Proceedings of the 8th Faculty of Science International Conference (FOSIC 2025), Delta State University, Abraka, Nigeria. 12th – 14th November, 2025. Pp. 170 - 178

EVALUATION OF THE EFFECTIVENESS OF LOCAL CLAY FOR USE AS WATER-BASED DRILLING MUD (A CASE STUDY OF AMAI IN UKWUANI L.G.A, DELTA STATE)

Chinedu O. Igili[a]; John E. Okonkwo[a]; Felix I. Chinyem[b] Ezekiel Enebrayekedou[a]; Roland E. Kolagbodi[a]

[a]Department of Energy and Petroleum Studies, Novena University, Ogume, Nigeria
[b]Department of Geology, Delta State University, Abraka, Nigeria
Corresponding author: chiigili@yahoo.com, ORCID: https://orcid.org/0000-0003-2313-2981

ABSTRACT

This study evaluates the suitability of local clays obtained from Amai communities in Ukwuani L.G.A., Delta State, for use as water-based drilling mud. Clay samples were collected from Amai-Nge and Umubu communities, processed, and formulated into drilling muds. Rheological and filtration properties—including density, apparent viscosity, plastic viscosity, yield point, pH, fluid loss, and filter cake thickness—were analyzed according to API standards. Results show that raw local clays exhibited low viscosities, weak gel strength, and acidic pH compared to commercial bentonite. However, beneficiation using barite ($BaSO_4$) and sodium carbonate (Na_2CO_3) significantly improved the performance of the clays. Beneficiated Umubu clay showed excellent rheological improvement, with apparent viscosity, yield point, and pH values exceeding those of imported bentonite. Filter cake thickness was within API limits. The results demonstrate that with proper beneficiation, Umubu clay can serve as a cost-effective substitute for imported bentonite in water-based drilling fluid systems.

Keywords: Plastic Viscosity (PV); Apparent Viscosity (AV); Yield Point; Fann viscometer

INTRODUCTION

Drilling muds are an essential component of rotary drilling operations, providing functions such as cooling and lubricating the drill bit, removal of cuttings from the borehole, wellbore stability, and control of formation pressures. The choice of drilling mud significantly influences drilling efficiency, cost, and safety. The most widely used mud additive for viscosity and filtration control is bentonite clay, a naturally occurring smectite-rich material. However, the high cost and import dependency of bentonite in Nigeria have created a need to explore local clay alternatives that are abundant, affordable, and environmentally sustainable.

Clay minerals are hydrous aluminosilicates with layered structures capable of swelling, ion exchange, and water absorption. Among the various clay types, montmorillonite (smectite) is the most desirable for drilling mud because of its high surface area and swelling characteristics. Bentonite, particularly Wyoming bentonite, is the industry standard. Aigbedion (2007), Olatunde et al. (2011), Igbalajobi (2013), Okon & Samuel (2014), and Amadi et al. (2020) have investigated local clays from various regions (Akwa Ibom, Edo, Delta, Anambra) for drilling mud applications. Findings consistently show that local clays often require beneficiation, usually by adding sodium carbonate (soda ash) to enhance swelling and barite to increase density. Prior studies indicate that raw local clays tend to have lower pH, lower plastic and apparent viscosity, reduced yield strength and poor filtration control. But after beneficiation, their performance improves significantly, often approaching API standards.

Delta State, particularly the Amai and Umubu areas of Ukwuani Local Government Area, is known for extensive clay deposits. These clays have historically been used for pottery, construction, and minor industrial applications. Their suitability for drilling mud formulation, however, has not been fully evaluated. This study therefore examines the physicochemical and rheological properties of raw Amai clay, determine the overall viability of Amai clay for drilling mud formulation, compares them with imported bentonite, and evaluates the impact of beneficiation using barite and soda ash. This study contributes to growing Nigerian research by focusing on clay from Amai and Umubu, areas with limited documented geological evaluation.

Geology of the Study Area

Niger Delta is located on the continental margin of Southern Nigeria and covers an area of 70km. It lies between longitude 5^0E and 8^0E and latitudes 30^0 and 60^0 Short and Stable (1997). Stable mega tectonic framework such as the Benin and Calabar flank mark the northewest and eastern boundaries. The Anambra basin and the Abakaliki high mark the northern boundary and it is bounded to the south by the west of guinea. The stratigraphic fill of the Niger Delta basin is composed primarily of three lithostratigraphic units that extend across the whole delta (Igili, and Ndubueze, 2024).These include basal marine pro-delta Akata Formation, the middle shallow-marine delta front Agbada Formation and, the overlying youngest continental, delta plain Benin Formation (Doust and Omatsola 1990; Adojoh et al. 2020). The Akata Formation, a prodeltaic lithofacies of Paleocene to Recent in age is composed primarily of marine shales with turbidite sands and continental slope channel fills It is estimated to be up to 7 km thick and generally considered as the source rock of the Niger Delta. The middle paralic Agbada Formation, estimated to be over 3.7km thick and ranges in age from Eocene to Recent (Tuttle et.al., 1999) is primarily composed of delta-front lithofacies and characterized by intercalations of sand and shale. The sandstone reservoirs facies within this formation are mostly shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in the lower part (Doust and Omatsola 1990). This unit serves as the hydrocarbon reservoir within the basin with sand percentage ranging from 30 to 70% (Doust and Omatsola 1990; Igili, and Ndubueze (2024). The deltaic sequence is capped by the topmost Benin Formation that is Oligocene to Recent in age, about 2km thick and is made up of continental fluvial sands (Avbovbo 1978; Doust and Omatsola 1990; Owolabi et al. 2019). Adegoke et al. (2017) described the formation as friable, white, fine to coarse and pebbly, poorly sorted sands, with lignites occurring as thin streaks or as finely dispersed fragments.

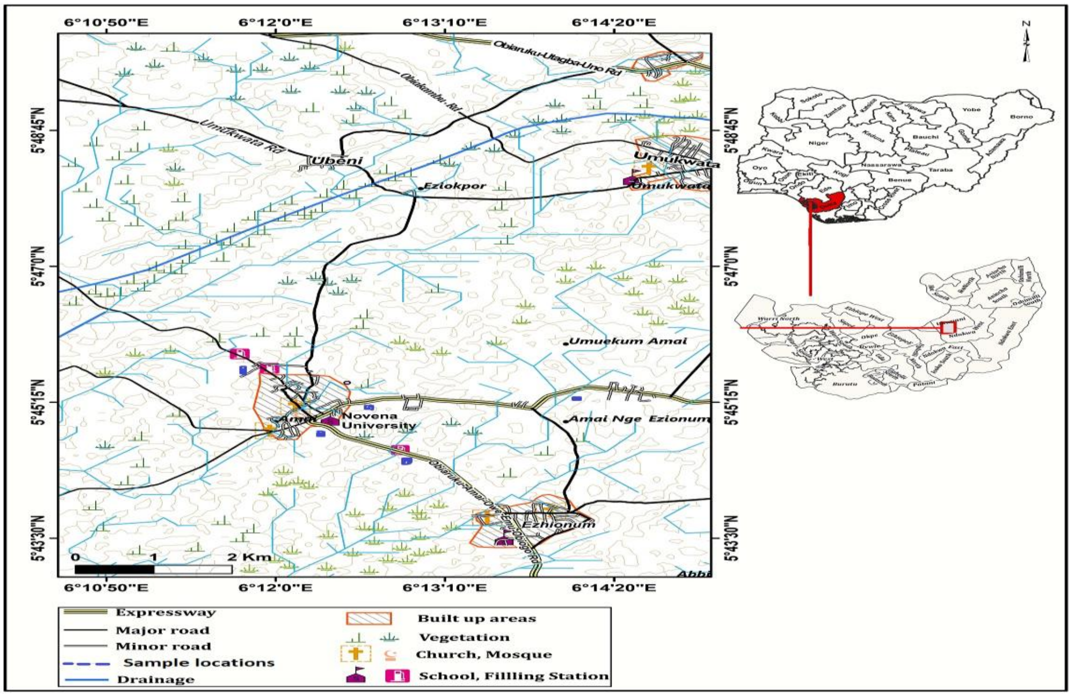

Fig. 1 showing map of the study area and sampling points

METHODOLOGY

Sample Collection

Clay samples were collected from Amai-Nge and Umubu communities using a GPS-guided sampling procedure. Samples were wrapped in aluminum foil, sealed, and transported to the laboratory.

Sample Processing

Samples were air-dried for seven days, mixed with water to form slurry, and sieved to remove coarse debris. The filtrates were allowed to settle for 3–5 days, decanted, sun-dried for four days, crushed, and sieved through 125-micron mesh to obtain fine clay powder.

Mud Formulation

24.5g of clay and 350mL (per API RP 13B) of fresh water were mixed using a high-speed mixer to form homogeneous muds. Additional beneficiation reagents included barite ($BaSO_4$) and soda ash (Na_2CO_3). Laboratory tests conducted are;

i. Density: Mud balance
ii. pH: pH meter
iii. Plastic Viscosity (PV): Fann viscometer
iv. Apparent Viscosity (AV): θ600/2
v. Yield Point (YP): YP = θ600 – θ300
vi. Cake Thickness: Filter press (for Sample B beneficiated)

Density Measurement

Density was measured using a mud balance following API procedures.

Rheological Measurements

Apparent viscosity (AV) and plastic viscosity (PV) were measured using a rotational viscometer at 600 and 300 rpm.

Apparent Viscosity (AV) = $\frac{\text{Reading at 600rpm}}{2}$

It has the SI derived unit Pa·s (Pascal-second), but the centipoise is frequently used in practice: (1 mPa·s = 1 cP).

Filtration and Fluid Loss Test

A filter press operated at 100 psi for 30 minutes was used to determine fluid loss and filter cake thickness.

pH Measurement

Colorimetric pH paper was used to measure the aqueous mud pH.

Plastic Viscosity (PV): Plastic Viscosity (PV) is a resistance of fluid to flow. According to the Bingham plastic model, the PV is the slope of shear stress and shear rate. Typically, the viscometer is utilized to measure shear rates at 600, 300, 200, 100, 6, and 3 revolutions per minute (rpm). In the field, the plastic viscosity can be calculated by a simple calculation shown below. Plastic Viscosity (PV) = Reading at 600 rpm – Reading at 300 rpm. The unit of PV is Centi Poise (CP).

Rate of Penetration (ROP): The ROP will be directly affected by the plastic viscosity. Thicker mud will have bigger hold down effect than thinner mud. Therefore, it causes in reduction in ROP (Dhiman, 2012).

RESULTS AND DISCUSSION

This work aimed at evaluating the effectiveness of local clay within Amai Delta State, Nigeria to substitute for imported bentonite in water based drilling mud and also look for additives that will improve the rheological properties of clay. Table 1 below presents the results of the mud prepared with local clay as well as the bentonite control.

Table 1 Raw Local Clay vs Bentonite

Property	Bentonite	Sample A	Sample B
Density	9.0	7.5	8.10
pH	10.00	5.77	6.14
PV	8.00	1.00	2.00
AV	13.00	4.50	5.00
YP	11.00	7.00	6.00

Raw clay performance vs bentonite

Results from local clay table 1, fig 2 and 3 were found to be out of the API standard compared to foreign bentonite mud. Though the density of the local clay match the API specification as they were almost the same especially that of Umubu. Both Amai and Umubu clays show much lower PV, AV, and pH than bentonite. This indicates poor swelling capacity and weak viscosity, confirming they are mainly calcium-based clays, typical of Nigerian clay deposits. The significant difference in their rheological properties such as density, pH, plastic viscosity, apparent viscosity and yield strength of the local clay necessitated the benefaction of the local clay, i.e. addition of chemicals to low quality clay to improve its performance. The local clay was beneficiated with barite ($BaSO4$) and soda ash ($Na2SO4$) to improve the mud density, viscosity and pH with their results shown in table 2, fig 4 below.

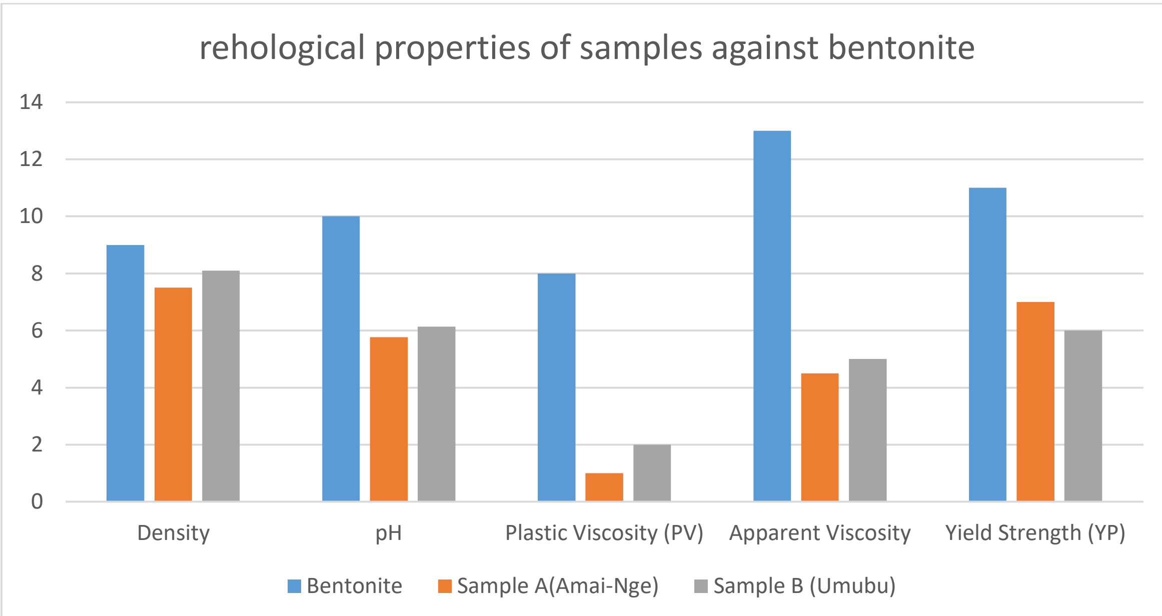

Fig 2. Showing the rheological differences between raw clay and bentonite

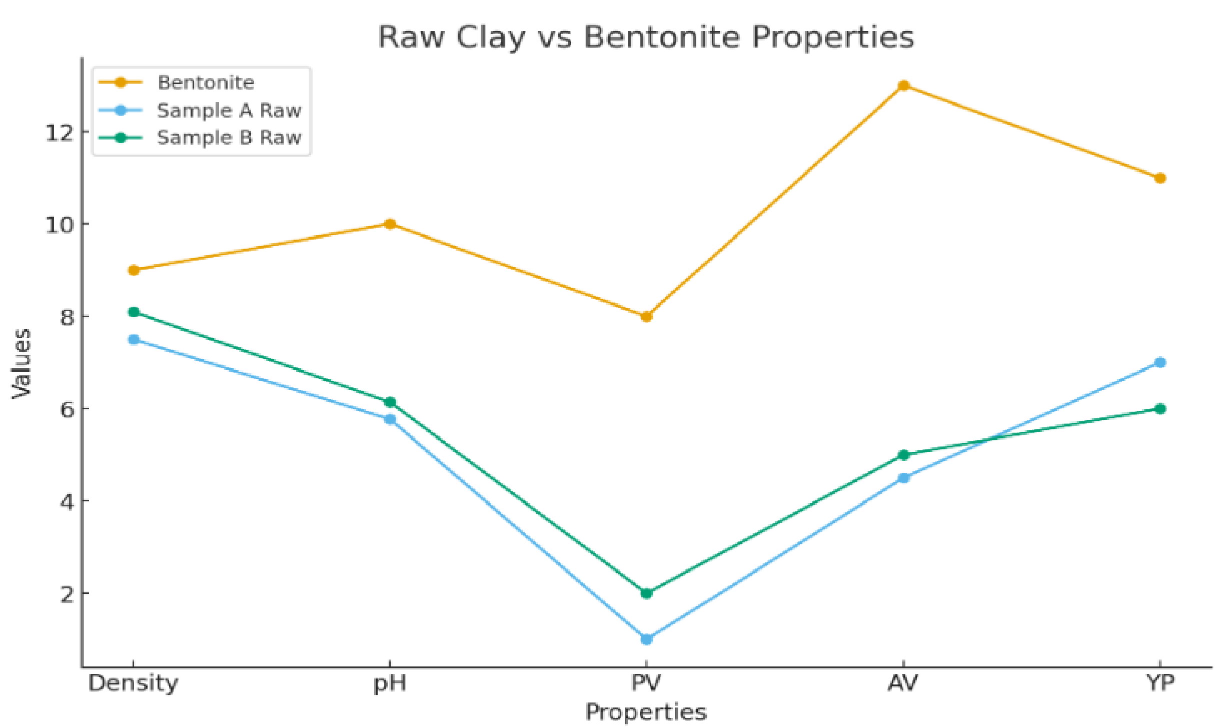

Fig 3. Showing the rheological differences between raw clay and bentonite

Table 2 Beneficiated Sample A

Property	Bentonite	Sample A Raw	Sample A Beneficiated
Density	9.0	7.5	7.9
pH	10.00	5.77	10.47
PV	8.00	1.00	2.0
AV	13.00	4.50	5.5
YP	11.00	7.00	7.0

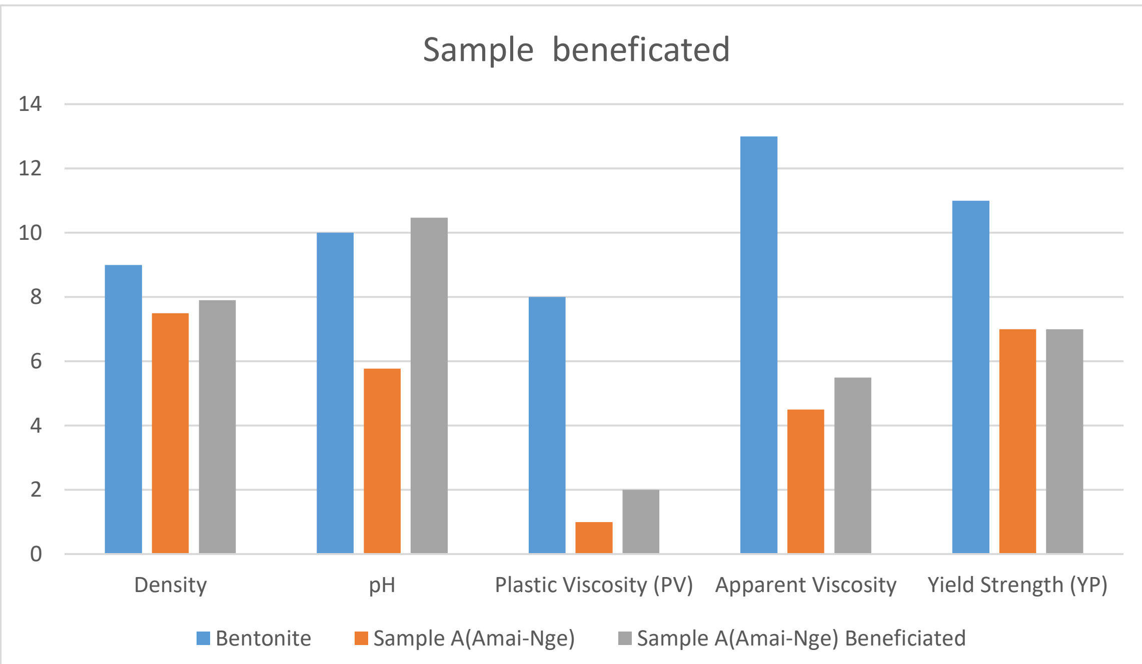

Fig 4. Showing the rheological differences between raw clay (Sample A), bentonite and beneficiation with barite ($BaSO_4$) and soda ash (Na_2SO_4).

Beneficiated Sample A

pH increased from 5.77 → 10.47, indicating successful sodium activation. AV improved from 4.5 → 5.5. YP remained moderate (7.0), suggesting limited structural improvement. Density improved to 7.9 but still below bentonite Fig 4.

Table 3 Beneficiated Sample B

Property	Bentonite	Sample B Raw	Sample B Beneficiated
Density	9.0	8.10	8.30
pH	10.00	6.14	10.05
PV	8.00	2.00	5.0
AV	13.00	5.00	15.00
YP	11.00	6.00	20.00
Cake Thickness	—	—	1.05 mm

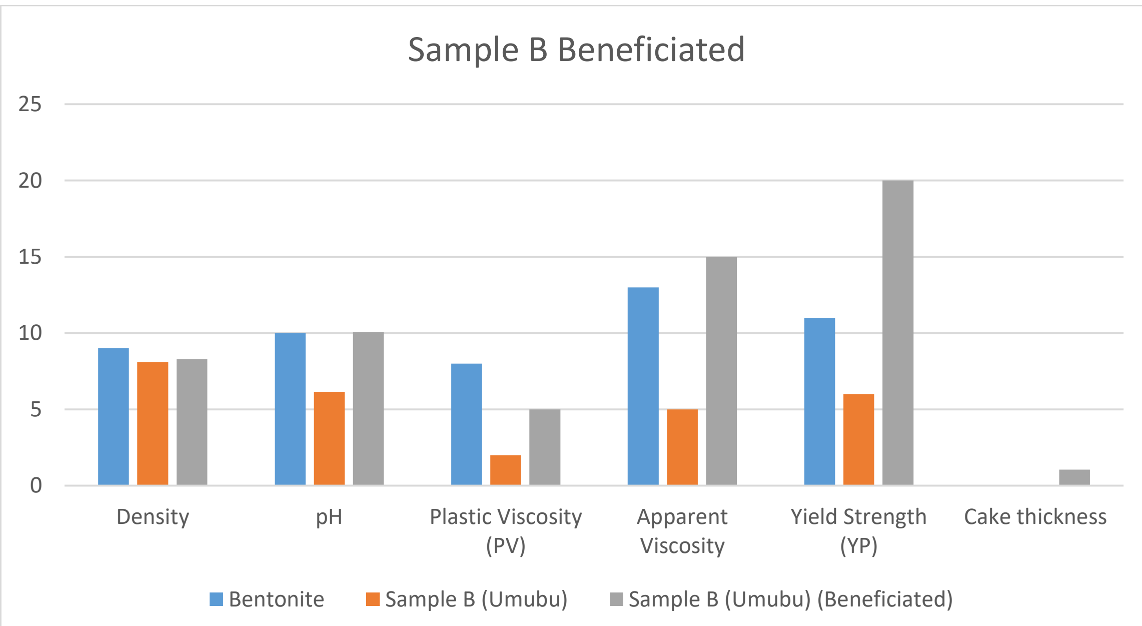

Fig 5. Showing the rheological differences between raw clay (Sample A), bentonite and beneficiation with barite ($BaSO_4$) and soda ash (Na_2SO_4).

Beneficiated Sample B

PV increased significantly (2.0 → 5.0), AV showed a major jump (5.0 → 15.00), indicating excellent viscosity response, YP increased sharply (6.0 → 20.0), showing strong gel strength, pH improved to 10.05. Cake thickness of 1.05 mm indicates acceptable filtration property fig. 5.

Sample B (Umubu) performed significantly better and approached or exceeded bentonite performance after beneficiation, while Sample A showed improvement but remains inferior to bentonite.

CONCLUSION

Local clays from Ukwuani LGA especially Sample B from Umubu have strong potential as substitutes for imported bentonite after beneficiation. This study evaluated Amai and Umubu clays for use in water-based drilling mud systems. Raw clay results showed insufficient rheological performance compared to bentonite. Beneficiation with soda ash and barite significantly improved properties. Sample B showed the most promising rheological characteristics, achieving viscosities and yield points suitable for drilling operations. The results demonstrate that rheological and pH characteristics can be adjusted to meet drilling mud requirements, reducing import dependency and lowering drilling costs in Nigeria.

Declaration of Conflict of Interest: Authors have declared that no competing interests exist. Data *Availability Statement:* Data are available upon request from the first author

REFERENCES

Adegoke, O. S. (2002). High Resolution Biostratigraphy, Sequence Stratigraphy and 3-D Modelling: Indispensable Tools for E & P Activities in the New Millenium. Nigerian Association of Petroleum Explorationists Bulletin 16(1), 46-65.

Adegoke, O. S., Oyebamiji, A. S., Edet, J. J., Osterloff, P. L., & Ulu, O. K. (2017). Cenozoic foraminifera and calcareous nannofossil biostratigraphy of the Niger Delta. *Elsevier, Amsterdam*, 18(3), 25-66

Aigbedion, I. (2007). Geology of clays in Nigeria. *Nigerian Journal of Applied Science*, 15(2), 45–58.

Amadi, A. N., (2020). Evaluation of local clay for drilling mud applications. *Nigerian Journal of Engineering Research*, 18(1), 33–41.

American Petroleum Institute (API), (1993), "Recommended Practice for Field Testing Water Based Drilling Fluid," 13A, pp 7- 28.

Annudeep, S.D. (2012). "Rheological properties & corrosion characteristics of drilling mud additives", Dalhousie University Halifax, Nova Scotia.

Apogu-Nwosu, T.U, Mohammed-Dabo, I.A., Ahmed, A.S., Abubakar, G., Alkali, A.S. and Ayilara, S.I. (2011) Studies on the suitability of Ubakalabentonitic clay for oil well drilling mud formulation. *Br J Appl Sci Technol* 1:152–171

Doust, H. & Omatsola, E. (1990). Niger Delta. In: Edwards, J. D. and Santogrossi, P. A. (Eds.), Divergent /Passive Margin Basins. AAPG Memoir 48, 201-238.

Igbalajobi, A. O. (2013). Characterization of Nigerian clays for drilling mud. *Journal of Mining and Geology*, 49(1), 71–79.

Igili, C.O. and Ndubueze, O.V. (2024). Diagenetic Quality, Extent of Altration and Preservation of Organic Matter of Wells A and B in Niger Delta Basin, Nigeria. *J. Appl. Sci. Environ. Manage.* 28 (11) 3513-3518

Okon, A. N. and Samuel, O. D. (2014). Influence of beneficiation on drilling mud properties. *Journal of Energy Studies*, 5(1), 20–29. API. (2010). *Recommended Practice 13B-1: Field Testing Water-Based Drilling Fluids*. American Petroleum Institute.

Olatunde, A. O (2011). Performance of local clay in drilling mud formulation. *SPE Nigeria Annual Conference*.

Osokpor, J, Ekwere U.J, Otele, A (2019): Paleoclimatic cycles, sea level history and sequence stratigraphic elements in Eocene– Oligocene sediments of BIMOL-1 Well Northern Niger Delta Basin, Nigeria. Journal of Applied

Science and Environmental. Management 23(2): 241-248.

Reijers, T.J.A (2011): Stratigraphy and sedimentology of the Niger Delta. Geologos. 17(3): 133-162.

Reijers, T.J.A, (1996): Selected chapters in geology: sedimentary geology and sequence stratigraphy in Nigeria and three case studies and field guide, Shell Petroleum Development Company, Nigeria: 197.

Saugy, L and Eyer J.A (2003): Fifty years of exploration in the Niger Delta (West Africa). In: Halbouty, MT (Ed) Giant Oil and Gas Fields of the Decade 1990–1999. AAPG Bulletin, 78: 211-226.

Short K. C. and Stauble A. J. (1967): Outline of Geology of Nigeria. American Association of Petroleum Geology v. 51, 761-791 Traverse, A (1988): Palaeopalynology. Unwin Hyman, London. 1-600.

Tuttle, M. L. W., Charpentier R. R. and Brownfield M. E. (1999): The Niger delta Petroleum system: Niger Delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa: United States Geologic Survey. United States Geologic Survey.