Increased production of oil reserves in low production deposits of West Siberian oil and gas province

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Abstract. The paper considers the issues of assessing the influence of various factors on the production of oil reserves of Jurassic deposits of Shaimsky oil and gas region. The study states the influence of the network of disjunctive tectonics dividing the deposit onto the network of blocks on the degree of oil recovery. Trace research was conducted. Dependencies showing that hydrodynamic connectivity between wells takes place along fault lines or close to them, which is caused by the formation of decompression zones with increased permeability, are obtained. It was found that in the central blocks of the deposit there are large effective oil-saturated thicknesses with higher reservoir properties, which does not allow faults with low displacement amplitude to disrupt the connectivity.

1. Introduction
The problem of increasing the efficiency of oil production of Jurassic deposits of the West Siberian oil and gas province has been and is being given the highest attention due to significant amount of oil reserves and low degree of their production [1–5]. One of such objects is the oil fields of Shaimsky region, brought into production in the 2000s and characterized by rapid decrease in fluid flow rates, increase in water cut and decrease in the energy potential of the deposits [6–10].

2. Methods and materials
One of the productive formations are deposits of the middle and lower Jurassic, namely the Tyumen (J₂–J₆) and Sherkalinskaya (J₁₀¹–J₁₀²) suites. Productive formations are combined into two operational objects: the first J₂–J₆, the second J₁₀¹–J₁₀². The operational objects differ from each other in terms of capacity, reservoir properties, recoverable oil reserves, and there is also sharp lithologic-and-facies inhomogeneity of reservoir rocks both in along the horizontal and through the section.
The West Tugrovskoe oil field was chosen as the object of study, which is complicated by a dense network of tectonic disorders and high variation of geological and field indicators.

In order to understand the distribution of oil reserves, the geological-hydrodynamic model (GHDM) was developed. Geological-hydrodynamic modeling allowed estimating the distribution of initial and remaining mobile reserves (Figure 1). The largest density of oil reserves within the object of study is concentrated in the area of increased effective oil-saturated thicknesses, in the central part of the deposit.

**Figure 1.** Extract from the density distribution map of remaining recoverable oil reserves of the objects under study

The distribution of effective thicknesses of Tyumen and Sherkalinskaya suites reveal \( J_{2-3} \), \( J_4 \) and \( J_{10} \) formations, which are characterized by higher net oil thickness \( (J_{2-3} = 6.8; J_4 = 4.3; J_{10}^1 = 3.6; J_{10}^2 = 5.4 \text{ m}) \) in comparison with \( J_5 \) and \( J_6 \), which net oil thickness amounts to \( \approx 2.0 \text{ m} \).

It should be noted that the maximum remaining oil reserves are related to high effective thickness of the Tyumen suite formations. With the total thickness of developed objects making more than 100 m, there are up to 38 interlayers in the section of wells, which makes it extremely difficult to solve the problem of their most complete involvement in the development process.

One of the most important reasons for weak production of deposit reserves is considerable variability of reservoir properties. According to A.A. Khanin, the reservoir rocks, which form the formations of Tyumen and Sherkalinskaya suites, mainly belong to reduced and low classes of permeability. The reservoirs of \( J_{2-3} \) formation have (V–VI) class of permeability, \( J_4 – (\text{III–VI}) \) class of permeability, \( J_5 – \)
(IV–VI) class of permeability, $J_6$ – (V–VI) class of permeability, $J_{10}^1$ – (III–VI) class of permeability, $J_{10}^2$ – (I–VI) class of permeability.

According to permeability distribution on histograms (Figure 2), it can be noted that the permeability across the formations varies between 0.5 and $12 \cdot 10^{-3} \, \mu m^2$, with a frequency greater than 85%, the permeability of the remaining part is higher than $12 \cdot 10^{-3} \, \mu m^2$. The formations have high degree of permeability anisotropy.

High porosity is observed in the central and northern parts of the deposit in the formations of Tyumen and Sherkalinskaya suites. The same areas have higher reserves depletion. The average porosity is 14%.

The field has a 9-point well spacing system. Non-uniform distribution of water injected into the formation, including due to the lack of hydrodynamic connectivity between production and injection wells, which in turn is caused by non-uniformity of the productive part of the section and disjunctive tectonics [7, 8]. The main faults have north-south direction; smaller faults pass into the cross of the main ones (Figure 3).

Figure 2. Histograms of permeability distribution across operational objects
3. Results

In order to determine the degree of interaction of production and injection wells in the field, the tracer analysis was carried out for 4 wells.

The tracer analysis showed that in two wells, the best hydrodynamic connectivity is ensured along or close to the fault line. This is caused by the fact that as a result of tectonic movements, rocks are exposed to elevated pressures and temperatures, which in turn results in decompression zones that increase permeability. It should also be noted that the faults themselves do not fade at their termination point, as shown in Figure 3, but most likely continue further, diverging as branches and having a maximum field displacement amplitude.

Through two injection wells maintaining the formation pressure in different areas of the field, the marker is found in the samples of 10 producing wells. An extensive hydrodynamically connected site is identified in the field. Thus, for example, tracer studies carried out on one injection well allowed recording the distribution of tracing fluid in 12 production wells. Figure 4 shows that the tracing fluid is detected in 7 observation wells located far from each other, through one or more transcurrent faults from the injection well. This made it possible to conclude that this site has the best reservoir properties. Besides, there is large effective thickness in these blocks, which in turn prevents faults with low displacement amplitude from disrupting the hydrodynamic connectivity.

The object of the study is characterized by uneven distribution of remaining oil reserves across the formations, as well as weak production. The share of recovered oil reserves from initial recoverable reserves does not exceed 10%. The reason for such indicators is high degree of heterogeneity both in the section and in the area of Tyumen and Sherkalinskaya suites, as well as uneven distribution of effective thicknesses.

High production of reserves is noted in the central section of the field near the folded part of the structure. This zone is characterized by high effective thickness and the best reservoir properties.

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**Figure 3.** Block structure of West Tugrovskoe field
The comprehensive analysis of the state of remaining reserves allowed identifying the main technologies to develop the remaining oil reserves.

On the basis of the analysis of maps of remaining mobile oil reserves low production of J$_5$ formation is observed, which in a number of wells is traced as sandy and heterogeneous body in terms of capacity (Figure 5). The perforation works with subsequent hydraulic fracturing are recommended in order to involve this interval in development.

Due to low reservoir properties, high degree of heterogeneity of formations, as well as the reduction of productivity, it is recommended to carry out hydraulic fracturing in a number of wells for additional recovery of remaining reserves in the upper part of Tyumen suite from formations J$_2$–J$_3$ and J$_4$.

In order to increase the efficiency of field development with poorly drained mobile oil reserves in certain sections of the production object characterized by high anisotropy, the cyclic flooding is envisaged.

**Figure 4. Interaction of injection and production wells**

| Legends: |
|---|
| – fault lines |
| – tracing fluid direction |
| – injection well |
| – wells without tracing fluid outflow |
The area chosen for this treatment method represents a complex geological-hydrodynamic system with considerable non-uniformity of porosity and permeability, with developed system of formation pressure maintenance (FPM), limited from both sides by fault lines. The area is characterized by increased remaining oil reserves, which are concentrated mainly in $J_5$, $J_{10}^1$ and $J_{10}^2$ formations. The average oil flowrate for the area was 3.95 t/day with an average water cut of 78%. The injection capacity of wells varies within wide limits: from 49 to 133 m$^3$/day for Tyumen suite and from 0.7 to 91 m$^3$/day for Sherkalinskaya suite.

The calculations were made for the test section comprising 27 wells, 9 of which are injection wells, 18 producing wells, optimal periods and half-periods of injection were determined. According to these parameters, the wells operating at these intervals of operational objects were ranked. Thus, by the ratio of injection and production wells, the greatest coverage is obtained in the $J_{10}^1$ formation. The duration of cyclic flooding is 5–6 months.

4. Conclusion

Thus, the degree of hydrodynamic connectivity of wells, as well as the compensation of fluid extraction by water injection, was determined in the test site, which in turn allowed estimating the efficiency of cyclic flooding. It is worth noting the different nature of the influence of injection wells on reactive producing wells. The best hydrodynamic well connectivity for the site is identified in the south-west direction.

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