STUDY OF THE PROCESSES OCCURRING AT INTERACTION OF FORMATION WATER OF THE IRELYAKH GOF WITH THE HIGHLY MINERALIZED AGENT FOR RESERVOIR PRESSURE MAINTENANCE

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The paper[1] considers compatibility of formation water of the Irelyakh gas and oil field of the Republic of Sakha (Yakutia) with the highly mineralized solution used as an agent of reservoir pressure maintenance (RPM) with an allowance for factors, which influence solubility of salts, salt effect in particular. Also, possibility of concurrent reactions and specific conditions characteristic of the fields of the southwest Yakutia (by the example of the Irelyakh GOF) have been taken into account. It is shown that with the increase of the time length of wells' flooding with the liquid for RPM the pore space structure undergoes changes due to its calcination and sulphatization, which causes deterioration of reservoir properties and subsequently can complicate the operation of producing wells and the field in the whole.

The advanced development of the national oil industry is stipulated not only by the increase in a number of production facilities but also by further improvement of technical equipment and oil production technology as well as optimization of production processes.

Specific feature of the fields of the southwest Yakutia is abnormally low formation temperatures, which causes the increase in oil viscosity and brings about the necessity of a more attentive approach to the choice of a displacement agent.

Experimental-industrial development (EID) of oil reservoirs of the Talakansky, Srednebotuobinsky and Irelyakhsky fields is being carried out more then 10 years. One of the main problems of EID of the above fields is the choice of the method and agent for reservoir pressure maintenance (RPM) in order to displace oil.

In all EID projects mineralized water is considered as a fluid for injection. At the same time the use of the mineralized water raises a lot of questions. Thus, for example, all experts and researchers recognize the problem of compatibility of the formation and injected water, because in the result of their interaction crystallization of salts of different composition in the pore space of the reservoir occurs decreasing its capacity and filtration properties.

One of the problems concerned with EID of the above-said fields is to investigate compatibility of formation and injected water. Unfortunately, in the national

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practice not enough attention is given to the above problem and, as a rule, only at the final stage of reservoir development.

Thus study of the influence of physical and chemical processes, occurring at mixing the formation water and RPM agent, on filtration properties of the reservoir rocks, particularly in thermobaric conditions of the above-named fields, takes on special significance now.

The aim of the paper considered is to investigate compatibility of formation water and injected brines with allowance for their individual chemical composition, ionic force of mixed solutions and possibility of concurrent reactions. The other purpose is to study the influence of physico-chemical processes in the bed (formation of insoluble salts) on filtration properties of reservoir rocks.

The objects of the study are as follows: 1) formation water of the Ulakhansky horizon from the well No. 155-019 of the Irelyakh GOF; 2) mineralized water obtained in the process of leaching from rock salts of the Charskaya suite (well No. 1РЭ) and used as the RPM agent; 3) samples made from the monolithic core of the Irelyakh GOF, which consists of fine-grained sandstone on gel-cement of inclined layered orientation and of quartz-feldspar composition.

To investigate compatibility of formation water with the solution for reservoir pressure maintenance of the Irelyakh GOF their individual chemical composition has been determined. Qualitative analysis of formation and mineralized water samples shows that they contain cations of calcium, magnesium, natrium, potassium, hydrocarbonate, sulfate and chloride anions. Quantitative composition of salts has been determined by the titrimetric and gravimetric (sulfate-ions) methods of analysis (Table 1).

As Table 1 shows formation water can be referred to the chloride-calcium type while RPM liquid – to chloride-natrium one.

To obtain a more correct estimate of the possibility of calcium sulfate deposition during mixing the formation water and RPM solution one must take account of factors, which influence its solubility, i.e. salt effect and possibility of concurrent reactions.

Due to the presence of calcium and magnesium ions in formation water, hydrolysis can take place. Moreover, ions of the sediment can react with the components of the solution: hydroxide anions, hydrogen cations, proper ions and

foreign substances. All these concurrent reactions depend on pH value of the medium, which is determined with the help of the ion meter “Ecotest-200”; for formation water $pH = 5.0$; for the solution $pH = 7.21$.

Table 1

Chemical composition of formation water samples
of the Irelyakh GOF and RPM solution

№	Ions	Formation water		RPM solution	
		моль/л	г/л	моль/л	г/л
1	Ca^{2+}	4,99	100,16	0,100	2,00
2	Mg^{2+}	0,932	22,66	0,005	0,12
3	Total hardness	5,93	122,82	0,105	2,13
4	$Na^{+} + K^{+}$	0,993	24,82	4,57	114,3
5	HCO_3^{-}	0,00732	0,45	0,00136	0,083
6	HSO_4^{-}	0,0163	1,56	0,0402	3,87
7	Cl^{-}	6,89	244,91	4,64	164,54
8	Sum of ions		394,57		284,92

The data obtained show that the formation water medium is low-acid, therefore in the solution $CaSO_4$ along with the reaction

$$CaSO_4 \Leftrightarrow Ca^{2+} + SO_4^{2-}$$

the following concurrent reactions can take place [1]:

$$SO_4^{2-} + H^{+} = HSO_4^{-}$$

and

$$HSO_4^{-} + H^{+} = H_2SO_4$$

For the data presented in Table 1 coefficient of the side concurrent reaction is 0,9999. Thus, in this case we can neglect the influence of the concurrent reactions.

One of the factors affecting sediment formation is salt effect. Due to the fact that formation water and RPM solution, along with the calcium and sulfate ions, contain cations of magnesium, natrium, potassium, hydrocarbonate and chloride anions, activity coefficients of the sediment-forming ions are not equal to 1. Therefore, solubility product can be expressed through the ions activity:

$$K_s^0 = a(Ca^{2+}) \cdot a(SO_4^{2-}) = f(Ca^{2+})[Ca^{2+}]f(SO_4^{2-})[SO_4^{2-}] \qquad (1)$$

where f - activity coefficients of ions determined by the third approximation of the Debye-Huckel equation [2]

For the electrolyte A_{zX} X_{zA} the above equation is as follows:

$$\lg(f_{\pm})_{A,X} = -\frac{A|z_A \cdot z_B| \cdot \sqrt{I}}{1 + B \cdot a \cdot \sqrt{I}} + b \cdot I \qquad (2)$$

where A and B are constant coefficients depending on characteristics of the solution and its temperature; z_A, z_X – charges of the cation and anion for the given electrolyte; *a* and *b* – empirical constants determined by reference data [3]; *I* – ionic force of the electrolyte solution.

Results of calculating the solubility product of calcium sulfate at mixing the Irelyakh GOF formation water and RPM solution are presented in Fig. 1. One can see that at a temperature of 10 ºC sediment formation of calcium sulfate occurs at mixing the formation water and RPM solution within the range of proportions 2/8 – 7/3 because solubility products are higher than the limiting values [3].

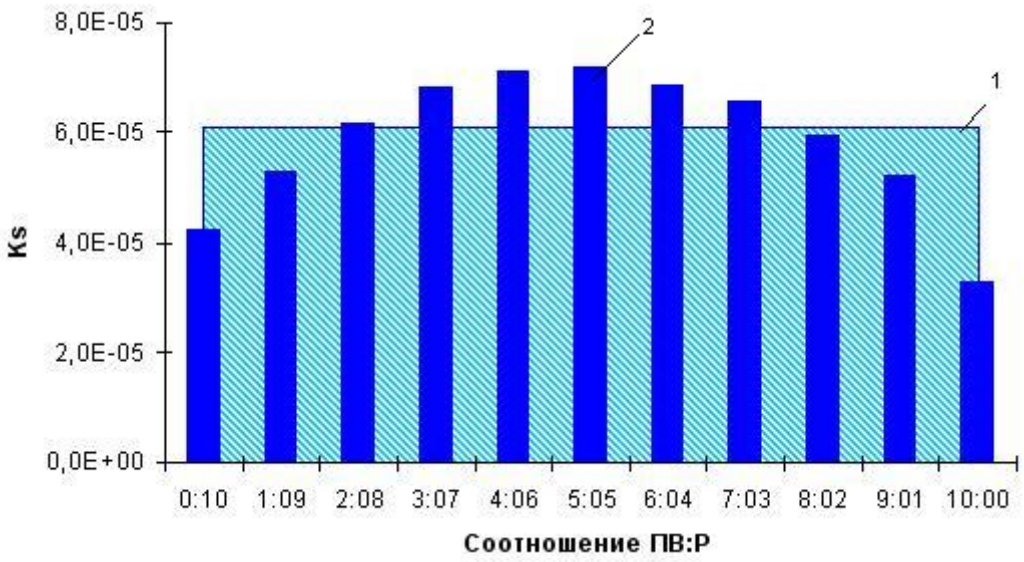

Figure 1. Results of calculating the solubility product of calcium sulfate at mixing the Irelyakh GOF formation water and RPM solution at 10 °C: 1- Tabular K_s^0; 2- calculate values

Table 2

Natrium chloride solubility in water (10 °C) at different proportions of the Irelyakh GOF formation water and RPM solution

Proportion formation water/solution	Tabular values [3]	0/10	1/9	2/8	3/7	4/6	5/5	6/4	7/3	8/2	9/1	10/0
S (10 °C), g/100 g of the solution	35.7	6.62	6.63	6.53	6.31	5.98	5.57	5.06	4.49	3.84	3.13	2.14

It is established that sedimentation of other low-soluble compounds (calcium and magnesium hydroxides), affecting filtration and capacity properties of the reservoir rock, will not take place because the product of their activities is lower than the tabular values of K_s^0.

The other important problem of compatibility of formation water and RPM liquid is the possibility of sodium chloride crystallization, the so-called halitization of the productive reservoir. Table 2 shows that natrium chloride concentration does not exceed its limiting concentration in water, i.e. at mixing of formation and mineralized water in the free volume salt crystallization will not take place.

Thus, it is shown that at combining the highly mineralized water, used as the RPM agent, with the Irelyakh GOF formation water in the existing thermobaric conditions formation of the solid sediment only in the form of calcium sulfate will take place, which will cause deterioration of filtration characteristics of the reservoir rock.

To estimate the effect of the RPM liquid on reservoir properties of the oil-bearing bed of the Irelyakh GOF we determined permeability of the reservoir samples (cores) by the highly mineralized RPM agent. Permeability was measured on the plant UIPK-02M, which was part of the research complex AKM, by the procedure [4] corresponding to GOST 26450.2-85. To increase the efficiency of the research process we modernized the factory set, which allowed to determine successively gas permeability of core samples and their permeability by liquid fluids.

Study of core samples' permeability of the productive horizons of the Irelyakh GOF by the RPM agent shows that permeability coefficient lowers with the increase in the volume of fluid passing through samples. During RPM agent pumping through samples in the volume of more than 100 volumes of the pore space permeability coefficient of cores decreases by 60-67 %.

Chemical analysis of the RPM agent after its filtration through the standard samples of cores shows different content of salts in the filtrate and in RPM liquid before its filtration.

Comparison of concentrations of Ca^{2+} and SO_4^{-2} ions in the RPM liquid of the initial composition and after its filtration through the sample shows that concentration of Ca^{2+} and SO_4^{2-} ions in the filtrate decreases by 20 % and 11 %, respectively.

According to the results of calculations and experimental study on permeability of samples by the RPM agent one can conclude that a certain amount of the low-soluble compound $CaSO_4$ remains in the reservoir rock, which causes a decrease in its filtration characteristics. The above suggestion is also confirmed by the fact of a significant and simultaneous decrease in concentration of Ca^{2+} and SO_4^{2-} ions in the filtrates.

Therefore, with the increase of the time length of wells' flooding with the liquid used for reservoir pressure maintenance the pore space structure undergoes significant changes due to its calcination and sulphatization, which causes deterioration of reservoir properties.

Results of the investigations show that it is necessary to carry out chemical analysis of formation water and flooding system at each producing and putting in production field in order to either reveal or exclude possibility of forming the low-soluble sediments at their interaction. The procedure of determining the formation of insoluble and soluble sediments in the reservoir rock is suggested. The above procedure takes account of the low formation temperature, which is typical of the fields of the Republic of Sakha (Yakutia).

It is shown that a careful selection of methods for preventing salt formation is required for each particular field depending on an individual composition of the flooding system and geological structure of the reservoir rock.

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