Development of microcalcite-based drilling fluid

R A Ismakov1, T D Dikhtyar2, F N Yangirov1

1 Ufa State Petroleum Technological University, 1, Kosmonavtov St., Ufa, Republic of Bashkortostan, 450062, Russia
2 Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russia

E-mail: ismakovrustem@gmail.com

Abstract. One of the most common hindrances to encounter during the construction of oil and gas wells is lost returns. The methods to select prevention and control measures are based on quantitative criteria that reflect the hydrodynamic capacity and geological structure of the strata. One of the ways to prevent this hindrance during the construction of oil and gas wells is pore-plugging – a sophisticated physicomechanical process to reduce the permeability of a reservoir formation, which takes place over time due to mud filtrates, dispersed particles or specially introduced fillers (plugging additives). For this reason, it seems relevant to use domestic microcalcite, as a component of drilling fluids, from the Minyar field. The paper aims to assess the effect of various microcalcite concentrations on the properties of drilling fluids and to assess as to whether this type of material is effective enough for pore-plugging under the specified drilling conditions.

1. Introduction
Well construction is characterized by drilling operations in permeable absorbing formations, which often entails lost returns. Untimely prevention of this type of hindrances can lead to additional technical and technological measures. Therefore, improved means and methods of handling lost circulation is a very urgent challenge to be addressed in drilling wells [1, 2]. One way to prevent lost circulation is to use plugging additives in the drilling fluid.

In addition, through the use of special complexes of different-sized acid-soluble colmatants in drilling fluids, it is possible to develop a thin impermeable pore-plugging screen in the productive matrix to reduce filtrate ingresses into a reservoir formation and preserve the permeability of the near-wellbore area.

A plugging material that meets the described requirements during drilling operations is a powder based on calcium carbonate (microcalcite). Due to its unique physicochemical properties, microcalcite is a highly demanded mineral filler and the most environmentally friendly material, chemically neutral, non-combustible and has low water absorption.

2. Materials and methods
Mud parameters were determined through instrumental methods according to GOST 33213-2014 (ISO 10414-1: 2008) “Monitoring mud parameters in field conditions. Water Based Solutions.” The effect of plugging additives and drilling filtrates on the change in rock permeability (core sample) in laboratory settings was studied using the device CPMU-1M.

Microcalcite is a finely divided carbonate product, which is obtained by mechanical grinding of...
limestone. This product is made of marble that is highly resistant to mechanical destruction, so, unlike other forms of calcium carbonate, it does not disperse. By its physicochemical properties and characteristics, microcalcite varies favorably from other carbonate fillers [3] in that it:
- is high in calcite;
- has high particle strength;
- has low porosity;
- has low moisture absorption;
- has high solubility in mineral acids.

Table 1 presents the technological parameters of the drilling fluid for drilling a borehole section with a possible complication in the interval 5580–5598 m of well No. 1 at the Tsekertinsky license site.

Table 1. Required technological parameters of the drilling fluid

| Density (kg/m³) | Funnel viscosity (s) | Filtration index (cm³/30min) | pH |
|----------------|---------------------|-----------------------------|----|
| 1220±0.03      | 30–36               | 5–6                         | 10 |

The above section in the upper part is represented by calcareous dolomites, dolomitic limestones, light gray, dense.

The study implied selecting the composition of drilling fluid and assessing the effect of microcalcite of the Minyar open pit on its properties. The following formulation was selected as a source mud composition:

\[ \text{NaOH (0.1 %) + Na₂CO₃ (0.2 %) + PBMA (6 %) + PAC–LV (0.5 %) + PAC–HV (0.2 %) + Lubriol (10 %) + water (balance).} \]

Microcalcite was introduced at a concentration of 50, 100, 150, 200 g/l (5, 10, 15, 20%, respectively):
- experiment No. 1: source solution;
- experiment No. 2: source solution + 5% microcalcite;
- experiment No. 3: source solution + 10% microcalcite;
- experiment No. 4: source solution + 15% microcalcite;
- experiment No. 5: source solution + 20% microcalcite.

The parameters of the above drilling compositions are presented in Table 2.

Table 2. Parameters of microcalcite-based drilling composition

| Experiment No. | Density (kg/m³) | Funnel viscosity (s) | Filtration index (cm³/30min) | Plastic viscosity (MPa·s) | DSS (dPa) | SSS (Pa) | Friction coefficient | pH |
|----------------|-----------------|---------------------|-----------------------------|---------------------------|-----------|----------|---------------------|----|
| 1              | 1210            | 35                  | 5.5                         | 12.4                      | 48.0      | 14/18    | 0.22                | 11 |
| 2              | 1220            | 37                  | 5.0                         | 12.9                      | 50.5      | 12/17    | 0.26                | 11 |
| 3              | 1230            | 34                  | 4.5                         | 13.4                      | 51.3      | 15/19    | 0.31                | 11 |
| 4              | 1240            | 36                  | 4.1                         | 14.3                      | 52.1      | 19/29    | 0.40                | 11 |
| 5              | 1250            | 33                  | 3.8                         | 15.2                      | 52.8      | 22/31    | 0.48                | 11 |

Due to the higher microcalcite grade in the drilling formulation, as the above table indicates, its density, plastic viscosity, static and dynamic shear stress, and friction coefficient of a mud cake increase. An increased amount of microcalcite introduced leads to a decrease in the filtration rate of the drilling fluid.

The pore-plugging capacity of drilling fluids that contain various microcalcite concentrations was further evaluated through the study of its granularity. The results are presented in Figure 1.
Figure 1. Microcalcite granularity

A fractional pore-plugging substance selected to constitute the drilling fluid will not only reduce lost circulation, but also reduce the rate of filtrate and solid ingresses into the pores and channels of a reservoir. With a view to preserving some reservoir properties, various options are proposed, namely: draw-down or over-balance drilling, high-quality drilling fluids with minimal negative impact on the reservoir properties [4–9], and pore-plugging. Therefore, the next, and most important stage, was the analysis of core samples taken in the interval 5580–5598 m along with an assessment of the effectiveness of the pore-plugging capacity of microcalcite from the Minyar site. A modified installation CPMU-1M was used to study the laws of liquid and gas filtration in a porous medium under the conditions close to the real reservoirs. The dimensions of target core samples were: diameter – 30 mm, height – 50 mm.

Based on the core filtration results (studied drilling compositions), the permeability coefficients of core samples were determined in accordance with the Darcy’s linear law before and after being exposed to fluid filtrate. The return permeability coefficient was calculated by the formula:

$$\beta_1 = \frac{k_1}{k_0} \times 100\%,$$

where $\beta$ is the return permeability coefficient; $k_1, k_0$ are the core permeability for oil before and after drilling fluid being introduced into the core, respectively.

The findings are presented in Table 3 and in Figure 2.

Table 3. Core return permeability coefficient

| Sample No. | Core flow rates | Pressure liquid rate | Permeability before $c_b$ (mD) | Permeability after $c_s$ (mD) | Return permeability coefficient, % |
|------------|-----------------|----------------------|---------------------------------|-------------------------------|-----------------------------------|
|            | time (s)        | volume (m$^3$)       | Q $10^{-7}$ (m$^3$/s)           |                               |                                   |
| 1          | 30              | 0.0000103            | 3.42                            | 56                            | 41.0                              | 73.2                             |
| 2          | 30              | 0.0000095            | 3.17                            | 56                            | 21.4                              | 38.2                             |
| 3          | 30              | 0.0000107            | 3.57                            | 56                            | 12.45                             | 22.2                             |
| 4          | 30              | 0.0000161            | 5.36                            | 56                            | 9.58                              | 17.1                             |
| 5          | 30              | 0.0000154            | 5.13                            | 56                            | 4.87                              | 8.7                              |
Figure 2. Varying core permeability depending on the type of drilling fluid: respectively, before ($c_b$) and after ($c_a$) filtration of the drilling fluid

The permeability of the core samples is reduced when any of the five drilling compositions examined is applied.

3. Results and discussion
The experimental results show the following. Microcalcite is compatible with drilling fluid, but once it increases in the formulation, the density and rheological parameters go up, while the filtration rate of the drilling fluid goes down. An increased friction coefficient of the mud cake produced by the drilling fluid implies a decreased lubricating effect and possible hindrances during drilling operations.

A decrease in the permeability of samples after being exposed to the studied drilling formulations indicates that the microcalcite available in their composition creates a pore-plugging screen in the core. In this respect, the most effective is the fluid with a content of 20% microcalcite (formulation No. 5), since it provides the most significant reduction in core permeability, but, based on geological conditions, the applicability of this formulation is not possible due to the excess of the required density.

The drilling fluid with a content of 5% microcalcite (formulation No. 2) is the most optimal for the initially set geological conditions. Once applied, it reduces the target core permeability and is acceptable for the density required for advancing said density range.

4. Conclusion
One of the ways to prevent lost returns to encounter during the construction of oil and gas wells is the use of pore-plugging additives in drilling fluids. It seems relevant to use a highly resistant to mechanical destruction, non-dispersible, acid-soluble microcalcite of the Minyarsky deposit. Due to the greater microcalcite grade in the drilling fluid, the density, plastic viscosity index, friction coefficient of a mud cake increase, whereas the filtration index decreases. The studies conducted on a modified installation CPMU-1M showed that the most optimal for the geological conditions initially set is the drilling fluid with a content of 5% microcalcite (formulation No. 2), which reduces the permeability of the test core and has the density necessary for advancing said density range.

References
[1] Polyakov V N, Chizhov A P, Kotenev Yu A and Mukhametshin V Sh 2019 Results of System Drilling Techniques and Completion of Oil and Gas Wells IOP Conference Series: Earth and Environmental Science (IPDME 2019 – International Workshop on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering) 378(1) 012119 1–7 DOI:
[2] Teptereva G A, Konesev G V, Ismakov R A, Kantor E A and Dikhtyar T D 2017 Obtaining drill reagents by modification of neutral sulphite alkali phosphonic compounds *Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering* **328**(9) 94-101

[3] Vagizov D I 2017 Fractional analysis of the natural microcalcite of the minyar quarry as a colmatating additive in the drilling washing liquid *Young researcher: challenges and prospects: collection of articles based on the materials of the 1 International scientific and practical conference* **25**(50)

[4] Petrov N A and Konesev G V 2017 Research of polymer reagent "gabrose" for use in drilling solutions *Oil and Gas Business* **15**(1) 53-57

[5] Khokhlov V I, Galimov Sh S, Devyatkova S G, Kotenev Yu A, Sultanov Sh Kh and Mukhametshin V Sh 2019 Justification of impact and planning of technology efficiency on the basis of limy-emulsion formulation in low-permeability highly-rugged reservoirs of Tyumen deposits *IOP Conference Series: Earth and Environmental Science (IPDME 2019 – International Workshop on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering)*** **378**(1) 012114 1–6 DOI: 10.1088/1755-1315/378/1/012114

[6] Yangirov F N, Yakhin A R, Dikhtyar T D, Loginova M E, Chudnovskaya A V and Shmagel M A 2018 Investigation of surfactants applicable in well drilling *Problems of Gathering, Treatment and Transportation of oil and oil products* **1**(11) 61-68

[7] Yangirov F N, Yakhin A R, Mustafin T S and Dikhtyar T D 2018 Substantiation of lubricant selection for drilling technology *Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering* **329**(1) 51-58

[8] Akhmetov R T, Mukhametshin V V, Andreev A V and Sultanov Sh Kh 2017 Some Testing Results of Productive Strata Wettability Index Forecasting Technique *SOCAR Proceedings* **4** 83–87 DOI: 10.5510/OGP20170400334

[9] Dick M A, Heinz T J, Svoboda C F and Aston M 2000 Optimizing the Selection of Bridging Particles for Reservoir Drilling Fluids *SPE International Symposium on Formation Damage Control, 23-24 February, Lafayette, Louisiana* 1-8