Use of low-mineralized water for displacing oil from clay productive field formations

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Abstract. The X-ray structural analysis of clay cement composition in the Jurassic sediments of the Shaim oil and gas region of Western Siberia carried out before and after the experiments identified that qualitative and quantitative clay cement composition does not change, i.e. water of the aquifer interacting with the fine rock component does not affect the injection process. Slight swelling of clay minerals does not decrease permeability due to the small amount of minerals with a moving crystal lattice. It was established that formation water does not cause swelling of clay rocks, i.e. it does not have a negative effect on the injection process. Decreasing permeability is due to the deposition of salts clogging filtration channels.

1. Introduction

Oil deposits confined to the Jurassic deposits of the Shaim oil and gas bearing area (OGBA) of Western Siberia are characterized by low output. The analysis of causes of formation of zones with residual oil showed that the geological structure influence the oil production. The fields are characterized by developed discontinuous violations which have a high amplitude or no amplitude. Complicating factors also include low permeability of reservoirs composing the layers of the reservoir (less than 0.005 μm²), as well as low productivity of wells (oil flow rates vary from 1 to 5 tons per day, taking into account intensification of the reservoir). In addition, productive layers of the Jurassic age are characterized by high clay content. Productive layers are characterized by high vertical and lateral dissection complicating development and selection of geological and technical measures aimed at increasing oil production. In order to increase profitability and oil production, numerous perforation and IPF works were carried out.

The analysis of the energy state of productive layers of the Middle Jurassic sediments indicates its significant “imbalance” which involves significant differences in reservoir pressure values. In some fields, the reservoir pressure varies from 12.5 to 23.2 MPa, the average pressure is 19 MPa. It differs from the initial one by 2.3 MPa. There are zones with insufficient injection and PRM efficiency. There
are zones with high reservoir pressure. The studies on the interference of wells by statistical methods and tracer studies showed a poor relationship between injection and production wells [1–5].

Efficiency of reservoir pressure and oil displacement by the working agent can be improved by choosing the proper type of injected water. High clay formation, including the presence of clay cement in the reservoirs, requires experimental justification when choosing a working agent for the system maintaining reservoir pressure and efficient oil displacement.

Interaction of the injected water and the clay component of the reservoir can cause the following problems: clay minerals swell and detach from detrital grains; then they are involved in the flow and clog filtration channels. These processes deteriorate filtration-capacitive properties of the rock by narrowing pore channels, clogging pores, increasing non-effective porosity which causes formation of residual oil reserves. Interaction of water with the surface of clay particles is due to crystal chemical characteristics of minerals [6–9].

In order to reduce the risk of deterioration of reservoir properties, saline water is used as a working agent. However, the use of formation water is more technological. This water is difficult to use due to its low mineralization.

2. Methods and materials
The influence of low-mineralized water of aquifers and formation water on the swelling of the reservoir rocks of the Middle Jurassic age in the Shaaim oil and gas bearing area was studied taking into account changes in the qualitative and quantitative composition of the fine-dispersed component and changes in cation exchange capacity in core samples included in the experimental models [9–14].

Formation water provided for the experiment has a mineralization value of 10286.7 mg / dm³, a density value of 1.0061 g / cm³, and a pH value of 8.10. The sample of aquifer water has the following values: mineralization - 101.9 mg / dm³, density - 0.9986 g / cm³, pH - 6.42.

In terms of lithology, rock samples included in the models are fine-grained, aleuritic, pelitist and aleurolite sandstones, fine-grained, sandy, pelitist, unevenly low carbonaceous sandstones. According to the data of particle size analysis and petrographic description of thin sections, the total content of the clay component varies from 18 to 25%.

3. Results and discussion
According to the results of the X-ray structural analysis of clay cement composition before and after the experiments, the qualitative and quantitative composition of clay cement in the productive reservoir does not change, or slightly changes (Table 1).

As can be seen from Table 1, there are insignificant quantitative changes in the clay cement of models No. 1, No. 2, and No. 3; it is not possible to identify any general change patterns.

According to Table 1, the number of minerals characterized by the greatest ability to swell, namely, the group of hydromica minerals before and after the experiments varies slightly. In some samples, it remains completely unchanged. Their total content is not more than 7% of the rock volume. According to the study of the cation exchange capacity (CEC), it is possible to assume that low mineralized water influences the volume of the fine component of the reservoir rocks. It is confirmed by CEC changes from 10–12 mg eq / 100 g before the experiment up to 12 –18 mg · eq / 100 g after the experiment.

This fact indicates the presence of ion-exchange reactions between the rock and water of the aquifer, but due to the small number of swelling components in the cement, they do not adversely affect the filtration-capacitive characteristics.

The results of X-ray structural analysis of the clay cement composition and studies of cation exchange capacity (CEC) for core samples before and after the experiments using formation water are presented in Table 2.

As can be seen from Table 2, there are insignificant quantitative changes in the clay cement composition in models No. 4 and 6 and insignificant quantitative changes in the clay cement composition in models No. 1, 2, 3.
Table 1. Results of the X-ray structural analysis of clay cement composition and studies on the cation exchange capacity for core samples before and after the experiments (low mineralized water of the aquifer).

| No. of the model | No. of the sample | Composition of clay cement, % | Cation exchange capacity (CEC) (mg · eq / 100 g) |
|------------------|-------------------|-------------------------------|-----------------------------------------------|
|                  |                   | Kaolinite Chlorite Hydro-mica mineral group | Kaolinite Chlorite Hydro-mica mineral group |
|                  |                   | Before the experiment | After the experiment | Before the experiment | After the experiment |
| 1                | 1                 | 63 17 20 | 65 14 21 | 10-12 | 12-18 |
| 2                | 78 14 8 | 82 9 9 | 77 12 11 | 11 |
| 3                | 1                 | 83 10 7 | 83 10 7 | 12 |
| 2                | 59 14 27 | 67 11 22 | 79 8 13 | 13 |
| 3                | 84 6 10 | 80 10 10 | 10 |

Table 2. Results of the X-ray structural analysis of clay cement composition and studies on the cation exchange capacity for core samples before and after the experiments (produced water).

| No of the model | No of the sample | Composition of clay cement, % | Cation exchange capacity (CEC) (mg · eq / 100 g) |
|------------------|-------------------|-------------------------------|-----------------------------------------------|
|                  |                   | Kaolinite Chlorite Hydro-mica mineral group | Kaolinite Chlorite Hydro-mica mineral group |
|                  |                   | Before the experiment | After the experiment | Before the experiment | After the experiment |
| 4                | 1                 | 65 15 20 | 66 12 22 | 10-12 | 12-14 |
| 2                | 81 11 8 | 78 12 10 | 10 |
| 3                | 81 11 8 | The sample is completely destroyed after the experiments. | |
| 5                | 1                 | Studies were not conducted due to disintegration (complete destruction) of the samples after the experiments. | 10-12 | 12-14 |
| 2                | 78 11 11 | 80 9 11 | 11 |
| 3                | 78 11 11 | 77 12 11 | 11 |

According to Table 2, the amount of minerals characterized by the greatest ability to swell, namely, the group of hydromica minerals before and after the experiments and the number of all other minerals varies slightly, within the permissible error of the method. In some samples it remains unchanged and does not exceed 7% of the rock volume.

The results of the X-ray structural analysis before and after the experiments suggest that formation water interacting with the rocks of the productive layer of the deposit does not have a significant effect on the clay component, i.e., it does not wash away clay particles from the cement. In addition, high
water mineralization and low content of minerals with a moving crystal lattice prevent the rocks from intensive swelling.

The results of measurements of the cation exchange capacity before and after the experiments indicate the presence of slight interaction between the rock and water. The cation exchange capacity varies from 10–12 mg · eq / 100 g to 12–14 mg eq / 100 g, respectively.

However, the results of the experimental studies show that permeability was deteriorated by the effect of formation water on the rock.

Pore channels can be clogged as a result of the action of the clay factor of rocks, namely the process of swelling of clay minerals, disaggregation, separation of particles of clay minerals from the surface of detrital grains. The research results showed that this is not the cause of pore channels clogging.

4. Conclusion
The following conclusions can be drawn:
- water of the aquifer interacting with the fine clay component of the rocks of the productive deposit formation of the field does not affect the injection process. Fixed slight swelling of clay minerals does not decrease permeability due to the small amount of minerals in the rock with a moving crystal lattice;
- formation water does not cause the swelling of clay minerals in the rocks of the productive field formation, i.e. it does not affect the injection process. Decreasing permeability is due to precipitation of salts clogging filtration channels.

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