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Hydrophobization of the Reservoir Surface in the Processes of Impact on the Bottomhole Formation Zone

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Гидрофобизация коллекторской поверхности в процессах воздействия на призабойную зону пласта

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Reservoir rock almost never consists of a single mineral. Thus, terrigenous deposits contain carbonates, clays and other components in varying quantities along with quartz. True wettability also depends on the liquids contained in the pores, i.e. on the properties of oil and water. Formation oil contains surface-active and polar substances that can be adsorbed by the rock. In this case, the wetting ability of water decreases, and oil wetting ability increases. As a result, oil can behave as a wetting phase, especially in rocks with a high content of organic matter. Formation water can also be surface-active. The study of the wettability of the reservoir rocks surface has been and remains relevant.

In the article, consisting of three parts, the role of wettability of the reservoir surface in the methods of influencing the bottomhole formation zone (BFZ) is considered from the standpoint of its general state, disturbed due to water saturation and the course of a number of colmatation processes. The fundamental principles of filtration of reservoir fluids through macro- and micro-open channels of oil and gas reservoirs indicate the preference for a hydrophilic state of their surface for the advanced inflow of oil along the curves of the relative permeability of oil and water. However, the incorrect idea that emerged in the early 1990s about the need for its hydrophobic state in order to reduce the water saturation of the BFZ and the hypertrophied role of capillary forces in this case attracted many specialists to its side and has proven to be stable to this day.

The authors consistently outlined the formation of these ideas and the positioned "efficiency" of hydrophobization mainly due to hydrocarbon saturation of the BFZ.

Ключевые слова:
нефтяное месторождение, скважина, призабойная зона пласта, технологические жидкости, фильтрация, относительная фазовая проницаемость, смачиваемость, коллекторская поверхность, гидрофобизация.

Порода-коллектор практически никогда не состоит из одного минерала. Так, в терригенных отложениях наряду с кварцем в различных количествах содержатся карбонаты, глины и другие компоненты. Истинная смачиваемость зависит и от содержащихся в порах жидкостей, т.е. от свойств нефти и воды. В пластовой нефти присутствуют поверхностно-активные и полярные вещества, которые могут адсорбироваться породой. При этом смачивающая способность воды уменьшается, а самой нефти – увеличивается. В результате нефть способна вести себя как смачивающая фаза, особенно в породах с высоким содержанием органического вещества. Пластовая вода также может быть поверхностно-активна. Изучение смачиваемости поверхности пород-коллекторов было и остается актуальным.

В статье, состоящей из трех частей, роль смачиваемости коллекторской поверхности в методах воздействия на призабойную зону пласта (ПЗП) рассматривается с позиций общего ее состояния, нарушенного вследствие водонасыщения и течения ряда кольматационных процессов. Фундаментальные основы фильтрации пластовых флюидов по макро- и микрораскрытым каналам нефтегазовых коллекторов свидетельствуют о предпочтительности гидрофильного состояния их поверхности для опережающего притока нефти по кривым относительной проницаемости нефти и воды. Однако сложившееся в начале 1990-х гг. неверное представление о необходимости ее гидрофобного состояния с целью снижения водонасыщенности ПЗП и гипертрофированная роль при этом капиллярных сил привлекло на свою сторону многих специалистов и оказалось устойчивым по настоящее время.

Авторами последовательно изложено формирование данных представлений и позиционируемая «эффективность» гидрофобизации преимущественно вследствие углеводородонасыщения ПЗП.

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Introduction

Rock wettability is of great importance in the exploitation of oil fields, as it has a strong influence on the process of oil displacement by water and due to the fact that the distribution of phases in the pore space is a wettability function.

A reservoir rock almost never consists of a single mineral. Thus, in terrigenous deposits, along with quartz, carbonates, clays and other components are contained in varying quantities. True wettability also depends on the liquids contained in the pores, i.e. the properties of oil and water. Formation oil contains surface-active and polar substances that can be adsorbed by the rock. In this case, the wetting ability of water decreases and that of the oil itself increases. As a result, oil can behave as a wetting phase, especially in rocks with a high content of organic matter. Formation water can also be surface-active. The studying wettability of the reservoir rock surface has been and remains relevant [1–38]. In this article consisting of three parts the problem of the reservoir surface wettability role is considered taking into account the general condition of the bottomhole formation zone (BFZ) which controls the flow of formation fluids into the wellbore of producing wells and the filtration of various process fluids (PF) in the opposite direction under various alternating loads during primary drilling-in, cementing, secondary drilling-in, development of productive formations, killing, acid treatments (AT), hydraulic fracturing (HF), water restriction operations, reperforation, bottomhole zone treatment (BZT) to remove asphaltene-resin-paraffin deposits (ARPD), salts, BFZ decolmatation, etc. As a rule, this is accompanied by the introduction and formation of new potentially hazardous colmatants from the composition of formation fluids and reservoirs. Bringing this “customs” barrier into line with the general condition of the exploited formations using which the oil recovery factor (ORF) values are determined is a difficult task that is solved within the framework of maximum preservation and restoration of the BFZ reservoir properties.

Retrospective review

In the technological processes of hydraulic fracturing the creating extended channels of acid dissolution makes it possible to involve in the development a network of isolated cracks, screened oil-containing zones, to build additional transport "arteries" that are not typical for reservoirs in the depth of the formation and to significantly increase the well productivity coefficient (K_{pr}) against the calculated values in the direction of negative values of the skin effect.

However, many technological processes are accompanied by an increase in the flow of water into the wellbore which negatively affects the oil recovery factor, the state of wells operation and the whole field. Such an increasing effect of the water phase is typical for undersaturated oil formations with a high content of residual water and at the second stage of field development with the approach of injected water to maintain reservoir pressure (MRP) to production wells when the relative phase permeability (RPP) sharply decreases for oil and increases for water. Additional introduction of the water phase into the BFZ from the composition of the TF aggravates this problem. Here, a number of "specialists" were tempted to use a miracle cure of "selective" action which helps to reduce the negative impact of the water phase on the well Kpr and manage it both from the wellbore and the formation depth.

In particular, the ability of many substances to change the wettability of the reservoir surface has been raised to the shield and for surface-active substances (SAS) this is manifested at their low concentrations in the composition of the PF. Without denying the extreme importance of this problem, even within the framework of field development and especially the state of the BZP, the fall of this "medicine" into the hands of unscrupulous "specialists" often turns it into «poison» which requires clarity in the depth of the problem posed, since it is acquiring an increasing number of "fans". The narrow view characteristic of such works associated only with water saturation of the BZP and its regulation by means of regardless «hydrophobizating» the general state of the BZP, the factors of its colmatation, the stage of field development, is also unacceptable.

Thus, N. Mangan [39] focusing on this process wrote: “Rock wettability is a very complex phenomenon; wettability should be studied with great caution, since it has a great influence on the filtration characteristics of water and oil ... with the possibility of changing it by using chemical additives ...”.

Researchers accept the initial state of wettability of three types reservoir surface:

- – predominantly hydrophobic;
- – intermediately wetted;
- – predominantly hydrophilic.

Taking into account the various mineral and morphological properties of reservoirs, the term microstructural wettability was introduced which assumes the presence even in a hydrophobic environment of individual hydrophilic sections connected or not connected to each other by filtration channels.

In this regard, N.S. Gudok in his book (1970) correctly notes: “The use of the terms “hydrophilic” or “hydrophobic” is justified only in the case of complete wetting by water or oil which is excluded under reservoir conditions”.

In hydrophilic rocks oil occupies the center of the largest pores and the expansion of medium-sized communicating channels and the residual water is concentrated along the network of the least permeable space. In hydrophobic rocks small pores accessible for filtration are filled with oil and a film coating of the reservoir surface occurs. In this case, water acquires a globular character in the center of the pore channels.

With identical saturation of the wetting and non-wetting phases the effective (individual) permeability of the wetting phase (for example, the presence of water in a hydrophilic reservoir) is lower than that of the non-wetting phase, due to its more intense intermolecular interaction with such a reservoir surface.

The non-wetting phase occupying the central part of the pore channels slides along the film of the wetting phase during its movement [40, 41].

Maximum oil recovery including during the anhydrous period is typical for hydrophilic or intermediate-wetting reservoirs with a piston type of its displacement along a network of macro-open channels. The share of water in the production of wells $f(S_w)$ with water saturation of the reservoir space S_w is determined by the ratio of the viscosities of water η_w, oil η_o and the values of their relative phase permeability k_w^*, k_o^* [40]:

$$f_{(sw)} = \frac{1}{1 + \dfrac{k_o^* \eta_w}{k_w^* \eta_o}}. \qquad (1)$$

With combined filtration of oil and water, with increasing hydrophilicity of the reservoirs, the RPP curves shift toward higher water saturation ($S_w > 50$ %) which is shown in Figure 1. With an increase in the hydrophobicity of the reservoir surface with equal S_w, the permeability increases for water and decreases for oil.

Among the apologists of "hydrophobization" there is a directly opposite opinion on these processes which we will highlight adhering to the chronological sequence of presenting the literary sources available on this topic.

The search for the original source of the emerging the topic of the need or expediency of hydrophobizing the reservoir surface in the BZP to remove the water phase from it led us to the well-known book by G.A. Babalyan et al. for 1962 [42].

Experimentally studying the displacement of oil droplets and films by various aqueous solutions from a solid surface, they came to an unambiguous conclusion about improving this process by imparting a hydrophilic state to the surface including the use of water-soluble non-ionic SAS (NSAS) such as OP-10. Now we will focus on the extremely important conclusion of these authors on p. 155: "When an oil film ruptures, not only physical adsorption of the SAS on a solid surface is possible but also chemical adsorption as well as the formation of a new, more hydrophobic surface.

In this case, despite the decrease in interfacial tension σ12, the contact angle (θ) may be large." Note, "more hydrophobic" and "the contact angle may be large." There is no mentioning the transition of the surface to a purely hydrophobic state, and the adsorption of even hydrophilizing NSAS on a purely hydrophilic quartz surface ($\theta = 0°$) imparts some hydrophobicity to it ($\theta > 0°$).

On such a partially hydrophobized surface, the oil droplets formed during the film rupture can spread again, disperse in the hydrophilic areas to smaller sizes, i.e. be displaced by water in a pulsating globular mode or even a piston mode.

With regard to the displacement of film water which the authors called "residual", the position on the decrease in the intensity of its retention on the solid surface in proportion to the increase in its hydrophobicity with a simultaneous decrease in the σ12 values is also acceptable. The authors wrote on p. 157: "The presence of water-soluble surfactants in water makes it possible to displace a larger amount of film water from the pore space, i.e. to reduce the residual water saturation when water is displaced by oil."

The following conclusion was "insidious" on p. 158: "… by using oil-soluble surfactants that are well adsorbed on a solid surface and weakly at the oil-water interface, it is possible to achieve better conditions for displacing film water."

It is absolutely right but what to do with such newly formed film oil? Return to the beginning of our reasoning? After all, the main task is not to displace water and the BZP but oil from the formation. However, there is also a way out for the thoughtful reader. Such surfactants should also be weak hydrophobizers of the reservoir surface and intensively reduce interfacial tension so that the formed water globules have a minimum size.

On p. 159 the authors recommend water-soluble non-ionic surfactants for intensifying well development and extracting water filtrates from the BZP. But they impart to oil-soluble surfactants the property of reducing the relative permeability of water also with simultaneous easier removal from the BZP.

It was in this not fully thought-out "conclusion" that the thesis was hidden, for some reason taken into "arms" by many subsequent supporters of the "hydrophobization" of the BZP.

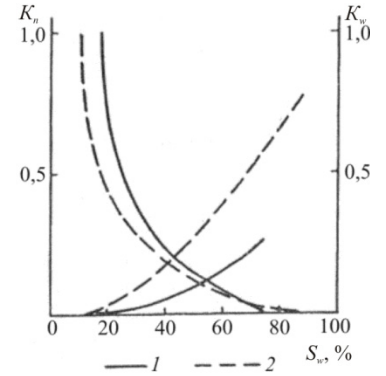

Fig. 1. Effect of wettability on the type of RPP curves, rocks: *1* – hydrophilic; *2* – hydrophobic

Naturally, the conclusion of G.A. Babalyan in a separate article of 1963 [43] went unnoticed: "Addition of oil-soluble surfactants to hydrocarbon liquids, while decreasing the phase permeability of the porous medium for oil, increases it for water."

As an example, let us consider the results of one of the latest works in terms of assessing the efficiency of hydrophobizing the reservoir surface for the relative permeability of oil and water by American scientists W.W. Owens and D.L. Archer [44].

Calcined hydrophilic cores of Torpedo sandstone, $L = 4.45$ cm and $d = 1.91$ cm, were saturated with a NaCl solution, then oil was filtered ($\eta_o = 1.7$ mPa•s) until residual water saturation Sw and an oil solution of barium salt of dinonyl naphthalene sulfonate (BDNS) of various concentrations was injected to create a given degree of hydrophobicity of the reservoir surface. On the surface of quartz glass treated with pure oil, the values of $\theta = 47°$ for a drop of water, 0.1 % BDNS solution – 90o, 1 % – 138°, and 4 % – 180°. The values of σ12 = 35 mN/m at the oil – water interface and σ12 = 2–2.5 mN/m for the BDNS solution – water interface. The effective permeability of oil ko was determined by filtration after the hydrophobizing solution, and k_w by pumping 50 pore volumes (PV) of the NaCl solution. Intermediate tests included measuring k_o and k_w at a given water saturation. The experimental data taking into account the core permeability for gas $k_g = 0.571$ μm^2 and $S_w = 20$ % are presented in Table 1.

We will also place the graphical points for the relative permeability of oil and water in hydrophilic and hydrophobic cores for their different water content (Table 2).

Their analysis allows us to note the "destructiveness" of the hydrophobic state of the reservoir surface for the relative permeability of oil, especially at water saturation $S_w \geq 40$ % PV.

Reducing the degree of water BZP saturation can be solved within the framework of several technological approaches:

– removing the aqueous phase which is most acceptable at the stages of putting wells into operation and approaching them with water injected for MRP;

– hydrocarbon saturation of the BZP at these same stages;

– decolmation of the BZP with imparting a predominantly hydrophilic character of wettability of the reservoir surface for advanced oil inflow through a network of macro-open filtration channels;

– carrying out water-limiting operations with selective action materials at all stages of development;

Table 1

Experimental data taking into account core permeability

Parameter	Value				
θ, degrees.	0	47	90	138	180
k_o, μm^2	0.561	0.472	0.459	0.380	0.357

Table 2

Data obtained in hydrophilic and hydrophobic cores for different water contents

Parameter	Value						
S_w, %	30		40		50		80
θ, degrees.	47	180	47	180	47	180	180
k_o^*	0.8	0.3	0.4	0.1	0.35	0.02	0
k_w^*	0	0.03	0	0.1	0.02	0.18	0.8

Table 3

Results of BZP hydrophobization with oil solutions of diamine dioleate in exploratory wells in Western Siberian fields

Parameter	Field, well				
	Megionskoe, 122	Ust-Balykskoe, 708	Three-lake, 22	Mortymya-Teterevskoe	
				272	734
Specific consumption of solution, m^3/m	0,75	0.12	1.7	1.0	0.75
DDO concentration, %	1.0	0.6	0.5	1.0	2.0
Oil flow rate, t/day:					
before BZT	48	167	30	43	65
after BZT	41	165	30	43	618
Oil water cut, %					
beforebefore BZT	8.4	15	28	22	7.2
after BZT	6.3	2.6	7.2	6.8	4.8
Duration of effect, days	6	4	72	16	60

– forced fluid extraction (FFE) with an analytical solution to some related issues of the BZP, formation and field development state taking into account the total water cut, gas factor, reservoir stability and others.

G.V. Rudakov and Yu.S. Sidorov wrote in 1969 [45]: “During well operation, as a result of natural inflows along the formation or bottom water, a gradual decrease in the hydrophobicity of the BZP occurs. This leads to a decrease in oil production rates and an increase in its water cut. To prevent rapid water breakthrough and extend the period of water-free production, preventive hydrophobization of the BZP is necessary. In the event of progressive wells flooding, hydrophobization is desirable to restore the original oil permeability.”

As an effective hydrophobicizing agent, the authors proposed pumping asphaltene-resin-containing oil into the BZP in order to prevent capillary penetration of water which is far from the truth. But in the subconscious of inexperienced specialists at that time, the idea of hydrophobizing BZP positivity was fixed precisely as a “water-repellent” means at any stage of well operation.

Some of the first targeted BZT with the aim of hydrophobizing the reservoir surface of polymictic rocks with oil solutions of the oil-soluble cationic SAS (CSAS) diamine dioleate (DDO) at a number of West Siberian fields were carried out in the mid-1960s under the supervision of V.A. Sidorovsky [46] with the results presented in Table 3. Their analysis, even taking into account the low water content, indicates a short-term effect with a tendency for it to increase with an increase in the specific consumption of the DDO oil solution which can be attributed to a local increase in the relative permeability of oil and the decolmatation of the bottomhole zone when inflow is caused. In his reasoning the author started from the possibility of preventing the intensity of well flooding with the filtrate of drilling fluids, bottom water and water for pressure maintenance or even preventing it: "Hydrophobization of the rock with surfactants in the bottomhole zone ... prevents water from penetrating into the rock and promotes oil filtration." The thesis is taking root. And what about the development of fields with a predominantly hydrophobic type of reservoir wettability in the mode of their flooding? M.A. Akhmetshin in 1968 [47] described in his candidate's dissertation the results of experiments on the evaluation of the efficiency of hydrophobization of model porous media with DDO oil solutions under reservoir conditions. In one experiment, permeability for oil was determined, saturated with formation water and displaced by oil with repeated recording of its permeability. In another, DDO oil solution was pumped into the model, displaced by oil, formation water was filtered and permeability for oil was evaluated. While analyzing the obtained data, the author recorded a sharp decrease in permeability for oil in a porous medium hydrophobized with DDO. A.I. Vashurkin [48] was perhaps the first to draw attention and showed by calculation the inexpediency of hydrophobizing the BZP. Based on experimental materials from the work of V.A. Sidorovsky (see Table 3) attributed the effect of "hydrophobization" entirely to preliminary oil saturation of the BZP with a decrease in the relative permeability

Table 4

The influence of hydrophobizating cores in the Tevlino-Russkinskoye field on the relative permeability of oil

k_g, 10^{-3} μm²	m, %	S_w, %	Kerosene permeability, 10^{-3} μm²		ß$_o$, %
			original	after DEDCS	
50.0	18.7	38.2	20.0	13.6	68
23.6	18.9	44.5	14.0	5.3	38
23.1	17.1	38.1	14.4	4.6	32
13.0	18.6	48.0	6.5	1.7	26
12.6	16.9	50.1	9.8	1.7	17

for water. The author also established the insignificant effect of capillary pressure opposite to the hydrodynamic pressure even after complete hydrophobization of the reservoir surface on the subsequent inflow of water from the formation into the well (capillary effects in the BZP are considered in the second part of the article).

With the advent of organosilicon products with gelling action in aqueous media on the oilfield chemistry market: ethyl silicates (ETS-16, ETS-40), methyl and ethyl siliconeates (GCL-11 and GCL-10), mixtures of ethyl and butyl esters of orthosilicic acid (ACOR) as well as oil-soluble organochlorosilanes cured under the influence of the aqueous phase, the topic of BZP hydrophobization "flourished in a new guise". They began to be positioned as effective hydrophobizers of the collector surface which does not contradict the mechanism of action in the form of a nanofilm on a solid substrate. However, since they gel or harden throughout the entire volume, such an effect can only be achieved with their diluted solutions which was not used in practice. It is impossible to correlate the effect of limiting water inflows and hydrophobization in a porous medium, although the emphasis was already placed in early works on the hydrophobic effect of these reagents.

Thus, in 1972–1973, successful well treatment operations were carried out at the low-water (Q_w = 3–12 %) well stock of the Novo-Troitskoye field in Krasnodar Krai by pumping phenyltrichlorosilane oil solutions with an oil buffer rim and squeezing oil in a volume of 2–3 volumes of tubing [49]. The authors of this work stated: "With the same physicochemical characteristics of oil, the rate of moving formation water will be greater, the more hydrophilic the surface of the pore space is, and, conversely, the less, the more this surface has hydrophobic properties." Who taught them the course on development at the university? And these "new" ideas continued to take root.

Similar work was carried out by A.G. Yagafarov et al. [50] on the low-water (Q_w = 4–10 %) exploratory well stock of the Krasnoleninsky district in Western Siberia by pumping 1–1.5 m^3/m q5–10 % solutions of reagents ETS-16 or ETS-40 + GCL-10 in diesel fuel into the BZP which were called "hydrophobizing agents" and the achieved effect was also due to the hydrophobization of the reservoir.

In this regard, V.N. Sergienko et al. [51] conducted special experiments on cores of the Tevlino-Russkinskoye field in Western Siberia with residual water. After filtration of 3–4 PV of a 3 % kerosene solution of diethyl dichlorosilane (DEDCS) with an exposure of 12–20 h for a film coating of the reservoir surface, the permeability for kerosene in the opposite direction was determined. The obtained data are presented in Table 4. Their analysis indicates a sharp decrease in the phase permeability of kerosene in hydrophobized cores and, accordingly, a low coefficient of recovery of their kerosene permeability proportional to the drop in the initial gas permeability of the porous medium kg.

These results echo the above data of American researchers which should have put an end to the questions of the feasibility of work on hydrophobizing the BZP. But this not only did not happen but also led to new results. For example, in the work of K.V. Kiselev trimethyltrichlorosilane "slowly transforms" into a cationic surfactant [52]. While combining a hydrophilizing SNAS and an organosilicon water repellent in an acid composition, according to the author, "... a synergy effect is observed, since rock treatments with two different components... cause a greater effect than with each component separately." True, "synergy" works in reservoirs with k_g values > 0.06 μm^2 (see Table 4). What can I say, "the shoemaker bakes the pies".

S. Ademakhin et al. [53], having conducted an experiment on a bulk model of a formation with a curable organosilicon product Sidox, in three articles of identical content, attributed all sorts of things to its action: "During the process of pumping a hydrophobic composition, the film of loosely bound water is destroyed, water is displaced from the bottomhole zone and thereby dried. The hydrophobic reagent is fixed on the surface of the rock, preventing its rehydration. The water saturation of the hydrophobic formation sections drops sharply which increases permeability for oil and reduces it for water." Finally, we will not have problems with water cuts in wells.

In the early 2000s in connection with the development of oilfield services in Russia science was replaced by marketing, veiled in "innovations" covered in commercial secrets. Thus, in the work [54] based on the results gained the BZT of 17 PJSC Tatneft production wells with the hydrocarbon solvent MPC of hydrophobic action in the volume of 3-8 m^3/m with oil squeezing and holding for 1 day, a more significant increase in oil flow rates was noted at sites with a water cut of 83–92 % than with > 90 % as well as high-flow rates. The role of the decolmation of the BZP and the short-term increase in the relative permeability of oil is obvious but again the phrase from this article is alarming: “The decrease in the productivity of production wells is also largely due to the hydrophilic nature of productive oil-containing reservoirs wettability».

In a later work by A.Sh. Gazizov et al. [55], already with a hydrophobic focus, it is proposed to wash away ARPD with this composition, accelerate capillary impregnation of oil into a porous medium and limit water filtration due to an increase in the oil's RPP which does not contradict general ideas. But what does hydrophobization have to do with it and how is capillary impregnation accelerated, compared to what? But A.Sh. Gazizov and A.A. Gazizov, co-authors of books on field development, are doctors of science.

A bold statement was made by V.G. Kozin et al. [56] on solving the problem of limiting water inflows and reducing water cut in production wells. The authors believe that one of the ways to solve it is "... the use of hydrophobizers in various technologies at all stages of development and operation of oil fields." The article presents the final data of bench and field results of the efficient hydrophobic hydrocarbon composition "TATNO-2002" without specifying its composition, brand and consumption of the hydrophobizer and only flashes a phrase about the recommended dosage of 0.5 % in hydrocarbon liquid and the conclusion that "the developed composite compositions of hydrophobizers effectively increase the relative permeability of oil and reduce it for water." Let us independently analyze the bench experiments of these authors [57] on a bulk model of quartz sand. Initially, water-saturated sand was created by filtering 1 PV of water, through it 1 PV of oil and then 30 PV of fresh water to residual oil saturation. By processing model 1 with 0.5 % hydrocarbon solution "TATNO-2002" at each of these stages, the hydrophobization of the porous medium was simulated, although at the same time its hydrocarbon saturation occurred and the calculating the multiplicity of the decrease in water permeability k_w and the increase in oil permeability was performed (Table 5).

Table 5

Influencing treatment of porous medium 1 PV
with 0.5 % TATNO-2002 solution on k_w and k_o values

Stage number	Reservoir model	Reducing k_w	Increasing k_o
1	Quartz sand	6.33	8.75
2	Initially water-saturated quartz sand	11.0	1.88
3	Initially oil-saturated quartz sand	0.04	4.90
4	Residually oil-saturated quartz sand	0.42	2.34

From these results it is easy to find that for the model with residual water saturation No. 3, hydrophobization accelerated water filtration by ~ 25 times, and with residual oil saturation - by ~ 2.5 times which levels out the increase in oil permeability.

A separate niche in the topic of hydrophobizing the bottomhole zone was occupied by hydrocarbon compositions with finely dispersed fillers of varying wettability.

Employees of JSC "RITEK" under the leadership of V.I. Graifer [58] proposed the addition of hydrophobized organosilicon silicon oxide "Polysil-1" with particle sizes of 0.1-30 μm (although their real size is 5-40 nm) and a specific area of 100–300 m^2/g for the BZT of both production and injection wells in hydrocarbon solvents at the rate of 1–1.5 m^3/m [59]. The success of about 81 % of the BZT of the low-flow well stock of OGEU "Aznakayevneft" of the Romashkinskoye field with water cut from 0 to 96.7 % with an increase in oil flow rates by 2 times or more with both a decrease and an increase in the proportion of water can only be explained by selective colmatation of water-conducting channels with the hydrocarbon suspension "Polysil-1" and the inclusion of unused oil-containing interlayers in operation with an increase in the relative permeability of oil. The well treatments with water cut over 97 % were unsuccessful: out of 10 well treatments, only one was successful [60]. The well treatments of 32 injection facilities of the Povkhovskoye field in Western Siberia using the Polisil-1 composition were accompanied by either a several-fold increase in their injectivity or its absence at the same pressure [61]. It is interesting to quote the achieved effect on injection facilities as interpreted by the authors: “While treating rock with Polisil, its pore space acquires organophilic properties. This reduces the interfacial tension at the oil-rock-water boundary resulting in an increase in phase permeability for oil and water. All these factors contribute to the improvement of capillary impregnation and, ultimately, increase the filtration rate of the injected water. Therefore, better oil recovery should be achieved by displacing oil from hydrophilic rocks with waters with low interfacial tension values." Everything is collected well. But how do the authors imagine a simultaneous increase in the RPP of oil and water, and improving capillary imbibition (with what liquid and in what environment?) requires a separate consideration.

These are the kind of "innovations" we have to deal with. In injection facilities, the RPP of water is increased, and in production facilities, the RPP of oil.

However, a later work [59] reports an increase in the RPP of water by approximately two times when treating a Berea sand core with the hydrocarbon suspension "Polysil-P1", which does not contradict the generally accepted facts. And here another quote is interesting: "... phobization of clay particles present in the reservoir reduces the thickness of hydrate shells, thereby increasing the effective sizes of pore channels." And the fact that they are covered with a hydrocarbon layer reinforced with "Polysil" is not taken into account.

Over time, the authors create a modification of the superphilic "Polysil-SF" for the BZT of production wells in order to reduce their water cut which is closer to the truth. It is proposed to treat proppant for hydraulic fracturing with it, and the treatment of proppant with hydrophobic "Polysil", on the contrary, increases the BZT of water. Finally, now everything is logical.

Similar work on 15 production wells of Bashkortostan fields was carried out with 1% hydrocarbon suspension of finely dispersed hydrophobic polypropylene at the rate of ≥0.50 m^3/m and squeezing ≥0.9 m^3/m of oil with a decrease in well flow rates for liquid, water cut and an increase in oil flow rates [62].

Conclusion

In this case, we can conclude that a positive effect has been achieved both due to an increase in the oil RPP with saturation of the BZP with a hydrocarbon phase and by limiting the water inflow due to the colmatation of the most permeable water-conducting channels with polypropylene particles as evidenced by a decrease in the flow rate of liquid. Only the title of the article connects such BZP with hydrophobization.

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