Improving Drilling Performance using Oily Graphite and Aluminium Silicate Minerals in Water Base Muds

Ejelonu Oby, Akpoturi Peters, Uti Mark & Umukoro George

ABSTRACT
Drilling performance is enhanced and improved by the use of a mud system that prevents or retards the dispersion of formation and cutting sand minimizes torque and drag on the drill string. Calcium and Potassium ions are being used in polymer muds to stabilize drilled formations. Good solids removal and fast rates of penetration have being realized. However, borehole stability in these muds are sometimes time dependent. Improvements upon their performance can be achieve by forming inorganic water repellant membranes on the wellbore to physical block the entry of water into the drilled formations. A formulation containing an “oily” graphite and Silicate type minerals has been field tested. It combines with polymers to provide a slick thin filter cake along the wall of a drilled formation and minimizes the invasion of filtrate into the shale beds. The application of this compound in water base muds shows a positive influence on drilling performance. When compared against estimates, faster drilling rates which can lead to substantial savings in drilling costs were observed. Torque values in the wells tested were generally low (between 250 and 450 Amps), Drilling days were reduced by more than 10% Of programmed. In comparison with other wells drilled in the area, fewer bits and fewer trips were utilized during the trials. The compound also showed cost effectiveness in stabilizing the mud properties by eliminating the need for a defoamer. This compound is environmentally safe, showing very low hydrocarbon retention on drilled cuttings and has a temperature stability of up to 260°C. Thus it can be used as a cost effective water base mud additive for drilling highly deviated wells and deep hot holes.

Keywords: Drilling fluids, enhancement, cuttings, formation, polymer, mud, Temperature, water base mud, Torque, filter cake

1. INTRODUCTION
The potentials of the oily graphite/silicate containing compound as a lubricant and its contribution to borehole stability were investigated. This compound was compared against known asphaltic/gilsonite type products. Furthermore, its effect on mud properties was also investigated. The product was field tested in KCI-Pac polymer mud on two deviated wells to confirm its ability to improve hole stabilization and to determine its influence on drilling performance.(1,2). Mud related Operating time indicators we employed for monitoring performance during the evaluation procedure. Torque, rates of penetration and number of bits used, together with overpulls at trips were also used. The product was also used on wells where other asphaltic/gilsonite type products were not available. Although no comparative data were available from offset wells, good drilling performance was observed from these wells.

a. The Nature of the Graphite/Silicate Compound
The compound is a formulation of selected platy Aluminium Silicate minerals and Graphite and a small percentage of hydrocarbons, ground to a very fine constituent. It forms a tight suspension in water base drilling fluids, oil base muds and invert emulsion fluids and is applicable in both low- and high temperature wells up to 260°C.
The hydrocarbons enhance the coating of the Potassium Aluminum Silicates and Graphite on the wellbore and the compound binds with polymers to produce thin, slicky and tough filter cake. This makes the filter cake hydrophobic, physically blocking entry of water into the formation (3).

Shale stabilization (or inhibition) may be obtained either by exchange of cations in the clay minerals by adding salts, eg. potassium chloride, and or by coating the edges of the clays with high molecular weight polymers. Inhibition can also be obtained by use of solvent type mud systems, eg. oil base muds. Asphaltic type products cannot give this chemical inhibition. However, they give physical inhibition. They promote the delay of the swelling mechanism of clays either by lowering the HPHT filtrate into formations where filter cake can be deposited on the borehole wall or by depositing inorganic water repellant membranes or films on the wellbore. This graphite containing compound acts in the same manner to provide physical inhibition.

Addition of the graphite/silicate compound to water base muds will impart lubricity to the wellbore and drill string and casing and drill string. Initial treatment of the mud system with 4 -6 ppb of this compound will help to minimize torque and drag on the drill string and produce a stable mud by eliminating foaming(3,4).

Daily dosage of 0.25 -0.5 ppb is required to maintain concentrations. At these concentrations, shales can be inhibited from hydration and dispersion. If high or excessive torque or overpulls occur a higher dosage may be required to treat the problem.

b. Expectations Of The Graphite/Silicate Compound
The overall effect of the graphite containing compound on the drilling performance is positive. A stable mud weight and rheology obtained from the absence of foaming, will help to achieve good mud management. The effect on water loss should be positive, providing low filtrate with thin, tough wall cake which is helpful in the prevention of differential sticking of the pipe. With a clean mud, low filtrate and thin filler cake, torque and drag on the drill string can be reduced and overpulls minimized in deviated holes (5). More hydraulic horsepower can be delivered to the bit and faster rates of penetration can be obtained. Good drilling performance resulting from fewer trips and shorter drilling days can lead to a substantial reduction in overall drilling cost.

2. LABORATORY INVESTIGATIONS AND RESULTS DISCUSSION
The graphite/silicate compound was first evaluated in the laboratory to determine its effect on the mud system currently in use. In a pilot test with a 0.52 psi/ft. KCl@PAC Polymer mud, this compound showed little effect on the Plastic Viscosity of the mud. The Yield Point can be adjusted to a desired level for adequate hole cleaning. A very low filtrate (4.0 cc) with thin, slick cake was obtained. No foaming was observed during the test.

A second laboratory investigation, using the Capillary Suction Time (CST) test method, was carried out to determine its effect on shale cuttings. In a comparative determination of the effectiveness of shale stabilizers on shale cuttings samples from a known well, the graphite/silicate additive performed better than Asphaltic/Gilsonite products. The base fluid used for the test was 5 ppb Gypsum. This was treated with 6 ppb of each competitive product.

It may be recalled that the Capillary Suction Time (CST) test is used to characterize shales as dispersible and non-dispersible and to select suitable drilling fluids for a particular formation type. In general, a fluid or mud system which can retard or prevent the dispersion of the clays of a shale formation is inhibitive. The lower the CST values obtained the greater the inhibitive ability of that fluid or mud. The results on Table I on the comparative effects of competitive products show that the graphite/silicate compound has the lowest CST values, indicating that it can inhibit dispersion of shale cuttings. This reduces the percentage of drill solids in the mud, a positive influence on borehole stability, figure (1).

Lubricating ability of the product could not be determined by laboratory measurement. This can be determined qualitatively in the field by observing the level of torque and drag on the drill string and the value of overpulls at trips.

The impact of the mud containing this graphite/silicate compound on the environment was investigated by determining the Total Organic Content (TOC) of the cuttings from the wells drilled. Only 3 ppm of hydrocarbon was found. This shows that the product is safe to use in drilling operations in environmentally sensitive areas (6,7).
a. Field Evaluation
The graphite/silicate compound was field tested on two wells in swamp locations in some selected reservoirs. KCI-Pac polymer mud was used, based on in-house experience and the system’s compatibility with most drilling mud additives. Expected bottom hole temperatures on both wells were below the system’s thermal stability limit of 270 degree Fahrenheit.

An initial treatment of 4 ppb concentration of this graphite/silicate compound was maintained with daily additions of .25-.5 ppb concentrations. No defoamer or drilling mud lubricant was used in the two wells. Drilling performance was monitored by measuring Mud Related Operating Time indicators: rate of penetration, hours spent on drilling, tripping, reaming and circulating to condition mud. Torque and drag on the drill string and overpulls at trips were also employed in monitoring hole condition.

b. Effect On Drilling Performance
Well A was drilled directionally to 12,712 ft at 32 degree angle of inclination. Maximum overpull experienced in the 12 l/4 phase white tripping at 11,028 ft was between 75 and 85 Kips. A significant increase in torque was observed (from 300-700 Amps). This was due to the break down of the Top Drive System which was later replaced with the Kelly. Increasing the concentration of the test compound from 4-5 ppb reduced the torque to 250 Amps and the over pull to 30 Kips. Drilling time was shorter than program min by 2 1/2 days until at 11,028 ft ah), when the Top Drive System broke down. Figure (ii) shows how fast the well could have ended without the Top Drive problems. Torque behavior is presented on figure (iii). This well was drilled to a total depth of 12,550 ft. in 9 days faster than programmed. Figure (iv) shows actual performance against programme. Figure (v) represents Torque behavior with depth and hole angle. Maximum deviation was 59.6.

In the 12 1/4 section, while drilling between 7,719 and 8,683 ft (ah) at 27 to 39 degree deviation, average torque was between 200 and 300 Amps. At higher deviations (43 to 59.6) between 8,920 and 12,550 ft. torque value remained constant at 450 Amps. However, while drilling at 10,137 ft (ah), at a rate of penetration of 120 feet per hour, a dog leg of 3.9 degrees caused the torque to increase from 450 to 600 Amps. An overpull of the magnitude of 85 Kips was experienced. The concentration of the graphite/silicate compound was increased from 4 to 6 ppb. The torque was reduced and the value came down to 450 Amps while the overpull was reduced to normal drag (20-25 Kips).

Charts on tables 2 and 3 summarize the effect of the graphite containing compound on drilling mud parameters and mud performance. Comparison of drilling performance on Figure vii ) show that one well with a TD of 12.660 ft., in the same field as well H, was drilled with 13 bits as against 9 bits used on well B, although both wells were drilled in same number of days.

c. Effect on Mud Performance
Mud properties were steady and stable, with low rheologies. In the 8 1/2” open hole section, Plastic viscosity was maintained between 26 and 29 cp, and the Yield point between 15 and 18 lbs/100ft². Water loss was low, between 4.6 and 4.0 cc. Filter cake was thin, tough and slick. Good solids removal resulting from shale inhibition is indicated by the low level of solids percentage in the mud (8 - 9 %) at 0.58 psi/ft mud weight

Figure (vi) is a graph of mud properties versus depth. Solid analysis on table 4 shows formation response to treatment. As can be seen from the values of the drill solids percentage (2. 12-733 %), very little dispersion of solids into the mud occurred. This indicates a good level of inhibition in the mud.

Limitations
(a) The pH of the mud decreases with increasing concentrations of the compound. This can be overcome by running a slow stream of caustic soda solution into the mud to maintain a steady level of alkalinity as drilling progresses.
(b) The product will blind the screen when added at a fast rate and cause the fluid to run over the shaker. This leads to escalation in mud cost due to losses. This problem can be avoided by adding the material slowly or by batch mixing and transfer into the mainstream.

Hole Problems Encountered
Drilling performance was similar on both trial wells. The following discussion will focus on the events on well-B as representative of the two wells. In the 12 1/4 section the string got stuck at 10,011 ft , while tripping out at 10436 ft. The string became stock again at 10,969 ft , while drilling in the 8 1/2 inch phase. In both Cases the string was freed. Four days were lost. These problems may have been caused by hydraulic
ledges in the annulus due to inadequate circulation. Circulating the hole to obtain a balance (or near balance) in the mud weight and funnel viscosity values of the suction pit and the flow line always help to avoid this type of problem.

After drilling to total depth 1 12,550 ft (ah) several attempts to log the 8 1/2 inch hole failed. The logging tool and the 7 inch liner were held up at the same point, 10,723 ft. At first the problem was thought to be mud weight related. Pore pressure prediction on the rig had put the formation pressure at between 0 54 and 0.58 psi/ft. The mud weight was increased from 0.52 to 0.58 psi/ft. in order to hold back the formation. However, after reaming through this point several times it was felt that the problem might be hole angle related which could also be associated with deviation problems. However despite the problems enumerated, drilling was accomplished 9 days shorter than was estimated for the well. Thus it can be said that the graphite/silicate compound contributed positively towards the drilling performance.

Other Wells
The performance of the graphite/silicate compound on other wells was good. On a location where the product was used in a KCL land Polymer mud to drill a 9,830 ft well in which 183 feet of core was taken. Core recovery was 100 %. Mud weight used in this well was 0.487 psi/ft. Mud rheology was stable. No foaming in the mud was experienced. There were no defoamers or drilling mud lubricants used in the mud. The hole was in-gauge figure (viii). The compound was also used to drill a 50 inclined well in the swamp. This well was drilled with a Gyp-Polymer mud with a mud weight of .524 psi/ft. Average torque in this well was between 200 and 250 AMPS. Maximum overpull reported at maximum deviation was 55 kips. The well was drilled to total depth of 12,250 ft. without hole problems. Electric logs were successfully run to bottom and the casing strings were run and cemented without problems. The hole was in gauge in the 12 1/4 in section. In the 8 1/2 in section, however, there was considerable washout due to reaming of tight spots which occurred between 10,650 and 12150 ft (figure ix).

Intangible Gains
Two observations were beneficial from the application of this product:
(i) No foaming was experienced during the trial. The benefit is that mud weight remained stable at all times with no reduction in the hydrostatic head. Additional expenses from the use of a defoamer were eliminated.
(ii) The drill String was temporarily stuck twice and was pulled freed. It is proposed that the thin filter cake of the mud contributed to reducing the contact area between pipe and formation in a differential sticking situation, allowing the pipe to be worked free.

Summary
The contribution of the ‘oily” graphite/silicate compound towards drilling performance has been positive. On wells tested torque reduction led to good penetration rates which resulted in shorter drilling days. Also overpulls were generally reduced to normal drag by treating the system with 1 or 2 extra ppb of the product. The benefit is that sufficient hydraulic power is available for the bit so that longer time is spent on drilling, resulting in fewer trips being made and fewer bits being used to drill the well. The compound showed cost-effectiveness by eliminating the need for defoamers in the mud. Stable mud weights were observed in all the wells tested. This means that sufficient hydrostatic head is available for borehole stability. The thin filter cake which this compound produces by binding with polymers further help to improve hole stability reducing the tendency towards differential pipe sticking .The compound is safe for our sensitive environment. Only very little hydrocarbon residue was found in drill cuttings.

CONCLUSION
The results obtained from the various tests are encouraging to conclude that application of this oily Graphite/silicate compound in water base drilling fluids can lead to improvements in our drilling performance. By reducing torque and the occurrence of tight hole, and by eliminating the use of defoamers in the mud, when fully evaluated, this graphite aluminum silicate mineral compound may prove to be a cost effective additive for drilling highly deviated and deep wells.
Nomenclature
AMPS = Amperes
cp = Centipoise
Gyp = Gypsum
KCI = Potassium Chloride
Kips = Kilo Pascal
lb — pound
Pak = Poly anionic cellulose
ppb = Pounds Per barrel
Psi/ft = pounds per square inch per foot

REFERENCES
FIELD TRIAL OF "OILY GRAPHITE/SILICATE COMPOUND"

TRIAL WELL B

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**TABLE 4**

**COMPARISON OF DRILLING PERFORMANCE**

*Figure (10)*
LAND WELL DRILLED TO 9,830 FT.
WITH TEST PRODUCT IN KCl-PAC POLYMER MUD

SWAMP WELL DRILLED TO 12,250 FT.
WITH TEST PRODUCT IN GVP POLYMER MUD

FIGURE (vii)  FIGURE (ix)
FIELD TRIAL OF "OILY GRAPHITE/SILICATE COMPOUND
TRIAL WELL B

SOLIDS ANALYSIS

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TABLE 4

COMPARISON OF DRILLING PERFORMANCE

FIGURE (mH)
LAND WELL DRILLED TO 9,830 FT.
WITH TEST PRODUCT IN KCl/PAC POLYMER MUD

SWAMP WELL DRILLED TO 12,250 FT.
WITH TEST PRODUCT IN GYP POLYMER MUD

FIGURE (viii)  FIGURE (ix)
COMPARATIVE TEST ON EFFECTIVENESS OF SHALE STABILIZERS ON SHALE CUTTINGS SAMPLES FROM A KNOWN WELL USING CAPILLARY SUCTION TIME (CST)

INTERVAL: 9,520 - 12,400 FT

COMPARATIVE TESTS ON ASPHALTIC/GILSONITE-TYPE SHALE STABILIZERS

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** TABLE 1 **

** ** TEST PRODUCT

** FIGURE (i) **

CST TIME (SEC)

- ** ** TEST PRODUCT
- PRODUCT 1: ASPHALT BASED URETHANE
- PRODUCT 2: MODIFIED HYDROCARBON
- PRODUCT 3: GILSONITE BASED

6 PPS

PRODUCT 2 6 PPS

PRODUCT 3 2% (W/W)