WATER-BASED MUD FORMULATIONS IN DRILLING TERENGGANU SHALE FORMATION

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ABSTRACT

Water-based muds are used in drilling operation due to its environmental friendly nature. However, water-based mud systems are usually associated with shale problems that can cause shale hydration, swelling, dispersion and abnormal pressure thus causing drilling problems like washout, stuck pipe and hole enlargement. The purpose of this study is to formulate water-based muds that can minimize shale problems while drilling offshore Terengganu fields.

Terengganu shale (also called K shale) is basically sedimentary rocks that have been laid down over geologic time in marine basins. They composed of quartz, feldspar, calcite and other clay fractions like kaolinite, illite and inter layered varieties in different proportions. Terengganu shale is used in this study to determine the classification of its shale. A series of x-ray diffraction, capillary suction test and shale inhibition rate test was carried out to determine the mineralogy and dispersive/brittle attributes of the Terengganu shale. The best suited mud system to drill Terengganu shale will be proposed.

MUD SYSTEMS

The mud systems used are the KCl polymer mud, KCl PHPA polymer mud and KCl PHPA Glycol polymer mud. Glycol and glycol derivatives are used to enhance water-based muds with high tolerance to solids, low dilution rates, low high temperature and high temperature fluid loss and increase in the lubricity of the fluid.

KCl Polymer Mud: Potassium fluids are inhibitive fluids used to solve problems caused by water sensitive shales. It interacts with clay, such as ilite, or montmorillonite, lowers the hydration energy and reduces swelling. Potassium chloride concentration is matched to the relative activity of the clays to be drilled. The KCl polymer mud gives penetration rate advantages due to very low solid contents. Temperature limitation makes this system unsuitable for deep, higher bottom-hole temperature wells, although it can be run [1]. This system is sensitive to calcium and is easily remedied by precipitating the Ca^{++} out as $CaCO_3$. The system performs best clay free and addition of dispersants is encouraged.

KCl PHPA Polymer Mud: This system is a non dispersed, inhibitive potassium polymer system. The inhibitive character of the system is achieved with a potassium source and a PHPA shale stabilizing polymer. PHPA (partially hydrolyzed polyacrylamide) is an anionic, high molecular weight synthetic polymer and its shape depends upon ionic environment, pH and temperature. The long polymer chain attaches itself to clay particles, such as bentonite particles. These systems are effective when solids are minimum, thus providing good rheological properties for optimum drilling rates. PHPA polymer is an excellent shale stabilizer and a viscosifier. The thick polymer filtrates stabilize troublesome shales that preferentially coats the active troublesome clays on the wellbore. It also reduces the depth of filtrate invasion. KCl PHPA mud systems encapsulates cuttings which aids in their removal and prevents dispersion effects contributing to fine solid buildups. The system is temperature stable to 400 °F and

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environmentally friendly, but is Ca^{++} sensitive and runs best when the Ca^{++} level is maintained under 100 ppm [2].

KCl PHPA Glycol Polymer Mud: Glycol and glycol derivatives are used to enhance water based muds and is applied where oil based muds would be originally used. Inhibition and drilling performance is achieved with a KCl PHPA mud containing 3% glycol volume per volume [3]. The KCl PHPA glycol mud has a high solids tolerance and low dilution rates. HTHP (high temperature high pressure) fluid loss is reduced, with increase in lubricity of the fluid. By reduction in fluid loss and filter cake build-up, hence a reduction in differential sticking potential in shale formations. It also eliminates BHA/bit balling, good hole conditions on trip and easy maintenance of acceptable rheology if high mud weights are required.

MATERIALS AND PROCEDURES

A series of experiments were performed to evaluate the performance of various mud systems in inhibiting Terengganu K shale. Shale cuttings obtained from an exploration well offshore Terengganu were used for these experiments. Shale samples are prepared first by drying it and later sieved to 120 mesh size. The formulation for the base mud is shown in Table 1. The addition of 2 ppb PHPA will form the KCl PHPA system while further addition of glycol DCP208 (3% vol/vol) into the KCl PHPA mud will form the KCl PHPA Glycol system.

Table 1 - Base Mud Formulation.

Component	Quantity
Water	350 ml
KCl	10.0 ppb
Soda ash	0.8 ppb
Caustic soda	0.3 ppb
Foralys	2.0 ppb
Pac-R	1.5 ppb
Pac-UL	0.8 ppb

The x-ray diffraction (XRD) is used to identify clay minerals of Terengganu shales. Capillary suction time instrument (CST) is used to measure the time taken to obtain a given volume of filtrate. The method by which capillary suction time operated is by the suction applied to the dispersion through the capillary action of an absorbent filter paper of a given grade.

The 'rotary wheel shale chip test' is a method used to evaluate shale inhibition and stabilizing properties of various additives and mud systems. Rolling shale particles in fluid tests indicate both the chemical inhibiting qualities of mud and instability due to mechanical abrasions.

Methylene blue capacity (MBC) tests determines the cation exchange capacity (CEC) of the reactive solids in the formation. The CEC is an indicator of the hydration and swelling of reactive clay contained in the shale.

All procedures and measurements to determine mud parameters and clay behavior were conducted according to API RP 13B-1 [4].

RESULTS AND DISCUSSION

The XRD results show that Terengganu K shale contains 49% illite, 36% kaolinite and 15% of mixed illite/smectite layers (no indication of montmorillonite clay). CST results for Terengganu shale gives the value of 65 seconds in comparison with Wyoming bentonite 788 seconds as shown in Figure 1. The addition of potassium chloride will further inhibit the hydration and swelling of clay samples and the optimum KCl concentration to inhibit the Terengganu shale is about 2 - 3%.

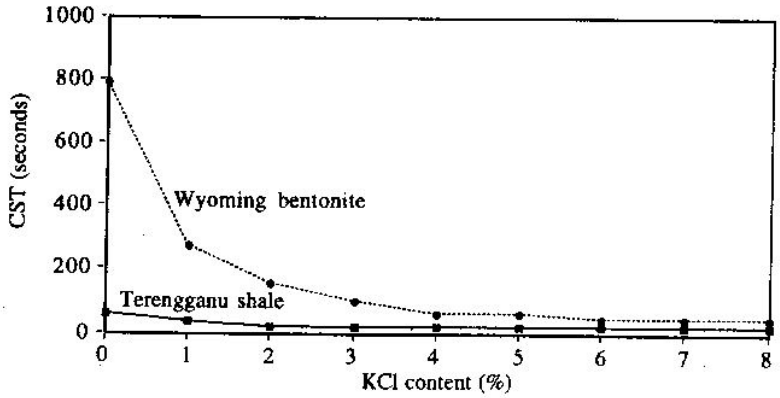

Fig. 1 - Effects of KCl on Wyoming bentonite and Terengganu shale.

Figure 2 shows that Wyoming bentonite gives a MBC value of 80 while the Terengganu shale has the MBC of 9.5. The KCl PHPA, KCl Glycol and KCl PHPA Glycol systems provide the best inhibition and lowest hydration of the shale cuttings at MBC of 5.5. From the XRD, CST and MBC test results, the Terengganu shale cuttings can be classified as brittle in nature, non-dispersive and medium hard.

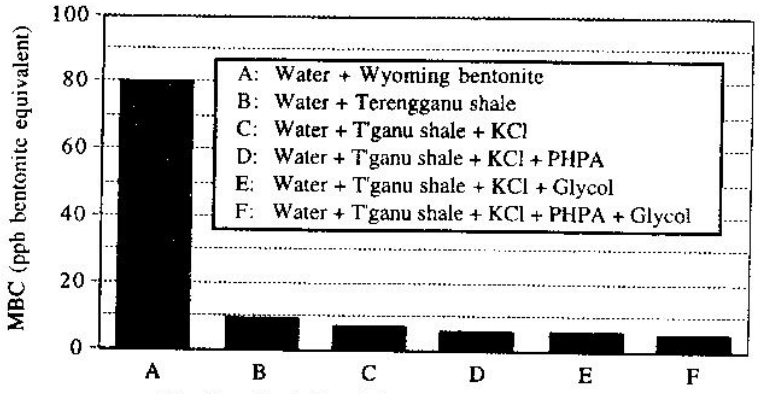

Fig. 2 - Methylene blue capacity of cuttings.

Figure 3 shows the percent recovery of cuttings with the various mud systems. The KCl PHPA mud system gives the highest percentage recovery of cuttings (42%). The addition of glycol in the PHPA system does not improve the recovery of cuttings since the inhibiting nature of glycol cannot prevent the brittle cuttings from disintegration during the rolling process.

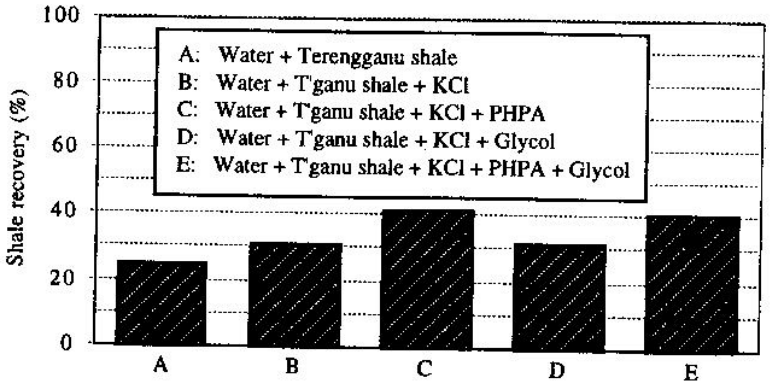

Fig. 3 - Recovery of Terengganu shale cuttings up to 60 mesh (0.25 mm).

The reduction of API fluid loss is controlled by Pac-R dan Pac-UL (fluid-loss control agents). Figures 4 and 5 show the effect of KCl, PHPA and glycol on fluid loss using standard API fluid loss and at HPHT respectively. The addition of PHPA will reduce the filtrate loss of the API fluid-loss from 8 ml to 6.4 ml (after hot-roll) and addition of glycol to the KCl PHPA will further reduce the API fluid-loss to 6 ml (after hot-roll). Glycol derivatives will not affect mud parameters like mud weight, plastic viscosity and its yield point but affects both the API and HPHT fluid loss values. The HPHT fluid loss for the KCl and KCl PHPA mud (after hot-roll) is at 24 ml while the KCl PHPA Glycol mud lowers the fluid loss value to 18 ml. The addition of PHPA to the KCl mud did not influence the HPHT fluid loss even though it reduces the API value.

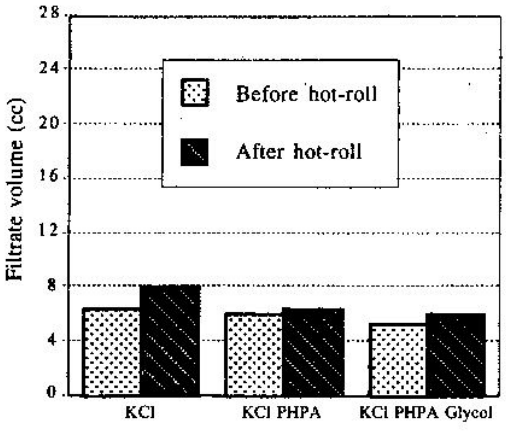

Fig. 4 - API fluid loss (hot-roll at160°F and 16 hrs, 100 psi).

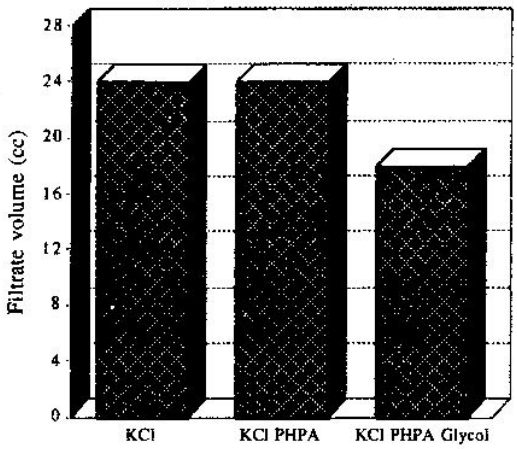

Fig. 5 - HPHT fluid loss (hot roll at 160°F and 16 hrs, 500 psi).

CONCLUSION

Terengganu shale can be classified as brittle, non-dispersive and medium hard. The KCl PHPA mud system is suitable to be used to drill Terengganu shale formation. The addition of glycol and fluid loss additives to the mud systems are recommended to reduce filtrate loss into the shale formation.

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