Development of oil deposits in tectonic conditions

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Abstract. The paper presents the detailed analysis of structural and tectonic structure of the foundation surface and Jurassic deposits of Western Siberia, which allows identifying complex, small-sized geological objects promising for the detection of small oil deposits, clarifying the location of exploration wells, searching for deposits in subvertical destruction zones in deposits of the middle and lower Jurassic, foundation rocks in territories with already discovered overlying oil deposits. The zones of excessive fissuring, connected, among other things, with the zones of horizontal shear, which made it possible to change the expected contours of existing deposits and to reveal perspective excessive fissuring zones.

1. Introduction

One of the most important tasks that the Russian oil industry is facing these days is the creation of a scientific and methodological basis for improving the management efficiency of hard-to-recover oil deposits development [1–10]. Such objects include the Jurassic deposits complicated by tectonic deformations.

The presence of fault block tectonics complicating the structure of Jurassic deposits was determined and proved in many fields of Western Siberia. Some tectonic deformations originate in foundation rocks and penetrates the sedimentary mantle to a different depth, the others have limited propagation within separate suites, and the third are almost not mapped by 3D seismic survey in view of low amplitude or due to formation of separate blocks at horizontal shifts.

In our opinion, one of the tools that can solve this issue is seismodynamic analysis. In Kogalym region it was first used at Povkhovsky field in 2013, using 16 dynamic attributes in the PARADIGM software complex. The zones of excessive fissuring associated with tectonic deformations were determined (Figure 1).

Using the seismodynamic analysis of the wave field the identification and determination of direct connection of extended zones and sections of excessive fissuring, low-amplitude vertical movements,
having different area and shape, with disjunctive disorders of foundation rocks, which, in turn, are confined to the boundaries of structural elements of elevated troughs (Figure 2), as well as with horizontal and vertical low-amplitude failure of rocks of lower and middle Jurassic introduced additional important factors in the strategy and principles of exploration drilling, operational drilling, selection of the main types of well interventions, such as sidetracking and hydraulic fracturing, optimization of the development system.

Figure 1. Comparison of results of dynamic analysis of various attributes to identify the tectonic zones in the pre-Jurassic complex: A – value of upper extremum of seismic signal amplitude; B – instantaneous phase of seismic wave signal, instantaneous phase value of the seismic wave signal at the top of the analysis window; C – instantaneous frequency band of the seismic wave, the average of the absolute values of the instantaneous frequency band of the seismic wave; D – envelope of the seismic wave signal, the value of the envelope of the seismic wave signal in the upper part of the seismic horizon; E – amplitude weighted by the instantaneous phase of the seismic wave, the value of the amplitude weighted by the instantaneous phase of the seismic wave in the upper part of the seismic horizon; F – amplitude weighted by the instantaneous phase of the seismic wave, the average value of the amplitude weighted by the instantaneous phase of the seismic wave; G – amplitude weighted by the instantaneous frequency of the seismic wave, upper extremum of the amplitude spectrum weighted by the instantaneous frequency of the seismic wave; H – zones of active tectonics (their boundaries) revealed through the trend analysis of the II order dynamic attribute values.
3. Methods and materials
The results of dynamic analysis should be considered in conjunction with seismic survey data with the results of geological and field analysis, geophysical well survey data, downhole logging data and other special surveys, if available.

On the basis of the performed analysis of the West Povkhoovsky section, it was developed and recommended to drill perspective edge regions of a developed deposit located in the zones of excessive fissuring and subvertical destruction, sidetracking with horizontal and inclined direction result.

3. Results
The southern part of the deposit, the area of well No. 82P, is partially covered by 3D seismic survey (Figure 3), where the dynamic analysis of the “instantaneous acceleration” attribute recommends sidetracking of 4 wells, 3 of which are horizontal and 2 new production wells.
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Figure 3. Mapping of planned measures on the distribution of the maximum absolute value of instantaneous acceleration of the seismic wave signal in the interval of SE-1 formation in the area of well No. 82P of the West Povkhovsky section

The wells for sidetracking were selected with critical current water cut, which made 99 % or more, except for well No. 7238, which is considered for the future in case of water increase (Figure 4).

The main criterion is the location of wells within the zones of tectonic deformations, or not at a long distance, not more than 200 m.

The geological structure of the productive part of the formation on the site is very similar, the sedimentation conditions are identical, the conclusion is made from the analysis of electric logging curves. The capacity of SE-1 reservoir is 9–10 m, porosity –15–16 %, permeability according to geophysical well survey – 16–40 mD, oil saturation – more than 0.6 unit fractions, interpreted as oil in all wells. In the northern part and the eastern part, the oil saturation of edge wells is 0.47–0.5 unit fractions (Figures 5, 6). Under these parameters we have a significant difference in fluid and oil production, which directly depends on the affiliation with excessive fissuring zones.
Figure 4. Extract of SE-1 formation development map, well area No. 82P

For example, the edge well No. 7240 located on the eastern side of the site in the zone of tectonic disturbances, was put to operation after drilling with fluid flow rate of 60 m$^3$/day, oil flow rate – 57 t/day without hydraulic fracturing. The neighboring wells located in relatively calm zones were put to operation with lower fluid flow rates – 2-3 times, which indicates the worst reservoir properties due to lower permeability directly related to the intensity of rock fracturing. Well No. 7246 – fluid flow rate $Q_w = 20$ m$^3$/day, 5% water, dynamic level $H_d$ – 1600 m, developed after drilling without hydraulic fracturing, rapid decrease of inflow was observed.

A good example of the influence of the zone of tectonic deformations fixed on temporary seismic sections is the location of well No. 7240 (Figure 7). From the foundation rocks to SE-1 basement there is a discontinuous fault, some operating faults fade in the deposits of the middle Jurassic.

According to the results of the dynamic analysis, it was recommended to conduct sidetracking with horizontal well No. 7246G eastwards with a distance of 200 m from the mother hole and opening of productive rocks in the zone of excessive fissuring. The well was drilled and launched with a flow rate of 35 m$^3$/day of clean oil, a dynamic level at the well mouth. Waterless operation during 1.5 years of this well, 100% water cut of adjacent production wells can indicate the presence of hydrocarbons in this area of faults.

In the eastern part of the section, after watering of well No. 7244 up to 100% into the zone of detected excessive fissuring, the second horizontal borehole was drilled in the north-west direction between wells No. 7238, 7243. The flow rate was 60 m$^3$/day, 34% water, oil flow rate – 35 t/day, $H_d$ – 580 m, in 5 months the water cut began to grow. The location of the zone of tectonic deformations was also confirmed here. In this area it is proposed to drill two lateral horizontal holes: No. 7243G with a distance of 200 m from the mother hole in the western direction, No. 7238G with a distance of 200 m in the azimuth of 290°, as well as to drill two new wells in the zones of fault tectonics development (Figure 3).
**Figure 5.** Geological section of formation SE-1 along line 1 of the West Povkhovsky section

**Figure 6.** Geological section of formation SE-1 along line 2 of West Povkhovsky section

**Legends:**
- Discontinuous faults identified in seismic section
- Drilled well

**Figure 7.** Tectonic deformations in the area of well No. 7240 according to 3D seismic survey
It is planned to drill 12 new operational wells, 7 of which are dependent, 2 directional second wellbores (well No. 7214H, 7355H), 1 second horizontal wellbore (well No. 7354G) (Figure 8) near well No. 83P.

**Figure 8.** Mapping of planned measures on the distribution of the maximum absolute value of instantaneous acceleration of the seismic wave signal in the interval of SE-1 formation deposits in the area of well No. 83P of West Povkhovsky section

The dependence of well flow rates on the distance relative to tectonic deformations is observed in almost all fields of Western Siberia up to deposits of Aptian-Albian-Cenomanian complex of gas deposits of northern regions (Yamburgskoye, West Tarkosalinskoe, Kharampurovskoe fields). Summarizing the available data on the development of oil deposits of the Upper Jurassic, the maximum distance of fault impact on well production was determined, which made 1.5 km. At West Povkhovsky section at a distance of 500 m from the detected fracture zone the well flow rate was on average 50% lower, at a distance of 1.5 km the decrease reached up to 4–6 times.
The detection of elevated trough systems, faults and overlap folds, different disjunctive breaks on the surface of the foundation and inherited structures in the Jurassic sedimentary mantle allows approaching the geological exploration and planning operational drilling more reasonably. This approach reduces the share of wasteful expenditures, which is important at the stage of field development to obtain large volumes of hydrocarbons, to develop subsoil more rationally.

This approach is particularly relevant in areas with developed infrastructure, where drilling and development of small areas is accompanied by minimal capital costs, the access to which is not so problematic.

4. Conclusion

The detailed analysis of structural and tectonic structure of the foundation surface and Jurassic deposits of Western Siberia allows identifying complex, small-sized geological objects promising for the detection of small oil deposits, clarifying the location of exploration wells, searching for deposits in subvertical destruction zones in deposits of the middle and lower Jurassic, foundation rocks in territories of existing deposits and to reveal perspective excessive fissuring zones.

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