CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Clay is generally fine-grained natural rock or soil materials with a particle size less than 0.002mm and predominately clay minerals with traces metal oxides and organic matter Grim, (1968). However, it played a significant part in ancient civilizations; for instance, it was used in brick buildings, iron casting, drilling fluids, wastewater treatment and pottery etc. (USC mineralogy Geol 215a Anderson, 2014).

According to Grim, (1968), minerals associated with clay may include quartz and feldspar and also detrital materials that were transported from the earth's surface.

Elueze, (1998) stated that several clay occurrences have been investigated and reported in Nigeria. Clay is generally used in the industries in recent time due to its characteristic plastic property and use as a drilling mud. Clay is plastic due to their water content and become brittle and non-plastic upon drying or frying. Usually the treatment of local clay affects the geotechnical index properties of the natural clays; however, it could also enhance their industrial potentials. (USC mineralogy Geol 215a Anderson, 2014).

As indicated by Nesthe, (1944), raw clays materials used for the mud making are usually selected clays with an appreciable amount of montmorillonite and are judged by their behaviour in water. Apugo-Nwosu et al, (2011) stated that clay suitability is determined by various criteria, such as; viscosity, the volumetric yield, and filtration characteristics. Bentonite is formed as a result of weathering of volcanic ash.

1.2 Statement of problem

Foreign clays imported into Nigeria for oil well drilling operations, although raw materials in abundance much money spent importing foreign clay thereby, affecting the economy

1.3 Application of clays and its relevance

According to (USC mineralogy Geol 215a Anderson, 2014) clay can be used in:

Oil and Gas Industry: Bentonite and other clay are applied during oil well drilling. It helps to control and lubricate the drill bit, transport the drill cuttings to the surface and provide hydrostatic pressure to stabilize the wellbore. (Bourgouyane et al, 1991)

Agriculture: in agriculture clay are used to decolorize, filter, and purify animal, mineral, and vegetable oils and greases due to their high absorbing properties.

Environment: Bentonite clay is used to establish low permeability liners in landfills, sewage lagoons, water retention ponds, golf course ponds, and hazardous waste sites.

Pharmaceutical industry: Bentonite is used as a binder in tablet manufacturing and in diarrhea medications. Clays are also used as thickeners in a wide variety of cosmetics including facial creams, lipsticks, shampoos, and calamine lotion.

Paint industry: clays are used in the paint industry to disperse pigment evenly throughout the paint, in order word without clay, it would be very difficult to evenly mix the paint base and color pigment.

1.4 Merit and demerit of local and foreign clays

Both local and foreign clays have two main merits and demerit which are stated below:

- Economical and,
- technological issues

  In teams of Economical issues, foreign clay is very expensive due to importation cost while local clay is very cheap and easy to access. However, in terms of technological issues, foreign clay has no technical issue because it has the ability to expand multiple times its original volume when it comes in contact with water; it is also characterized by high cation-exchange capacity due to its ability to form viscous suspensions and thixotropic gels when mixed with large amounts of water, via high adsorption capacity and ability to form an impervious seal (Rath, 1986). While local clay possesses some technical issue that required treatment because of its low swelling capability when comes in contact with water, hence lacked the ability to form an impervious seal.

Parkes, (1982) noted that the weathering processes by which the clay minerals are formed from the present minerals are complex but the main factors are climate, topography, vegetation and time of exposure. In addition to montmorillonite, bentonite may also contain feldspar, biotite, kaolinite, illite, cristonite, pyroxene, zircon and crystalline quartz.

According to Apugo-Nwosu et al, (2011), the term Bentonite by extension is applied commercially to any plastic colloidal and swelling clay regardless of its geological origin. Thus, this type of clay comprises the mineral of the montmorillonite group.

Currently, there is no major exploitation of Nigerian bentonitic clay for the intention of drilling mud formulation, even as it has been proven of it large deposit in the country at deferent locations (Falode et al.; 1989; Onah, 1994; and R.M.R.D.C.; 2005). Majority of the bentonite applied during a drilling operation in Nigeria is imported into the country which is not really healthy to the national economy. Hence, it is very important to devise an alternative means to foreign bentonite and other additives that are used during the drilling of oil and gas well.

During upstream activities such as; exploration and development of oil and gas reserves, drilling mud is needed in substantial quantities. The major concern of this research is to compare the local clay to foreign sample, by carrying out laboratory test and the activation by polymer according to the American Petroleum Institute (API) and Oil Company Materials Association requirement to ascertain the rheological properties of both clays.

1.5 Aim and objectives of the Study

The main aim of this research is to compare the rheological properties of Okrika and Etche clay with the Wyoming clay. In achieving this aim, the researcher has set the following objectives:

- To carry out rheological properties test on both clays in accordance with the API standard
- To analyze the rheological properties of the various clay in accordance with API specification and give reasonable recommendations.

1.6 Significance of the Study

The oil and gas industry is the major source of revenue generation to the Nigeria Government. Therefore, additive is very important during oil well drilling. It has been observed that imported clay is commonly used as a drilling mud and it is very expensive as a result of it importation cost. However, this research focuses on the Comparative study of rheological properties of local and foreign clays. It will help to ascertain if local clay will actually be a substitute for the foreign sample.

1.7 Scope of study

The scope of this work is to compare the rheological properties of local clay within Rivers State (Etche, Okrika) and Wyoming clay. (Gel strength, plastic viscosity and Yield point).

CHAPTER TWO

LITERATURE REVIEW

2.1 introductions

Clays are mostly formed on land but are often transported to the oceans, covering vast regions. (USC mineralogy Geol 215a Anderson, 2014)

According to work done by Apugo-Nwosu et al., (2011) in the early 90‟s via the Bureau of Mines of the United State of America (USA), indicated that the amount of bentonite accumulated in the world was about 1.36 billion tons; moreover the United State of America (USA) possesses more than 50.0% of the accumulate world bentonite. Apiam, (1985) stated that clay is a natural substance which occurs in a large quantity. Also (Apiam, 1985; Raymond, et al, 1990) claimed that the origin of clay may be traced to either of the two geological processes namely: sedimentation and weathering.

A comparative study of clay samples from Adiabo in the Cross River State of Nigeria was carried out by Abuh et al (2014) and he observed that the swelling volume of the Adiabo clay reached a level of 48% after been mixed with distilled water and allowed to stay for 24hours, however, the results show that the local clay is still below the recommended standard for use as additive during drilling.

Ajugwe, (2012) investigated swelling volume of clay samples from Akokwe, and Akperhe-Olomu. He concluded that the local samples do not possess any appreciable swelling.

However, Falode (2008) contested that clay samples obtained from Pindiga in Borno State had a swell volume of 64% when beneficiated with Na_2Co_3. Falode agrees that beneficiated Pindiga clay gives a good promise for drilling purposes at optimum additives concentration.

Nmegbu (2014) carried out research on clay samples collected from three different geological locations: namely; Egbamini, Afam Street and Oboboru in Rivers State. A measuring cylinder was filled with water at the 100ml mark, and 2g weight of all three samples was transferred in small amount (about 2.5g) unto the surface of water (sample in powdered form) using a thin spatula the process was done continuously without stirring until the 2g powered clay had completely dissolved into the water. Nmegbu noted that clays that are suitable for use as drilling mud would have a swelling volume increase of about 12-16ml mark measuring cylinder. Thus, if clays have swelling volume increase to the 12-16ml mark on the measuring cylinder it will not effectively coat the side of the wellbore during drilling and therefore should not be used as thickening agent. Finally, all the three samples fail to meet the swelling test criteria of 12-16ml mark on the measuring cylinder.

Nweke et al (2015) also compared clay samples from Abakiliki formation with commercial bentonite clay; He reported that clays are composed predominantly of little and mixed layer clays, with the presence of montmorillonite which is responsible for the swelling potential of the clay, ranging 20-30%. However, the range when compared with Wyoming bentonite which has a range of 35-85%.

Apugo-Nwosu et al.; (2011) perceived that the presence of kaolinite in Abakaliki clay could lead to poor rheological properties since the indicated type of clay has the low swelling capability.

Falode et al., (2007) on his study noted that Clays of various types and grades flourish all over Nigeria's sedimentary basins.

The latest research conducted by the Nigerian Mining Corporation concluded that over 700 million tons of bentonitic clay reserves are deposited in the country, and a community known as Afuze in Edo State contained the highest deposit ranges 70-80 million tonnes (Apugo-Nwosu et al., 2011).

Rath, (1986) noted that in as much there is no general established method set up for industrial condition of the clay properties used as drilling mud, the properties of the active Wyoming bentonite which majority of oil and gas drilling companies utilize as an effective drilling mud have been set up as benchmark apply to analyze the potential of other clays use in drilling operations.

Omole et al. (1989) studied the suitability of the black cotton clay soil of northeastern Nigeria as drilling mud. On his research, he analyzes the geotechnical index properties of the clay soil and how beneficiation affects it. From the results of his research, he noticed that the beneficiated clays were not still appropriate to use directly as oil and gas drilling mud although could be used for drilling water wells.

According to Mihalakis et al. (2004), he elucidates that the rheological properties of the black cotton clays enhanced with the addition of Na_2CO_3, is capable to be used as multipurpose drilling mud.

According to research conducted by Ezeribe and Oyedeji, (2005) they added lignite to clay mud to enhance its rheological and filtration properties. The lignite was activated with sodium hydroxide and added to freshwater mud at different concentrations. The two researchers aggress that the addition of 3% of lignite has a great improvement on the suitability of the clay. Okogbue and Ene (2008) discovered that some southeastern Nigeria natural clays have similar properties to those of naturally active bentonitic clays from Wyoming and Texas which are majorly used in the industry as drilling mud. However, Physical and rheological properties of the local clays collected in Etche and Okririka both in the Rivers State will be analyzed in this research and compared to Wyoming bentonite.

2.2. Clay Chemistry

Clays are minerals that have the ability to swell, absorb water and break up into colloidal-sized particles when coming in contact with water and agitation. The amount to which the clays separate is guided as follows:

i. clay type,

ii. exchangeable cations associated with the clay, and

iii. The electrolytic make-up of the water.

There are three main groups of clay minerals:

• Kaolinites

• Illites

• Smectites or montmorillonites

Kaolinites: Kaolinites is a type of clay that formed as a result of decomposition of orthoclase feldspar. It is also the least of clays; this is because it varies little in composition and also does not absorb water and does not expand when it comes in contact with water that is why is been used in ceramic industry is. Kaolinite clay $Al_2Si_2O_5(OH)_2$ have long been used in the ceramic industry, most especially in fine porcelains, because they can be mold easily, have a fine texture and are white when fired. It can also be used as a filler in making paper. kaolinite is a two-layer clay composed of a tetrahedral silica sheet and an octahedral alumina sheet. The silica sheet is oriented so that the tips of the tetrahedra are in the same plane as the oxygen or hydroxyl groups on the alumina sheet. The kaolinite particles are held together by hydrogen bonding and the spacing between layers is about 2.76 Å.

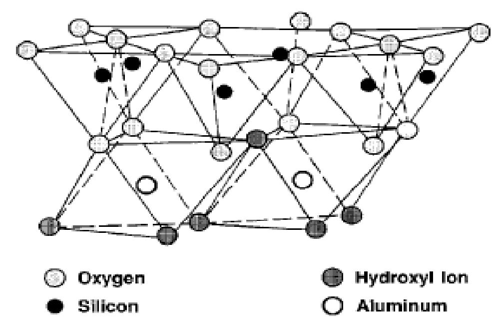

Figure 2.1. Lattice Structure of Kaolinite
Source: (USC mineralogy Geol 215a Anderson, 2014)

Illites: Illites is the most common clay mineral similar to muscovite and composing more than 50 percent of the clay mineral suite in the deep sea. Illite clay form as a result of weathering of Potassium (K) and Aluminum (Al) rich rocks under high pH conditions. However, they form via muscovite and feldspar. Also, they are the major constituent of shales. The Illite clays have the same structure to that of muscovite but usually lack in alkalies, with less Aluminum (Al) substitution for Silicon (Si). However, the general formula for the illites is $K_yAl_4(Si_{8-y},Al_y)O_{20}(OH)_4$, normally with $1<y<1.5$, but always with $y<2$. Due to possible charge imbalance Ca and Mg can also use to replace potassium (K). The K, Ca or

Mg interlayer cations prevent the entrance of water (H_2O) into the structure. However, the illite clays are non-expanding clays.

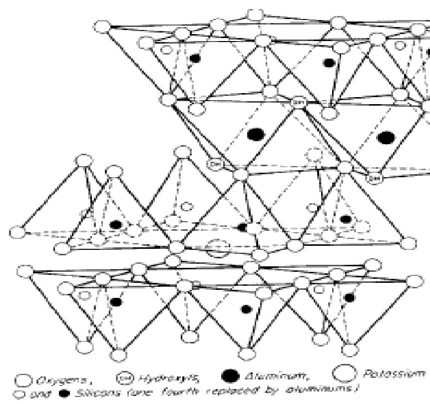

Figure 2.2. Structure of Illite
Source: (USC mineralogy Geol 215a Anderson, 2014)

Smectites (Montmorillonites): montmorillonite is the major constituent of bentonite formed as a result weathering of volcanic ash. Montmorillonite clays can expand multiple times its original volume when it comes in contact with water. This makes it useful as a drilling mud because it will keep drill holes open and to plug leaks in soil, rocks, and dams. However, montmorillonite is a hazardous type of clay to encounter if found tunnels or road cuts. Due to its expandable nature, it leads to serious slope or wall failures. Smectites or montmorillonite are a family of expansible 2:1 phyllosilicate clays having permanent layer charge due to the isomorphous substitution in either the octahedral sheet (usually from the substitution of low charges species such as $Mg^{2+,}$ $Fe^{2+,}$ or Mn^{2+} for Al^{3+})

.montmorillonite is most common smectite with a general chemical formula: $(1/2Ca,Na)(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4.nH2O$

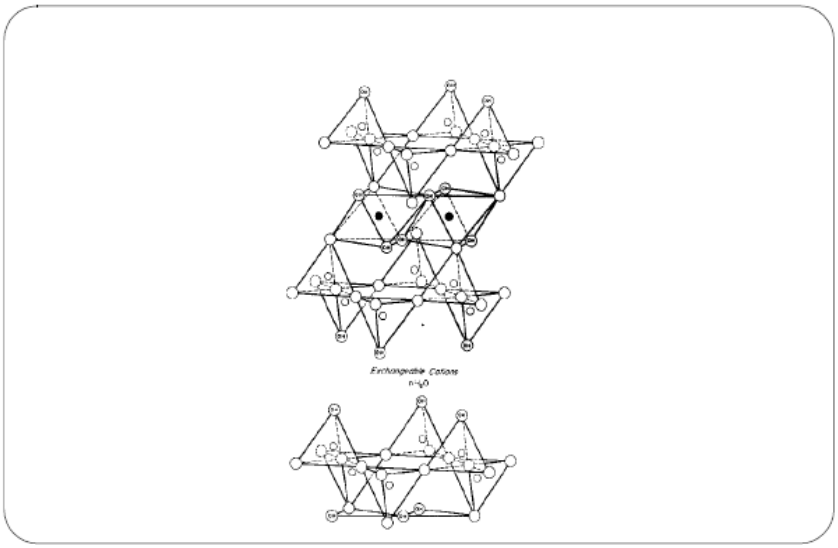

Figure 2.3. Structure of Smectites
Source: (USC mineralogy Geol 215a Anderson, 2014)

The aluminum atoms in the central layer may be replaced by magnesium or iron atoms causing a charge imbalance. This imbalance is countered by the association of positive cations at the particle surface.

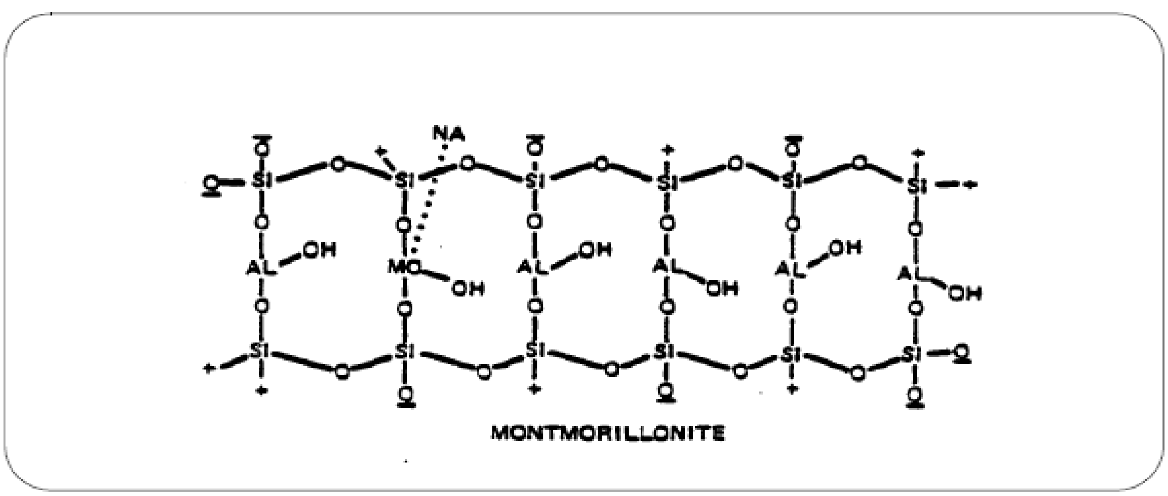

Figure 2.4. Structure of Sodium Montmorillonite
Source: (USC mineralogy Geol 215a Anderson, 2014)

The character of the exchangeable cation influences the extent to which the montmorillonites will swell. The divalent cations, because of the extra charge, tend to associate with adjacent particles and consequently, restrict swelling of the clay. For this reason, calcium montmorillonite is a poorer viscosifier than sodium montmorillonite. Due to their structure, the bonds between particles are weaker than other clays which add to the ability of the montmorillonite to hydrate. This is the principal reason sodium montmorillonite is the most common commercial clay. The cation exchange capacity for smectites is 60-150 meq/100g.

2.3 Clay Properties

2.3.1. Clay Particle Size

Clays are too small to be seen by optical methods and require electron-beam microscopes for the study of size and shape. In general, individually layered clays are from 7 to 21 Å thick, but 1000 to 100,000 Å in their width and length. (A 44 micron-325 mesh silt particle is 440,000 Å). Having this small size and relatively large surface area gives layered clays (such as bentonites) unique behavior when they are dispersed into water. Being highly charged as well, their behavior is more pronounced in terms of clay-clay particle interactions. The surface area that can be created by clay dispersion is very large, about 200 m2/g. The size and shape of clays allow them to be useful in building viscosity (when highly flocculated) or in building a tightly packed filter cake (when not dispersed or when deflocculated by a thinner). Polymer chains are extremely long when compared to clay particle dimensions. When high molecular weight (several million) polymer chains become linked with multitudes of clay particles in a water system, there is a combined effect that creates highly viscous, but shear-thinning, rheology.

2.3.2. Cation Exchange

In the active clays, magnesium ions (Mg^{++}) may be substituted into the octahedral matrix for aluminum ions (Al^{+++}). This substitution leaves the clay particle with a net negative charge which must be balanced. This balancing of charge takes place in the form of cations which are adsorbed onto the surface of the clay platelets. These cations are loosely associated with the clay and may be displaced or exchanged by other cations. The quantity of cations available for exchange is referred to as the cation exchange capacity and is reported in milliequivalents per 100 g of shale (Table 2.1). The strength, or the ability of cations to exchange, varies. (Table 2.2)

Table 2.1.Cation Exchange capacity of minerals in MED/100g

Kaolinite	3-15
Illite	10-40
Montimorillonite	60-150

illustrates the relative strengths of various cations.) A cation will tend to displace any of those to its right at equal molar concentration.

The presence and type of exchangeable cations will have an effect upon the hydration or swelling ability of clay. Strongly swelling clays, such as montmorillonite, will absorb a water layer to the surface of the clay due to the presence of electrical charges on the surfaces and edges of the clays. This water layer will vary in thickness depending upon the type of cation associated. Sodium montmorillonite will form a thicker layer which will tend to move the clay platelets farther apart and make them more susceptible to dissociation. On the other hand, calcium montmorillonite, because it is less hydratable, will provide less viscosity than sodium montmorillonite in equal quantities (Figure Figure 2.1).

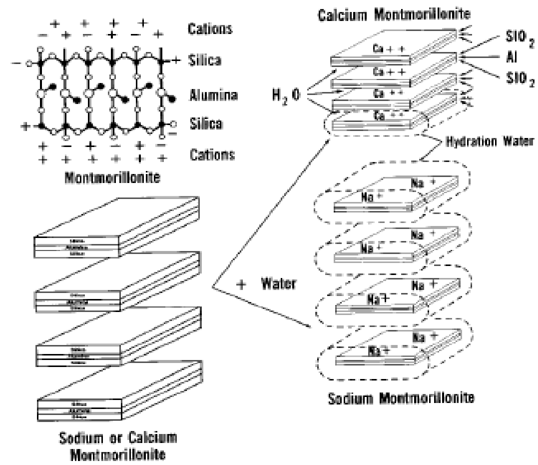

Figure. 2.5. Hydration of Sodium and Calcium Montmorillonites
Source: (USC mineralogy Geol 215a Anderson, 2014)

Electrolyte makeup will have a similar effect on the water associated with a clay platelet. This water layer, also called the electric double layer, will be forced to shrink if the clay is immersed in a fluid with a high cation concentration. While this effect is greater with divalent cations such as calcium or magnesium, high concentrations of sodium will have the same effect. This shrinking of the electric double layer will allow the clay particles to approach each other more closely. They may reach the point when the physical attraction between the clay particles exceeds the repulsive force of the electric double layer at which time the clays will flocculate or clump together. It is difficult sometimes to understand why cations added to bentonite-water slurry will cause an increase in viscosity, while bentonite added to an electrolyte solution will provide little if any viscosity. In freshwater bentonite slurry, the clay platelets are dispersed and kept apart by the electric double layer surrounding each platelet. This electric double layer consists of a cloud of charged ions and water molecules loosely associated with the clay particle. Since all the particles have this similarly charged cloud surrounding them, they cannot approach close enough for their natural attraction to overcome the repulsion of the cloud. The addition of a cation, however, causes a decrease in the thickness of the electric double layer. This allows the particles to associate the first edge to face, which will cause an increase in viscosity, and as cation concentration continues to increase, they will associate face to face which decreases viscosity.

Clay added to an electrolyte solution, on the other hand, is never allowed to form a substantial electric double layer and tends not to hydrate or viscosity.

2.3.4. Clay Interactions

We use several terms for describing the specific behavior of clay-water interactions. These are aggregation, dispersion, flocculation, and deflocculation (Figure 2.2).

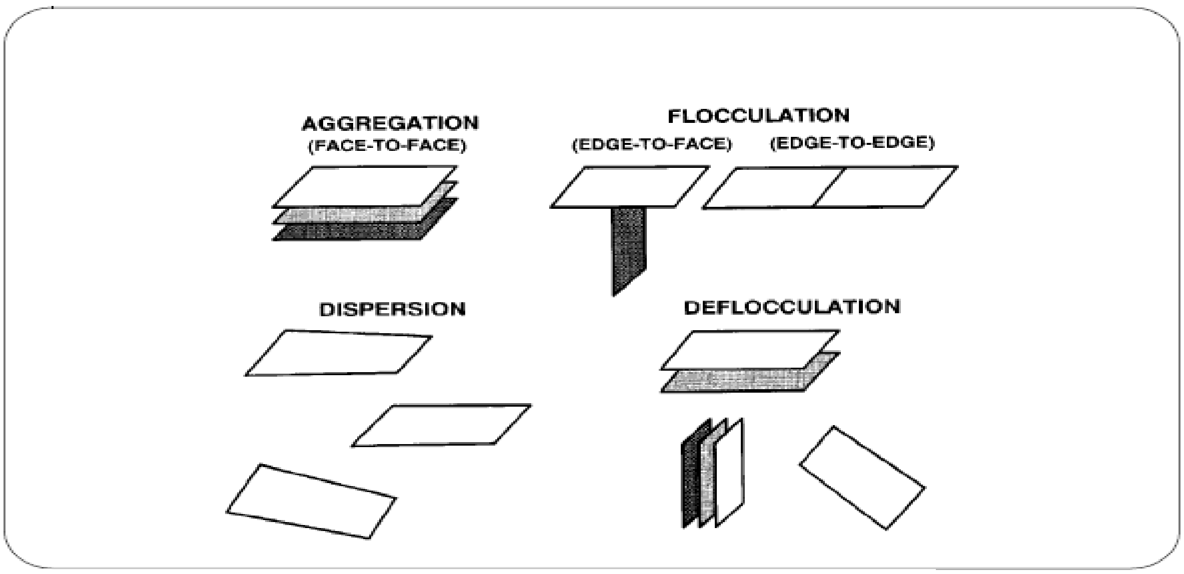

Figure 2.6. Types of Clay Associations
Source: (USC mineralogy Geol 215a Anderson, 2014)

The clay in its dry state has platelets stacked in the face-to-face association, like a deck of cards. This is **Aggregation**. When the dry clay is placed into fresh water with no agitation, the packets adsorb water, hydrate, and swell. Upon agitation, the swollen packets disintegrate into individual plates or smaller packets of plates.

This is **Dispersion**. As long as agitation continues, dispersion will be retained and further dispersion can occur. When agitation is stopped, clay platelets will be mutually attracted in edge-to-edge or edge-to-face association. This forces a structure similar to a house of cards, termed **Flocculation**. If an anionic chemical thinner (deflocculant) is added, such as polyphosphate, lignosulfonate or lignite, etc., it neutralizes the positive edge charges on clay platelets and the flocculated state is now **Deflocculated**. When this deflocculated clay slurry encounters strong ionic contamination (NaCl, CaSO4, Ca(OH)2, etc.), the deflocculant chemical is often overpowered - leading again to **flocculation** and even to a sort of **aggregation** where water is lost from the clay surfaces.

Currently, there are three API bentonites available (Table 2.3). They are listed in order of degree of chemical treatment (**beneficiation**):

- API Nontreated Bentonite (no treatment)
- API Bentonite (some treatment level)
- API OCMA Grade Bentonite (high treatment level)

Table 2.2. Comparison – API Bentonite Specification			
Requirements	Non treated Bentonite	Bentonite	OCMA Grade Bentonite
Water, cm^3 Clay, g/350 cm^3	350 25	350 22.5	350 22.5
Test for Spec: 600 rpm, minimum YP/PV, ratio, maximum Filtrate volume/30 min. maximum +200 mesh. Wt%. maximum Moisture, wt%. maximum	 - 1.5 - - -	 30 3 15.0 4 10	 30 6 16.0 2.5 13
Added SHMP to Slurry: PV, minimum Filtrate Volume/ 30 min. maximum	 10 12.5		
Nontreated Bentonite, in its testing, is treated with sodium hexametaphosphate thin-ner (SHMP) to assure that it has not previously been treated during manufacture.			

Source: https://www.netwasgroup.us/fluids-2/commercial-bentonite.html

Beneficiation is a process where chemicals are added to low-quality clay to improve its performance. Soda ash is added for peptization (Figure 2.4) and polymers are added to improve rheology and filtration control. All of this is done to make the clay pass API viscosity specifications.

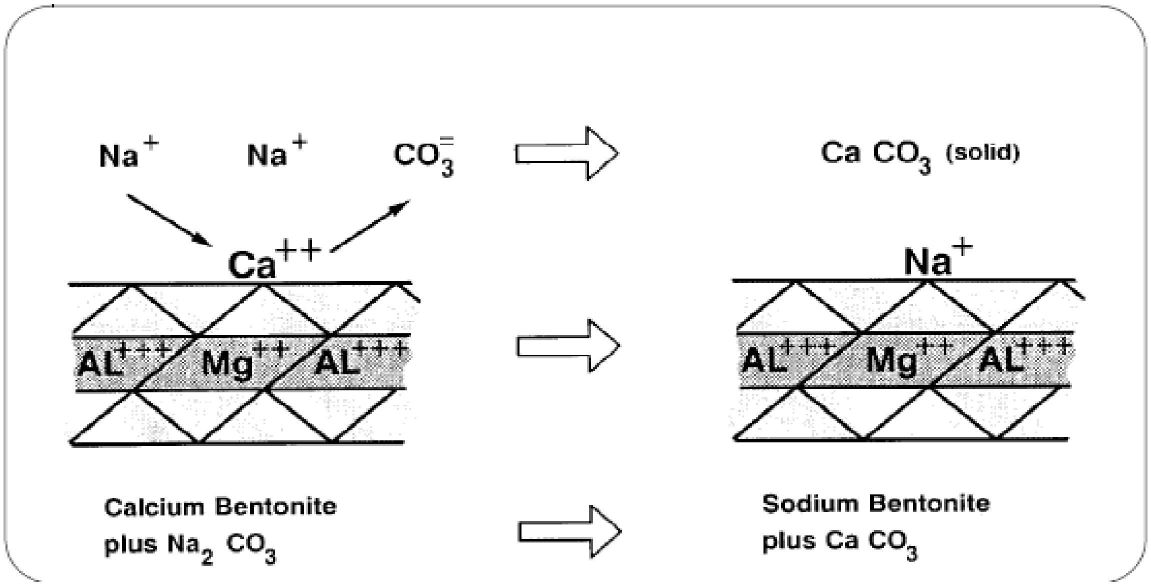

Figure 2.7. Peptizing Calcium Clay to Sodium Clay
Source: https://www.netwasgroup.us/fluids-2/commercial-bentonite.html

Bentonites that have been treated may exhibit poor performance in five respects:

1) intolerance to hardness ions,

2) incompatibility with other polymers in a mud,

3) low thermal stability,

4) limited shelf life, and

5) polymer structure break down as it passes through the bit.

For some drilling operations, API or OCMA bentonite may be economical and not create problems.

However, based on the five items above, their performance in many of the mud systems we currently use can be unpredictable and increase bentonite consumption.

API Bentonites

API Nontreated Bentonite - API Nontreated Bentonite is a premium quality material without any chemical additives for beneficiation. Being premium clays, they bring a premium price; however, they can be cost-effective in terms of predictable performance and lower usage.

API Bentonite - API Bentonite is generally predominantly sodium bentonite; however, some degree of beneficiation is allowed under specifications for this material. The YP/PV ratio specification (3 maximum) limits this amount of beneficiation. Hence, API bentonite, under many conditions, performs similarly to the nontreated bentonite.

API OCMA Grade Bentonite - API OCMA Grade Bentonite is predominantly a calcium bentonite and as such, cannot meet specifications of either of the other two API-grade bentonites. Even with less stringent performance requirements, OCMA Grade bentonites require high levels of chemical treatment (beneficiation) which is reflected by the high YP/PV ratio (6 maximum) allowable. However, API OCMA Grade Bentonite is used in many areas where the drilling fluid will not encounter excessive temperature nor contamination, and where suspension and hole cleaning are the primary requirements.

2.4. Properties of Drilling Mud

There are five primary properties which are usually defined by the well program and monitored during drilling: viscosity, density, filter cake or filtration of water loss and wall cake thickness, soiled content, and quality of water make up.

2.4.1. Rheology

Rheology is the study of the deformation and flow of matter. The study of rheology is important because it allows the drilling fluid to be specifically analyzed in terms of fluid flow profile, viscosity, hole cleaning ability, pressure loss, and equivalent circulating density - in general, wellbore hydraulics.

According to Garvey et al., (1988) 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. The value is 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 viscometer can be obtained by subtracting the 300rpm reading from the 600rpm reading.

According to Garvey et al., (1988) yield point is the resistance to initial flow and represents the stress required to start a fluid movement. The resistance is believed to be due to electrical charges located on or near the surface of the particles. As per Lyons, (1996) yield point is 1qused to evaluate the ability of a mud to lift cuttings out of the annulus. A rotational viscometer is used to measure shear rate/shear stress of a drilling fluid - from the Bingham Plastic parameters, PV and YP, are calculated directly. Other rheological models can be applied using the same data. The instrument is also used to measure thixotropic properties, gel strengths. The following procedure applies to a Fann Model 35, 6-speed VG Meter.

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

2.4.2. Density

Mud Density is used to control subsurface pressures and stabilize the wellbore. Mud density is commonly measured with a mud balance capable of ±0.1 lb/gal accuracy. A mud balance calibrated with fresh water at 70° ±5° should give a reading of 8.3 lb/gal. 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, the rate of drilling decreases, the chances for differential sticking accidentally fracturing the good increases, and the mud cost will be higher.

2.4.3. Fluid loss

The major 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 chances of differential sticking. The static fluid loss is determined on the rig using a standard cell that forces mud through a screen, and also using a high-temperature, high-pressure test cell.

CHAPTER THREE

METHODOLOGY

3.1 Materials and Method

The study area is a section of Etche and Okrika both located in Rivers State. The clay samples were collected in the creeks of riverine (Okririka) and upland (Etche).

3.1.2 Methods

3.1.3. Samples collection

The research was conducted by field visit and laboratory testing. Disturbed clay samples were collected from two locations (Etche) and (Okrika) both in Rivers State with a hand auger and carefully packed each of the samples in cellophane bags and labeled them well according to their location, the clay deposit is found exposed to the side of the river. Test on the clay samples was carried out at the Pollution Control and Environmental Management (POCEMA) in Rumuodomaya, Port Harcourt, Rivers State, Nigeria.

3.1.4 Materials

3.1.5. Laboratory Materials

Hamilton Beach mixer, Faan Viscometer, Thermometer, Foreign clay (control), Local clay, measuring cylinder, fresh water, and weighing balance

3.4. Laboratory Test

The clay samples were subjected to a different experimental test in accordance to API standard to ascertain the rheological properties of the local and foreign clay.

3.5. Rheological properties determination

300ml of brine was prepared and mounted on the Hamilton Beach mixer and stirred.

12g of clay for different samples were added slowly, after certain additives were added, to make a mixture of 350ml of mud, while stirring. It was stirred for 5 minutes and the sides of the cup were scraped to ensure that all the mixture enters the suspension. It was stirred for another 15 minutes to ensure homogeneity. It was then poured into the viscometer cup and stirred. The dial readings at 600 and 300 rpm, plastic viscosity and gel strength were respectively determined at different temperatures and recorded using fan viscometer, model 35.

3.5.1. Plastic Viscosity (PV) and Yield Point (YP)

Plastic viscosity and yield point can be calculated with the following formula:

PV, cp = $(\Theta600 - \Theta300)$

YP, lb/100ft^2= $(\Theta300 - PV)$

Where:

PV= plastic viscosity

Cp=centipoises

YP=yield point

lb/100ft^2= barrel per 100ft^2

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The results of the rheological properties of local and foreign clays are presented below:

4.1 Presentation of Data

Table 4.1.1: **Result of Water-based Mud Rheology @ 80°F**

RPM	Foreign Clay	Okrika Clay	Etche Clay
Ɵ600	61	34	36
Ɵ300	45	24	26
Ɵ200	35	20	22
Ɵ100	28	15	16
Ɵ6	12	5	6
Ɵ3	8	4	5
PV (cP)	16	10	10
YP (lb/ $100ft^2$)	29	14	16
10 secs	8	4	5
10 mins	12	5	5
Density (ppg)	9.1	9.0	9.0

Table 4.1.2: **Result of Water-based Mud Rheology @120^{o}F**

RPM	Foreign Clay	Okrika Clay	Etche Clay
ϴ600	58	33	34
ϴ300	40	23	23
ϴ200	32	19	20
ϴ100	25	14	15
ϴ6	11	4	5
ϴ3	6	3	3
PV (cP)	18	10	11
YP (lb/ 100ft^2)	22	13	12
10 secs	7	4	4
10 mins	10	5	4

Table 4.1.3: **Result of Water-based Mud Rheology @ 160°F**

RPM	Foreign Clay	Okrika Clay	Etche Clay
ϴ600	51	27	28
ϴ300	32	19	21
ϴ200	31	16	18
ϴ100	21	12	12
ϴ6	9	4	4
ϴ3	5	3	3
PV (cP)	19	8	7
YP (lb/ $100ft^2$)	13	11	14
10 secs	5	3	4
10 mins	8	4	4

Table 4.1.4 **Result of Water-based Mud Rheology @ 190^{o}F**

RPM	Foreign Clay	Okrika Clay	Etche Clay
ϴ600	46	24	26
ϴ300	30	15	16
ϴ200	27	12	12
ϴ100	18	9	8
ϴ6	8	1	1
ϴ3	3	1	1
PV (cP)	16	9	10
YP (lb/ 100ft^2)	14	6	6
10 secs	4	1	2
10 mins	6	1	2

4.2 Discussion of result

The results obtained from the properties of local and foreign clay are presented in table 4.1 through 4.4 and the relationship of the result was also represented by bar chart in figure 4.1 through 4.4. The results of the rheological properties between the local and foreign clays are dominated by foreign clays as indicated in the tables of results.

4.2.1 Plastic viscosity (PV) test results

The results gotten from the plastic viscosity of mud samples are shown in the table below.

Table 4.2. The result of the plastic viscosity of foreign and local clays at different temperature

	Plastic viscosity (PV) in centipoises (cp)		
The temperature in (^{0}F)	Foreign clay	Okrika clay	Etche clay
80	16	10	10
120	18	10	11
160	19	8	7
190	16	9	10

Plastic viscosity Vs Temperature

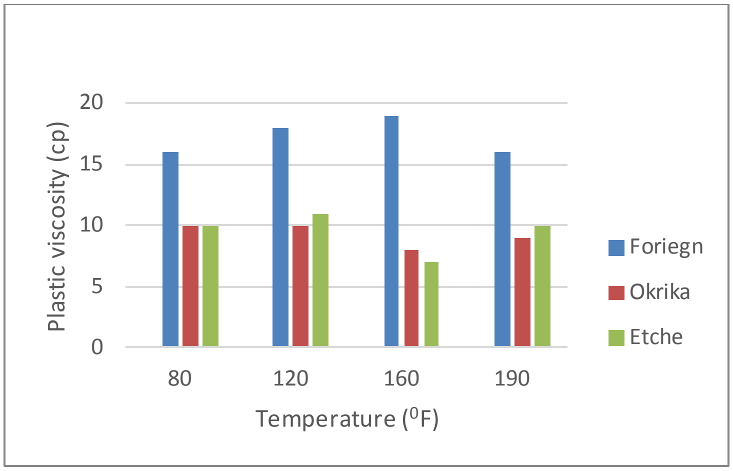

Figure 4.1. showing the relationship between temperature and plastic viscosity (PV) of Okrika, Etche and foreign clays.

From the plastic viscosity analysis, table 4.2, shows that the local clay plastic viscosity, range from 7cP to 11cP and foreign clay range from 16cP to 19cP at different temperatures. From the above results, it is clearly indicated that foreign clay has the highest plastic viscosity. However, this means that the plastic viscosity of local clays is comparatively low to foreign clay. The poor plastic viscosity indicated by the local clay may lead in its failure to control the degree of shear stress of fluids which may result in fluid failure during oil well drilling.

4.2.2 Yield point (YP) results

The results gotten from the yield point of mud samples are shown in the table below.

Tale 4.3. Results of the yield point of foreign and local clays at different temperature

	Yield Point (YP)		
The temperature in (^{0}F)	Foreign clay	Okrika clay	Etche clay
80	29	14	16
120	22	13	12
160	13	11	14
190	14	6	6

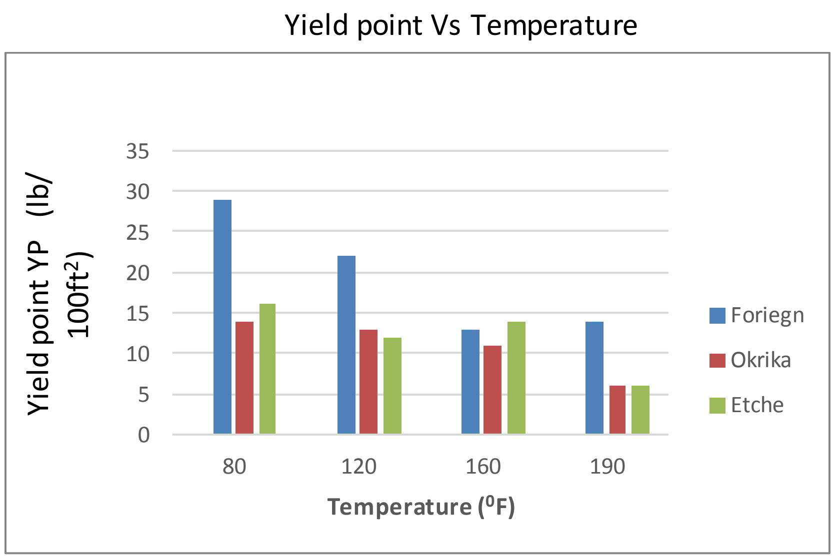

Figure 4.2. showing the relationship between temperature and yield point (YP) of Okrika, Etche and foreign clays.

The yield point analysis from Table 4.3 shows that the foreign clay varies from 13 to 29 lb/ 100ft^2 and local clay varies from 6 to 16 lb/ 100ft^2. It is clearly indicated that local clays are comparatively low to foreign clay. However, yield point (YP) which is the resistance of the initial flow of fluid or the stress required in order to move the fluid. Based on this result The Okrika and Etche clay did not meet API standard of yield point, while the foreign clay that has the higher yield point meet API standard of yield point.

According to Irawan et al., (2010) the low yield point may also cause the failure of local clay to develop and retain its structure during drilling operation. However, beneficiation of local clay might help to improve its properties.

4.2.3 Gel Strength test results

The results gotten from the Gel strength of mud samples are shown in the table below.

Table 4.4 results of Gel strength of foreign and local clay at a different temperature

		Gel strength (10 sec), lb/100ft^2 and Gel strength (10 min), lb/100ft^2		
Temperature in (^{0}F)	10sec/10min	Foreign clay	Okrika clay	Etche clay
80	10sec	8	4	5
	10 min	12	5	5
120	10sec	7	4	4
	10min	10	5	4
160	10sec	5	3	4
	10min	8	4	4
190	10sec	4	1	2
	10min	6	1	2

Gel strength Vs Temperature

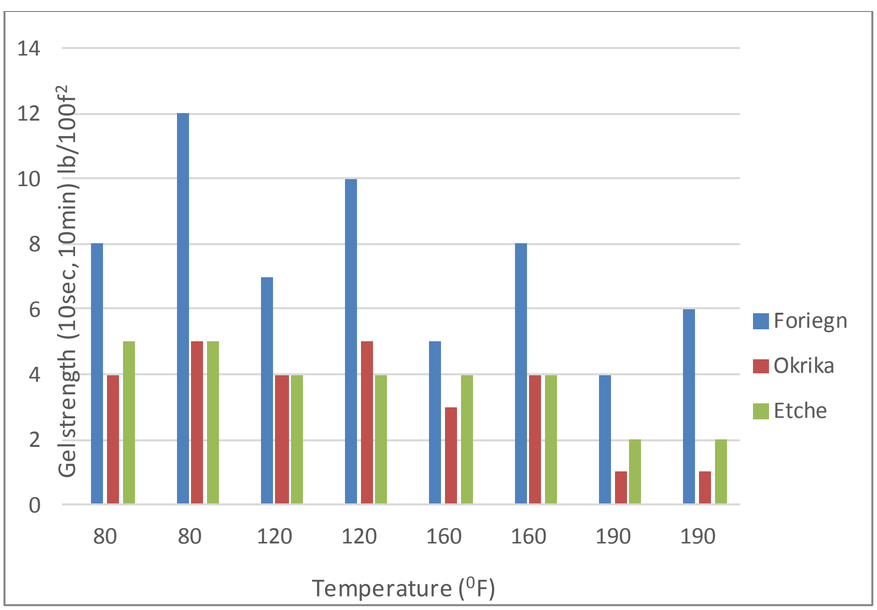

Figure 4.3. Showing the relationship between temperature and Gel strength (10 sec), lb/100ft^2 and Gel strength (10 min), lb/100ft^2 *of Okrika, Etche and foreign clays.*

Gel Strength analysis form tabl4 4.4 shows the foreign clay range from 4-12 lb/100ft^2 at 10 seconds and 10 minutes while Okrika and Etche clay range from 1-5 lb/100ft^2 at 10 seconds and 10 minutes. Based on this result it is obvious that Okrika and Etche clay is comparatively low to foreign clay. Okrika and Etche clay has fragile gels strength while foreign clay has favorable gel strength.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research evaluated the rheological properties of Okrika, Etche and Wyoming clays. The results from the laboratory tests show that local clays did not meet API standard of rheological properties while foreign clay meets API standard of all the rheological properties.

However, local clays cannot be used as drilling mud due to its poor rheological properties but can be improved through beneficiation which is the addition of some chemicals in order to improve low-quality clay properties.

Mihalakis et al., (2004) perceived that local clays can be improved with the addition of Na_2CO_3 and can be used as drilling mud. Also, Falode (2008) concluded that beneficiated local clay with Na_2CO_3 meets for drilling purpose at optimum additives concentration.

5.2 Recommendation

Due to poor rheological properties inherited by Okrika and Etche clay as indicated in the results of this experiment, more research and experiment should be carried out on the local clays to devise an alternative means of enhancing its rheological properties to meet API standard.

References

American Petroleum institute. “specification for drilling fluids”Spce, BA, 10th Edition (1993).

Apiam, (**1985);** Raymond, et al., (1990); An introduction to soil and plant growth. USA: Prentice Hall.

Apugo-Nwosu TU, Mohammed-Dabo IA, Ahmed AS, Abubaka G, Alkali, AS, Ayilara, SI (2011). Studies on the suitability of Ubakala bentonite clay for oil well drilling mud formation. British Journal of Applied Science and Technology. 1(4):152-171.

Bourgouyne, A.T., Millhiem, K.K., Chenevert, M.E., Young, F.S. (1991). Applied Drilling Engineering, 2nd edition, society of petroleum Engineers, Richardson, Taxas.

Ezeribe IE, Oyedeji OA (2005). The suitability of Nigerian bentonites and black Colton soils as drilling mud. Report submitted to Nigerian Geological Survey Agency Vol. 2B. 244pp.

Falode O.A (2008) “Evaluation of Local bentonitic clay as oil well drilling fluids in Nigeria”. Journal of applied clay science. Vol. 39,pp 19-27. Available online at www. Freepaperdownload.us [June 2015].

Garvey, C.M, Savoly, A., Resnick, A.L. (1988). Fluid loss control Additives and Drilling fluids containing same, United States patent 4741843, Avaiable online at www.freepatentsonline.com/4741843.

Grim RE (1968). Clay mineralogy. 2nd Edition, McGraw-Hill, New York, 596pp.

Irawan S., Sum C.W., Mohammed, K.B (2010). Formation of drilling fluids for high temperature well application using Sabah Bentonite. Proceedings world Geothermal congress, Bali, Indonesia, 25-29.

Lyons, W.C (editor), starded Handbook of petroleum & natural Gas Engineering, Vol. 1, 3rd Edition, Goulf Publishing company, Texas, 1996.

Nmegbu (2014) “International Journal of Engineering Research

Nweke, O.M; Igwe, E.O; Nnabo, P.N (2015) “comparative evaluation of clays from Abakaliki formation with commercial bentonite clay for drilling mud”. Africa Journal of environmental science and technology. Vol. 9(6) pp. 508-518. Available online at http://www.academicjournals.org IJEST [June 2015].

Mihalakis TS et al., (2004); improving rheological and filtration properties of drilling mud with additives of Green lignite. Paper presented at the 7th National congress on soil mechanics, 24-26.

Okogbue, CO & GE **Ene** (2008) "Journal of Mining and Geology

Okorie, O.M. (2006). Formulation of Drilling Fluid (Mud) With Local Materials, Petroleum Training Journal, Vol.3, No.2. pp 92-112.

Omole. et al., (1989). Suitability of Nigerian black soil clays as drilling mud clays, I. Nature and technical properties

Rath DL (1986). Origin and characteristics of Wyoming bentonite deposits. Public information circular No. 25, the Geological society of Wyoming.pp.84-90.

(USC mineralogy Geol 215a Anderson, 2014).