



Studies on the Suitability of Ubakala Bentonitic Clay for Oil Well Drilling Mud Formulation

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Research Article

Received 1st June 2011
Accepted 25th June 2011
Online Ready 25th September 2011

ABSTRACT

The suitability of a Nigerian bentonitic (Ubakala) clay material to be used as drilling mud for oil well drilling was investigated, with Wyoming bentonite being used as a standard. Particle size distribution, Cation Exchange Capacity of the sample were determined and compared. X-ray diffraction and X-ray fluorescence of the samples were also determined. Rheological properties of the samples were determined using a rheometer (OFITE model 900 viscometer). Properties of the local clay improved appreciably when beneficiated with Carboxyl Methyl Cellulose (CMC), Poly Anionic Cellulose-Regular (PAC-R) and Sodium Carbonate (Na_2CO_3). The best result which came close to the properties of Wyoming clay was Ubakala mud at 24.5g/350ml of water beneficiated with 2g CMC and 1.5g Sodium Carbonate (Na_2CO_3). The Plastic Viscosity improved by about 1207%. This study indicates that Ubakala clay has a good potential for drilling purposes when beneficiated appropriately.

Keywords: Bentonite; rheometer; carboxyl methyl cellulose; poly anionic cellulose; sodium carbonate; rheological properties;

1. INTRODUCTION

Drilling mud may be defined as a suspension of solids in a liquid phase. Drilling mud consists of solid liquid fractions and chemical additives. Drilling for oil or gas is facilitated by

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the drilling mud which is designed to perform a number of functions during drilling operation. It cools and lubricates the drill bit, provides hydrostatic pressure to stabilize the wellbore and transports the drill cuttings to the surface (Bourgouyne et al., 1991).

Raw materials used for the mud making are usually selected clays and are judged by their behavior in water (Nestle, 1944). Their suitability is determined by various criteria, among which are the volumetric yield of given clay, soluble impurities, abrasives content, and filtration characteristics. The raw material which meets most of these requirements for drilling is the bentonite clay. Bentonite is formed by the weathering of volcanic ash. The weathering process, by which the clay minerals are formed from the parent minerals are complex but the main factors are climate, topography, vegetation, and time of exposure (Jackson, 1957). Bentonite was named after Fort Benton (Wyoming, USA), the locality where it was first found. In addition to montmorillonite, bentonite may also contain feldspar, biotite, kaolinite, illite, cristobalite, pyroxene, zircon, and crystalline quartz (Parkes, 1982). By extension, the term bentonite is applied commercially to any plastic, colloidal, and swelling clay regardless of its geological origin. Such clays are ordinarily composed largely of minerals of the montmorillonite group.

Research performed in the early 90's by the Bureau of Mines of the U.S.A, showed that the sum of bentonite deposits in the world was about 1.36 billion tons, and the U.S.A. has more than 50.0% of the total (Amorim et al., 2004). Clays of various kinds and grades abound throughout Nigeria's sedimentary basins and on the basement (Falode et al., 2007). Recent investigations by the Nigerian Mining Corporation established the existence of bentonitic clay reserves of over 700 million tonnes in the country, with the largest single deposit at Afuze in Edo State holding 70–80 million tonnes (R.M.R.D.C., 2005). In Abia state alone, 5.8 million tonnes of bentonite has been proven while 7.5 million tonnes are inferred.

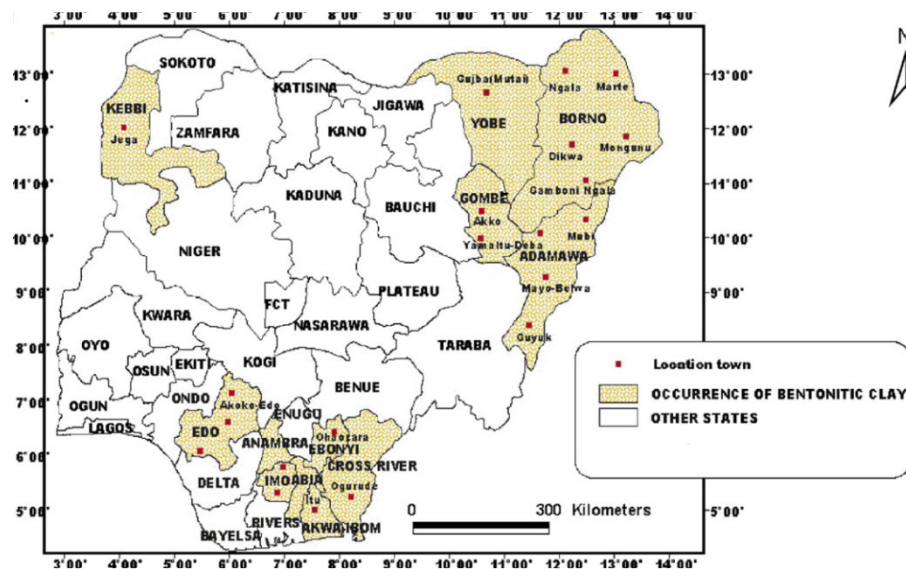


Fig. 1. Map of Nigeria Showing States with Occurrence of Bentonitic Clay
(Modified from Raw Materials Research Development Company Bulletin (R.M.R.D.C.), 2005).

1.1 Location and Geological Setting of Study Area

The study area chosen for this work was Ubakala town. The town is located in Umuahia South Local Government Area of Abia State, south-eastern Nigeria and lies on longitude 7°24'E and latitude 5°10'N on the geological map of Nigeria (Encarta, 2009).

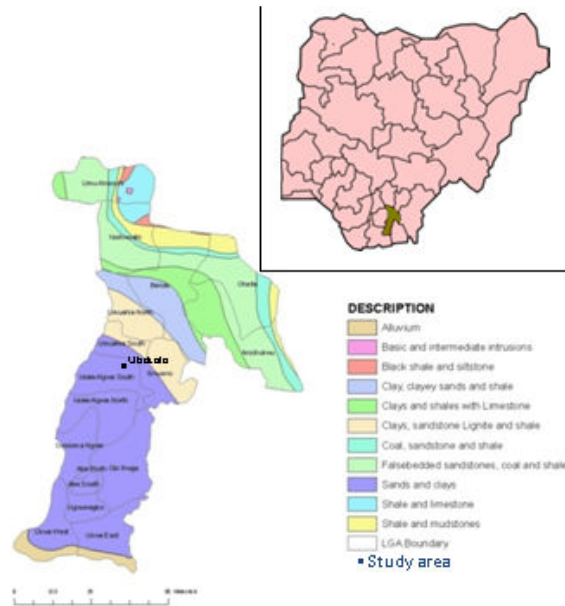


Fig. 2. Map of Abia Showing Study Area with Map of Nigeria Insert
(Modified from Nigerian Geological Survey Agency)

Presently, there is no significant exploitation of Nigerian bentonitic clay for the purpose of drilling mud formulation, despite its proven large deposits at different locations of the country (Falode et al., 2007; Omole et al., 1989; Onah, 1994; R.M.R.D.C., 2005). Most of the bentonite used for drilling activities in Nigeria is imported into the country thereby increasing demand for scarce foreign exchange and import dependency on the economy.

The need to search for local alternatives to bentonite and other additives, which are used in the drilling of oil and gas, is imperative and timely. Apart from the significant infrastructural development in the area of mining (Falode et al., 2007), the industry could be developed to the extent of exporting locally produced bentonite out of the country hence increase the country's revenue.

This research work focuses mainly on studying the rheological performance of clays obtained from Ubakala region of Abia State and comparing them with Wyoming clay.

1.2 Properties Required for Drilling Mud

Among the many factors to consider when choosing a drilling fluid are the well's designs, anticipated formation pressures and rock mechanics, formation chemistry, the need to limit damage to the producing formation, temperature, environmental regulations, logistics, and

economics (Falode et al., 2007). To meet these design factors, drilling fluids offer a complex array of interrelated properties. Five basic properties are usually defined by the well program and monitored during drilling: viscosity, density, filter cake or filtration of water loss and wall cake thickness, solids content and quality of water make up. For any type of drilling mud, all of these five properties may, to some extent, be manipulated using additives. However, the resulting chemical properties of a fluid depend largely on the type of mud chosen. And this choice rests on the type of well.

1.2.1 Rheology

A high viscosity fluid is desirable to carry cuttings to surface and suspend weighing agents in the mud. However, if viscosity is too high, friction may impede the circulation of the mud causing excessive pump pressure, decrease the drill rate, and hamper the solids removal equipment. The flow regime of the mud in the annulus is also affected by viscosity. Measurements made on the rig include funnel viscosity using a Marsh funnel-an orifice viscometer-and plastic viscosity, yield point and gel strength using a Fann 35 viscometer or equivalent.

Plastic viscosity is a measure of the internal resistance to fluid flow attributable to the amount, type and size of solids present in a given fluid (Garvey et al., 1988). The value expressed in centipoises, is proportional to the slope of the consistency curve determined by the region of laminar flow for materials obeying Bingham's Law of plastic flow. When using the direct indicating viscometer, the plastic viscosity is found by subtracting the 300rpm reading from the 600rpm reading.

The yield point is the resistance to initial flow and represents the stress required to start fluid movement (Garvey et al., 1988). This resistance is believed to be due to electrical charges located on or near the surfaces of the particles. It is used to evaluate the ability of a mud to lift cuttings out of the annulus (Lyons, 1996).

The gel strength is the ability or measure of the ability of a colloid to form gel as a function of time (Garvey et al., 1988). It is believed to be a measure of the same inter-particle forces of a fluid as determined by the yield point except that gel strength is measured under static conditions. The 10 seconds gel strength measurements are initial measurements. The 10 minutes gel strength measurements are later measurements.

1.2.2 Density

Sufficient hydrostatic pressure is required to prevent the borehole wall from caving in and to keep formation fluid from entering the well bore. The higher the density of the mud compared to the density of the cuttings, the easier it is to clean the hole- the cuttings will be less inclined to fall through the mud. If the mud weight is too high, rate of drilling decreases, the chances of differential sticking accidentally fracturing the well increase, and the mud cost will be higher. The most common weighing agent employed is barite. Density is measured in the field using a mud balance.

1.2.3 Fluid loss

The main aim is to create a low permeability filter cake to seal between the wellbore and the formation. Control of fluid loss restricts the invasion of the formation by filtrate and minimizes

the thickness of filter cake that builds up on the borehole wall, reducing formation damage and the chances of differential sticking. Static fluid loss is measured on the rig using a standard cell that forces mud through a screen, and also using a high-temperature, high-pressure test cell.

1.2.4 Solids content

Solids are usually classified as high gravity (HGS)-barite and other weighing agents-or low gravity (LGS)-clays, polymers and bridging materials deliberately put in the mud, plus drilled solids from dispersed cuttings and ground rock. The amount and type of solids in the mud affect a number of mud properties. High solids content, particularly LGS, will increase plastic viscosity and gel strength. High-solids muds have much thicker filter cakes and slower drilling rates. Large particles of sand in the mud cause abrasion on pump parts, tubular, measurement-while-drilling equipment and downhole. Measurement of total solids is traditionally carried out using a retort-which distills off the liquid allowing it to be measured, leaving the residual solids.

1.2.5 Chemical properties

The chemical properties of drilling mud are central to the performance and hole stability. Properties that must be anticipated include the dispersion of formation clays or dissolution of salt formations; the performance of other mud products- for example, polymers is affected by pH and calcium; and corrosion in the well.

Sodium montmorillonite particles are laminar in shape carrying surface electrical charge not homogeneously distributed. The faces bear a permanent negative charge while the edges are conditionally charged depending on the pH of medium (Kelessidis et al., 2005). It is the imbalance in the electrical charge that characterizes the type of interactions of clay particles with other materials.

1.3 Geology of the Study Area

Geologically, Umuahia South, where Ubakala is located, is within the Benin formation which comprises of shale/sand sediments with intercalation of thin clay beds (Asseez, 1976 and Murat, 1972).It is a part of the coastal plain sands of the Cenozoic Niger-Delta region of Nigeria.

The Cenozoic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of the continents of South America and Africa in the late Jurassic. Subsidence of the African continental margin and cooling of the newly created oceanic lithosphere followed this separation in early Cretaceous times. Marine sedimentation took place in the Benue Trough and the Anambra Basin from mid-Cretaceous onwards. The Niger-Delta started to evolve in early Tertiary times when Clastic River input increased. Generally the delta prograded over the subsidizing continental-oceanic lithospheric transition zone and during the Oligocene spread onto oceanic crust of the gulf of Guinea. The weathering flanks of out-cropping continental basement sourced the sediments through the Benue-Niger drainage basin. The delta has since Paleocene times prograded a distance of more than 250km from the Benin and Calabar flanks to the present delta front. Thickness of sediments in the Niger-Delta averages 12km covering a total area of about 140,000km (Obaje, 2009).

2. MATERIALS AND METHODS

2.1 Sampling and Collection

Field sampling exercise of the local clay sample was done during the dry season (in the month of January, to be precise). Fresh samples were collected from pits dug to depths of 1.5m at a choice deposit of the clay sample. The local clay sample was gotten from Ubakala region, Umuahia South Local Government Area of Abia State. The Wyoming bentonite clay sample was obtained from Schlumberger Company Ltd., Port-Harcourt, Nigeria.

2.1.1 Particle size distribution

50g of each soil sample was weighed and put into separate beakers. 10ml of Calgon plus 400ml of water were added and left to stand for 24 hours. The solution was emptied into a measuring cylinder (1000ml capacity), where the particles were washed thoroughly from the beaker. The cylinder was filled up to the 950ml mark; each clay sample was placed in a separate measuring cylinder. The temperature of the solution was taken using a thermometer. The top of the measuring cylinder was covered and shaken for one minute, immediately after shaking the hydrometer was inserted into the suspension for 40 seconds and the first readings were obtained for each of the samples in a bouyoucos cylinder. The sample was left for 2 hours and another reading taken.

2.1.2 Preparation of clay sample

The clay sample was soaked in water for 72hours (Baba, 1999, Unpublished results). It was stirred every 24 hours to release organic materials. After 72 hours, the clay was sieved using a 200 mesh Tyler sieve and allowed to settle down. Water was then decanted from it. The concentrated clay was then transferred to a jeans bag for dewatering.

After a while, the clay sample was spread on a pan and sun-dried for a period of 5 days. The dried clay was grinded to a fine size (about 75 μ m) with mortar and pestle while continuously sieving with a 75 μ m Tyler sieve until a homogeneous sample was gotten.

2.1.3 Methylene blue cation exchange capacity test

1.5g of each of the clay sample was placed in wide-necked plastic screw-topped bottles (Inglethorpe et al., 1993). 20ml distilled water were added to the sample and left to agitate for 2 hours in a reciprocal shaker. They were left overnight to hydrate. The clay sample was transferred to 100ml flask and 1ml of 5M sulphuric acid was added to each of the samples to increase the acidity. 0.01M methylene blue chloride was prepared using distilled water. 2ml of the 0.01M methylene blue chloride was added intermittently to each of the clay samples until end point was reached. After 2ml addition, a drop of suspension was placed on a filter paper using a glass stirring rod ("spotting"). End-point was considered to have reached when spotting produced a dark blue spot of clay absorbed dye surrounded by a pale blue halo of excess dye.

2.2 Mineralogical Characterization

2.2.1 X-Ray diffraction

The clay minerals were mineralogically characterized to identify their mineralogical compositions and hence their characteristics. This was done using a diffractometer (MD-100.000 UM, version 2.00) the X-ray CuK α radiation (1.54 $^{\circ}$ A) and a Nickel filter. Scans of oriented clay aggregates were run at 40kV and 35mA over a range of 10.5 to 76.2 $^{\circ}$ at a rate of 1 $^{\circ}$ 2 θ /min and a step size of 0.01 $^{\circ}$ 2 θ . Identification of the clay minerals was achieved through the X-ray diffraction pattern using ASTM cards, indexed to X-ray powder data files (Apugo-Nwosu, 2011). The diffractograms of the clay samples are as presented in Figure 3.

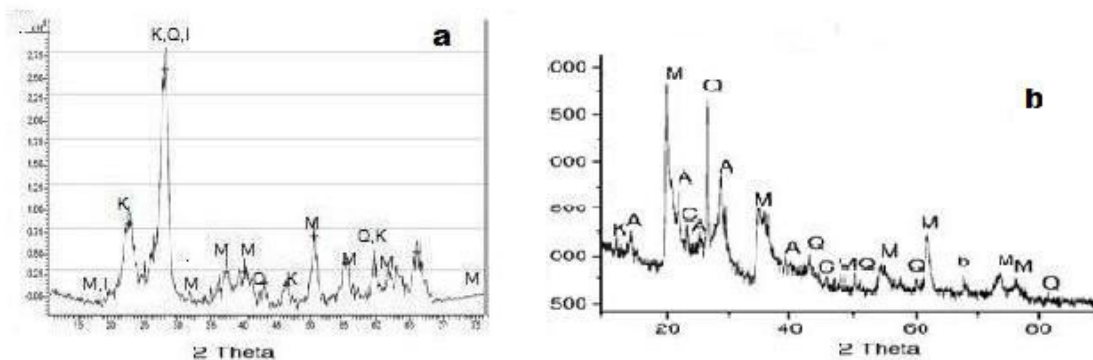


Fig. 3. X-ray Diffractogram of the investigated Clays:
(a) Ubakala Clay (b) Wyoming Clay (Falode et al., 2007)

K= Kaolinite; Q=Quartz; I= Illite; M= Montmorillonite, b = Biotite; C = calcite; A = Feldspar (Albite)

2.2.2 X-Ray fluorescence

The crystalline component of each material was determined using Energy Dispersive X-Ray Fluorescence Spectrometer (ED-XRF), MiniPAL4 model. 20g of the sample was finely ground to pass through a 200-250 mesh size. The clay sample was dried in an oven at 105 $^{\circ}$ C for at least an hour and cooled. Thereafter, the sample was intimately mixed with a binder in the ratio of 5.0g sample(s) to 1.0g cellulomase flakes binder and pelletized at a pressure of 10-15 tons/in 2 in a pelletizing machine. At this stage, the pelletized sample(s) were stored in a desiccator.

The ED-XRF machine was switched on and allowed to warm up for 2 hours. Finally appropriate programs for the various elements of interest were employed to analyze the sample material for their presence or absence. The result was reported in percentage (%) for minor and major concentrations of elements.

2.3 Mud Preparation

In this study, the Hamilton beach multi-mixer (Model 9B with 9B29X impeller) was used extensively to prepare the mud samples.

The mud samples were prepared by weighing out 24.5 grams of the clay samples using a triple beam balance (Ohaus Model 1650-00). These measurements of each of the clay samples were poured into separate mixer cups containing 350ml of fresh water each. The clay samples and water were vigorously agitated with the multi-mixer to produce a homogeneous mixture. The mud samples were aged for 24 hours to allow for adequate hydration after which the density, the rheological properties, the pH and the sand level were tested. At this stage, the rheological properties and density were found to be low, hence the need to treat the mud to meet the required API standards.

To improve the viscosity of the mud samples, CMC and PAC-R were added to the mud samples formulated in increasing proportions of 0.2g, 0.5g, 0.8g, 1.0g, 1.5g and 2.0g. The mixture of clay, water and viscosifiers were vigorously mixed and the homogeneous mixture with increased viscosity was allowed to age for 24 hours.

2.4 Mud Characterization

Characterization of mud involves testing for the following parameters:

1. Mud Density
2. Rheological properties
3. Sand content
4. pH

2.4.1 Mud density determination

To determine the mud density, a mud balance was used. The lid of the mud balance was removed and the cup filled to the brim with the formulated mud sample. The cup was tapped briskly to let out trapped air bubbles. The lid was then replaced and turned to ensure that it was firmly put in place. Excess mud spillage through the vent was wiped off from the lid. The balance was then placed on the base with knife edges and the rider moved along the graduated arm until a balance was obtained. The mud density (lb/gal) was read off and recorded (Okorie, 2006).

2.4.2 Rheological properties determination

To determine the rheological properties of the formulated mud a rheometer (OFITE Model 900 viscometer) was used. The equipment was put on and allowed to stabilize. The thermal cup was filled to 2/3 full of the mud sample. The thermal cup was placed on the viscometer stand and adjusted with the stand until the rotor sleeve was immersed in the formulated mud at the scribe-line. The viscometer stand was held in position by tightening the lock screw on the left leg of the instrument. The button 'mud test' was pressed on the equipment and the dial readings at 600rpm, 300rpm, 200rpm, 100rpm, 60rpm and 3rpm were taken. The Plastic Viscosity (PV), Average viscosity (AV), Gel Strengths and Yield Point (YP) were automatically calculated and read off.

2.4.3 Sand content determination

Sand content kit was used to determine the sand value of the mud. It consists of a 200 micron U.S. mesh sieve size, a funnel and a glass tube graduated from 0-20 percent (Okorie, 2006). The principles of sand sieve analysis were applied for the determination of sand content. Here, the Baroid sand content tube is filled to the mark, 'mud to here' with the

formulated mud samples. Water was then added to the mark 'water to here'. The mixture of mud and water was poured out through the screen; the held back sand was carefully washed to ensure that the mud was washed out in a gently running tap. The sand left on the screen was then washed back onto the tube through a funnel that was fitted over and inverted slowly into the mouth of the tube. Care was taken to ensure that all screened sand was washed back into the tube and allowed to settle. The quantity of sand that settled in the calibration tube was then read and recorded as the sand content of the mud in percentage by volume of mud.

2.4.4 pH determination

To determine the pH of the mud, the phydriion dispenser (pH paper) was used. It provides a series of indicator strips that determines the pH from 1.0 to 14.0 through colour change or intensity over a range. About one-inch strip of the indicator paper was reeled out and placed on the mud. Sufficient time (a few seconds to a minute) was allowed for the paper to soak up filtrate and change colour. The pH of the mud sample was read by matching the change in colour with ones provided in the phydriion dispenser chart (Okorie, 2006). The value was recorded.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of the Mud Samples

The result for the Particle Size Distribution is as shown in Figure 4. This result shows that Ubakala clay is predominantly clay, hence can be consider as a pure clay sample.

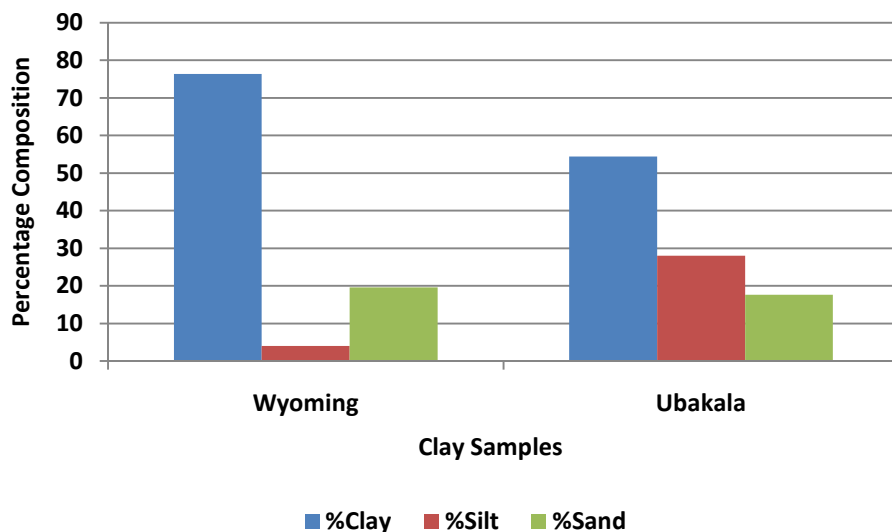


Fig. 4. Particle size distribution of the clay samples

The results of the Cation Exchange Capacity of the clay samples are as given in Figure 5. The explanation of the results from literature indicates that Ubakala clay is bentonitic and is calcium dominant, while Wyoming clay is sodium dominant (Taylor, 1985).

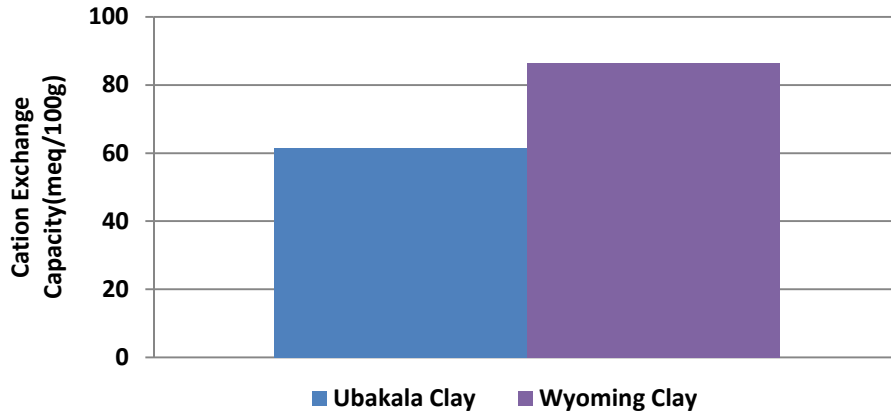


Fig. 5. Methylene blue cation exchange capacity of the various clays

The results of the determination of the density of the mud prepared from the Ubakala clay sample show that as concentration of clay and concentration of additives increased, the density also increased in turn (Figure 7). The increase in density was gradual as additive increased in concentration. The sand content did not show significant increase with increase in concentration of additive in the clay sample (Figure 6), this implies that the coarseness of the mud is not affected by beneficiation of the clay sample. The sand content signifies solids that do not contribute to beneficial mud properties. Ubakala clay shows a sand content value of about 1%, signifying that the sand content is within desirable limit (0-4%) (Amorim et al., 2004). This implies that the Ubakala mud formulation can provide lubrication to the drill-string and other drill tools, since the mud contains solids softer than the pipe and casing.

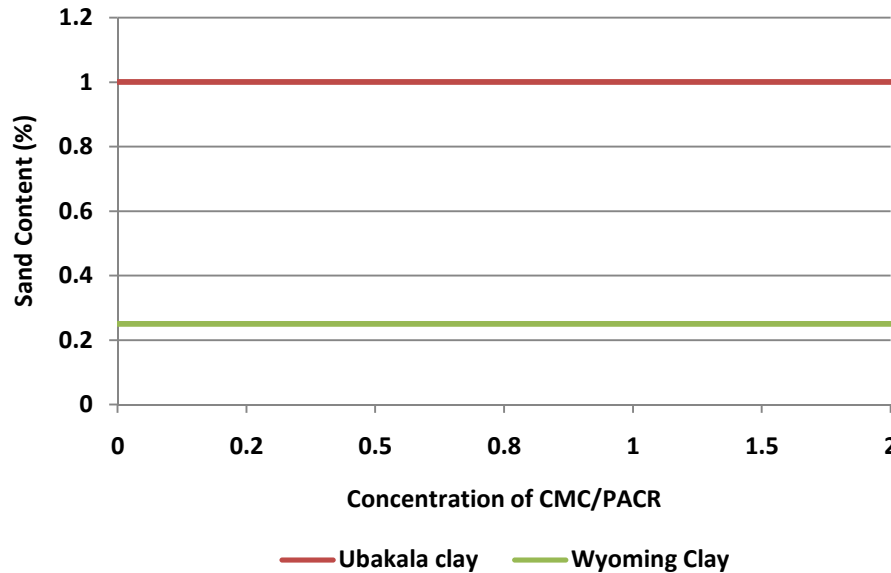


Fig. 6. Sand content of Ubakala clay sample with varying concentration of PACR/CMC

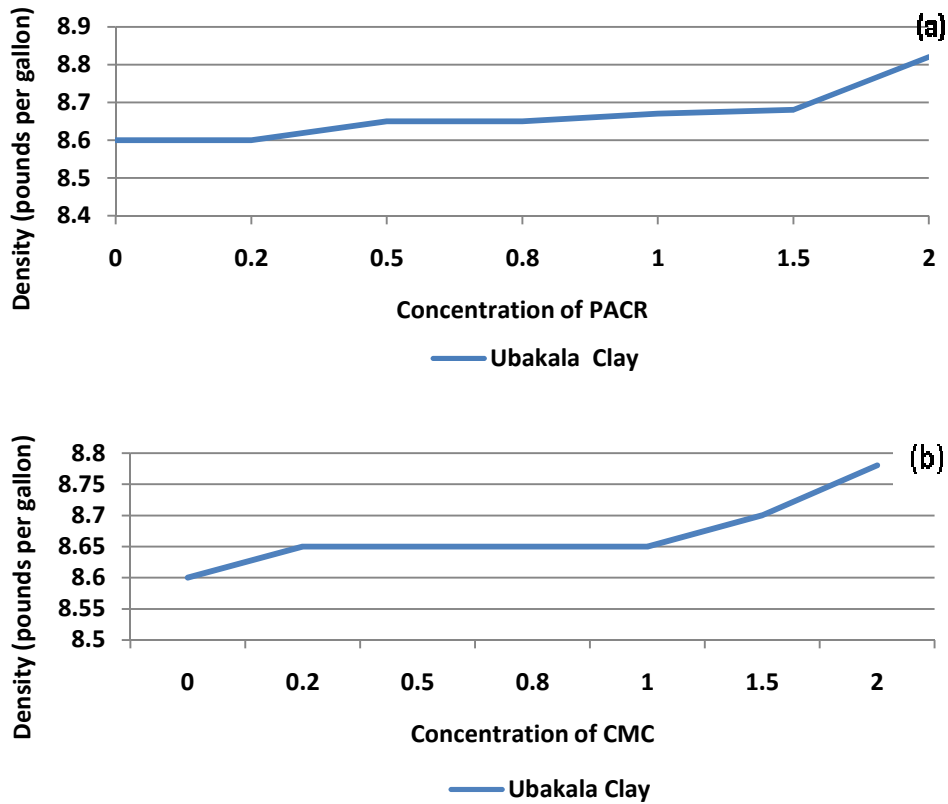


Fig. 7. Density of clay samples with varying concentration of (a) PACR (b) CMC

3.2 Mineralogical and Chemical Analysis

X-ray diffraction analysis as shown in Figure 1 was carried out in order to identify the mineralogical structure of the clay samples studied. The clay samples composed mainly of smectite, kaoline, albite. For Ubakala clay, there is almost complete absence of basal reflections in the $2-20^{\circ} 2\theta$ ($\text{CuK}\alpha$) range hence it is suspected that there is interstratifications between kaolinite and montmorillonite (Cradwick and Wilson, 1972). The mineralogical composition of Ubakala clay is summarized below and compared with that of Wyoming clay, as reported by Falode et al. (2007).

Table 1. Summary of crystalline minerals in clay samples

Clay/Mineral	Wyoming	Ubakala
Montmorillonite	35.85	25.6
Kaolinite	5.01	11.01
Quartz	23.98	35.2
Calcite	8.32	Tr
Biotite	3.23	Tr
Feldspar(Albite)	23.98	28.66
Total	100.00	100.00

Impurities which can constitute problems can be identified. The presence of quartz, which acts as an abrasive, could lead to poor physio-chemical performance of the clay. The presence of kaolinite in the local clay could lead to poor rheological properties since this clay have low swelling capabilities (Apugo-Nwosu, 2011). The chemical analyses of the samples are as shown in Table 2e. Chemical analyses results showed that Al_2O_3/SiO_2 ratio was approximately 1/3 in Wyoming bentonite as expected for montmorillonite, which is the main component of bentonite. In the Ubakala clay, the Al_2O_3/SiO_2 ratio was about 1/4.35. The presence of alkalis and magnesia in the samples suggests significant presence of montmorillonite. The Wyoming clay is richer in MgO than the Ubakala clay sample. This compound is normally used to enhance gel strength of mud samples (Falode et al., 2007). Ubakala clay showed low value of Fe_2O_3 , this indicates low laterite concentrations.

Wyoming showed higher sodium ion concentration, which shows increase in attraction of clay and water. Potassium may act as an exchangeable cation, located between unit layer and act as an interlayer cation.

Table 2. Chemical composition of the clay samples

Chemical Oxide	Composition, %	
	Ubakala clay	Wyoming clay
MgO	0.156	0.330
Na ₂ O	0.056	2.7
Al ₂ O ₃	16	17
SiO ₂	69.6	45
SO ₃	0.45	-
K ₂ O	0.599	0.048
CaO	0.22	1.77
TiO ₂	2.64	1.68
V ₂ O ₅	0.11	0.098
Cr ₂ O ₃	0.039	0.11
MnO	-	0.15
Fe ₂ O ₃	2.99	11.10
NiO	0.0096	0.026
CuO	0.057	0.010
ZnO	0.007	0.034
Rb ₂ O	0.0098	-
SrO	0.034	0.046
Y ₂ O ₃	0.028	0.034
ZrO ₂	0.219	0.034
Nb ₂ O ₅	-	-
RuO ₂	0.384	0.39
Re ₂ O ₇	0.01	0.03
OsO ₄	0.02	-
Au	-	-
Yb ₂ O ₃	-	-
L.O.I.	6.6	12.1
Total	100.00	100.00

Bentonites with higher clay percentages (lower non-clay mineral content) as Wyoming should show high rheological properties. Clay such as montmorillonite that has a high cation

exchange capacity swells greatly and forms viscous suspensions at low concentrations of clay, particularly when sodium is in the exchange position. Considering the relative higher swelling volumes of Wyoming bentonite indicated by higher montmorillonite content, it should make better suspensions with water and therefore good rheological properties can be obtained whereas the Ubakala bentonitic clay would require some beneficiation to improve the swelling properties.

3.3 Rheological Properties of the Clays

The rheological properties including plastic viscosity, apparent viscosity, yield point and gel strength of the mud samples (24.5g in 350ml of water) with increasing concentration of viscosifiers were compared with that of the Wyoming mud sample. The rheological properties showed a significant increase in apparent viscosity, plastic viscosity and yield point as concentrations of PAC-R and CMC increased in the clay samples. This indicates capability for drilling purposes. The results are shown in Figure 8.

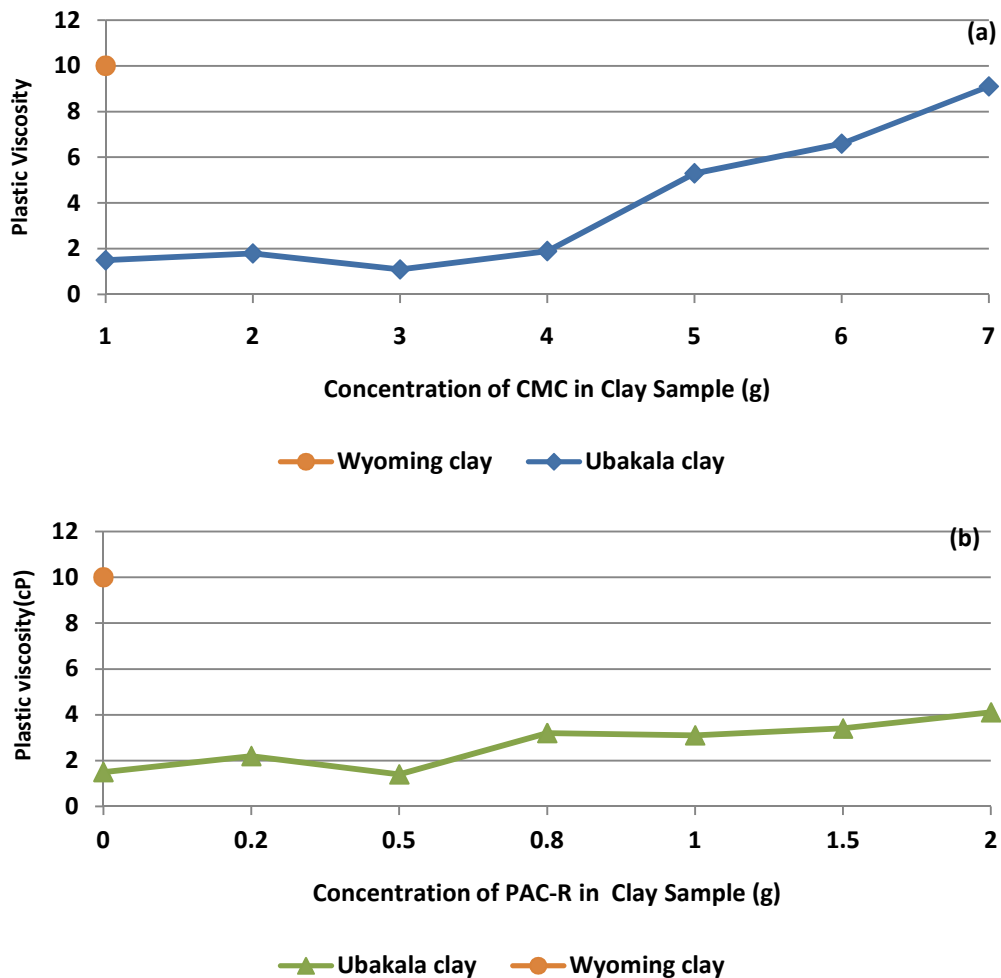


Fig. 8. Plastic viscosity of tested clay samples beneficiated with various concentrations of (a) CMC; (b) PAC-R; compared with Wyoming clay

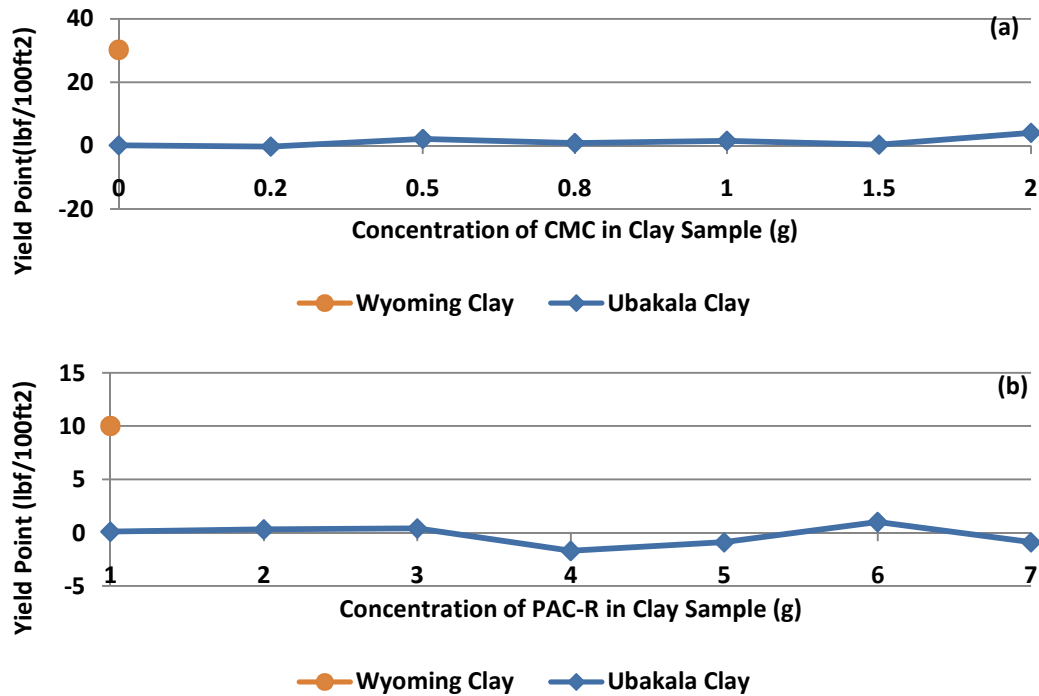


Fig. 9. Yield point of tested clay samples beneficiated with various concentrations of (a) CMC; (b) PAC-R; compared with Wyoming clay

The increase in yield point values suggest that the inter-particle attraction between the particles increase with increase in concentration of the viscosifiers. Though, there seem to be fluctuations in the values due to attraction and repulsion between the particles.

As shown in Figure 10 the gels formed from Ubakala clay and PAC-R were fragile gels (Uba, 1988). From the results, it showed that the attractive electrical forces were minimal. The gels formed from Ubakala clay and PACR were fragile gels (Uba, 1988). Fragile gels have extremely low values where the ten seconds and ten minute gel strengths are almost alike (e.g. 1/1, 2/2, 2/3 lb/100 sq. ft). Favourable gels are those with low to intermediate 10 seconds gel strength that build up to intermediate values in 10 minutes (e.g. 2/4, 3/6, 4/8 lb/100 sq. ft), while progressive gels have low to intermediate 10 seconds gel strengths building up rapidly to high levels in 10 minutes (3/20, 6/35, 8/50 lb/100 sq. ft.) (Uba, 1988).

As seen in Figure 10(a) for Ubakala mud with various concentrations of CMC, the highest value of gel strength found was at the amount 2g CMC, with 1g of Na_2CO_3 per barrel (24.5g of clay/350ml of water). While the lowest value was gotten when concentration of CMC was zero. From the results, it showed that the attractive electrical forces were minimal. The gels formed from Ubakala clay and CMC were fragile gels (Uba, 1988). However, when Na_2CO_3 was added to the sample, the attractive electrical forces in the mud system seemed to improve immensely into a progressive gel (Uba, 1988); this implies that the mud has the ability to prevent the cuttings from settling in the hole and sticking to the drill stem (Lyons, 1996).

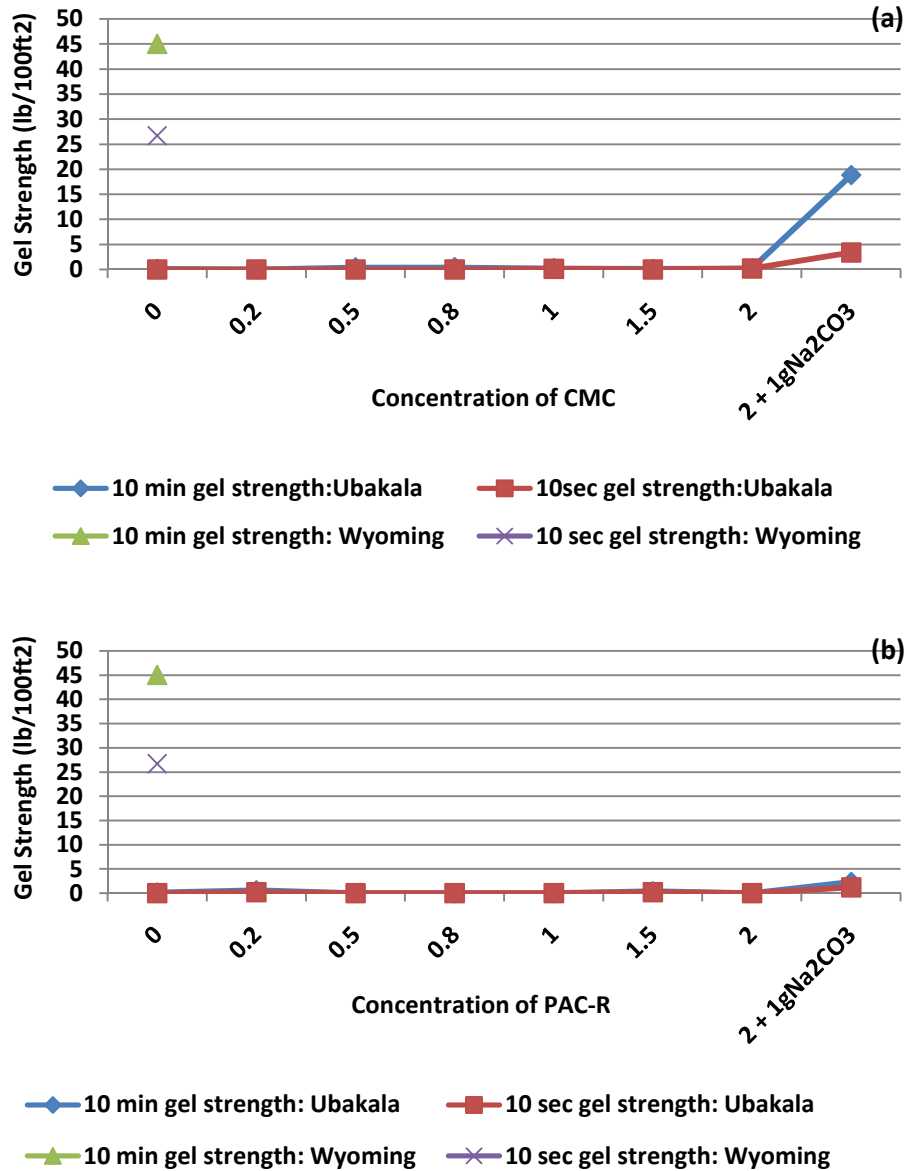


Fig. 10. Strength of tested clay samples beneficiated with various concentrations of (a) CMC (b) PACR

3.4 Rheological Properties of Beneficiated Clay Samples

3.4.1 Clay samples beneficiated with soda ash

Rheological properties on the samples beneficiated with a viscosifier and Na₂CO₃ showed remarkable increase in dial readings at all rotor speeds tested. This shows that the

viscosifiers used (i.e. PAC-R and CMC) were prone to function better in more basic medium. The results of the dial readings against rotor speeds for Ubakala clay are shown in Figure 11 below.

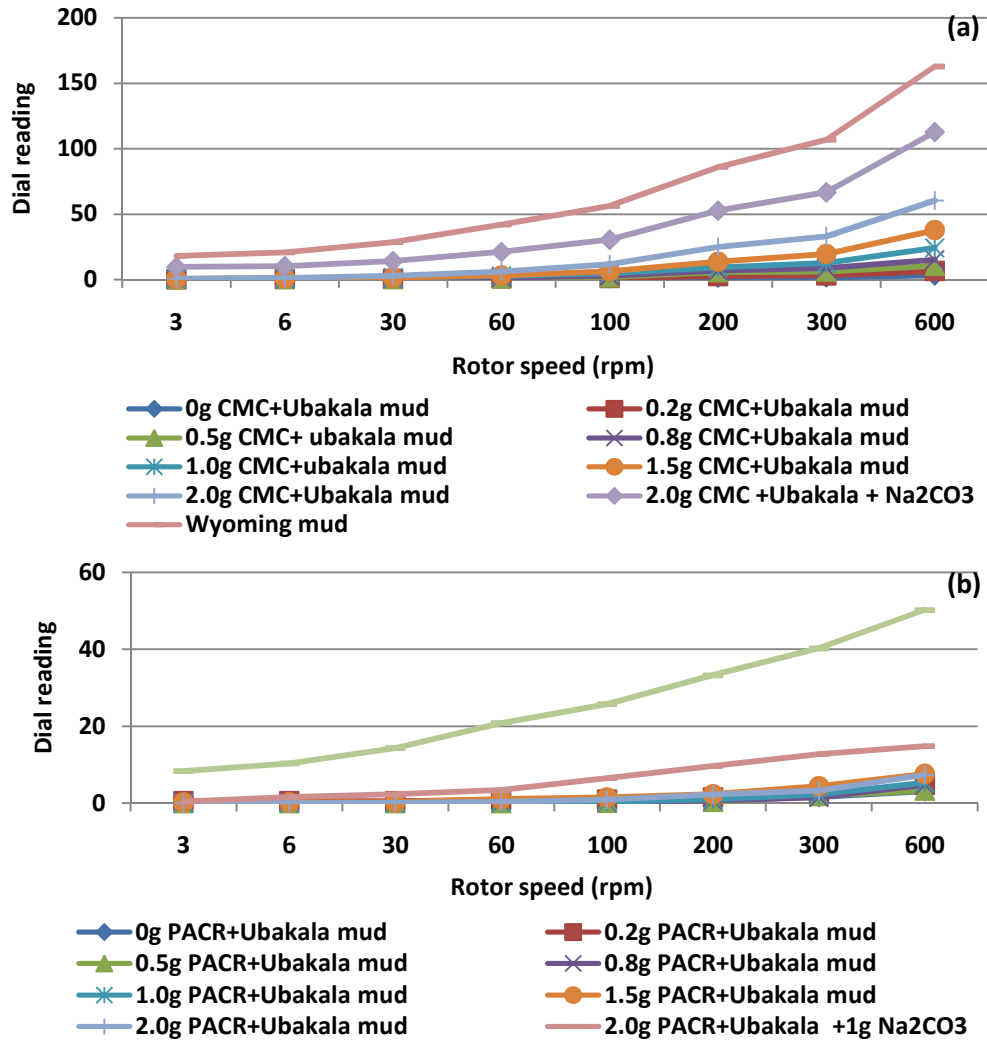


Fig. 11. Effects of (a) PACR and Na₂CO₃ (b) CMC and Na₂CO₃ on flow properties of Ubakala clay compared to the flow properties of Wyoming clay

None of the local clays tested met the standard API viscosity reading for 600rpm. The readings were too low compared with the Wyoming clay tested. The low plastic viscosities exhibited by the local clays without additives (as shown in figure 11) may result in its failure to control the magnitude of shear stress of fluids and this may lead to fluid failure during an operation (Irawan et al., 2010). The low yield point may also cause the failure of the local clays to develop and retain its structure during operations. Wyoming clay exhibited a much better result. This is due to the fact that Wyoming bentonite has a higher content of montmorillonite (from XRD result in Figure 3), which is a very soft phyllosilicate mineral that

typically forms in microscopic crystals (Irawan et al., 2010). The function of the montmorillonite is to make the mud slurry viscous, which helps in keeping the drill bit cool and also in removing broken rock fragments in the drill hole.

The dial readings of the mud samples beneficiated with viscosifiers, PAC-R and CMC; at each rotor speed tested, increased with increase in the viscosifier. For clay samples viscosified with PAC-R, when concentration of PAC-R was increased from 0 to 0.2g in 24.5g of clay sample in 350ml of water at rotor speed 600rpm; dial reading increased from 3.1cP to 4.7cP for Ubakala clay. The dial reading continues to increase with increase in concentration of PAC-R till the viscosifiers got to a maximum of 2g concentration. With the addition of Na_2CO_3 solution, the dial reading increased remarkably, this is because the stability of the mud samples improved by a modification of the surface charge of the clay particles (Miano and Rabaioli, 1993).

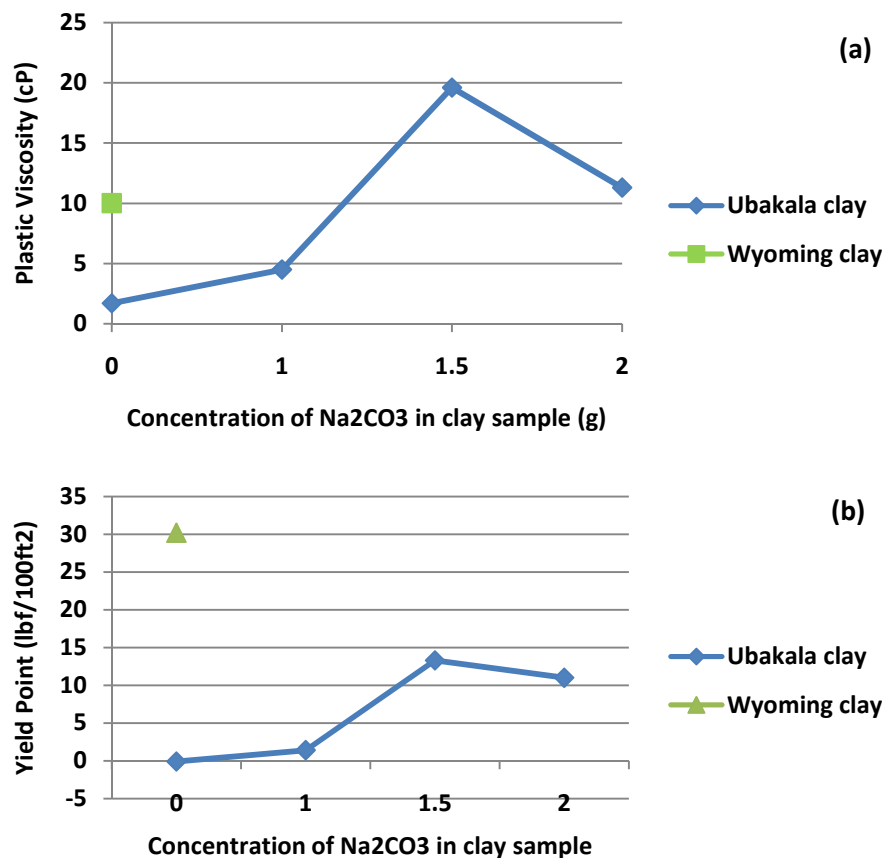


Fig. 12. (a) Plastic Viscosity (b) Yield Point; of Ubakala mud at various concentrations of Na_2CO_3 compared to that of Wyoming clay

For clay samples viscosified with CMC, the dial reading increased appreciably with increase in concentration of CMC in the clay samples.

When Na_2CO_3 solution was added to the clay samples the dial reading increased appreciably, especially with Ubakala clay. With addition of 1g of Na_2CO_3 to 24.5g Ubakala

clay+2g CMC/350 ml of water, dial reading increased from 18.2cP to 52.4cP for 600rpm rotor speed. This is because most viscosifiers require an environment with pH>9 to operate (Cark and Nahm, 1980). In clay-based systems, the differing surface and edge charges of clay platelets lead to a formulation of a gel-like network (Tehrani, 2007). the Na₂CO₃ provides the enabling environment for the gel-like network to form. Ubakala clay being predominantly calcium-based clay was ion-exchanged into a sodium based clay hence the sharp improvement in the dial reading. Darley and Gray (1988) stated that the interaction between sodium (monovalent) and montmorillonite determines the swelling of the particles. As can be seen from the results, CMC had a much better effect in viscosifying Ubakala mud than PAC-R had.

The rheological properties for Ubakala mud showed remarkable improvement of rheological properties at concentration of 1.5g of Na₂CO₃ and 2g of CMC in 24.5g of Ubakala clay gave the best result. This result is comparable to that given by Wyoming clay as can be seen in figure 10.

Beneficiation with Sodium Carbonate (Na₂CO₃) and Carboxymethyl Cellulose (CMC) significantly improved the thixotropic properties of the clay samples. The highest dial readings were gotten at 1.5g of Na₂CO₃ and 2g of CMC in 24.5g of Ubakala clay/350 ml of water.

4. CONCLUSION

The local clay samples; Ubakala clay samples possess no property at all on their own for use as drilling mud for oil well drilling. However, when beneficiated with Na₂CO₃ and PAC-R or CMC; depending on the concentration of additives, much better results that satisfied American Petroleum Institute (API) specification were derived.

From the results obtained Ubakala clay when beneficiated with 2g of CMC and 1.5g Na₂CO₃ per 350ml of water gave the best result when compared with Wyoming bentonite. This can be observed by a geometric increase of plastic viscosity by about 1207%. Ubakala clay showed a remarkable ability to develop a gel structure when beneficiated with the required amount of additives.

ACKNOWLEDGEMENT

The authors would like to thank the Staff of Chemical Engineering Department, Ahmadu Bello University, Zaria; Staff of National Research Institute for Chemical Technology, Zaria; Staff and Students of Petroleum and Geology Department, Petroleum Training Institute, Effurun, especially Rev. C. O. Okorie and Mr. R. Esabunor for their assistance during the course of this work.

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