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Development of a Water-Based Drilling Fluid for Shale Reservoirs with Emede Clay

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Abstract

This paper documents the design of a drilling fluid using Emede clay (south Nigeria) customized for shale reservoirs. Preliminary investigation suggests that Emede clay has a good potential for use in drilling operations when beneficiated appropriately.

Keywords: Nigerian shale, Emede clay, drilling mud.

1.0 Introduction

The Niger Delta consists of three stratigraphic units overlain by the Quaternary deposits; namely: the Benin, the Agbada and the Akata formations. The Agbada formation consists of marine shales and sand beds; the underlying Agbada is a sequence of sandstones and shales[1].

Figure 1: Map of Nigeria

2.0 The Nigerian Shale

The Nigerian Shale used in this paper is from Okpekpe; a town in Etsako East Local Government Area of Edo State, Nigeria (see Figs. 1 and 2). It is located about 25 kilometres (16 mi) north East of Auchi. It has a population of 3155 inhabitants [2].

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Figure 2: Edo State, Nigeria

Shale is adark fine-grained, laminated clastic sedimentary rock. It is composed chiefly of mud, clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. The ratio of clay to other minerals is variable [3, 4].

This paper centred on the design of a water-based drilling fluid. The drilling solution is customized for the Okpekpe shale and was produced using Emede clay and not the commercial Bentonite.

From XR-D analysis Emede clay was observed to be predominately of quartz, microcline with a little quantity of some clay minerals (kaolinite, illite and some montmorillonite) Figure 4.

Figure 3: Okpekpe Shale, Nigeria

Okpekpe shale is primarily composed of quartz and clay (Fig. 3 and Table 1). The clay was observed to be the non-swelling illite with smectite/chlorite mixed layer. The smectite/chlorite was not osmotically swelling although it undergoes reaction with water. It was observed to be prone to fissuring or delaminating in aqueous systems [4].This delamination, if left unchecked can lead to wellbore instability, rheological problem such as particle size distribution [5].

3.0 Formulation of Drilling Mud

A fresh water formulation was designed with the expectation of providing a seal and protection from the smectite / chlorite possible delamination. An application of solid silicate chemistry with a sulfanated as phaltenes was used. Other additives used are shale stability; fluid loss control and pH control were combined with Guar gum [6].

Table 1: Mineralogical composition of Okpekpe shale from analysis

S/N	Mineral	Component (wt %)
1	Quartz	40
2	Plagioclase Feldspar	1
3	Potassium Feldspar	Trace
4	Calcite	Trace
5	Pyrite	Trace
6	Smectite/chlorite	24
8	Illite	24
9	Dolomite	10
10	Chlorite	1

11	Kaolin	1

In this investigation three mud formulations are used with oil (diesel) or water as the continuous phase (Table 2). This was done with a view to the requirements for a good drilling fluid as listed in Table 3.

Table 2: Mud Formulations

S/N	Oil/ Water ratio	Continuous phase
1	80 : 20	Diesel
2	50:50	None ; equal proportion of each fluid
3	20:80	Water

Table 3: The Requirements for a Good Drilling Fluid

S/N	**Requirements**	**Values**
1	Density	12-14 ppg
2	Oil-Water ratio	80/20 50/50 and 20/ 80
3	Emulsion Stability	400-1000
4	YP	14-25
5	Gel Strength	Progressive over time

Table 4: Materials for the design of Drilling Fluid

Product	**Example**	**Description**	**Function**
Base oil	Diesel	A yellow non-viscous liquid	Base fluid
Emulsifier	Invermul	Emulsion of water in oil. Thick dark viscous liquid	Emulsifier
Viscostifier	Geltone	Organopholic clay."Milky" colour	Viscosifier
Dispersant	Duratone	Black- coloured Organophilic colloid power	Filtrate control agent
	Calcium Chloride	White –coloured Powered salt	P^H control agent
Quick lime	Sodium Hydroxide	Colourless aqueous solution	P^H control agent
Water	Water	Non-viscous liquid	Solvent
Barite	Barium Sulphate	Brownish Power	Weighting material
Slake lime	Calcium hydroxide	White Power	

PROCEDURE4.0 Discussion

17.5G of Emede clay is mixed with 350 ml of water and the pH recorded. 0.5 ml of molar/dm3 solution of potassium chloride is added and the pH recorded. The mixture is allowed to hydrate for 6-12 hours .This is known as "aging" the mud.
The aging process reveals how the fluid would behave down hole with the passage of time. Analyses were undertaken with the mixture after aging. (Namely, viscosity and Gel strength determination). These analyses give a Mud Engineer an idea of how the drilling fluid would behave on the site. The dial strengths were taken at different dial values to determine the viscosity (Table 5) and the gel strength (Table 6).

Table 5: Rheological Properties Of Emede Clay- Water Suspension At 120 Deg F

Dial Reading	**Values (cp)**
600 rpm	5
300 rpm	3
200 rpm	2
100 rpm	1
6 rpm	0.7
3 rpm	0.5

Table 6: The Gel Strength Of Emede Clay -Water Suspension At 120 Deg F

Gel Strength Reading (Ibs/100ft ^{2})	**Values**
10 sec	1
10 mins	1.5

The gel strength of drilling fluid is a very important property that determines if the drilling fluid is be able to carry out its basic functions of adequately suspending the cuttings and transporting them to the surface while supporting the stability of the formation [7].

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Several other properties of the drilling fluid were examined. This includes the plastic viscosity (PV), apparent viscosity (AV), yield point (YP) and the p^H at 120 degree F(Table 7).

Table 7: Other Properties of Emede Clay-Water Suspension At 120 Deg F

	Parameters	Values
1	PV	2
2	AV	2.5
3	YP	1
4	p^H	7

Additives added to the Emede clay –water suspension includes Guar gum and PAC(Table 8). Four mixtures were produced (Table 8). Contents of specific blends are shown in Table 9.

Table 8: Nomenclature of Mixtures

Mix Number	Mix (Blend)	Description/ Content Of Each Mixture
1.	Mix-A	Emede clay- water suspension + grinded shale
2.	Mix-B	Emede clay - water suspension with 1g guar gum+ grinded shale
3.	Mix-C	Emede clay water suspension with 1g PAC+ grinded shale
4.	Mix-D	Emede clay water suspension with 32 g gum Arabic + grinded shale

Table 9: The Constituent of each shale mix

Constituent	Mix A	Mix B	Mix C	Mix D
PAC (g)			1	
Guar gum (g)		1		
Gum Arabic (g)				32
KCl (ml)	0.5	0.5	0.5	0.5
Water (ml)	350	350	350	350
Okpekpe Shale (g)	322.5	322.5	322.5	322.5
Period / Time (Days)	10.5	10.5	10.5	10.5
Temperature (deg F)	150	150	150	150

Guar gum is a natural polymer. An important property of Guar Gum is its ability to hydrate rapidly in cold water to attain uniform and very high viscosity at relatively low concentrations [8]. Industrial grade Guar gum powder is use in oil well fracturing, oil well stimulation, mud drilling due to its cost effective emulsifying and thickening properties [9].

Polyanionic Cellulose (PAC) is extensively used in the oil drilling industry. It is used to adjust drilling and completion fluids, its main function is in reducing filtrate loss and as a thickener. PAC forms a thick absorption solvent layer and enhances coalescence stability of the drilling fluid. It reduces the permeability of mud cake by increasing the viscosity of filtrate and plugging holes function. PAC is strongly water-soluble, with good anti-salt, anti-calcium and magnesium properties. It exhibits excellent capability to reduce filtration loss. This is very important in salt water drilling, seawater drilling, and in saturation salt water drilling [10]. Gum Arabicis used in the production of drilling fluids [7]. It serves as a binder and demonstrates good filtration loss property. The effect of these additives (at different concentrations of 0.5g, 1.0g, 1.5g, 2.0g, 2.5g and 3.0 g) on the Emede Clay was observed and documented (Tables 13, 14 and 15).

The passage of time and high temperatures can degrade the components of a drilling fluid, and alter its performance[11].For this reason the rheological properties of drilling fluid is determined not only at laboratory temperature but also after aging and hot-rolling.

After undergoing aging, the fluid was evaluated using the same tests that are applied to non-aged to determine the effect(s) aging and hot-rolling had on the drilling fluid.

Each blend (Mix A, B, C and D) was hot-rolled at 150 degrees Fahrenheit for 10.5 days and their rheological properties determined (Tables 9, 10 and 11).

Table 10: The Results after Hot-Rolling For 10 Hours at 150 Deg F

Constituent	Mix A	Mix B	Mix C	Mix D
600 rpm	18	53	54	26
300 rpm	15	44	35	17
200 rpm	11	39	25	15
100 rpm	9	30	17	10
6 rpm	2	15	5	5
3 rpm	2	14	4	5
10 sec	4	16	10	11
10 mins	8	32	20	20

AV	9	26.5	27	13
PV	3	9	19	9
YP	12	35	16	8

Another property of the drilling fluid considered in this investigation was filtration loss. Signs of filtration loss are monitored closely in the field. Excessive loss of fluid in the field can lead to the following [12].
Namely:

i.) Formation instability
ii.) Formation damage
iii.) Fractured formation and loss of drilling fluid

In the field fluid loss tests are performed routinely. The result of the fluid loss (filtration test) for the designed drilling fluid is shown on Table 11.
From the test, Mix B showed greater tendency to loss fluid if used on site than the other mixtures. Mix C showed the fewer tendencies. The filter cake consequently was the greatest for mix B. However Mix A, the blend with the next greatest API fluid loss, revealed a thinner filter cake than Mix C and B thus demonstrating the importance of composition of drilling fluid on cake thickness.

Table 11: The results for Filtration Test for the different mix (blends)

	Mix A	**Mix B**	**Mix C**	**Mix D**
Pressure (psi)	100	100	100	100
API fluid loss	26.5	45	11	19
pH	7.0	8	10	9.5
Filter cake	1/3	6	3	2

The performance of drilling fluid may be altered in the presence of drilled cuttings. This is significant especially if cutting erosion occurs before its removal from the drilling fluid. The fluid's colloidal content can increase, and interfere with drilling performance.
Also, cuttings erosion usually is accompanied by wellbore erosion, which leads to hole- washout. Two tests are available to aid in designing fluids that reduce cuttings erosion [13]

Table 12: Rheological properties of Emede clay -water suspension with gum Arabic and grinded shale At 120 deg F

	Gum Arabic (g)		
	32	**64**	**96**
600rp m	84	100	74
300 rpm	59	68	44
200 rpm	49	58	32
100 rpm	36	43	20
6 rpm	9	11	5
3rpm	10	9	4
Gel 10 sec	10	10	6
Gel 10 min	15	15	10
PV	42	50	37
AV	25	32	30
YP	34	36	14

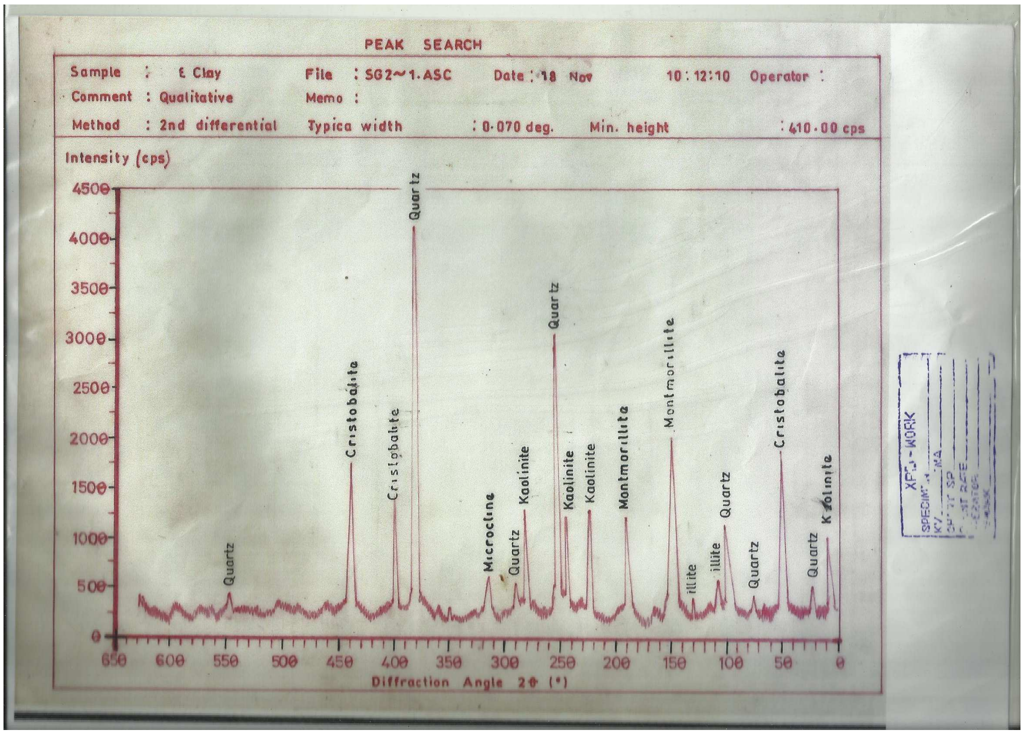

Figure 4: XR-D of Emede clay

Table 13: The Effect Of Different Concentration Of Guar Gum On Emede Clay-Water Suspension

	Concentration of Guar gum (g)					
	0.5	**1.0**	**1.5**	**2**	**2.5**	**3**
600rp m	4	9	12	19	28	38
300 rpm	3	7	8	11	17	25
6 rpm	2	2	2	2	2	3
3rpm	1	1	1	1	1	2
Gel 10 sec	1	1	1	1	2	2
Gel 10 min	2	2	2	2	3	3
PV	1	2	4	8	11	13
AV	2	4.5	6	9.5	14	19
YP	2	5	4	3	6	12

Table 14: The Effect Of Different Concentration Of KCl on Emede clay-water suspension

	Concentration of KCl (g)			
	0.5	**1.0**	**1.5**	**2**
600rp m	11	8	16	6
300 rpm	7	5	9	4
6 rpm	2	2	3	2
3rpm	1	1	2	1
Gel 10 sec	1	2	2	2
Gel 10 min	2	1	1	2
PV	4	3	7	2
AV	5.5	4	8	3
YP	3	2	2	2

Table 15: The Effect Of Different Concentration Of PAC on Emede Clay-water suspension

	Concentration of PAC (g)		
	0.5	**1.0**	**1.5**
600rp m	26	28	50
300 rpm	16	18	30
6 rpm	2	2	3
3rpm	1	1	2
Gel 10 sec	1	1	1
Gel 10 min	2	2	2
PV	10	10	20
AV	13	14	25
YP	6	8	10

5.0 Conclusion

Water based drilling fluid is developed using bentonite, guar gum, polyanionic cellulose PAC and gum Arabic. From an examination of the results after hot-rolling, there was an improvement of the rheological properties (Figure 5) of the different mix (blends). The local additives used displayed good beneficiation properties.

The rheological behaviour and the filtration loss property of each drilling fluid developed were measured. However this is preliminary and much work is still to be done to determine its stability.

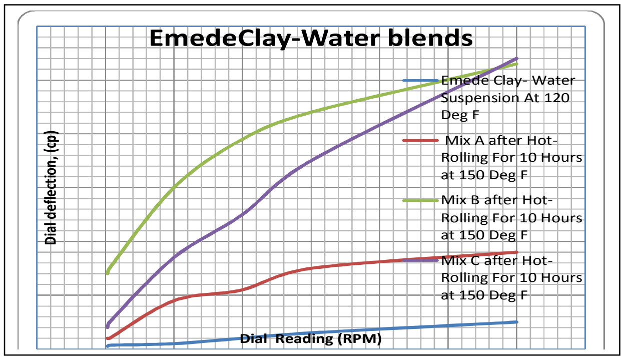

Figure 6: The effect of hot rolling on blends

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