaolinite (13.1%), Illite (13.1%), Albite (8.19%), Bentonite (9.84%), Tiemanite (9.84%) and Montmorillonite (0.2%). Hence, the result suggests that the clay deposits in the study area are good raw materials for the ceramic industries.

Keywords: Clay mineral, Erusu clay, Physico-Chemical, Mineralogical.

Introduction

The need to determine the dominant type of clay mineral in the study area as well as assess the quality of this abundant geologic earth material and its suitability as raw material for the ceramic industry becomes pertinent. Hence, clay is known to be a common name for a number of fine-grained, earthy materials that become plastic when wet. Chemically, clays are hydrous aluminium silicates containing impurities.

Examples include potassium, sodium, calcium, magnesium and iron in small amounts (Grimshaw, 1959). They are

divided into two classes to include residual clay found in the place of origin and as transported clay, also known as sedimentary clay. The clays are removed from the place of origin by agents of transportation and deposited in a new and possibly distant position. Residual clays are most commonly formed by surface weathering, which gives rise to clay in three ways by the chemical decomposition of rocks, such as granite, containing silica and alumina; by the solution of rocks, such as limestone, containing clayey impurities which being insoluble are deposited as clay; and by the

disintegration and solution of shale (Manukaji, 2004). One of the commonest processes of clay formation is the chemical decomposition of feldspar.

Studies of the geology occurrence and utilization of both residual and sedimentary clays for burnt bricks, ceramics, paper and agricultural purposes are documented by many workers including the likes of Meshida (1978), Ajayi and Agagu (1981), Aribisala (1989), Elueze (1993), Elueze and Bolarinwa (1995) and Bolarinwa (2001). Result of their investigations show that quite a substantial quantity of clay bodies of industrial proportions abound in this part of Nigeria.

Olaolorun and Oyinloye (2010) examined clay deposits around Ijero-Ekiti, where he opined that the major clay deposits is the Kaolin rich which accounts for 84% of their bulk compositions. Other clay minerals in the Ijero deposits include quartz (10.6%), illite (2.0%), chlorite (1.21%), pallygosite (0.9%), Montmorillonite (0.2%) and feldspars (0.6%). He concluded that the clay deposit at Ijero and its environs are Kaolinitic clays in which Kaolinite is the dominant mineral and these are residual clay deposits. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. Clay deposits may be formed in place as residual deposits in soil, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Geological studies were carried out on the clay deposits and their parent rocks because clay of different rocks are formed as result of physical and chemical weathering of crystalline rocks in tropical and subtropical environments. The factor affecting the disintegration process (weathering) is climate, biological activities, topography, parent rocks and time. With increasing population, the

provision of more houses with ceramic wares becomes pertinent. Hence the need for constantly mapping and conducting quality assessment of clay deposits located within the southwestern Nigeria which is a way out of the shortage in the supply of this geologic earth material globally used as raw material for ceramic industries.

Location and Accessibility of the study area

The study area lies within the Southwestern Nigeria. Erusu Akoko lies within latitude $07^{\circ} 36' - 07^{\circ} 38'N$ and longitude $05^{\circ} 56' - 05^{\circ} 57'E$ respectively. It is accessible through major roads and footpaths. Sections within the study area where samples were collected from were accessible through footpaths.

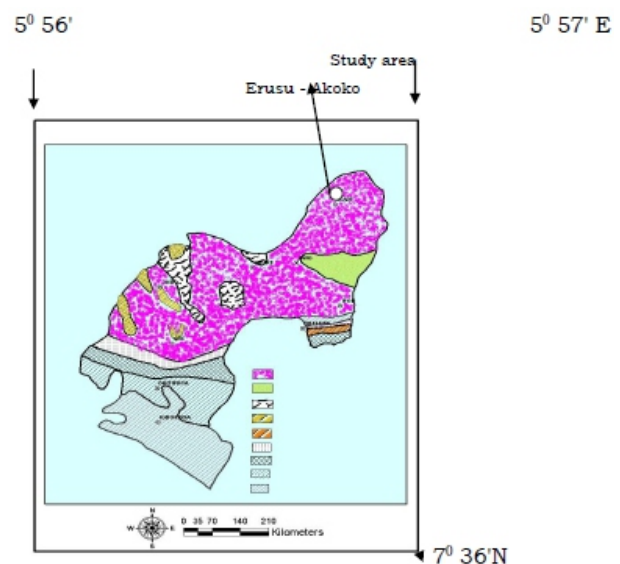


Figure 1: Map of Ondo State Showing the Study Area (Federal Survey Agency)

Topography and Drainage System of Study Area

The study area exhibits different forms of topographic distinction which lies in the Precambrian Basement Complex of Southwestern Nigeria. The North-Eastern and the South-western show a higher topography. The area is mostly undulating to uplands and lowlands. The topography is characterized by different but impressive physiographic features with varying lithology ranging from conspicuous highlands to older granites to fairly undulating terrain of ironstone (Rahaman, 1976). The drainage pattern of the study

area is the combination of both trellis and dendrite type of drainage. They show the resistance of the underlying crystalline basement rock and displaced structural features. Stream and rivers are developed

during major joint direction and foliation trend with generally straight courses. These factors also imposed the trellis and dendrite patterns. Most of the streams are seasonal.

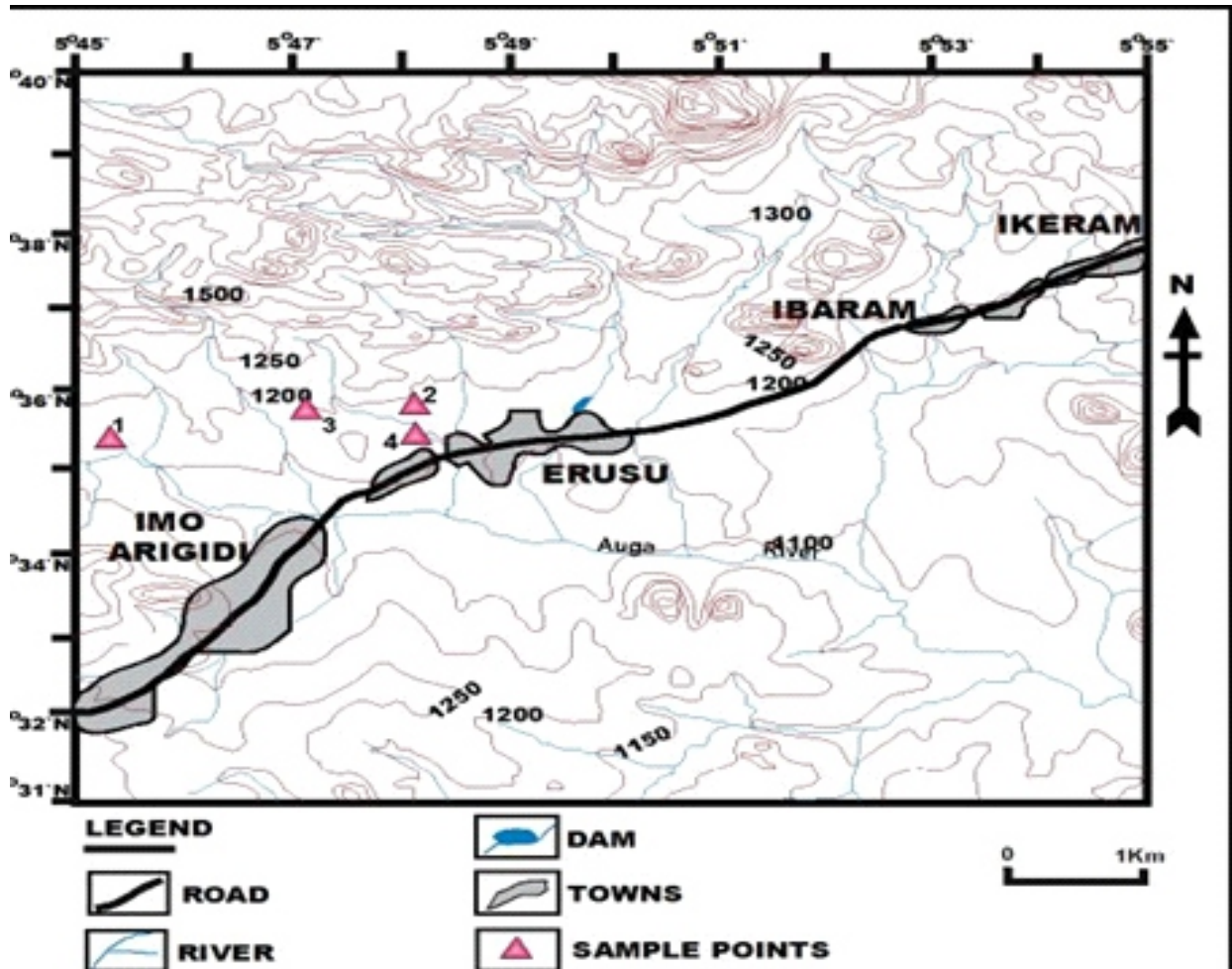


Figure 2: Topographical Map of the study area showing sampling points (Nigeria Geological Survey Agency)

Table 1: Coordinates of the Sampling Points

Sample Code	Latitudes (N)	Longitudes (E)
L1	07° 33' 05"	05° 46' 05 "
L2	07° 33' 59"	05° 46' 04"
L3	07° 34' 18"	05° 46' 13"
L4	07° 34' 43"	05° 46' 18"
L5	07° 34' 50"	05° 46' 16"

L= Location

Soil Type, Vegetation and Climate of Study Area

The soil type in the study area is characterized by clayey lateritic materials which, in some places, partly comprise of decomposing rock fragments. The soil

occurs as a result of *in-situ* weathering of underlying crystalline rocks under tropical conditions. It is composed of greyish to reddish-brown, loose, medium to coarse-grained mineral matters with some clayey component (Meshida, 1987). The soils may

however be dark in colour probably as a result of decomposing floras and faunas. The study area belong to the tropical rain forest region and can be described as good and support agricultural activities due to the texture of the soil and nature of vegetation in the area. The vegetation of the area is in relation to climate, soil, elevation and human impact on the environment. The vegetation comprises of tall trees with buttress roots, evergreen and broad leaves and numerous species of trees like Mahogany, Iroko and African walnut

Geology of Study Area

The study area has heterogeneous assemblage of rocks such as migmatite, orthogenesis, paragneisses and a series of basic and ultra-basic metamorphosed rocks (Rahaman, 1988). Rahaman and Ocan (1988), found out that the region is underlain by quartzo-feldspathic gneiss, pelitic gneiss, granite gneisses and basic and felsic components.

The study area is underlain by Migmatite, Granitic and Charnockitic rocks. Principal lithologies constituting the study area Migmatite gneiss, Quartzite, Granite gneiss, Charnockite, Granite and Porphyritic granites.

Materials and Methods of the study

Materials used for this study includes the GPS for taking the coordinates, sledge hammer masking tape, marker for labelling the samples, sampling bag for collection of samples, digger and cutlass were used to dig and collect the soil samples. Fresh and undisturbed samples were collected and immediately kept in sample bags to minimize loss of moisture. For the purpose of obtaining good results, organic soils, decayed debris, plant residues and animal remains were removed from the samples. Five locations were selected for sample collection. Samples were taken at 100m intervals at the depth of 1.5m. All the samples were collected in Erusu-Akoko. Samplings were carried out from hand dug test pits along road cuts in the studied locations. The samples were collected manually by using auger. The choices of sampling locations were determined during field investigation along the road. Topographic observations confirmed that similar residual soil profiles were developed along similar slope within the same lithological units. Rocky outcrops were also mapped in order to know the origin of the soil developed in the area. The following analyses were conducted on the samples collected; to include Natural moisture content (NMC), Atterberg or consistency limit test, (Liquid Limit, Plastic Limit, Plasticity Index, Linear Shrinkage), Specific gravity, Grain size analysis, Compaction test and California Bearing Ratio (CBR) All the laboratory tests conducted were in conformity with the procedures specified in the British Standard Institution (BS 1377, 1975).

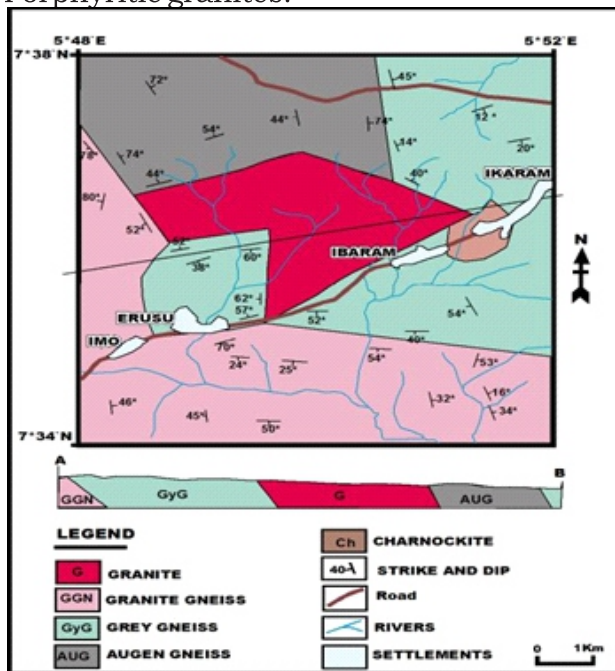


Figure 3: Geological Map of the Study Area (Source: AAUA Field Mapping Exercise, 2017)

Table 2: Results of the Physical Properties of Deposits of Clay Samples.

Depth(1.5m)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Linear shrinkage (%)	Plasticity Index (%)	Particle Size (%)	MDD (%)	OMC (%)	Unsoaked CBR (%)	Soaked CBR (%)	Specific Gravity (%)	Hydrolysis (%)
L1	5.1	46.6	8.9	9.1	32.54	463.4	1988	12.1	14	3	2.733	48.5
L2	5.2	45.1	9.0	8.2	36.10	462.5	1992	12.0	31	9	2.785	48.8
L3	5.1	44.6	8.8	8.7	35.80	461.3	1916	14.8	16	4	2.968	55.1
L4	5.0	43.3	8.7	8.7	34.60	453.7	1957	137	29	9	2.542	52.2
L5	5.0	45.9	8.6	9.6	37.30	458.3	1969	12.6	28	8	2.737	60.3

Results and Discussions

From the result of the physical analysis carried out on the samples, the natural moisture content of the soil from Erusu Akoko ranges between 5.0% to 5.2%. Sample L4 and L5 have the lowest value of while Sample L2 has the highest value of 52%. This can provide useful method of classifying cohesive soil. The strength as well as the state of

consistency of a soil can be inferred by relating its moisture content to its index properties. Samples collected at location L2 have high moisture content in their natural state. An increase in soil moisture above the optimum implies weakness in the soils that leads to swelling which cause damage to the pavement and when losing the water, there will be shrinkage.

Table 3: Fire Linear Shrinkage

Sample Cod	Location 1	Location 2	Location 3	Location 4	Location 5
Original Length, Lo(mm)	134	133	138	121	126
Final Length Lf(mm)	132	131	137	116	122
Linear Shrinkage (1-(Lf/Lo))*100	1.5	1.5	0.7	4.1	3.2

Table 4: Fire Linear Shrinkage on Colour, Temperature and Fire Ability Test

Sample Code	Colour before firing	Colour aft firing	Temp(°C)	Fireability
L1	Medium grey	Light brown	1200	Good
L2	Yellowish grey	Greyish orange	1200	Good
L3	Medium dark	Moderate reddish brown	1200	Good
L4	Yellowish grey	Moderate reddish orange	1200	Good
L5	Medium dark	Light brown	1200	Good

Table 5: Fire Test Before and After Immersion and Water Absorption

Sample code	Mass of fire Sample before immersion in water (g)	Mass of fire sample after immersion water (g)	Mass water absorbed (g)	Water absorption capacity (%)
L1	16.0	17.8	1.80	11.25
L2	17.3	19.3	2.00	11.56
L3	16.8	18.9	2.10	12.50
L4	17.2	19.1	1.90	11.05
L5	17.8	19.9	2.10	11.80

The reason for high moisture content in some of the soil samples is influenced by the season, clay content and drainage condition of the environment, because these factors do influence in-situ moisture (Arumala and Akpokodge, 1987). The strength and cohesion capacity of the soil is averagely low. It can be considered for simple engineering purposes. Excessive moisture content is detrimental to collapsible and swelling soils (Jegede, 1994).

The summary of the test carried out on the soil samples to determine their specific gravity, the values ranges between 2.73% to 2.92%. Sample collected at location L1 have the lowest value specific gravity of 2.54% while the Sample collected at location L3 has the highest value of 2.92%, the high values may be explained by presence of

heavy mineral content from the underlying parent basement rocks which are mainly mica. The values of the liquid limit ranges from 43.3% to 46.6%. From the result obtained it was observed that the sample collected at location L1 has the highest liquid limit (46.6%) while the sample obtained at location L4 at the has the lowest liquid limit (43.3%). The values obtained for plastic limit ranges from (8.2%) to (9.6%). It was observed that samples at location L1 and L3 crumbled before 3mm; this is due to the non-plastic nature of the soil samples at this location. It is observed that the sample obtained at L5 has the highest plastic limit (9.6%) while the sample collected at location L2 has the lowest plastic limit (8.2%). Samples collected at locations have plastic limit indicating that they are silty clay of high compressibility.

Table 6: Soil Classification Based on Plasticity Index (British Standard Institution, 1975)

PLASTICITY INDEX	SOIL DESCRIPTION
0	NON PLASTIC
1-5	SLIGHTLY PLASTIC
6-10	LOW PLASTIC
10-20	MEDIUM PLASTIC
21-40	HIGH PLASTIC
>40	VERY HIGH PLASTIC

The hydrolysis values ranges from 48.5% to 60.3%. Sample collected at location L1 and L5 have the lowest value of 48.5% while the Sample collected at location L5 has the

highest value of 60.3%, Indicating that the sample in location 5 has more pore spaces for water intake.

Table 7: Percentage Mineralogical Composition of Clay Samples

Depth (1.5m)	Al ₂ O ₂	CaO	Fe ₂ O ₃	K ₂ O ₃	MgO	Na ₂ O	SiO ₂	TiO ₂	P ₂ O ₃	Mn ₃ O ₄
L1	32	0.7	1.4	4.24	0.4	0.001	0.0004	0.0001	0.0003	0.0001
L2	34	0.5	1.2	3.55	0.6	0.005	0.0003	0.0007	0.0009	0.006
L3	33	0.9	1.3	3.40	0.5	0.002	0.0002	0.004	0.0005	0.006
L4	35	0.4	1.1	4.00	0.4	0.0004	0.0001	0.0002	0.0008	0.0001
L5	31	0.7	1.2	4.22	0.7	0.003	0.0002	0.004	0.00001	0.0004

From the result of the mineralogical analysis carried out on the samples, the major element determined were; Al₂O₂, CaO, FeO₃, K₂O, MgO, Na₂O, SiO₂, TiO₂, P₂O₃ as the highest value of FeO₃ in Location 1 is 1.4 %. This shows that the sediments in these areas are rich in iron- bearing minerals such micas and feldspars. The lowest value of FeO₃ was observed in Location 4 with values of 1.1%. This may be as a result of the fact that the iron content may have been substituted by a less stable iron in these and also as a result of leaching of mica, feldspar, and clay mineral from the parent rock. Aluminium (Al₂O₂) values ranges from (31 -35%) having an average value of 33%. The abundance of Al₂O₂ indicates that the samples are rich in aluminium and silicates mineral such as feldspar and mica. The Al₂O₂ content in L5 with value which shows that they are less

feldspathic in terms of composition. Calcium oxide (CaO) values ranges from (0.4 – 0.9%) with an average value of 0.64%. The CaO content of sediments in location 3 is relatively high while that of L1, L2, L4 and L5 having values (0.7, 0.5, 0.4, 0.7%) respectively which are very close to each other. Potassium oxide (K₂O₃) value ranges from (3.55 – 4.24%) with an average value of 3.92%. The highest value of K₂O₃ is found in L1with a value of 4.24% and very low in other areas. These show that feldspar-bearing rocks such as granites and gneisses may be absent in the area. Magnesium oxide (MgO) value ranges from (0.4- 0.7%) with an average value of 0.52%. The MgO values around L1 and L4 are the same with value of 0.4%. The highest MgO values in the samples were found in L5 with value of 0.7%. Other major element like Na₂O, Mn₃O₄ and K₂O are in low quantity.

Table 8: Clay Mineral Composition of Samples as Obtained from Laboratory Analysis

Minerals	Prese	Range	Mean	Percent
Rutile		0.8-1.0	1.3	14.75
Haematite		0.6-0.8	1.0	11.47
Kaolinite		0.6-1.0	1.10	13.1
Illite		0.7-0.9	1.15	13.1
Albite		0.3-0.7	0.65	8.19
Quartz		1.0-1.4	1.7	19.6
Bentonite		0.5-0.7	0.85	9.84
Tiemanite		0.5-0.6	0.8	9.84

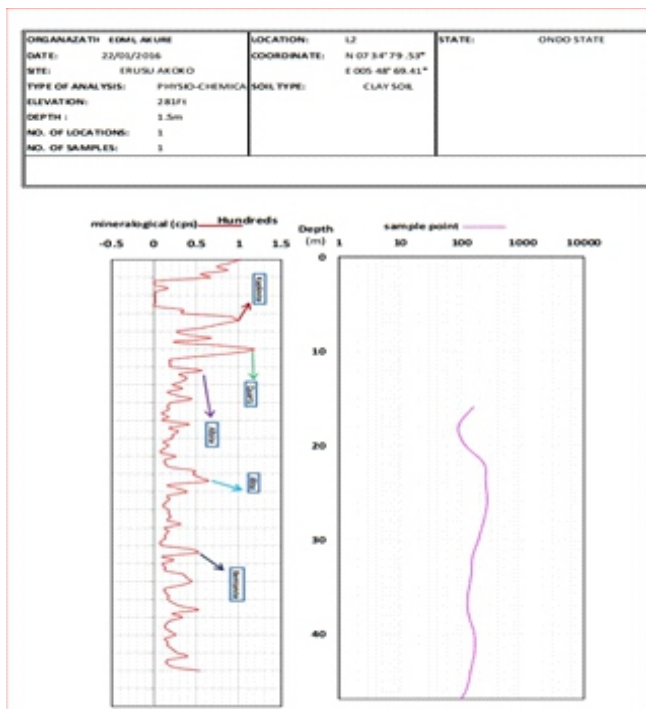


Figure 4a: XRD Mineralogical Composition of Sample 1

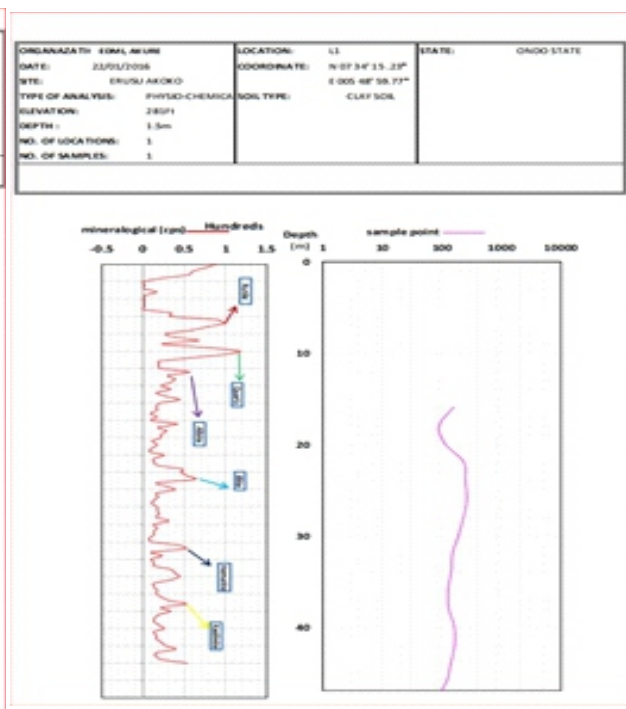


Figure 4b: XRD Mineralogical Composition of Sample 2

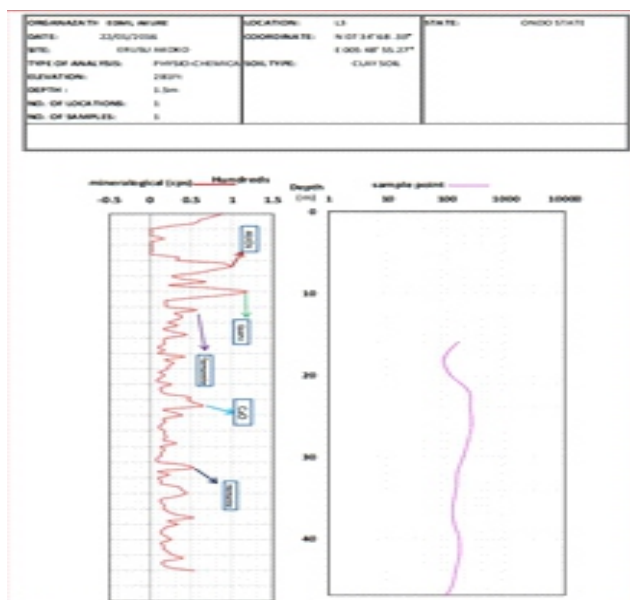


Figure 4c: XRD Mineralogical Composition of Sample 3

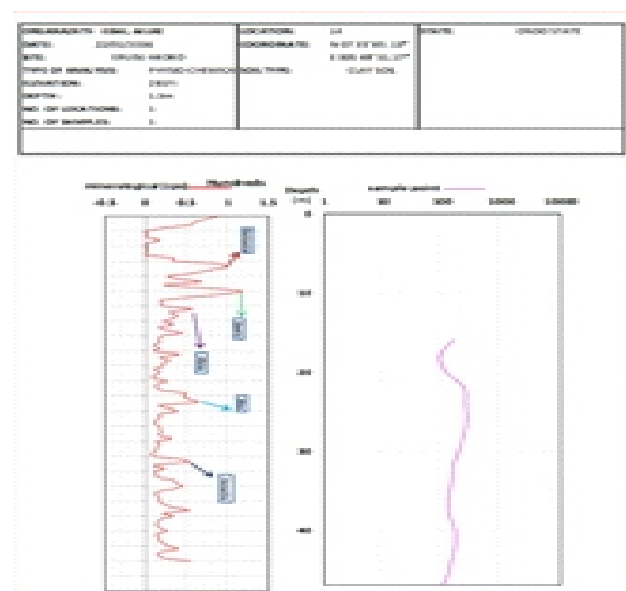


Figure 4d: XRD Mineralogical Composition of Sample 4

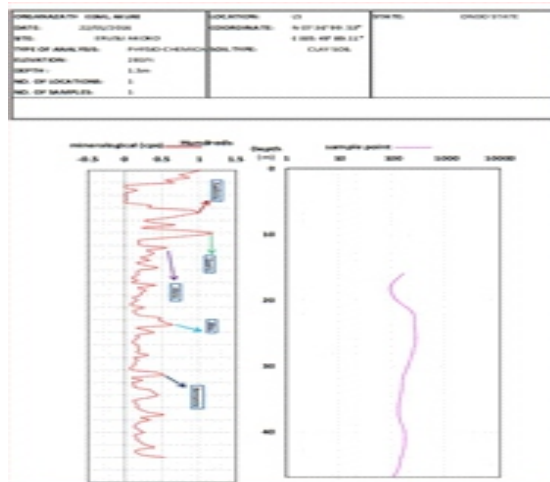


Figure 4e: XRD Mineralogical Composition of Sample 5

Conclusions

From the result of the mineralogical analysis carried out on the sediments the major elements found are Al_2O_3 , CaO , FeO , K_2O , MgO , Na_2O , SiO_2 , TiO_2 , P_2O_5 . The abundance of Al_2O_3 indicates that the samples are rich in aluminium and silicate minerals such as feldspar and mica. Sodium (Na) and Potassium (K) in the sample show a low proportion of clay mineral, and indicate that the breakdown feldspar have leached away.

From the analysed clay deposits in Erusu Akoko, it is observed that the major clay deposit is the quartz rich which accounts for 19.6% of their bulk compositions. Other clay minerals in the study area include Rutile (14.75%), Haematite (11.47%), Kaolinite (13.1%), Illite (13.1%), Albite (8.19%), Bentonite (9.84%), Tiemanite (9.84%) and Montmorillonite (0.2%). Hence the result suggests that the clay deposit at Erusu Akoko is a quartz dominated clay mineral. However, Rutile and Kaolinite clay minerals are also present which are all found to be very good raw materials for the industrial production of ceramics, refractories, paints, low alumina chemicals, pharmaceutical products and as additives in cement industries.

It is therefore recommended that further studies be conducted on the study area for its clay deposit potentials.

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