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INVESTIGATION OF THE EFFECT OF SEAWATER INJECTION ON OIL DISPLACEMENT FROM CARBONATE ROCK (ON THE EXAMPLE OF A FIELD IN KAZAKHSTAN)

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Abstract: *Increasing oil recovery is one of the most pressing issues today. Since the last century, scientists have been actively researching to enhance oil recovery. A huge number of scientists have turned their attention to this issue by using low-mineralized water (LMW). Thus, since the 90s, both theoretical and experimental research has been actively studied. Increased oil recovery depends on rock wettability and surface tension. This approach was key to a significant amount of experimental work. But, despite a lot of research, scientists still have not come to a consensus on the mechanisms that contribute to increased oil recovery. One of the main mechanisms is considered to be the movement of fine particles (i.e., clay particles) during flooding with low-mineralized water (LMW). As shown by the study of the topic of LMW, experimental work was often carried out on light oil. Experimental work with light oil has been positive. However, the interaction of the LMW with high-viscosity oil has not been deeply studied, which is relevant to the fields of Kazakhstan.*

Key words: *hydrophilic rock, hydrophobic rock, wettability, mineralized water, oil recovery, high-viscosity oil*

ТЕҢІЗ СУЫН АЙДАУ АРҚЫЛЫ КАРБОНАТТЫ ЖЫНЫСТАРДАН МҰНАЙДЫҢ ЫҒЫСУЫНА ӘСЕРІН ЗЕРТТЕУ (ҚАЗАҚСТАН КЕН ОРНЫ МЫСАЛЫНДА)

Аңдатпа: *Мұнай өндіруді негұрлым қолайлы шарттарда арттыру – қазіргі кездегі өзекті мәселелердің бірі. Өткен ғасырдан бастап ғалымдар мұнай өндіруді күшейту үшін белсенді зерттеулер жүргізіп келеді. Көптеген ғалымдар бұл мәселеге теңіз суды (ТС) пайдалану арқылы назар аударды. Сонымен мұнай өндірудің жоғарылауы тау жыныстарының сулануы мен беткі керілуіне байланысты, 90-жылдардан бастап теориялық және эксперименттік зерттеулер белсенді түрде зерттелді. Осы тәсіл эксперименттік жұмыстың едәуір көлемінің кілті болды. Бірақ көптеген зерттеулерге қарамастан, ғалымдар мұнай өндірудің артуына ықпал ететін тетіктер туралы әлі де бір шешімге келе алмады. Негізгі тетіктердің бірі – тұздылығы төмен сумен толтырылған кезде ұсақ бөлшектердің (яғни саз бөлшектерінің) қозғалысы деп саналады. ТС тақырыбын зерттеу көрсеткендей, эксперименттік жұмыстар көбінесе ашық мұнайға жүргізілді, өйткені жеңіл маймен эксперименттік жұмыс оң нәтиже берді. Алайда ТС-нің тұтқырлығы жоғары мұнаймен өзара әрекеттесуі терең зерттелмеген бұл Қазақстанның кен орындары үшін өте маңызды..*

Түйінді сөздер: *гидрофильді тау жынысы, гидрофобты тау жынысы, сулану, минералданған су, мұнай өндіру, тұтқырлығы жоғары мұнай*

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ЗАКАЧКИ МОРСКОЙ ВОДЫ НА ВЫТЕСНЕНИЕ НЕФТИ ИЗ КАРБОНАТНЫХ ПОРОД (НА ПРИМЕРЕ МЕСТОРОЖДЕНИЯ КАЗАХСТАНА)

Аннотация: *Увеличение нефтеотдачи на более выгодных условиях – один из острых вопросов на сегодняшний день. Начиная с прошлого века ученые активно ведут исследовательские работы по увеличению нефтеотдачи. Огромное количество ученых обратили свое внимание на данный вопрос путем примененния низкоминерализованной воды (НМВ). Таким образом, с 90-х годов была активно изучена, как теоретическая, так и экспериментальная часть исследований. Увеличение нефтеотдачи зависит от смачиваемости породы и поверхностного натяжения. Данный подход был ключевым для значительного количества экспериментальных работ. Но, несмотря на множество исследований ученые до сих пор не пришли к единому мнению по механизмам, способствующим увеличению нефтеотдачи. Одним из главных механизмов считается движение мелкодисперсных частиц (т.е. частиц глин) при заводнении низкоминерализованной водой. Как показало исследование темы о НМВ, зачастую экспериментальные работы проводились на легкой нефти. Экспериментальные работы с легкой нефтью оказались положительными. Однако не было глубоко изучено взаимодействие НМВ с высоковязкой нефтью, что является актуальной для месторождений Казахстана.*

Ключевые слова: *гидрофильная порода, гидрофобная порода, смачиваемость, минерализованная вода, добыча нефти, высоковязкая нефть*

High-viscosity oil represents a large share of the world's undeveloped hydrocarbon reserves. Today, the world's reserves of high-viscosity and heavy oil are estimated at 3,396 billion tons. barrels [1]. The main limiting factor in the development of such fields is the high density (more than 900 kg/m3) and viscosity (more than 100 MPa•s) of reservoir oil, which requires high economic and technological costs for production, compared to light oils. The recovery rate of high-viscosity oils from the reservoir generally does not exceed 20%. According to the classification of the American Petroleum Institute (API), high-viscosity (heavy) oils have a density, in API degrees from 10° to 20° at a temperature of 60° F (15.6° C) and have a viscosity of more than 100 SP (100 MPa•s). Anything below 10º API is natural bitumen.

In Kazakhstan, the main reserves of heavy and high-viscosity oil are concentrated mainly in the Western part of the country and are equivalent to 726 million tons [2, 3, 4]. The main fields of heavy and high-viscosity oil are Karazhanbas, Kalamkas, Buzachi, and Kenkiyak [3, 5].

At the initial stages, oil fields are developed in a natural mode, then after reaching an economically unprofitable level of oil production, they switch to secondary or tertiary methods of impact on the reservoir (mainly chemical methods). Compared to light oil fields, high-viscosity oil fields use enhanced oil recovery methods from the beginning of field development. Various types of thermal methods of impact on the reservoir will be used.

Flooding is currently the main method of increasing oil recovery and maintaining reservoir pressure since the technology is available and cheap compared to other methods. Today, the physicochemical properties of the water injected into the reservoirs are of great interest. Over the past twenty years, many laboratory studies have been performed on samples of carbonate and terrigenous rocks to identify the influence of mineralization and ionic composition of the injected water on the increase in oil displacement from the core [6-14].

Pilot work was carried out to pump low-mineralized water into oil reservoirs. For example, in [1] it is reported that starting from the '80s, water injection of low mineralization began in the Bystrok and Zychebash deposits. The test results showed that the residual oil saturation in these areas decreased during the injection of LMW. According to the results of

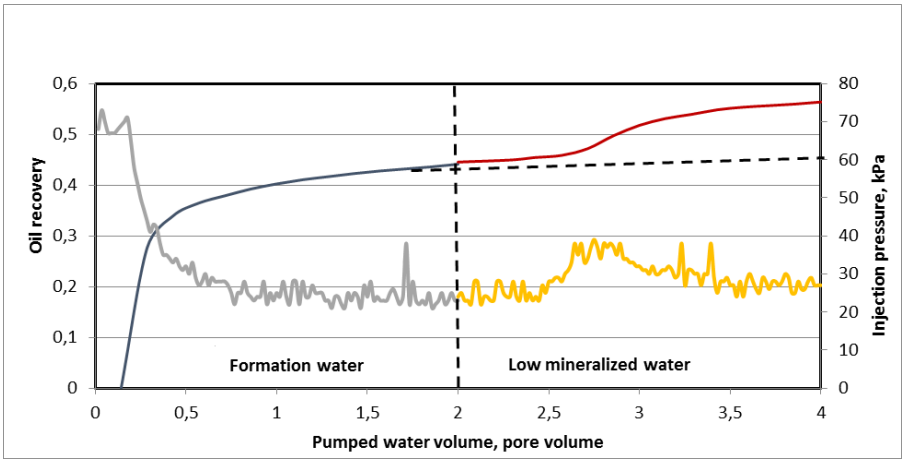

Figure 1 – Pressure and oil recovery graph of experiment № 2

tracer studies that were conducted in the fields of Alaska after the injection of LMW, oil recovery increased from 8% to 19%. The authors point out that a significant effect was obtained when water mineralization was below 5 g/l. [10] It was also shown in [7] that oil production increased at the North Slope field in Alaska after the injection of LMW and the water-oil factor decreased. Moreover, in [15] it is reported that, in the fields of Oman and Syria, after injection of LMW into the terrigenous reservoir, the reservoir wettability changed from hydrophobic to hydrophilic.

Many researchers have concluded that the injection of low-mineralized water makes the wettability of the rock hydrophilic. Although various mechanisms for increasing oil recovery have been proposed, such as the movement of fine particles, clay swelling, an increase in the pH of the medium and an increase in the double equipotential field, etc. [8-15].

In [6], the author proposed a mechanism for multi-ion exchange between the rock surface and the injected water. This is due to the interaction between the clay mineral ions, such as Ca2+ and Mg2+, and the acidic components of the oil. As a result of this ionic interaction, the compounds between the oil and the rock weaken, and the oil is removed from the rock surface.

In another work [10], the influence of water mineralization on the wettability of the rock surface was revealed. Water salinity varied from 0 to 174 g / l at various temperatures and pressures. Zeta potentials were measured. When pumping low-mineralized water, a decrease in the wetting angle of oil compared to high-mineralized water, and an increase in the double electric layer were observed. This indicates the ability of low-mineralized water to change the wettability of the rock, making it more hydrophilic.

The injection of low-mineralized water demonstrates an increase in oil recovery in many experimental studies and field tests. According to the results of scientists' research, it can be concluded that the effect of pumping low-mineralized water in terrigenous reservoirs is manifested when the clay is present in them, and reservoir water contains divalent cations of calcium and magnesium. In this case, the salinity of the injected water should be less than 3-5g/l. But the main mechanisms for increasing oil recovery are still not fully understood.

Experimental part

To determine the efficiency of displacement of high-viscosity oil by low-mineralized water from terrigenous cores, a series of filtration experiments were carried out on an installation for studying cores UIK (S) - 2. During laboratory research, the following materials were used:

- hydrophobic rock;
- formation water and oil;
- low-mineralized water.

Experiment №1 was conducted on hydrophobic rocks.

The main data on the reservoir properties of the physical model are presented in Table 1. The

total volume of the pumped formation and low-salinity water was equal to four pore volumes. The results of the second experiment are shown in Figure 1. When the model was flooded with low-salinity water, after the injection of 7 cm3 of water, the injection pressure began to increase and remained at the level of 35 kPa, while the volume of displaced oil began to increase.

Table 1 – Reservoir properties of the physical model

Parameters	Values
Porosity	0,28
Gas permeability	12,5
Pore volume	15,075
Initial water saturation.	0,3
Initial oil saturation	0,7

In experiment №2 on a hydrophobic rock, the initial injection of formation water displaced 42% of the initial oil reserves, and the injection of low-salinity water gave an oil increase of 13%.

It can also be seen from the graphs that the injection pressure increases with the injection of low-salinity water. This indicates that, when injecting low-salinity water, there was swelling of clays, movement of fine particles and redistribution of the filtration flow.

Conclusion

Filtration experiments were conducted on the flooding of hydrophobic rocks with the formation and low-mineralized water. Based on the laboratory studies performed, the following conclusions were drawn:

– filtration experiments have shown that a decrease in the mineralization of injected water improves the displacement of high-viscosity oil in the hydrophobic rock

– injection of low-salinity water into a hydrophobic rock gave the best result in oil displacement

– an increase in oil recovery in a hydrophobic rock is associated with swelling of clays and migration of fine particles

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