ANALYSIS OF SULFATE SALT DEPOSITION IN OIL PRODUCTION

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Abstract. *The modern stage of oil production is characterized by the need to extract significant volumes of associated water to the surface, which are pumped back into the reservoir. As a result of watering of extracted products at all stages of development, salt deposition occurs. Sediments, accumulating in the filtration channels of productive formations, on the surface of well equipment, in systems inside the field collection and preparation, lead to significant losses in production and high material costs.*

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The modern stage of oil production is characterized by the need to extract significant volumes of associated water to the surface, which are pumped back into the reservoir. As a result of watering of extracted products at all stages of development, salt deposition occurs. Sediments, accumulating in the filtration channels of productive formations, on the surface of well equipment, in systems inside the field collection and preparation, lead to significant losses in production and high material costs.

The main reasons for salt deposition are the mixing of incompatible waters during flooding and changes in thermobaric conditions during oil production. Forecasting the process of salt formation during oil production is an integral part of measures to prevent it. Analytical forecasting of salt formation, carried out for specific objects and conditions based on physical and chemical calculations of the composition of produced waters, makes it possible to predict the possibility of salt precipitation along the entire path of the oil production process.

Groundwater is a complex physical and chemical system that is in close relationship and equilibrium with other phases of the earth's crust. One of the physicochemical equilibriums is sulfate-calcium, which characterizes the balance between the contents of calcium and sulfates in groundwater.

There are three main types of sulfate-calcium equilibrium in groundwater:

1. when the content of calcium ions and sulfate ions is approximately equal;
2. when sulfate ion predominates over calcium ion in waters;
3. when the content of calcium ions is greater than sulfate ion.

The first type of sulfate-calcium equilibrium is characteristic of the process of leaching of gypsum and anhydrites, which includes impermeable waters C_1s(tr+st), they are enriched with sulfate ion. The second type of sulfate-calcium equilibrium is characterized mainly by mineralized groundwater, found in zones of significant water exchange. The third type of sulfate-calcium equilibrium is observed in highly mineralized waters in zones of slow and extremely slow water exchange.

Reservoir waters of oil fields in the northern part of the Trade and Production Enterprise (TPE) belong mainly to the third type of sulfate-calcium equilibrium, i.e. highly mineralized waters of zones of slow and extremely slow water exchange, impermeable waters C_1s(tr+st) belong to the first type and are a source of sulfate ion.

Predicting the process of salt formation during oil production makes it possible to determine the critical parameters at which salt deposition begins. There are many methods for predicting the formation of sulfate salts. Each method has its own area of application; in this work, methods are used that are based on experimental data on the solubility product.

The degree of saturation of formation waters in the northern part of the TPP with calcium sulfate ($CaSO_4$), strontium sulfate ($SrSO_4$), was calculated using the Chistovsky method and is shown in Table 1.

Table 1 - Degree of saturation of formation waters with calcium and strontium sulfates according to the Chistovsky method

Field	Saturation degree $CaSO_4$	Saturation degree $SrSO_4$
Ardalinskoe	0,8624	1,1116
East Kolvinskoe	1,3118	2,0317
Dyusushevskoe	1,7213	1,9901
Oshkotynskoe	1,2503	1,4204

It should be noted that the waters of the East Kolvinskoye, Dyusushevskoye, and Oshkotyn deposits are highly saturated with calcium sulfate, and the waters of these deposits and the Ardalinskoye deposit with strontium sulfate.

Index of formation water saturation with calcium and strontium sulfates, calculated using the method of J.E.Oddo and M.B.Thomson, is given in tables 2, 3.

Table 2 - Saturation index of formation waters with calcium sulfate according to the Oddo method and Thomson

Field	Temperature °C	Pressure, MPa	Saturation index (gypsum)	Saturation index (anhydrite)	Saturation index (bessanite)
Dyusushevskoe	82	34	0,5566	0,5424	0,821405
East Kolvinskoe	87	37	0,0724	0,1430	0,38607
	78	33	0,7176	0,8069	1,068622
	81	34	0,4372	0,4707	0,735868
	75	32	0,1216	0,0145	0,34208

Based on calculations, it can be noted that formation waters of oil fields have a high degree of saturation with calcium sulfate. Among the calcium sulfate salts, the maximum saturation index with bessanite and high saturation with gypsum and anhydrite of the formation waters of the Dyusushevskoye and Vostochno-Kolvinskoye fields are noted, and the Oshkotynskoye field - only with gypsum and bessanite.

The maximum index of formation water saturation with strontium sulfate is observed in the waters of the Upper Devonian sediments of the Dyusushevskoye field, high saturation is observed in the waters of the East Kolvinskoye and Oshkotynskoye fields.

The studies carried out show that according to both methods, the formation waters of the Ardalinsky group of fields are saturated with calcium and strontium sulfates.

Table 3 - Index of water saturation with strontium sulfate according to the Oddo and Thomson method

Field	Age	Temperature, °C	Pressure МПа	Saturation index (целестин)
Dyusushevskoe	D_3 f_3 +fm	78	32	0,2432
	D_3 f_3 +fm	77	32	0,3966
	D_3 f_3 +fm	83	34	0,3878
	D_3 f_3 +fm	76	31	0,3001
	D_3 f_2 (dm)+f_3	88	37	0,3415
	D_3 f_2 (dm)+ f_3	75	32	0,2361
	C $_1$s(tr+st)	65	29	0,1327
Oshkotynskoe East Kolvinskoe	C_3	65	29	0,2458
	D_3 f_3 +fm_1	87	36	0,3458
	D_3 f_3 +fm_1	88	37	0,0056
	D_3 f_3 +fm_1	90	38	0,1913
	D_3 f_3 +fm_1	89	38	0,1188
	D_3 f_{2+3} +fm_1	78	33	0,1099

The results of determining the structure of the pore space and the distribution of pores along the radius were carried out on the sediment core of the productive horizons of the Upper Devonian of the Ardalinsky group of fields (Polar Lights Company LLC), which are represented by dense and organogenic-detrital limestones, dolomites. Porous, porous-fractured, porous-cavern type reservoirs with a sharp anisotropy of filtration properties are installed here.

Based on the analysis of laboratory core studies, it was established that for the reservoirs of the Vostochno-Kolvinskoye and Dyusushevskoye fields, pore radii of up to 0.12 μm are most characteristic, and for the Oshkotynsky field, several intervals of pore radii are noted (up to 0.145; 1.45-14.5; more than 29 μm).

Calculations of the parameters of in-situ deposition of calcium and strontium sulfates were performed (Tables 4, 5).

Based on the values of the pore radii from which sedimentation begins in the formation when crossing the line of average values, the boundary values of the proportion of pores in which deposition of calcium sulfate (Figure 1) and strontium sulfate (Figure 2) are possible are identified. Similar graphs were constructed for all fields of the Ardalin group.

The deposition of calcium sulfate in the productive formations of the East Kolvinskoye and Dyusushevskoye fields should be expected up to 50% of the pores, and in the Oshkotynskoye field - up to 77% at low values of surface tension (Figure 1, Table 6).

The conducted studies show that in the productive formations of the fields under consideration there is a significant probability of changes in the filtration characteristics of the reservoir due to the deposition of calcium and strontium sulfates.

Table 3 - Parameters of calcium sulfate deposition in the pore space productive formations

Field	Saturation index C/Co	Surface tension, H/м	The radius of the pores from which it begins salt deposition, мкм	Quantity salts in the pores, fg	Portion of pores in which it is depositedCa SO_4, %
Oshkotynskoe	1,250251	0,012	0,189	0,0002	77
		0,370	5,820	6,40	32
		1,050	16,500	145,85	22
Dyusushevskoe	1,721257	0,012	0,053	1,54	50
		0,370	1,630	0,45	38
		1,050	4,620	10,18	28
	3,73742	0,012	0,015	1,072	50
		0,370	0,452	0,.031	42
		1,050	1,290	0,724	40
East Kolvinskoe	1,311764	0,012	0,148	0,0001	49
		0,370	0,456	0,004	48
		1,050	1,300	0,083	37
	3,186525	0,012	0,018	0,000002	50
		0,370	0,566	0,046	48
		1,050	0,750	0,106	47
	6,249529	0,012	0,009	0,0000004	50
		0,370	0,290	0,012	49
		1,050	0,375	0,027	48

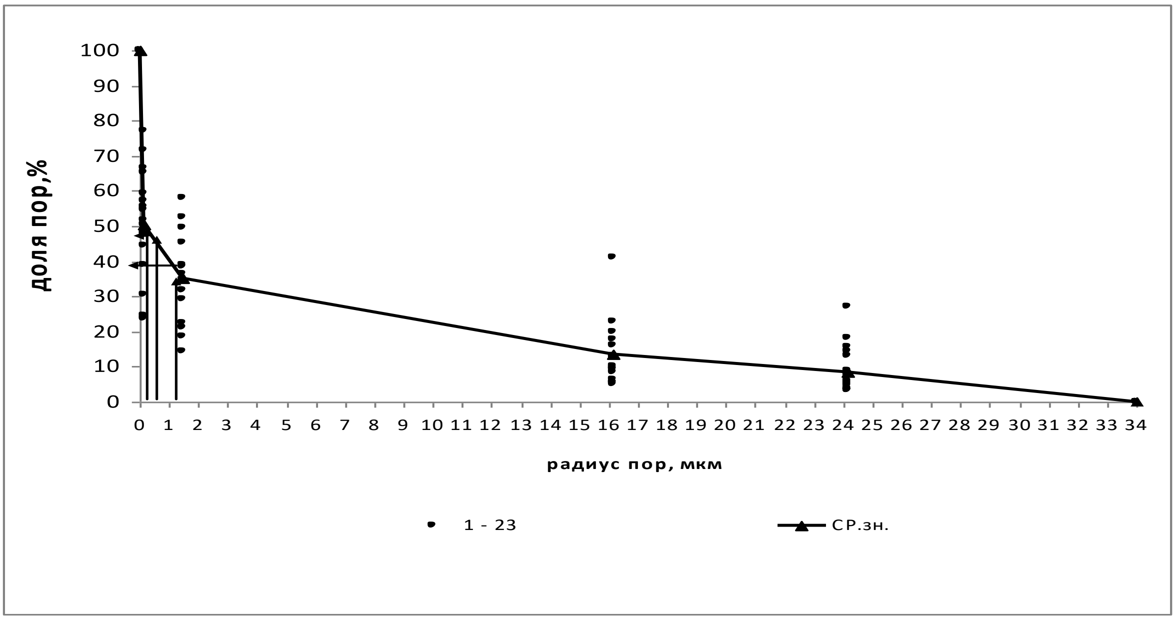

Figure 1 - Distribution of pores along the radius in the East Kolvinsky reservoir Place of Birth

Thus, when pumping produced water into the productive formation of the Ardalin field, one should expect the deposition of calcium sulfate in 75% of the pores at low values of surface tension, and at high values - up to 50% of the pores.

Strontium sulfate deposition when pumping produced water into the formation should be expected in up to 75% of the pores.

The above studies show that when producing produced water is pumped, calcium and strontium sulfates are deposited in the productive formation of the Ardalin field.

Conducted studies indicate that with each subsequent treatment, the hydrochloric acid solution affects new layers, and the filtration channels are gradually filled with deposits of sulfate salts.

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