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POLYGLYCOL MUD FOR DRILLING IN CLAY AND SHALES***

1. INTRODUCTION

Most wells go through shale formations before reaching productive oil and gas zone. Drilling a wellbore in formations containing water-sensitive shales can cause many serious and expensive drilling problems [1].

Clay hydration causes significant changes in the mechanical properties of rock and can produce technical problems such as instability of wellbore, stuck pipe, solids buildup in the drilling fluid, bottomhole fill, high torque drag. Consequences may be very serious including losing the hole, having to sidetrack, poor cementations because of excessive washouts, inability to log etc.

To avoid mentioned problems we need to reduce hydration, therefore the mud has to be designed to limit hydration of shales [3].

Ones of the the newest solutions are mud fluids with addition of polyglycols. The effectiveness of inhibiting action of such muds is comparable to the dispersed oil based fluids which are expensive and are environmentally unsafe.

2. SHALES AND HYDRATION

Shales are fine grinded sedimentary rocks that contain significant amounts of different clay minerals.

They have been laid down over geologic time in marine basins, and are usually composed of quartz, feldspar, calcite and many clay fractions. The most clay minerals in shales are

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illites, followed in decreasing order by montmorillonites, chlorite and kaolinite. Some clays have very high hydration energies and therefore will absorb and "swell" [1].

Most common water-sensitive clays are montmorillonite and illites, kaolinite and chlorite have no strong swelling tendencies. Clay texture in shales is the result of the compaction process.

Swelling clays are disordered microcrystals of layered aluminosilicates with defect structures.

Each clay layer unit consists of octahedral aluminate layer placed between two tetrahedral silicate layers. The silicate surfaces of the microcrystals have negative charges because of isomorphous substitution in the octahedral and tetrahedral layers [1, 3].

We can divide hydration into two different phenomenon.

Surface hydration is based on the adsorption of water by the inter-packet cations.

Amount of adsorbed water depends on the chemical structure of the clays. For example minerals containing sodium cations have a much higher water adsorption than potassium, calcium or magnesium (Fig. 1b).

Osmotic hydration is the result of osmotic imbalance between the activity of ions in the interlayerspaces of clays, and their activity in the mud – is based on the movement of solvent particles from lower to higher concentration of electrolytes in order to balance the osmotic pressure of electrolytes (Fig. 1c).

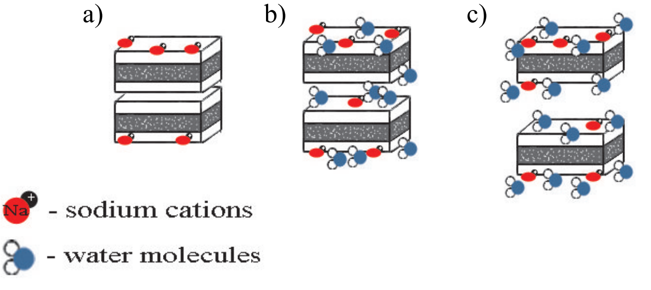

Fig. 1. Shales' hydration process: a) non hydrated clay molecues; b) surface hydration; c) osmotic hydration

3. USED SHALE INHIBITORS

During laboratory investigation we used ingredients which act a shale inhibitors:

- potassium ions (from KCl potassium chloride),
- PHPA – partially hydrolyzed polyacrylamide,
- polyglycol.

In the search for a replacement to oil-based muds the development of water based, inhibitive muds has focused on use of active cations (potassium or calcium) and also on mechanical inhibitors.

This high molecular weight materials physically block the capilary network on the shale surface [2].

To this group we can include PHPA.

In many studies mechanism of PHPA action is called "ecapsulation". This term implies that a given PHPA polymer is large enough to create a net to cover surface of the cutting. The hydrodynamic volume of PHPA is relatively large and may have a tendency to form a netting layer to cover the drill cutting, and isolates clay minerals from water and reduces hydration.

Polyglycols and polyglycerols are oligomeric or polymeric forms of the simple glycols (dihydric alcohols containing two hydroxyl groups) and are members of the general chemical class of polyhydric alcohols. The idea of using glycol as a component of mud fluid isn't new. The first documented use of glycol or glycerol in drilling fluids was by G.E. Cannon in 1940 to control swelling in "heaving shale" [4].

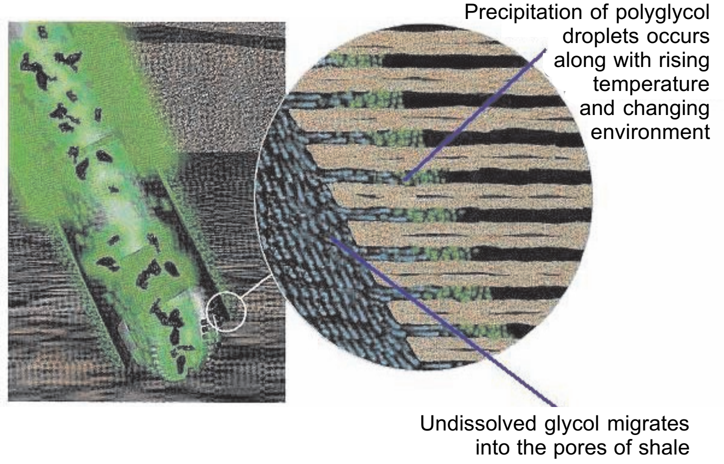

Fig. 2. Polyglycols' inhibition process [4]

Above the Cloud Point Temperature of the polyglycol separates as a relatively viscous, oillike, hydrophobic, water-insoluble, polyglycol-phase which could form a barrier film to stop hydration (Fig. 2).

4. LABORATORY TESTS

The main purpose of the laboratory investigation was to develop an optimal formula of glycol potassium mud fluid. We assumed that our final mud should be characterized by yield point between 20–30 lb/100 ft^2, plastic viscosity as low as possible, API filtration less than 5 ml, density about 1.2 g/cm^3.

During laboratory tests we have tested different concentrations of components in order to achieve parameters close to the established values. In the table 1 we can see some of tested compositions of mud. We can observe differences in rheological parameters between samples (Fig. 3).

Table 1

Compositions of tested mud

Components	Mud II	Mud III	Mud IV	Mud Va	Mud Vb	Mud VI
PAC-UL	0.5%	0.6%	0.4%	0.4%	0.4%	0.4%
PHPA	0%	0.4%	0.4%	0.4%	0.4%	0.4%
PAC-RG	0.5%	0.2%	–	–	–	–
XC-Polymer	0.25%	–	0.3%	0.4%	0.4%	0.4%
Polyglycol	–	–	–	4%	4%	4%
KCl	–	–	–	–	5%	5%
K_2CO_3	–	–	–	–	–	0.021%

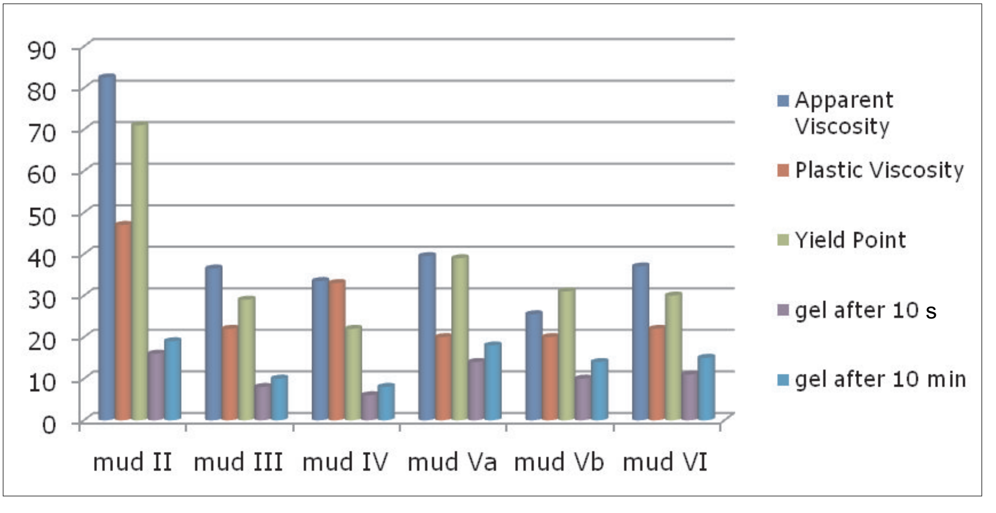

Fig. 3. Rheological parameters of tested mud

After analyzing rheological parameters, mud number VI was selected for further tests.

This mud contains all assumed ingredients, and is characterized by good rheological parameters and high value of gels (after 10 sec and 10 min).

Final composition of drilling fluid:

- PAC UL 0.4%,
- PHPA 0.4%,
- XC-Polymer 0.4%,
- polyglycol 4%,
- weighting agent-Baryte to increase density from base 1.02 to 1.20 g/cm^3 ~ 240 g/l,
- Potassium carbonate K_2CO_3 to increase pH to 8.5–9 (0.21 g/l).

In the figure 4 we can see rheological model (sheer stresses as a function of shear rates) – best correlation achieved with Hershell–Bulkley model.

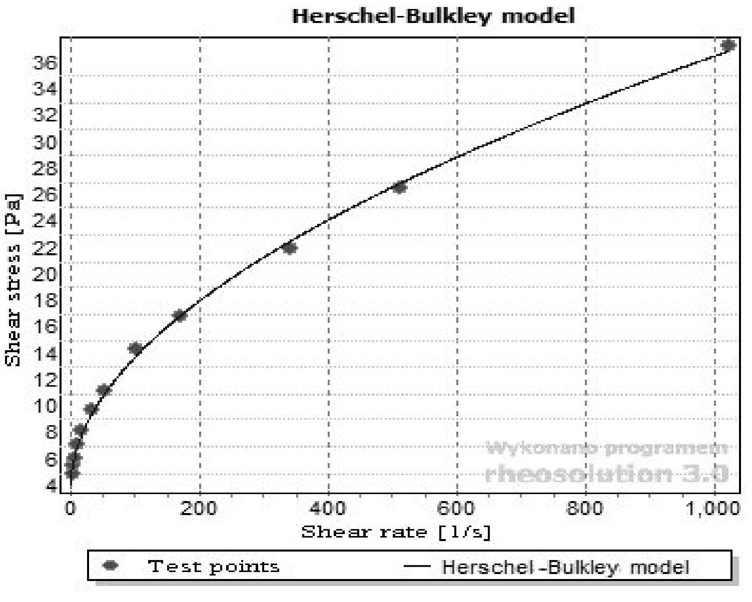

Fig. 4. Rheological model of mud VI

Resistance to high temperature

Drilling fluids works in high temperatures especially on the bottom of the borehole which is the result of a geothermal gradient and process of drilling itself (friction between drill bit and rock may produce much heat. Therefore good drilling fluid should be resistant to elevated temperature.

Rheological parameters of tested mud VI were measured in changing temperature conditions (tested every 20 ^oC beginning with ambient temperature). We have also tested reaction on cooling down the sample after short and long exposure to high temperature (heating in roller oven, for 24 hrs in 90 ^oC). Results of this tests are shown in the figure 5.

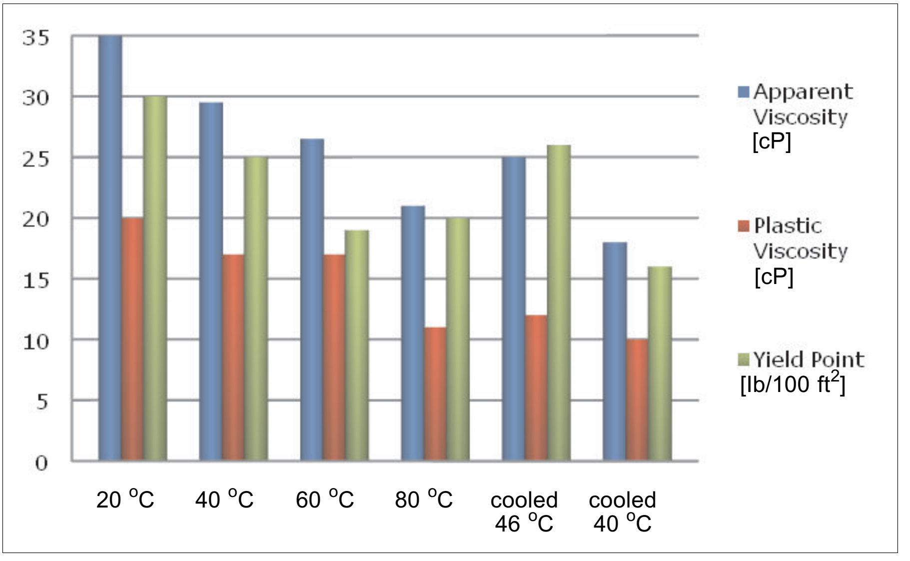

Fig. 5. Resistance of mud VI to temperature

In the diagram we can observe changes of rheological properties of composed mud as the result of temperature rise. In general we can see linear decrease of each parameter, but results received in highest temperature conditions are satisfying. (AV – 21, PV – 11, YP – 20 lb/100 ft^2).

After cooling the sample we have observed partial increase (reconstruction) of rheological parameters (AV – 25, PV – 12, YP – 26 lb/100 ft^2).

After long exposure to high temperature (heating in roller oven, for 24 hrs in 90 ^oC) every observed parameter was decreased (AV – 18, PV – 10, YP – 16 lb/100 ft^2) but acceptable.

In general test confirmed that in reasonable interval of temperature tested mud fluid deals assumed functions.

Resistance to ions

Every mud fluid has to be ion-resistant, because many drilled formation contains ions that can permeate to the mud.

Therefore next test we have run was mud resistance to ions (monovalent and also divalent). In the diagrams we can see changes of rheological properties depending on addition of different bivalent salts and also addition of different amounts of monovalent salt (sodium chloride).

In the figure 6 we can see changes of rheological properties depending on addition of different divalent salts.

Addition of 0.5% of magnesium chloride, 0.5% of calcium chloride and combination of both salts have been tested. In comparison with base mud, addition of each salt (0.5% weight percent) caused slight decline of rheological parameters and also reduction of filtration.

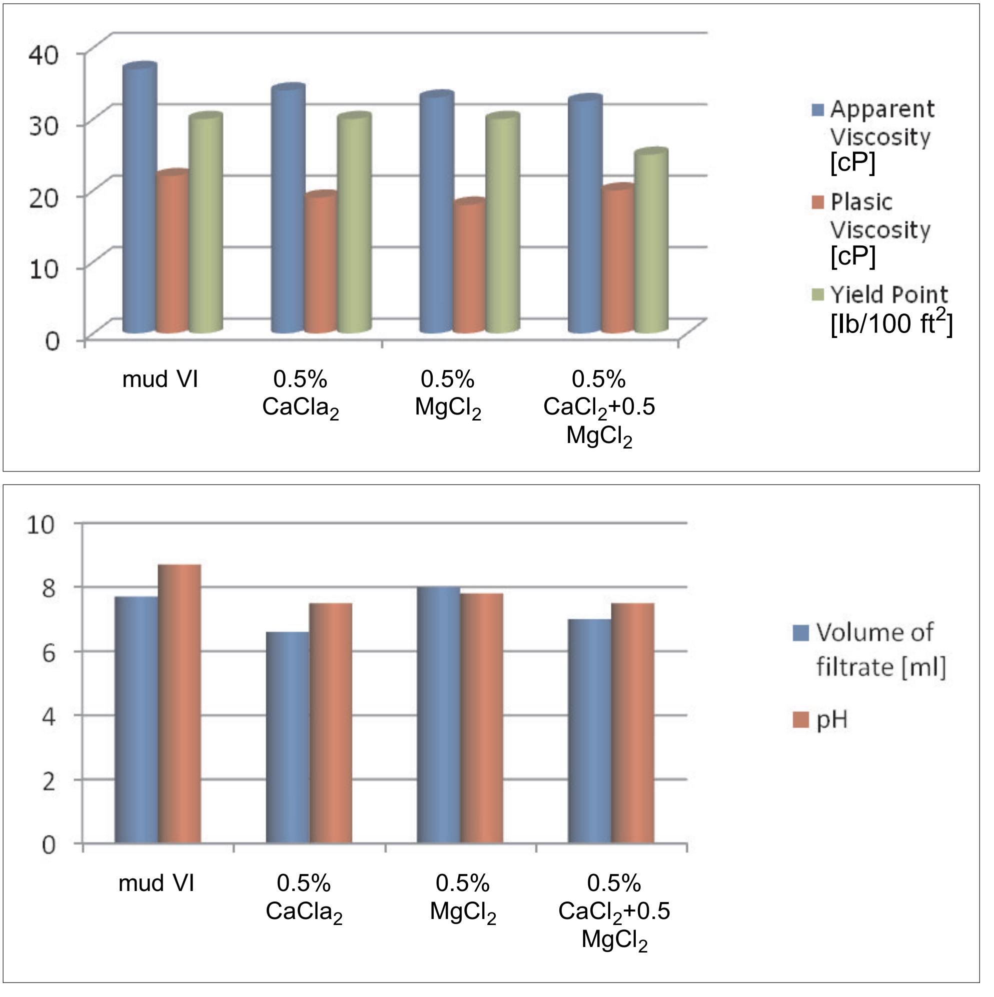

Fig. 6. Resistance of mud VI to bivalent ions

Results of using single salts are similar (figures of AV, PV, YP drops slightly) and simultaneously used salts caused change in value of Yield Point (which increased to 25).

In the diagram 7 we can see results of analogical tests with the use of sodium chloride.

Each sample contains different amount of salt (from 5% to 20%)

Addition of 5% of sodium chloride caused decrease of rheological parameters, in comparison with base mud fluid, but constant increase the amount of salt caused almost linear increase of each parameter (AV, PV, YP) and also slight increase of gels after 10 s and 10 min.

Another diagram shows that increasing quantity of added salt resulted in pH increase and decrease of filtrate volume.

In general addition either monovalent and divalent salts didn't cause significant changes in rheological parameters, and even reduced water loss in tested mud.

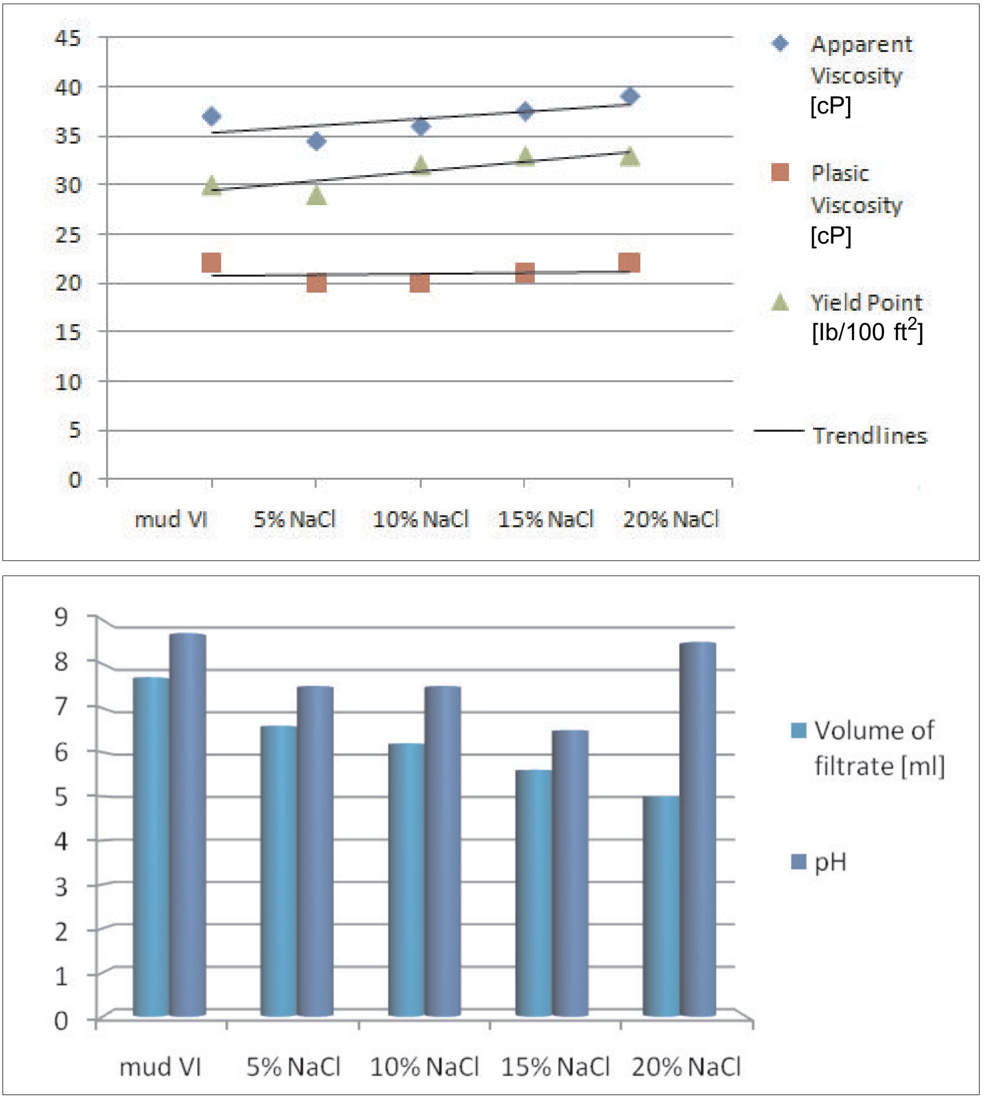

Fig. 7. Resistance of mud VI to monovalent ions

Lubricity

Level of lubricity is another very important feature of good mud fluid. In the process of drilling reducing friction is one of the main functions of drilling fluid. Mud is acting as a lubricant and reduce friction between drilling pipes and wellbore.

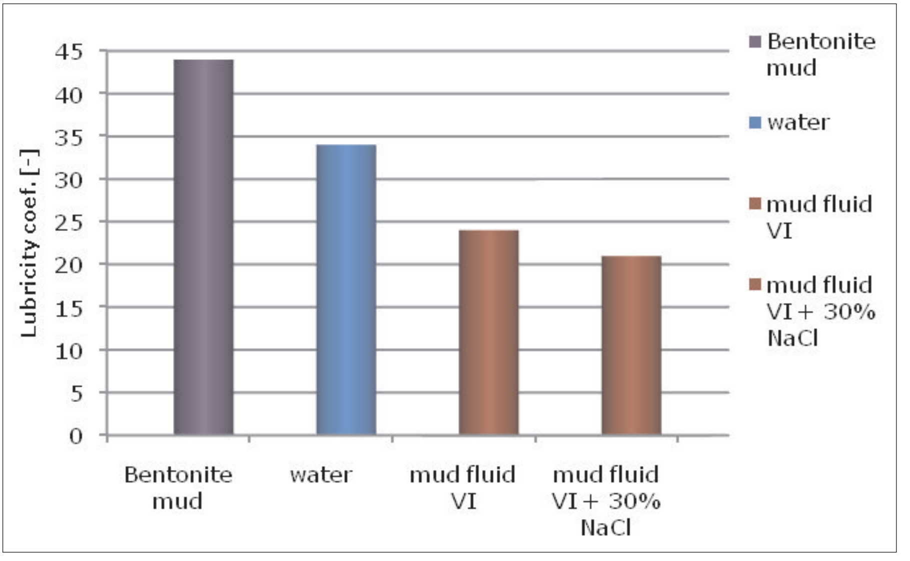

Fig. 8. Lubricity coefficient

Results on lubricity tests are satisfying, base mud fluid VI causes much less friction than simple bentonite mud, and also clear water. Addition of sodium chloride to saturated salinity caused further decline of lubricity level (from 24 for mud VI to 21 for saline mud) (Fig. 8).

5. SUMMARY

Results of laboratory tests confirmed that final mud fluid (nr VI) is characterized by:

- good rheological parameters,
- low filtration – reducing hydration of clays (tested in high temperature, and with presence of ions),
- resistance to high temperature, mono and bivalent ions,
- good lubricity.

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