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The integrated method to select drilling muds for well construction in difficult geological conditions

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Abstract. The article is concerned with the integrated approach to choose drilling mud composition for pay horizons penetration. An optimal choice of drilling mud composition would not only mean ensuring basic fluid properties, but also should minimize the impact on the pay zones when penetrating the pay horizons for the first time. To carry out better assessment of drilling mud impact on pay horizons, it is reasonable to study both technological parameters and filtration analyses, which would allow us to estimate the level of drilling mud impact on the pay horizon.

1. Description of the drilling mud and the experimental data

As it was mentioned above, several types of drilling mud were proposed as initial formulations. The parameters of the obtained drilling muds were studied in terms of thermal stability. The colmatation ability of drilling muds was determined; the return permeability tests under formation conditions were carried out [1, 2].

The following types of drilling muds were considered as the initial formulations:

Polymer mud. Being used at the beginning of the 90-s, this formulation is considered to be obsolete nowadays. Though, it is still widely used due to its relatively low cost. There is a considerable amount of bentonite, which adversely affects the reservoir properties. Thus, while penetrating the pay zone the drilling mud pollutes the bottom-hole zone significantly. It should be noted that large amount of bentonite and solids content increase flow resistance in the circulation [1, 3] It adversely affects not only the colmatation parameter, but also well cleaning and brining the well on to stable production during its development.

Oil-based mud (OBM). Hydrocarbon-based drilling muds have positive properties due to the fact that the liquid phase is diesel fuel, mixed with service water in various proportions to form an emulsion. This emulsion is an inert low density solution.

Along with the inertia, this drilling mud is highly tolerant of contamination (during operating time), so it can be re-used many times after negligible solution treatment. This type of mud being clay-free, it influences positively the reservoir properties while penetrating the pay zone as well as it is less exposed to colmatation by acid insoluble components. [4, 5].

*Biopolymer-carbonate mineralized mud (BCMM).*Being clay-free, this type of mud has a big advantage at the stage of pay zone penetration.

The solid phase of the drilling mud consists of acid soluble colmatation particles, which reduces the required degree of (technological) colmatation of reservoir horizon.

The developed drilling mud formulation has a high ability to inhibit clay deposits. It ensures better factors/conditions to increase penetration rate in the complicated intervals. Bio-polymeric reagents used in the drilling muds degrade if being in situ for a long period after well completion. While well-bore perforation it improves reservoir properties because bio-polymeric reagents lose their original colmatation properties.

To illustrate and prove feasibility of using the proposed drilling mud formulations, thermal stability of drilling muds have been tested [6].

To perform the experiment, 3 time spans, 24, 48 and 72 hours, were used. The timing was based on statistical observations as the common time periods, during which the drilling mud is in the borehole without further processing. The data on thermal stability of the solutions are presented in Tables 1-3.

Table 1. Process parameters of polymer mud after the aging chamber.

Parameters	**units**	**Parameters' values after 24 hours**	**Parameters' values after 48 hours**	**Parameters' values after 72 hours**
Mud density	g/cm^3	1.08	1.08	1.08
Relative viscosity	St	54	46	45
Shearing strength 1/10	pound/100 pounds^2	4/18	4/7	4/6
Water loss by API	cm^3/30 min	6	7	7
Filter cake	mm	0.5-0.7	0.5-0.7	0.5-0.7
Plastic viscosity (PV)	cps	20	16	15
Yield point (YP)	pound/100 pounds^2	16	16.5	18
pH	-	9	9.5	9.5

Table 2. Process parameters of oil-based mud after the aging chamber.

Parameters	**units**	**Parameters' values after 24 hours**	**Parameters' values after 48 hours**	**Parameters' values after 72 hours**
Mud density	g/cm^3	1,08	1,08	1,08
Relative viscosity	St	45	45	45
Shearing strength 1/10	pound/100 pounds^2	4/6	4/6	4/6
Water loss by API	cm^3/30 min	2.1-3	2.1-3	2.1-3
Filter cake	mm	0.5-0.6	0.6-0.7	0.6-0.7
Plastic viscosity (PV)	cps	21	22	21
Yield point (YP)	pound/100 pounds^2	10	10	10

Table 3. Process parameters of biopolymer-carbonate mineralized mud after the aging chamber at temperature of 65 ℃.

Parameters	**units**	**Parameters' values after 24 hours**	**Parameters' values after 48 hours**	**Parameters' values after 72 hours**
Mud density	g/cm^3	1.08	1.08	1.08
Relative viscosity	St	60	52	52
Shearing strength 1/10	pound/100 pounds^2	4/5	4/5	4/5
Water loss by API	cm^3/30 min	5.0	5.0	5.5
Filter cake	mm	0.5	0.5	0.4-0.5
Plastic viscosity (PV)	cps	17	16	16
Yield point (YP)	pound/100 pounds^2	20	18	18
pH	-	9	9	9

The data obtained show that the original formulations have high thermal stability, however, the process parameters of the polymer mud have changed after long staying in the aging chamber. It can be explained by a change in behavior of polymeric additives under high temperature.

2. Filtration study

The next stage of the laboratory research was to determine the colmatation ability of the drilling muds. The filtration studies aimed at assessing the dynamics of core samples permeability exposed to drilling muds were carried out under formation conditions using a laboratory setting PIC-PS.

Schematic diagram of the experiment is shown in Figure 1. With irreducible water saturation, core samples were placed in a core holder of the setting that simulated the conditions similar to downhole environment and confining lithostatic pressure. Kerosene was filtered through the core samples in the "forward" direction (from the formation into the wellbore). When permeability to oil was measured, the tested drilling mud was allowed to flow through the core sample in the “reverse” direction (from the wellbore to the formation) in the mode of dynamic filtering imitating the penetration stage.

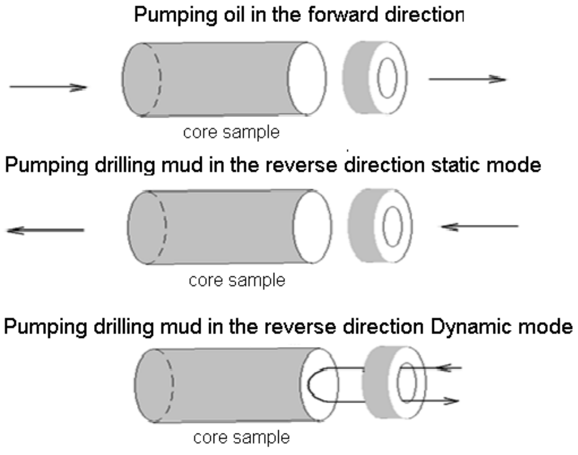

Figure 1. Schematic diagram of the experiment.

The filtration experiment was finished by pumping kerosene again in the “forward” direction to measure core sample permeability to oil before and after contact with the drilling mud. The experiment resulted in calculating the coefficient of return permeability to oil in % (formula 1).

$$K = \frac{K_{oil_1}}{K_{oil_2}} * 100\% \tag{1}$$

where K – coefficient of return permeability to oil of core samples, %; K_{oil_1} – coefficient of return permeability to oil of core samples before contact with drilling mud, mD; K_{oil_2} – coefficient of return permeability to oil of core samples after contact with drilling mud mD.

The composition and basic parameters of the core material used in the laboratory tests are listed in Table 4. The results of the filtration studies are presented in Table 5.

Table 4- Core samples for laboratory analysis.

№	Lithological composition	Permeability, 10^{-3} mcm^2
1	Sandstone, fine-grained, silt, clayey	from 5.237- to 5.851
2	Siltstone light gray with a cream shade, sandy, clayey, micaceous, non-calcareous cemented	
3	Grey sandstone, fine-grained, quartz-feldspar, calcareous cemented, non-layered, homogeneous. Cement clayey.	
4	Sandstone, fine-grained, silt, clayey	
5	Sandstone light gray, fine-grained, silt, clay, cemented, non-calcareous, slightly micaceous. Cement clay	
6	Siltstone light gray with a cream shade, sandy, clayey, micaceous, non-calcareous cemented	
7	Sandstone light gray with a cream shade, fine-grained, slit, clayey, non-calcareous, cemented	
8	Grey sandstone, fine-grained, clayey, quartz-feldspar, non-calcareous, cemented, with inclusions of fossils of flora	from 2.807 – to 2.552
9	Grey sandstone, fine-grained, quartz-feldspar, non-calcareous, cemented, non-layered, homogeneous. Cement clayey.	
10	Grey sandstone with greenish-brown shade, fine-grained, with a mixture of grains of medium-grained fraction, clayey, quartz-feldspar, micaceous, non-calcareous, cemented, patchy weakly-cemented. Cement clayey.	
11	Sandstone light grey, grey, consertal, silty, quartz-feldspar, weakly micaceous, non-calcareous, cemented, non-layered, homogeneous. There is dense packing of the grains and cementless fixation	
12	Grey sandstone, fine-grained, weakly clayey, quartz-feldspar, weakly micaceous, non-calcareous, cemented, non-layered, homogenous. Cement clayey.	

Table 5 - Results of filtration studies.

Experiment	**Interval**	**Drilling mud type**	***K* of permeability, 10^{-3} mcm^2**	***K* of recovery, %**
1	2815.00-2826.20	Polymer mud	75.7337	75.734
2	2816.37-2815.07	BCMM[1]	15.309	61.249
3	2504.0-2509.6	OBM[2]	45.494	41.583
4	2957.70-2970.70	Polymer mud	3.279	66.915
5	2815.0-2834.0	BCMM	8.025	69.238
6	2834.0-2853.0	OBM	182.9	73.356
7	2834.0-2853.0	Polymer mud	160.9	17.1
8	2834.0-2853.0	BCMM	215.461	32.98
9	2834.0-2853.0	OBM	505.449	86.857
10	2853.0-2867.5	Polymer mud	28.678	60.60
11	2853.0-2867.5	BCMM	36.858	93.49
12	2853.0-2867.5	OBM	39.916	108.92

The impact of drilling muds on colmatation of the bottom-hole zone is more obvious shown in Figure 2 (an example of core samples № 1 – 5).

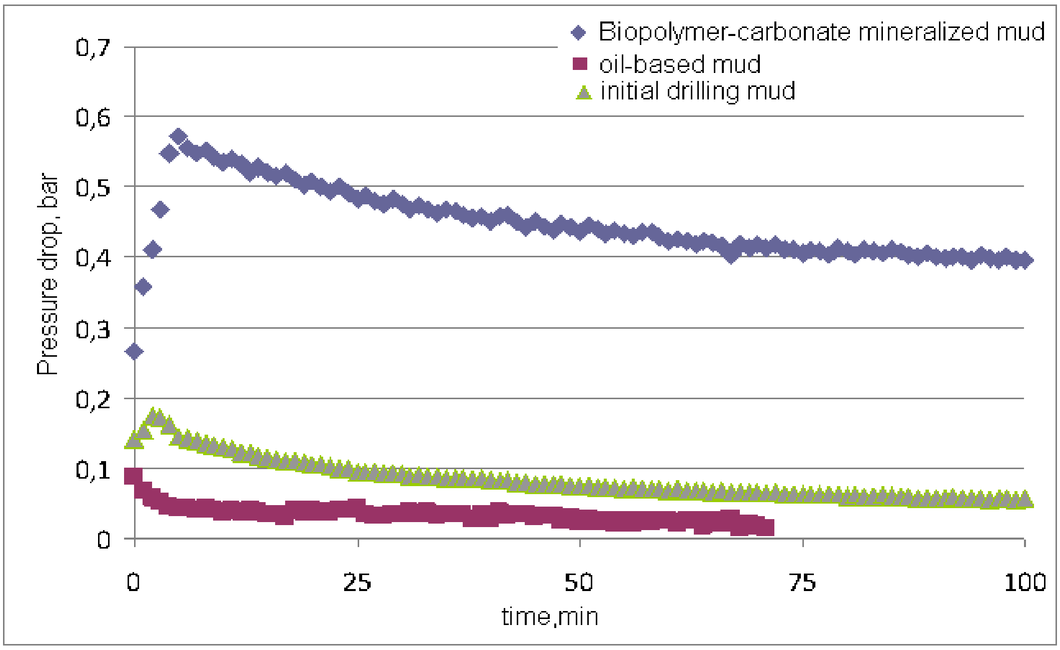

Figure 2. Dynamics of pressure drop while disrupting the crust of drilling muds for samples № 1 – 5.

Filtration study of drilling muds shows advantage of OBM over other drilling mud formulations in terms of coefficient of return permeability. Dependence of the coefficient of different mud formulations return permeability on sample permeability to gas shows strong tends to lower permeability to kerosene (low coefficient of return permiability). It was proved by the study of all drilling muds being filtered through the most permeable core samples. The analysis of oil/water-based drilling muds reveals that application of BCMM in the real condition demonstrates relatively high coefficients of return permeability for all studied suites. The oil-based formulation regularly shows the

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[1] Biopolymer-carbonate mineralized mud

[2] Oil-based mud

best results. This fact can be explained by the minimal impact of filtrate penetrating the sample pore space on phase permeability. Basic polymer mud and biopolymer carbonate mud showed almost equal efficiency.

3. Conclusions

The proposed algorithm of drilling mud formulation selection showed its feasibility and objectivity. It is aimed at minimizing the decrease in permeability. The research was carried out to develop integrated approach to drilling mud formulation selection with regard to particular geological conditions. It proved the method to be reasonable and promising. The method allows us not only to select the required process parameters, but also to evaluate its thermal stability, the degree of colmatation effect and quality of reservoir cleaning after acid treatment.

References

[1] Myslyuk M A and Malygin YU M 2003 O vybore optimal'noy retseptury obrabotki burovogo rastvora *Stroitel'stvo neftyanykh i gazovykh skvazhin na sushe i more* **4** 35 – 38
[2] Lind YU B, Kletter V YU, Akhmatdinov F N and Mulyukov R A 2009 Optimizatsiya sostava burovykh rastvorov i operativnoye upravleniye ikh svoystvami *Neftyanoye khozyaystvo* (M.: VNIIOENG) **5** 90 – 93
[3] Medentsev S, Kretsul V and Kuskov V 2003 «Sildril» rastvor na vodnoy osnove s ingibiruyushchimi sposobnostyami rastvora na uglevodorodnoy osnove *Tekhnologii TEK* **6**. 43 – 44
[4] Gaydarov M M and Rogov Ye A 2010 *Burovoy rastvor na uglevodorodnoy osnove* Patent Rossii № 2388784 Byul № 13
[5] Parshin G YU, Vasil'chenko S V and Ryabtsev P L 2014 Modifikatory reologicheskikh svoystv burovykh rastvorov na uglevodorodnoy osnove *Sovremennyye naukoyemkiye tekhnologii* **2** 103 – 104
[6] Ovchinnikov V P, Aksenova N A, Grosheva T V and Rozhkova O V 2013 *Sovremennyye sostavy burovykh promyvochnykh zhidkostey* (Tyumen': TyumGNGU) p 156