SHORT COMMUNICATION

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Types of reservoirs of the Ufa stage of the Republic of Tatarstan. Genesis and reservoir properties

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Abstract. In this paper, we studied core material from well No. 15 of the extra-viscous oil field, geographically located within the western border of the South Tatar arch. Under laboratory conditions, reservoir properties (porosity, permeability), oil saturation and particle size distribution of Sheshmin sandstones were measured. It was established that the terrigenous reservoir belongs to class I and II according to the classification of A.A. Hanin, with high permeability. In addition, in well No. 15 , a downward trend was identified in reservoir properties downstream of the section, the reason for which is probably the migration of underlying formation waters from carbonate sediments of Sakmar age. By analyzing the grain size data distribution, the reservoir is represented by well-sorted fine-grained sandstone with a dominant fraction of 0.1-0.25 mm (about 65% of the entire sample); paleodynamic analysis was carried out using the Passega diagram; It was established that the formation of the reservoir took place under conditions of gradation suspension (P-Q-R area in the diagram), in the lower parts of fast river flows, directly at the bottom. The findings are consistent with data from previous researchers. According to the study of the cores of other wells, maps of changes in reservoir properties have also been constructed, which highlighted reservoir zones with high reservoir properties – the central parts of the North and South Uplifts.

Keywords: extra-viscous oil field, reservoir properties, grain size data distribution, classification of A.A. Hanin, Passega diagram

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The key alternative to the light oil reserves of the Devonian complex are deposits of extra-viscous oils (EVO), concentrated in the Ufa and Kazan deposits in the south-eastern part of the Republic of Tatarstan (RT). Ufa sediments are of greater interest for the following reasons: 1) biggest part (about 60%) of EVO reserves (Vafin et al., 2010) are concentrated in sediments of the Sheshminskaya package of the Ufa stage; 2) Kazan deposits are made up of carbonates, which are hard to develop; 3) Currently existing technologies for the development of reserves, such as SAGD, CHOPS, VAPEX (Nikolin, 2007), are more effective in terrigenous sediments than in carbonates. It should be noted that the RT has accumulated considerable experience in the development of EVO deposits using thermal-steam formation treatment methods (Muslimov, 2009).

The origin and characteristics of the formation of the Ufa have been studied by geologists since the 1970s (Sementovsky, 1973; Troepolsky, 1976; Gusev, 1996; Badamshin, 1995; Geology of Tatarstan, 2003; Syurin, 2017). Most scientists are inclined to believe that Ufa sediments are deltaic deposits and partly coastal-marine; The main source of drift was igneous sediments of the Ural (Krinari, 1998). In order to identify the paleodynamic situation and assess the reservoir productivity, the samples of core material from well no.15 of the EVO field in the south-eastern part of the RT were investigated (in agreement with the users of the subsoil, the name of the field is not disclosed; the names of the elements have been changed; the numbering of the wells is arbitrary).

The EVO field is located in the Cheremshansky district of the Republic of Tatarstan, in which there are 2 local uplifts – the Northern and the Southern (Fig. 1). Both uplifts have a brachymorphic structure with an amplitude of 15-18 m (Table 1, Fig. 2). The effective oil-saturated reservoir thickness in the deposits increases from the periphery to the center. The maximum net thickness observed in well no. 5 on the South Rise is 22 m. The OWC is set at minus 63 m according to the results of probing the formation of a near field (NF) and the results of exploration drilling.

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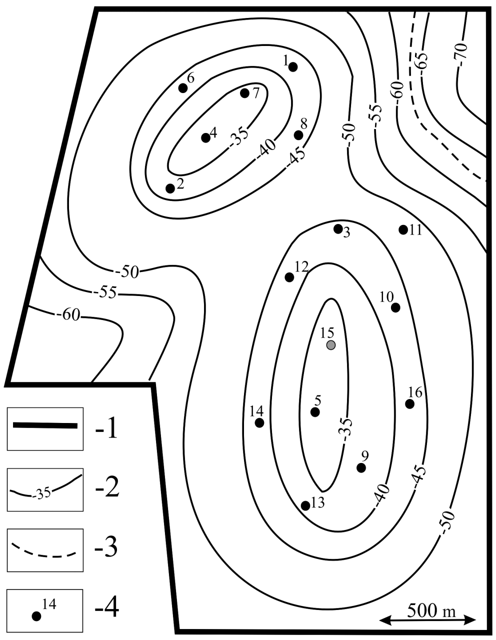

Fig. 1 Structural map of the top of the Sheshminsky horizon of the EVO field. Legend: 1 – licensed area limit; 2 – isogypsum on the top of the sand package; 3 – internal contour of oil; 4 – wells

Reservoir	Size (km x km)	Effective oil-saturated reservoir thickness (m)	Number of wells, entered the reservoir
Nothern	1,5x0,7	11-19	6
Southern	2x1,1	11-22	10

Table 1. The parameters of the deposits of the EVO field

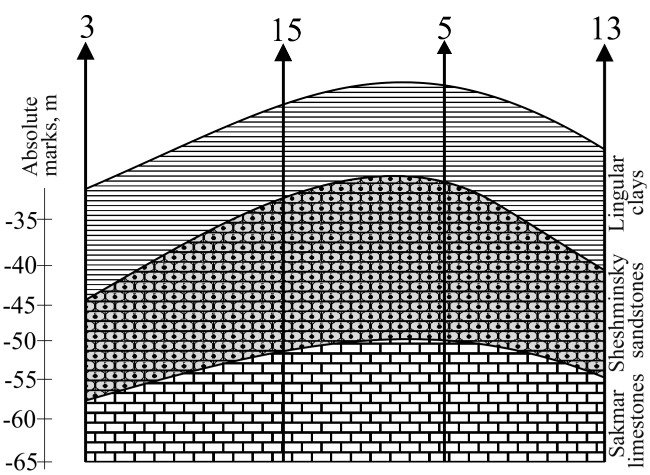

Fig. 2 Geological profile along the line of wells 3-15-5-13. South Deposit. Conventions of lithology – Fig. 3

The object of the study of the group of authors was core material of well no. 15, drilled on the southern uplift of the EVO field. The total effective oil-saturated thickness of the Sheshminskaya package according to macro-descriptions of the core in the studied well no. 15 is 20 m. The core sampling interval covers the overlying package of "lingular clays", the entire thickness of the reservoir and part of the underlying sediments of the Sakmar age.

According to the results of the macroscopic description of the core material, the productive layer is represented by fine-grained sandstones with varying degrees of saturation of EVO (Fig. 3, 4). The texture of the saturation of rocks is mostly continuous, even if small areas (from 0.1 to 0.5 m) are observed with patches with a banded and oblique texture of saturation (Fig. 4).

The authors selected 10 samples for research with an average sampling step of 2 m (Fig. 3) for carrying out the following laboratory analyzes: a study of reservoir properties, grain size distribution. All samples before the study were pre-extracted with the determination of the percentage of viscous oil.

During sample preparation, part of the samples was rejected for various reasons (sample destruction, insufficient degree of extraction, etc.). Full information on the studies performed is shown in Table 2.

According to the study of the reservoir properties, the reservoir has rather high values of porosity and

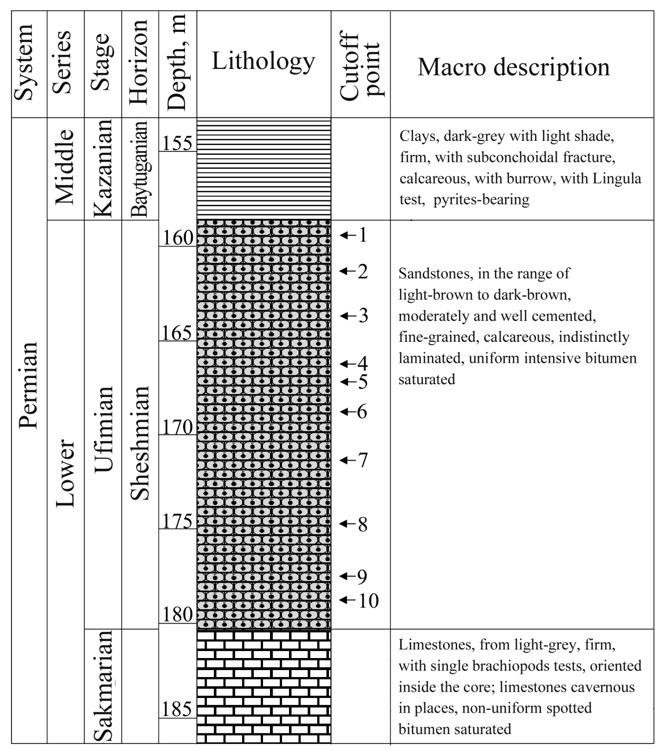

Fig. 3 Litho-stratigraphic section, built according to the macroscopic description of the cores of well no. 15

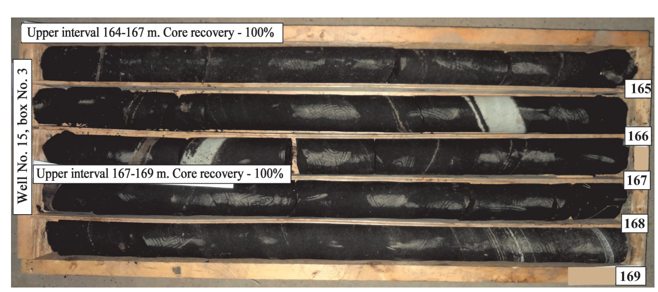

Fig. 4 Photo of the box no. 3 of the well 15. The photograph clearly shows a continuous and oblique striated texture of oil saturation

Sample (No.)	Reservoir properties	Grain size distribution
1	+	+
2	-	+
3	+	+
4	+	-
5	+	+
6	-	+
7	+	+
8	+	+
9	+	+
10	-	+

Table 2. Full information on research samples no. 1-10 with laboratory methods of analysis

permeability, and according to the classification of A.A. Khanin (Gimatutdinov, 2005) belongs to the I and II type reservoirs (Table 3). A trend of deterioration of reservoir properties can be noted: with an increase in the depth of the sand package, porosity, permeability and oil saturation decrease (Uspenskii, Vafin, 2016). Most likely, there is a process of formation of secondary calcite in the pore space of the reservoir during the migration of highly mineralized formation waters from the underlying sediments of Sakmar age. A similar phenomenon is noted in the work (Vedenina et al., 2018) where the EVO field was investigated for changes in the reservoir properties across the section and by area.

According to the particle size analysis, the biggest proportion in all samples falls on the interval of 0.1-0.25 mm (Table 4, fig. 5), which characterizes the reservoir as fine-grained sandstone.

According to the data of particle size distribution, the parameters (Nedolivko et al., 2011) of Md and C were calculated for the reconstruction of the sedimentary

No. sample	K_p (%)	K_{pe} (μm^2)	K_s (%)	Type reservoirs
1	13	1,56	19	I
3	15,6	0,99	45	II
4	22	1,22	51	I
5	18	1,71	60	I
7	12,4	0,66	41	II
8	13,75	0,37	н/о	III
9	11,86	0,22	28,6	III

Table 3. Laboratory data of reservoir properties of well n° 15 indicating the classes of reservoirs according to A.A. Khanin (Gimatutdinov et al., 2005)

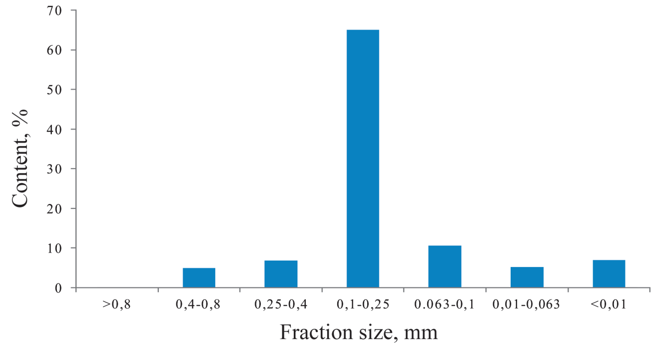

Fig. 5 The average histogram of the particle size distribution of the productive formation of well 15

paleodynamic environment; and Q3 and Q1 – to determine the degree of sorting So (So = $\sqrt{\frac{Q3}{Q1}}$).

As can be seen from table 5, all the rock samples studied have a good degree of sorting of sandy material, which probably indicates sedimentation in a calm paleodynamic setting. For reconstruction, the Passega paleodynamic diagram was used. Figure 6 shows that the scatter plot distribution lies on the P-Q-R area corresponding to the field of gradation suspension formed in the lower parts of fast river flows, directly at the bottom. The obtained data is consistent with the findings of previous researchers. Such a method of paleodynamic analysis is applicable both on sedimentary deposits of the territory of the Republic of Tatarstan and the West Siberian OGB (Khaziev et al., 2017), where, according to the paleodynamic analysis, the Jurassic stratum Y1-1 within the Ety-Purovsky arch has a similar origin with the Ufa package of RT.

To study the patterns of distribution of reservoir properties of rocks in the field, we used tabular data from the reservoir properties research at other wells. A total of 579 samples were examined using tabular data (including samples from well 15). For each well, weighted average reservoir properties values were calculated for the Sheshminsky horizon section (Table 6).

With the data of table 6, maps of porosity and permeability on the territory were constructed using the Surfer 8.0 software package (Maltsev et al., 2014) and using interpolation methods (Kriging, Radial Basic Function, Nearest neighbor). As the results of the

No. sample	>0,8	0,4-0,8	0,25-0,4	0,1-0,25	0,063-0,1	0,01-0,063	<0,01	Total %
1	0	10,21	11,71	58,09	6,51	5,31	8,17	100
2	0	12,65	10,63	50,5	12,53	5,71	7,98	100
3	0	1,63	5,46	51,69	28,86	5,54	6,68	100
5	0	3,91	7,66	81,62	1,68	1,07	4,06	100
6	0	4,33	7,6	69,83	11,34	2,8	4,1	100
7	0	2,38	8,63	79,99	1,9	1,72	5,38	100
8	0	5,17	4,56	62,38	19,84	4,54	3,51	100
9	0	3,47	2,68	72,85	3,95	4,51	12,54	100
10	0	1,62	2,53	59,04	10,9	15,23	10,68	100

Table 4. Data of particle size distribution of samples

No. samp.	Md (μm)	C (μm)	Q3 (μm)	Q1 (μm)	So	Degree of sorting
1	150	520	170	90	1,37	Good
2	130	510	160	80	1,41	Good
3	90	450	130	75	1,31	Good
5	120	490	160	100	1,26	Good
6	125	500	170	90	1,36	Good
7	130	510	170	110	1,24	Good
8	140	500	160	100	1,26	Good
9	100	460	120	75	1,26	Good
10	80	500	140	75	1,36	Good

Table 5. Design parameters for the reconstruction of the situation of sedimentation

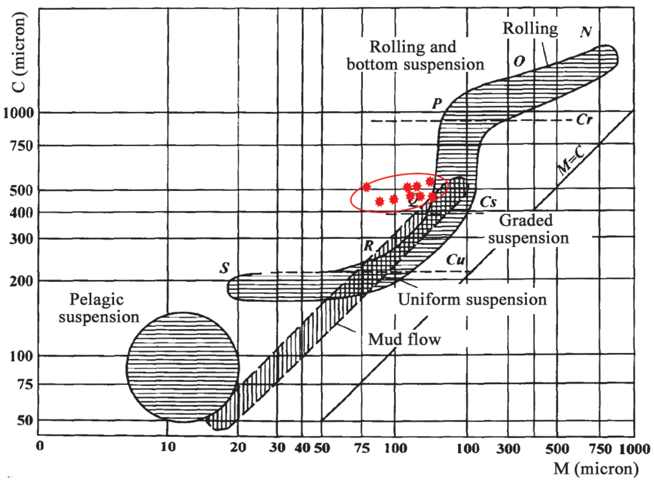

Fig. 6 Passega diagram with scatter plot distribution

No. of well	K_p (%)	K_{pe} (μm²)
1	0,11	0,371
2	0,13	0,182
3	0,12	0,230
4	0,13	0,571
5	0,14	0,432
6	0,09	0,196
7	0,14	0,532
8	0,09	0,346
9	0,11	0,429
10	0,08	0,299
11	0,07	0,139
12	0,09	0,372
13	0,11	0,411
14	0,09	0,363
15	**0,14**	**0,677**
16	0,11	0,292

Table 6. Weighted average values of reservoir properties by wells. (The weighted average reservoir properties value for well no. 15 is calculated considering previous core studies (in total 123 samples))

construction showed, the most optimal method, based on a small data array, is Radial Basic Function. Maps are constructed with this method (Fig. 7).

Using the constructed maps (Fig. 7), it was found that the most favorable areas are the central parts of the Northern and Southern uplifts. At this location, reservoirs of classes I and II with high permeability are present (from 0.45 to 0.6 μm²).

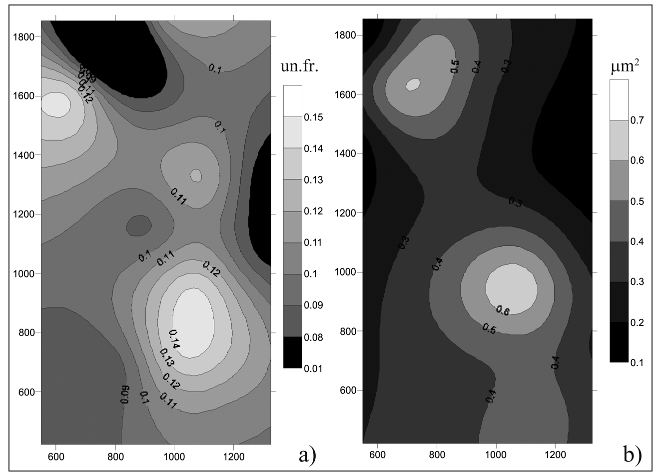

Fig. 7 Maps of porosity (a) and permeability (b) of the field

Conclusion

This work has shown the following conclusions:

The reservoir on the territory of the field belongs to class 1 and 2 according to the classification of A.A. Hanin

The tendency of deterioration of reservoir properties going down through the section was underlined, the reason most likely being the migration of underlying formation waters from sediments of Sakmar age;

According to the grain size composition, the reservoir is represented by well-sorted fine-grained sandstone with a dominant fraction of 0.1-0.25 mm (65% of the entire sample);

Paleodynamic analysis was performed using the Passega diagram; It was established that the reservoir was formed under conditions of gradation suspension (P-Q-R region in the diagram), in the lower parts of fast river flows, directly at the bottom. The findings are consistent with data from previous researchers.

Distribution maps of reservoir properties in the field were constructed, revealing that the deterioration of reservoir properties goes from the central part to the periphery.

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