Laboratory evaluation of desalted water influence on properties of Priobskoe oil field`s clay-containing reservoir

Pavel Gladkov [1], Aleksander Valerevich Maksyutin [1] and Igor Borshchev [2]

[1]Federal State Budgetary Educational Institution of Higher Professional Education "National Mineral Resources University "Mining". 199106, Russia, Saint-Petersburg, Vasilievskiy ostrov, 21-st line, 2.
[2]St.-Petersburg State Polytechnical University, 195251, St.-Petersburg, 29 Polytechnicheskaya St., St.-Petersburg, Russia

Abstract. Problems of desalted water and low-permeable clay-containing Priobskoe oil field matrix interaction are considered in the paper. In order to understand and study processess in in-situ conditions several experiments were conducted among them electronic-microscopic research of core sample slides, filtration experiments of injection of water with different ions content, filtration experiment for displacement coefficient determination. Conclusions about desalted water effect on core sample permeability and final oil saturation are shown.

[Gladkov P., Maksyutin A.V., Borshchev I. **Laboratory evaluation of desalted water influence on properties of Priobskoe oil field`s clay-containing reservoir** *Life Sci J* 2014;11(11s):317-319-] (ISSN:1097-8135). http://www.lifesciencesite.com. 72.

Keywords: Clay-containing reservoir, low permeability, kaolinite, hydration, filtration, water flooding

Introduction

Priobskoe oil field is considered to be a unique one according to its size and oil geological reserves. Main oil accumulations associated with AS10 and AS12 horizons that characterized by high lithologic and facies variation and low porosity and permeability (average permeability k_{perm}=6 mD) and are like alternation of sandstones, siltstones and clays. Seven-point flooding system and other workover operations are to provide final oil recovery factor 0,3 on south licensing territory where JSC "Gaspromneft-Khantos" is an operator.

Applying of areal modification of flooding exploitation system on the oil deposit that is complicated by reservoir low permeability is easily explaining by positive results that were obtained while using this system on less complicated objects. However it is necessary to have a scientific approach to make this exploitation system efficient, and particularly while oil displacement fluid selection.

Problems of injection water and oil reservoir clay fractions interaction had raised since the very moment when artificial flooding systems were used while oil deposit exploitation. Clay particles referred to granular deposits specific components and determine its permeability and porosity [1].

It is widely known that while interaction with water two layers form around the clay mineral particle: adsorptive and diffusive. Diffusive layer can modify its thickness depending on water mineralization and its saturation of different cations. When fluid where monovalent cations prevail (like K^+, Na^+) influences on the clay particle diffusive layer thickness increases. On the other hand fluid where polyvalent cations prevail (like Ca^{2+}, Mg^{2+}, Al^{3+}) will lead to decreasing of the layer. Thick diffusive layer means that some clay particles will transfer to fluid and produce suspension. It makes favorable conditions for active hydration of clays and thus permeability reduction of clay containing reservoir [2].

Nevertheless in literature there is no single opinion about influence of injection water mineralization on oil deposit exploitation technological efficiency [3,4,5,6,7]. Particulary in paper [8] it is written that clay hydration may cause both negative effect on permeability of rocks and positive effect on waterflood displacement factor.

Materials and methods

In order to give impersonal view to the processes that take place while interaction of water and rock in the Laboratory of Enhanced Oil Recovery of National Mineral Resources University "Mining" experiments using natural core samples of Priobskoe oil field were carried out.

Data of producing rocks mineral composition were obtained by means of core samples slices electronic-microscopic researches. As a result it was obtained that the rock refers to polymineral sandstones with following mineral content: quartz – 50-54%, potassium feldspar – 18-20%, plagioclase – 15%, biotite – 4-5%. Cement is clayish, kaolinite type (app. 55%), content in rock vary from 8 to 13%, cementing type – contact.

Two series of filtration experiments were carried out in order to estimate formation damage while filtration of various mineralized water and obtain its oil displacement capacity.

First series included researches of determination of water mineralization gradual lowering influence on water permeability of natural core samples. Initially core sample was saturated with oil filed water model reproduced by three components ($CaCl_2$, NaCl, $MgCl_2$) with general mineralization 18.9 grams per liter. Then water permeability was measured (fig.1, curve 1). After that through the sample desalted waters with following mineralizations were injected: 15.4 grams per liter (fig.1, curve 2), 11 grams per liter (fig.1, curve 3), 9,5 grams per liter (fig.1, curve 4), 5.7 grams per liter (fig.1, curve 5), 0.25 grams per liter (fig.1, curve 6). During the experiment water injection rate was constant and water injection pressure gradient was observed.

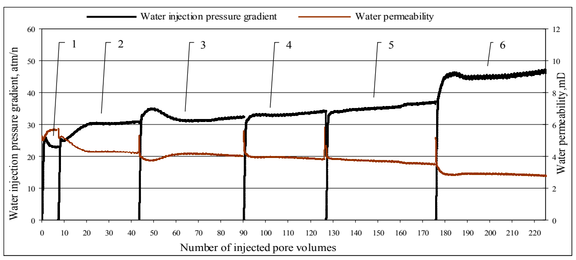

Fig. 1. Pressure gradient and core sample water permeability curves while gradual water injection (flowrate Q=const=0.5cm^3/min).
1 – oil field water model filtration, 2 – water filtration (15.4g/l), 3 – water filtration (11g/l), 4 – water filtration (9.5g/l), 5 – water filtration (5.7g/l), 6 – water filtration (0.25g/l).

Continuous increase of water injection pressure gradient may be caused both by small particles presented in injected water or by clay minerals hydration process (kaolinite, hydromica).

Therefore an extra experiment of determination of mineralization repeated alteration influence on core sample`s water permeability was conducted.

Initially studied core sample was saturated with the oil field water model and then water permeability was measured (Fig.2, curve 1). Then fresh water (mineralization 0.25 g/l) was filtrated through the core sample (Fig.2, curve 2) and after that treated core sample was placed into a container filled with oil field water model and set to thermostat in the field condition`s temperature for 5 days. At the end of the period field water model was filtrated again (Fig.2, curve 3) with fresh water following (Fig.2, curve 4).

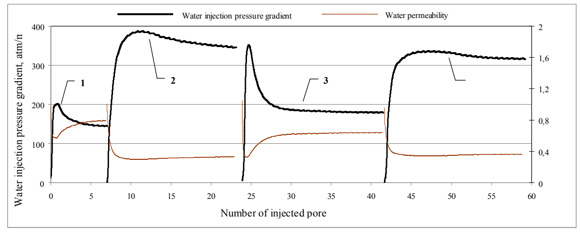

Fig. 2. Pressure gradient and core sample water permeability curves while water injection (flowrate is constant, 0.5cm^3/min).
1 – oil field water model filtration, 2 – fresh water filtration, 3 – oil field water model filtration (5 days later), 4 – fresh water filtration (5 days later)

Oil recovery factors while injecting water of different mineralization were obtained during carrying out the second series of a filtration experiments. The investigations were conducted on natural core samples with degassed oil of Priobskoe field in close to in-situ conditions. The results of the experiment are shown on figure 3.

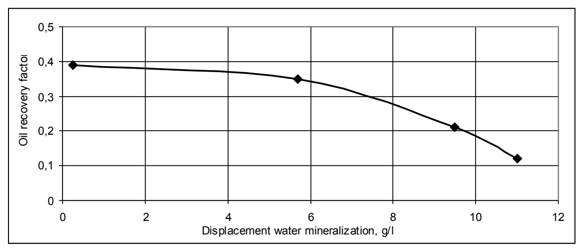

Fig.3. Oil recovery factor and displacement water mineralization's correlation (core sample`s permeability is 5 mD)

Results and discussion

Results of the first filtration experiment showed that reduction of injection water mineralization is accompanied by rise of water injection gradient pressure or according to Darcy`s law by reduction of permeability of core sample. More than that when injection desalted waters (fig.1, curves 2-6) it was noticed that pressure gradient rosen from 6 to 9% on each 10 filtrated pore volumes. Formation damage statistic data was estimated and given in Table 1.

In paper [9] it is mentioned that kaolinite has relatively high ion-exchange capacity so it hydrates in water and increases its volume on 20%. That is why in porous media where filtration channels are very small hydration of contact cement may significantly diminish its diameter and lower rock permeability.

Table 1. Priobskoe oil field water permeability decrease while desalted water injection

Water mineralization, g/l	18.9	15.4	11.0	9.5	5.7	0.25
Rate of water permeability decrease (on $10V_{pore}$), %	0	6	6.1	6.2	8,4	9.5

According to figure 2 water injection pressure gradient significantly grows while fresh water filtration so it means that water permeability of core sample decreases. After holding sample under field temperature conditions and following water model filtration was followed pressure gradient dramatically surged till fresh water injection level was observed. This behavior can be explained by residual fresh water displacement and its replacement by field water model. Further mineralized water filtration leads to water injection pressure gradient smooth decreasing till initial mineralized water pressure gradient. After that fresh water injection was repeated and as a result pressure gradient sharply increased again. There is an idea that increasing of water injection pressure gradient is connected with permeable channels` colmatation by rock particles that had come off the rock during filtration. However in this case pressure gradient curve is to increase while total filtrated volume is increasing. According to figure 2 curves 2 and 4 are falling thus degradation of core sample filtration property is caused by clay cement particles hydration but not the permeable channels colmatation.

According to the results of the second filtration experiment (displacement experiment) the highest oil recovery factor was obtained when using fresh water as a displacement fluid [10]. It can be associated with shifting of phase mobility ratio to advantageous direction due to core permeability decreasing in water saturated zone and increasing of water density. Influence of these factors is also considered in the paper [2].

Surface phenomena investigations namely surface tension on oil-water contact were also conducted. Experiments were conducted according to the anchor-ring and pendant drop methods in room conditions. It was determined that surface tension changes slightly while reduction of water mineralization from 18.9g/l to 0.25 g/l. This is the reason why influence of surface tension on final oil saturation is insignificant.

Corresponding Author:
Dr.Gladkov Pavel
Federal State Budgetary Educational Institution of Higher Professional Education
"National Mineral Resources University "Mining"
21-st line, 2, Vasilievskiy ostrov, Saint-Petersburg, 199106, Russia

References

1. Zheltov, Yu.V., V.E. Stupochenko, A.Ya. Khavkin, V.N. Martos, V.N. Rizhik, 1981. Some peculiarities of clay-containing oil reservoirs flooding. Oil industry, #7: 42-47.
2. Abizbaev, I.I., A.Sh. Sirtlanov, P.F. Viktorov and E.V. Lozin, 1994. Problematic resources of oil reservoirs` exploitation in Bashkortostan. «Kitap», pp: 180.
3. Slobod Robert L., 1969. Restoring Permeability to Clay-Containing Water Damaged Formations. In the Fall Meeting of the SPE of AIME, 28 September-1 October 1969, Denver, Colorado.
4. Economides, M. J. and Kenneth G.Nolte, 2000. Reservoir stimulation. John Wiley &Sons Ltd, pp: 854.
5. H.C.Slider, 1983. Worldwide practical petroleum reservoir engineering methods. PennWell Publishing company, pp: 849.
6. Agbalaka, C.C., A.Y. Dandekar, S.L. Patil, S. Khataniar and J.R. Hemsath, 2009. Coreflooding studies to evaluate the impact of salinity and wettability on oil recovery efficiency. Transport in Porous Media, 76 (1): 77-94
7. Morrow, N. and J. Buckley, 2011. Improved oil recovery by low-salinity waterflooding. Journal of Petroleum Technology, 63, pp: 106-113.
8. Babalyan, G.A., 1974. Physical-chemical processes in oil production. Nedra, pp: 200.
9. Sidorovskiy, V.A., 1978. Well completion and stimulation.Nedra, pp: 256.
10. Bernard George G., 1967. Effect of Floodwater Salinity on Recovery Of Oil from Cores Containing Clays. In the SPE California Regional Meeting, 26-27 October 1967, Los Angeles, California.

7/4/2014