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Evaluating the Potentials of Drilling Mud Production from Clayey Solis Derived from Imo Shale Formation in Okada, Near Benin, South Western Nigeria

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Abstract:

Samples from Okada area in the Southwestern, Nigeria were collected to evaluate their likely potentials in drilling mud production with comparison with some commercial bentonite. In order to carry out this evaluation mineralogical, geotechnical and geochemical analysis were used to assess these drilling mud potential. The geotechnical analysis involving the determination of moisture content, specific gravity, particle size analysis, atterberg/ consistency limits test was combined with geochemical analysis of Xray Fluorescence (XRF) and Xray Diffraction (XRD) to determine the qualitative, (types of clays) and quantitative (compositions of each mineral in clay component) and the mineralogy percentages in the clay. The geotechnical results showed particles size of < 60% with very high plasticity (88-140%) having clay activity of <1.25%. Geochemical analysis shows significant amount of Silicate (SiO_2), Alumina (Al_2O_3), Iron (Fe_2O_3), Magnesium (MgO), Calcium oxide (CaO), Titanium oxide (TiO_2) and Manganese oxide (MnO). In CEC, Ca, K, Na (in order of decrease) oxides in Okada and high LOI (38%). The Okada clay revealed the dominance of montmorillonite (30-35.1%) and Kaolinite (2-20.1%) with Quartz (2-24%), Calcite (7-91%) and a very unique occurrence of Palygorskite (2-33%) in the study area which has never been seen in Nigeria. The attributes of the Okada clay were compared with the natural commercial bentonite of Wyoming and Moscow and it was observed to meet the requirement as drilling mud except in the plasticity and swelling potentials which would have to be taken into consideration in beneficiation of the okada clays.

Keywords: *Clay, Drilling mud, drilling fluid, Okada, Palygorskite.*

Introduction

In geotechnical engineering, drilling mud is used as an aid in oil and water exploitation. The need of this drilling mud is to bring cuttings, cooling of the drilling bits, modifying its viscosity (Zhang et al., 2020) and provide hydrostatic pressure to create a seal of the bore walls. Drilling muds are used based on the addition of clay minerals, although the clay composition varies from deposit to deposit but the most

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significant is that it must have a swelling rich clay (Zhang et al., 2020). These drilling muds are made up of clay and clay minerals such as (bentonite, palygorskite, sepiolite and mixtures of clay minerals): Bentonite is a swelling clay that swells and shrink in response to moisture and these is due to the presence of the montmorilonite as the dominant clay mineral (Okogbue and Ene, 2008; Kassif and Baker, 1971 and Ola, 1980). Palygorskite is suitable for use in oil-based drilling fluids, but the gelation and gel structures of palygorskite-added drilling fluids have not received much attention (Zhang et al., 2020).

Clay minerals are the basic constituents of the drilling fluids. The demand for these drilling mud, which is in high demand and costly has lead to seeking for local clay deposits that can serve as possible alternatives i.e. locally. This study is to evaluate the Okada clay deposits in Southwestern Nigeria by assessing their potentials as drilling mud using mineralogy, geochemistry and geotectonic characteristics. This result of this study can help reduce import cost of bentonite and maximize profits as well as sustainability of the oil industry.

Study Area Description

Location of Study Area

The area is located in the table below and it occurs as ridges and flat lands. Its located in the tropical region of Okada close to Benin-city all in Edo state (Figures 1-2).

Table 1. Location of Study Area

Okada (ridge 17m high) (2-3m Dug Deep)	N 06° 38' 59.1" N 07° 38' 21.2"	E 005° 17' 59.4" E 005° 19' 71.5"

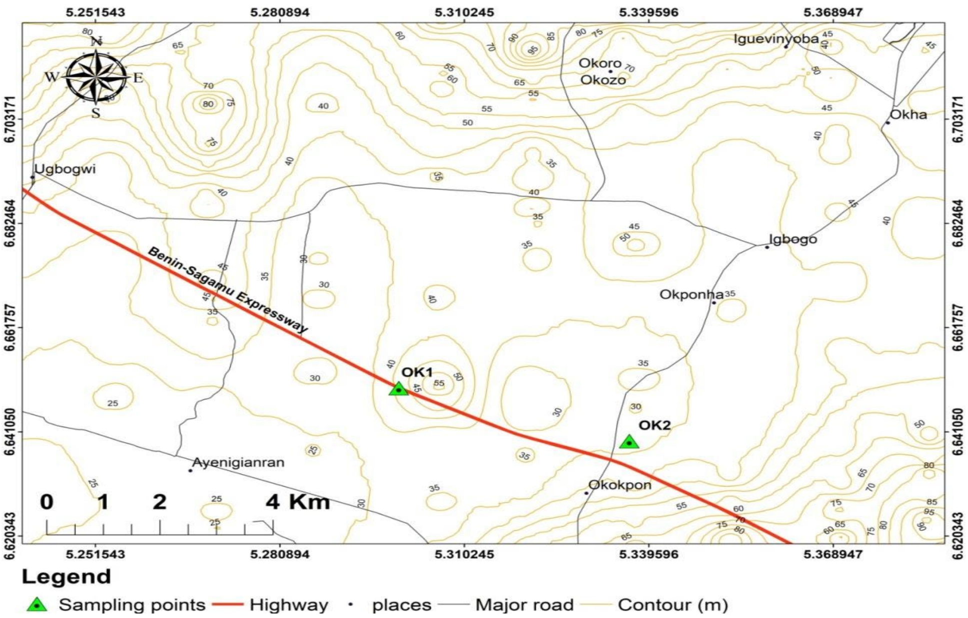

Figure 1. Location Map of Sampled Location in Okada Area

Geology of the Study Area

The Imo Shale is essentially thick clayey shales that are fine textured, dark grey to bluish in colour with occasional admixture of clay ironstone and thick sandstone beds in which carbonized plants remain may occur and limestone intercalations with abundant pyrite crystals but poorly fossiliferous. The Imo Shale is Paleocene to Eocene in age (Kogbe 1989). The Imo Formation outcrops at Okada as Okada

Shale (fig 2) and it is typically dark grey, very thinly laminated and fissile (Osadebe et al., 2011).

The Imo Formation is the surface equivalent of the subcropping Akata Formation in the Niger Delta Basin (Table 2), which is coequivalent with Ewekoro Formation in the Dahomey Basin in Western Nigeria and Kalambaina Formation in the Sokoto Basin (Ogbe, 1970). As seen in the geology map (Figure 3).

Table 2. General Stratigraphic Sequence in Niger Delta Basin

AGE	BASIN	STRATIGRAPHIC UNITS	
Miocene-recent	Niger- Delta Basin	Surface	Subsurface
		Benin Fm	Benin Fm
Oligocene		Ogwashi- Asaba Fm	
Eocene		Ameki/ Nanka Fm / Nsugbe Sandstone (Ameki Group)	Agbada Fm
Thanetian		**Imo Fm**	Akata Fm

Source: Modified from Nwajide (2005)

Figure 2. Okada Sample

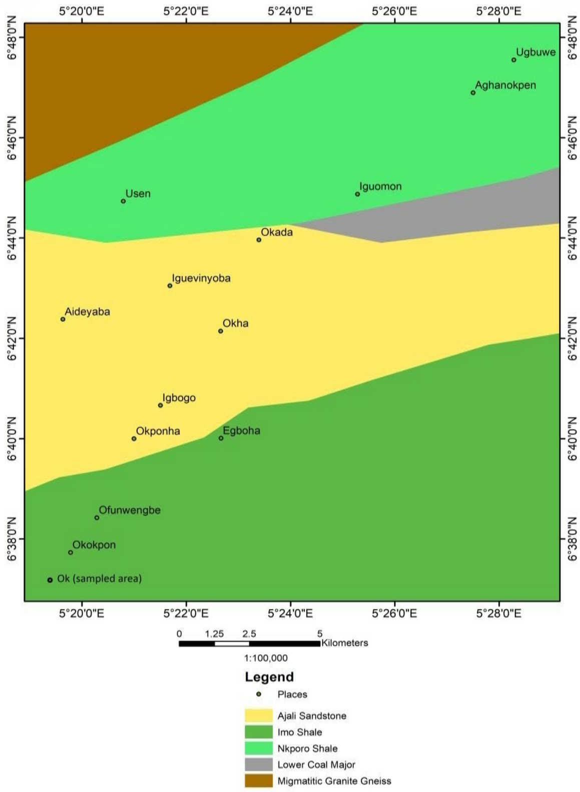

Figure 3. Geology Map of Sampled Area

Materials and Methods

Field Studies and Sample Collection

Field work was conducted using traverse method to access sample locations and fresh soils were taken from quarry faces, hand dug pits between 2m to 4m in depth, and each soil sample collected was observed in hand specimen and later stored in separate polythene bags and labeled accordingly for easy identification and laboratory analysis.

Laboratory Analyses of Soil Sample

Geotechnical test

The samples for were dried and it became lumped up which had to be crushed. Firstly, particle-size analysis was done with a combination of wet sieving and hydrometer method. The liquid limit and plastic limit were determined after passing thru a 425 sieve and defining the boundaries of several state of consistency in accordance BS 1377 (1990).

Geochemical test

The Thermo Fisher ARL Perform'X Sequential XRF instrument with Uniquant software was used and PANalyticalX'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The values were normalised, to include LOI, to determine crystal water and oxidation state changes. A standard sample material was prepared and analysed in the same manner as the samples and is reported as such.

Mineraological tests

The mineralogy (XRD) was determined by selecting the best–fitting pattern from the ICSD database to the measured diffraction pattern, using X'PertHighscore plus software (University of Pretoria Laboratory, South Africa).

Result and Discussion

Geotechnical Result

Particle size analysis

The Figure 4 above shows both the graph and Table 3 with the result of particle size (percentage passing) indicating Okada samples are mostly fines. Seed et al., 1962 observed clays with >56% passing are clay particle and occur more in montmorillonite clays than other clay, these can be inferred that the studied clays then are likely montmorillonite. In addition, Okogbue and Ene, 2005 says active clays having both high water retaining/water holding capacity and high cation exchangeable capacity. Using the Activity value by Skempton (Table 4), which are the ratio of the plasticity index and the percentage of the clay fraction. Activity is a measure of the water-holding capacity of the clay soils; the studied samples are therefore active which ranges from 1.35 to 3.94 (Table 3) further indicating swelling clay probably a montmorillonite.

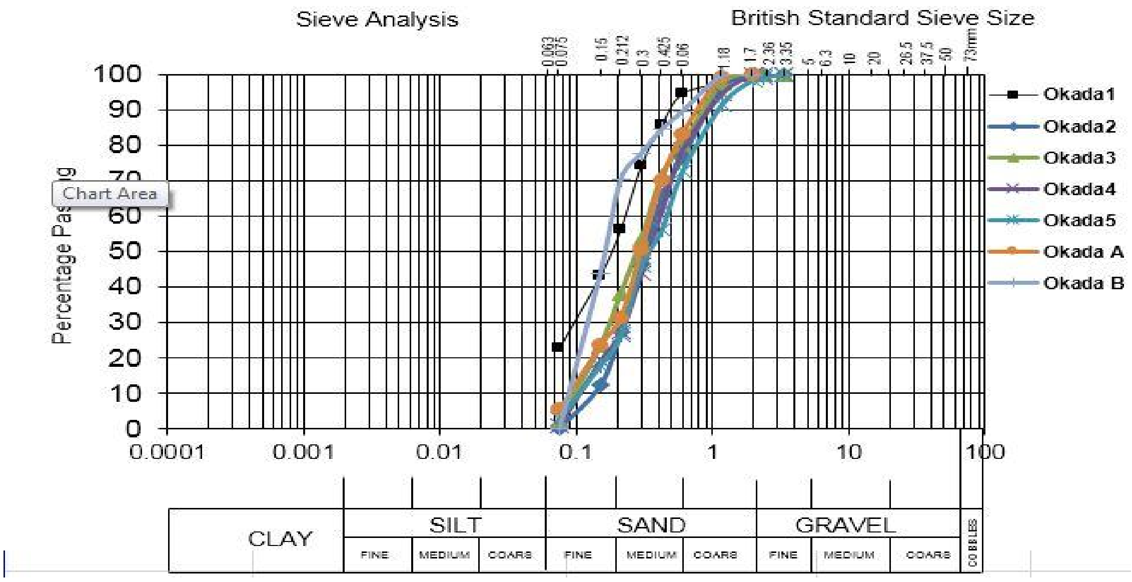

Figure 4. Particle Size Analysis for Okada

Table 3. Geotechnical Index Properties of Clayey Soils in Okada

Location / Parameters	Liquid limit (LL %)	Plastic limit (PL %)	Plasticity Index (PI =LL-PL %)	Shrinkage Limit (SL %)	Activiyty (A)	Clay Fractions (%)
OKADA 1	205.37	72.58	132.79	25.70	3.94	56.69
2	180.71	77.20	103.51	25.00	1.28	85.73
3	194.66	78.64	116.02	27.86	1.75	74.41
4	181.29	77.20	104.09	25.00	1.16	90.77
5	206.02	85.61	120.41	26.43	1.72	72.09
A	157.46	57.12	100.34	23.57	1.90	53.94
B	162.43	73.56	88.87	25.00	1.25	76.51

Table 4. Activity of Clay Classification after Skempton

ACTIVITY	CLASSIFICATION
Less than 0.75	Inactive
0.75 -1.25	Normal
Greater 1.25	Active

Atterberg limits and Swelling potentials

Comparing the results of the atterberg limits of Table 3 with the Unified system classification scheme (USCS), the Okada clay samples have very high plasticity. The liquid limit values of the samples indicate that they are clays of high compressibility which corresponds with the particle size analysis (Smith, 1978). Also using the Deo, 1972; Okogbue and Ene, 2005, Okeke and Okogbue,2010 and Nweke et al., 2015 suggests the clay soils with liquid limit and plastic limit between 21-45 and 15-28% respectively are either dominated by kaolinite or illite and the studied samples are way higher (Table 3) suggesting the smectite group dominates the studied clay..The Swelling limits reveals that the samples are fine because the greater the fines the greater the swelling especially if montmorillite is present. In addition, the swelling potentials (Andre-Obayanju., et al 2022). (Table 4) Using Holtz and Gibbs (1956) and Ola (1981), the clays exhibited high swelling potentials having LL as >150% and PI >88% which Akpokodje et al., 1991 said it is attributed to the absence of a quantifiable sand sized particle, presence of montmorillonite and/ or organic matters.

Table 5. Relationship between Liquid Limit, Plasticity Index and Swelling Potential

Liquid Limit (%) LL Holtz and Gibbs (1956)	Plasticity Index PI Ola (1981)	Swelling Potential	Sampled location
< 35	0-15	Low	
35-50	15-25	Medium	
50-70	25-35	High	
> 70	>35	Very high	Okada clay

Mineralogical Results

The diffractograms of the clay samples are as presented in Figures 5-7. The results of the mineralogical composition presented in Table 3 and chemical compostion in Table 6.

Table 6. Clay mineralogy and composition Result

SAMPLE /MINERAL	OKI	OK2	OK3	WYOMING	DASHKOVSKOE (Moscow)
MONMORILLONITE	31.4	1.0	35.1	35.85	57.3
KAOLINITE	8.3	2.9	20.3	5.01	-
QUARTZ	20.2	2.6	18.3	23.98	22.5
POLYGORSKITE	33.0	3.1	10.8	-	6.4
CALCITE	7.2	90.4	15.9	8.32	1.1

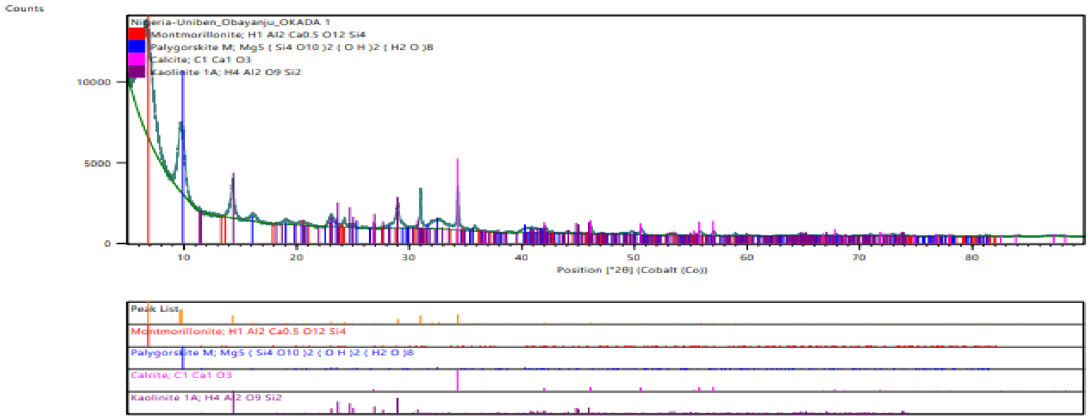

Figure 5. XRD for Okada1

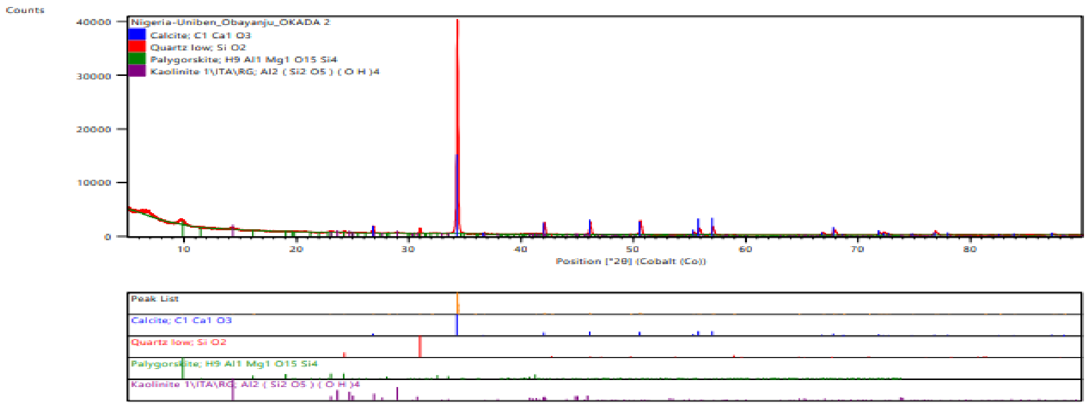

Figure 6. XRD for Okada2

From the XRD diffractograms (qualitative) and quantitative analysis and mineralogy in Table 6, Okada Samples is rich in Montmorillonite (Mt), kaolinite, Calcite (this was evidence of effervescences upon addition of acid) with Okada2 having as high as 90%, Palygorskite(Pal) (a hydrated magnesium aluminium silicate clay mineral with the theoretical formula of Si8Mg8O20(OH)2 (H2O)4·4H2O by Giustetto & Chiari, 2004). These clay soils in engineering are called expansive clay, the amount of water often varies upon the type of alkali ion present, thus a Na montmorillonite will absorb more water molecule that K and Ca montmorillonite. Nevertheless, the Ca, K, Na (in order of decrease) oxides in Okada sample attributes to the swelling potential of the sample. This can also be observed in the LOI (Table 6) which is relatively high , this might implies, they are fined grains and an indication of high water of crystallinity . The presence of palgorskite with montmorillonite (Fig 7) as suggested by Truath (1977) and Xie and Balsam (2013) where montmorillonite is the starting for its formation and a primary mechanism for palygorskite occurrence. This occurrence is as a result of intense dissolution of montmorillonite while adjusting its structure were the Mg between the sheets interacts with the montmorillonite causing a reorganization , these is evidence in Alumina content and Magnesium. This can only occur in tropics with dry-warm climates with high rainfall and evaporation (Neaman and Singer,2004). The presence of palygorskite also clogs the pore spaces forming duripans which makes it excellent colloidal properties, including high-temperature resistance, salt and alkali endurance and high adsorbing capabilities (Galan & Singer, 2011). Therefore, Pal is often used as a thixotropic agent and viscosity controller, and it may act as an inhibiting agent for circulation loss in oil-well drilling fluids (Darley & Gray, 1988). Presence Mt and Pal are suitable for use in oil-based drilling fluids, with the former providing excellent rheological properties and the latter providing good thermal stability (Zhuang et al., 2017a, 2017b, and 2017c).

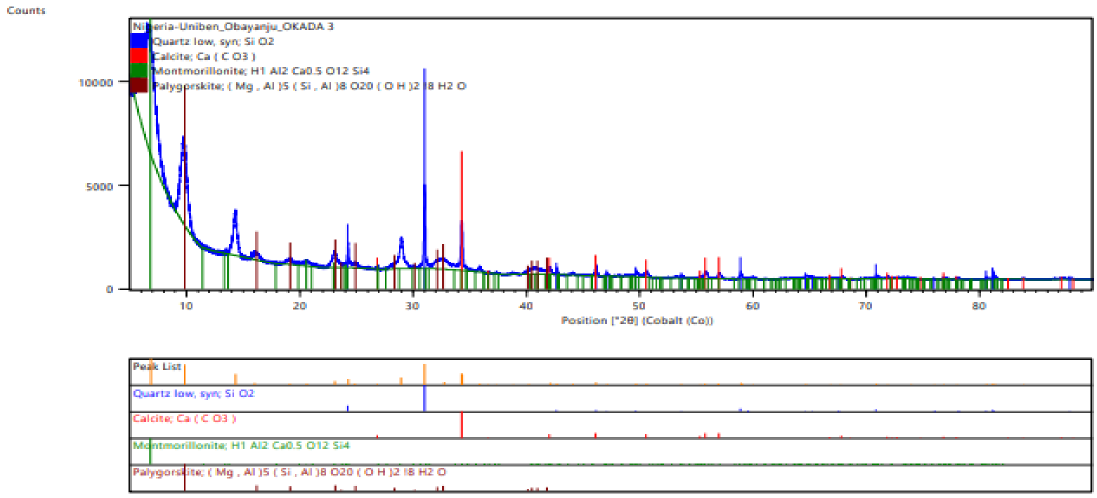

Figure 7. XRD for Okada3

Geochemical Results

The Summary of the mineral and chemical compositions of the studied sample is presented in Table 7, showing the silica to alumina value are < 50/ <59 comparing them with standard bentonite and Wyoming bentonite silica/alumina of 48.80/15.54 and 64/18 respectively. The Okada samples are almost the same as standard bentonite. According to Osadebe et al, 2011 said if values MgO,CaO, Na2O and MnO are higher than the standard or Wyoming are low indication little or no effect on shrinkage but the studied sample are higher.

Table 7. Chemical Composition with Two Specifications from Wyoming and Standard Bentonite

Elemental Oxides %	**OK 2**	**OK3**	**OK 1**	**Standard Bentonite**	**Wyoming**
SiO_2	50.36	49.52	48.75	48.80	64

Al_2O_3	18.64	16.46	16.85	15.54	18
MgO	0.31	5.36	5.53	3.50	3.2
Na_2O	<0.01	<0.01	<0.01	2.19	2.7
Fe_2O_3	0.08	5.40	4.91	6.44	2.8
K_2O	<0.01	0.88	0.91	0.75	0.05
CaO	0.01	5.50	5.76	5.22	1.77
TiO_2	0.02	0.68	0.68	0.49	1.68
MnO	0.01	0.07	0.05	0.07	0.15
LOI	38.65	15.41	15.85	15.73	13.2

Conclusion and Recommendation

The investigations carried out, revealed the presence of kaolinite, montmorillonite, palygorskite with variable quartz content with the SiO_2 and Al_2O_3 being the predominant oxides, the presence of montmorillonite was also evident in the geotechnical analysis inferring from the very high plasticity. These analyses indicated that the clay bodies of Okada area are suitable in the petroleum industry as drilling mud because of the montmorillonite clay with presence of calcite and especially because of the unique presence of palygorskite which would help to agglomerate i.e., increase the reduction in pore spaces by clogging the pore spaces forming seals/duripans and increase water absorption making them good lubricant and environmental friendly.

Acknowledement

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