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Structural features and formation of lower Cretaceous AV_1 layer in the Soviet oil field (Tomsk Oblast)

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Abstract. The analysis of the collected geological and geophysical information on AV1 layer known as Ryabchik formation is carried out. The facial conditions of this formation which define structural features of «Ryabchik» sandstones formations are considered. Maps characterizing permeability and porosity of reservoir are plotted. Areal tracking technique of sand streaks is given.

1. Introduction

Oil industry development in Tomsk Oblast began in 1962 with discovering of the Soviet field located in the northwestern part of the region, 10 km from Strezhevoy (figure 1). In 1966 it was included into pilot well program, 75 exploration and 1397 producing and injection wells from 1682 to 2795 m in depth were drilled here. The field is multilayer, oil-bearing potential is proved by 18 reservoirs and it belongs to the category of the largest fields by its reserves. The field is at the fourth stage of extraction, water influx is more than 80%.

The Alymsky AV_1 layer represents a periodic, thin-layer, lens-shaped interlayering of clayey sandstones, siltstone and clays, it is characterized by the distinctive low permeability and porosity, high structural discontinuity, which results in low well yields and low well flow index [1]. The AV_1 layer oil reserves contain more than 70.9% of the residual extractable C1 reserves. Oil-bearing strata range from 4.8 to 24.9 m between wells, averaging at 15.6 m. In the AV_1 horizon five oil-bearing sandy rider seams are allocated: $AV_1^{\,1}$, AV_1^{2a}, AV_1^{2b}, AV_1^{3} and AV_1^{4}.

Production geologists call the AV_1 layer «Ryabchik» formation due to its distinctive appearance and a lenticular structure (reminds of hazel grouse feathers, ryabchik being the name of the bird in Russian). Research conducted in Reservoir Engineering Laboratory has established low values: permeability from 0 to 107 10^{-3} micron^2, porosity from 0 to 10%; which practically identifies this layer as non-collector and therefore it was considered as no-prospect [2]. In addition, there were no techniques to estimate oil reserves and the field was not developed. However, with advances in hydraulic fracturing, there appeared an opportunity to extract oil from this reserve, thus determining the timeliness of this research.

Oil production in Tomsk Oblast has decreased since 2012 [3]. Development of underexplored Alymsky AV_1 layer, as well as exploration and development of the Neocomian reservoir [4] [5], is urged to stabilize a source of raw materials.

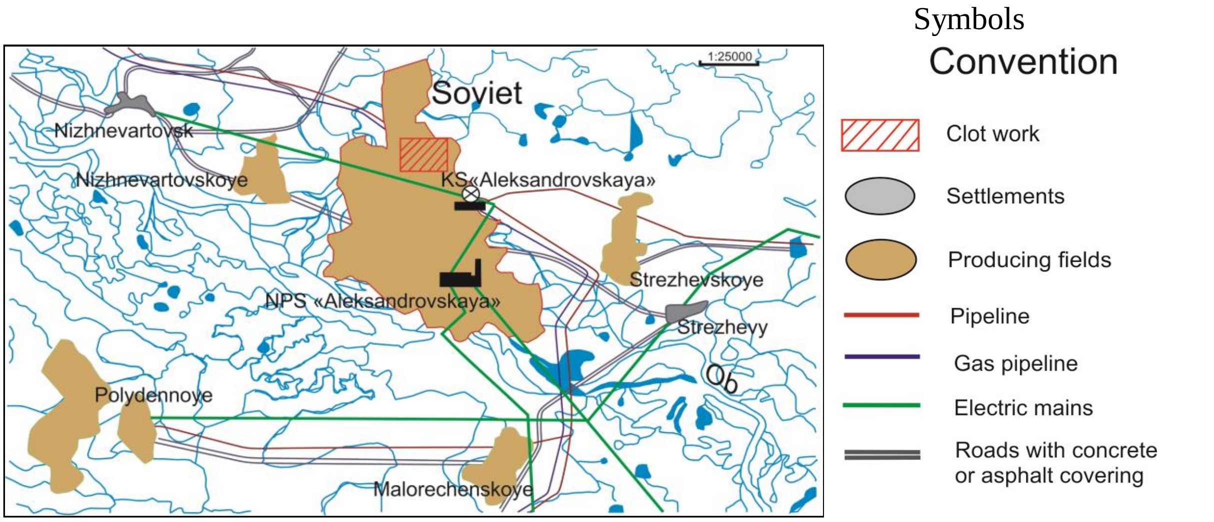

Figure 1. Works site location on the survey map of hydrocarbons fields in Tomsk Oblast

2. AV_1 layer characteristics

Formation genesis of the «Ryabchik» formations of sandstones can be explained in terms of their structural features. The typical structural distinctive features of the sandstones allow classifying them with faltering lamination. Sedimentology links formation of such lamination with consecutive frequent alternating stages of quiet and vigorous hydrodynamic activity resulting in deformation of primary layer structure [6].

Considering that the complex of deposits in question was formed in the sea pool, the model of "storm" sandstones is the most acceptable to it. On the one hand, it explains extensive development of the «Ryabchik» sandstones, on the other hand, it explains their structural features. Storm sandstones are one of widespread elements of sandy component in a shelf zone. Their formation is linked to sites subjected to coastal storms [7]. Destruction of barrier coastlines due to strong hydrodynamic activity promotes transportation of coarse-grained materials for considerable distances to remote shelf sites of the sea basin (figure 2).

Alternation of the storm periods with quiet stages of sedimentation are favorable for interlayering of well-sorted sandy and clay material. However, clay interlay in "storm" sandstones of a shelf zone does not form a homogeneous lithological layer. It is due to the fact that the thin clay cover formed during quiet sedimentation is subjected to the subsequent storm situation with strong hydrodynamic impact. At the same time clay material mixes up with sandy varieties, forming a sandy-argillaceous band with wavy faltering, the typical «Ryabchik» structure. One of the storm sandstones important features is considerable lateral development of separate thin sandy band [8].

As showed in figure 2, packs of storm layers are formed as a result of periodic destruction of barrier structures, when well-sorted sandy material is transported to considerable distance from the coastline towards the sea in short time, covering the sea bottom with a thin but extensive (tens of square kilometers) sandy cover. Subsequent calm period promotes accumulation of the blocking band of clays, and further activation of wave activity resumes process of coarse-grained material transportation. Hydrodynamic activity promotes crushing of the previously formed clay sublayer and introduction of separate parts into the spreading sandy reserves, which leads to faltering lamination formation [6].

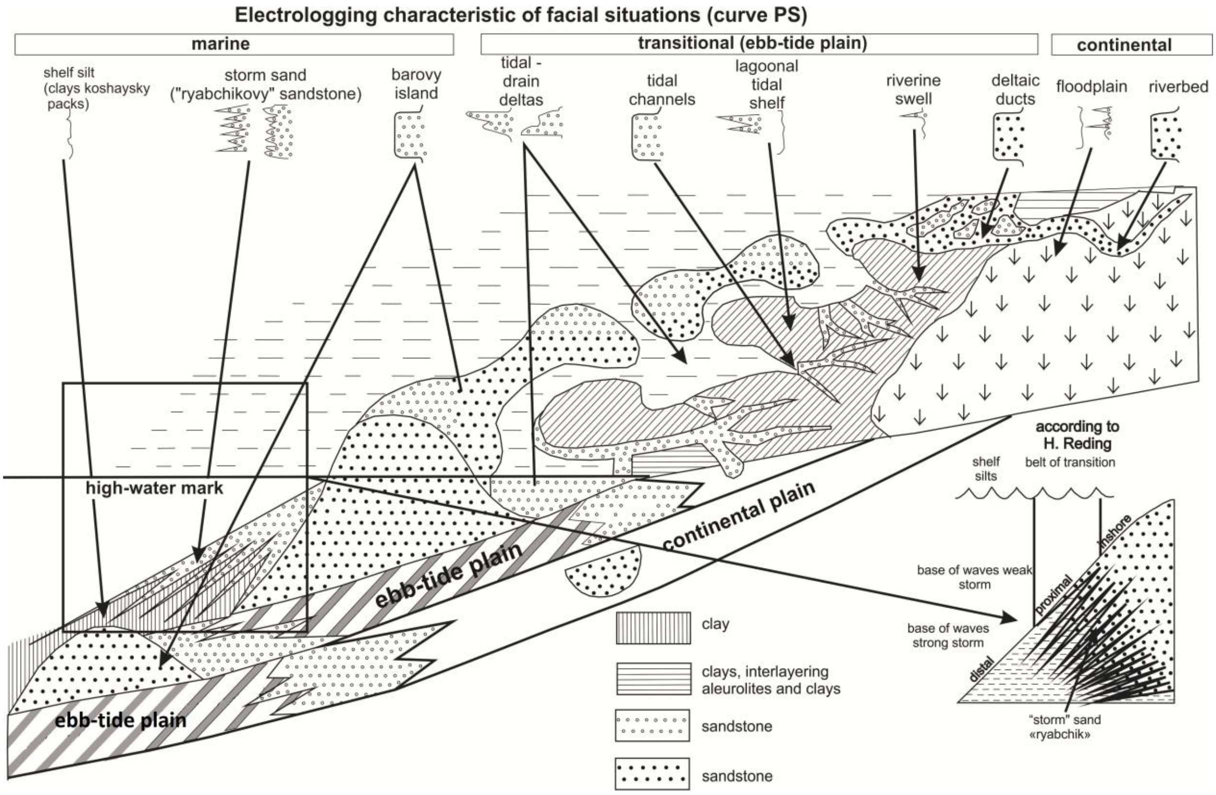

Figure 2. Paleogeographic facial conditions of «Ryabchik» sandstones formation [7].

3. AV_1 layer porosity and permeability analysis

The studied AV_1 layer permeability and porosity have been determined from data of geophysical surveys, carried throughout the history of the Soviet field development. In our research, the analysis of porosity and permeability of the northeast part has been carried out.

Research has shown (figure 3) that porosity is practically identical throughout the site, while the permeability coefficient significantly increases around wells 379, 381, 646, i.e. filtration characteristics of rocks increase in the northeast direction (figure 4).

Analysis of the permeability map shows:

• The layer is mainly sandy and has graded layering in a coastal zone in close proximity to barrier structures. While it advances towards the sea, the number of clay sublayers increases and in the deepest zones accumulation of clays prevails.

• Coastal storm sands represent lithological uniform section of storm deposits limited by erosion surfaces with thickness from 5 to 130 cm without slate interlayers.

• Proximal storm sands (layers from 5 to 100 mm thick) usually keep the lithologic and structural characteristics demonstrating their single-shot formation from a uniform stream.

• Distal storm sands are evident in the zone of shelf silt facies. They are fine-grained formations usually with thickness of less than 50 mm, with horizontal or slanting lamination [2].

The studied deposits being storm sandstones is confirmed by the following:

- broad development and close similarity of the geophysical characteristic among the composing packs all over the studied area;

- «Ryabchik»-type appearance of separate packs that can be linked to faltering lamination development;

- considerable content of clay in the section testifies to remoteness of the area from the coastline during the deposit formation [9].

According to logging charts there are post-sedimentation carbonated sandstones within low thickness sublayers, which being the uniform stratigraphic level of dissociation of a collector, can be used for distinguishing the horizons to correlate sandy layers of sea, coastal and continental genesis [10]. Together with clay sublayers, they represent the reliable intra-reservoir confining beds dividing a reservoir into hydrodynamically isolated systems. Repeated change of thickness and weakening of hydrodynamic processes promote formation of the interstratifying layers of considerable thickness and extent in the form of a "puff pie" which can also have various lithologic "stuffing" (figure 2).

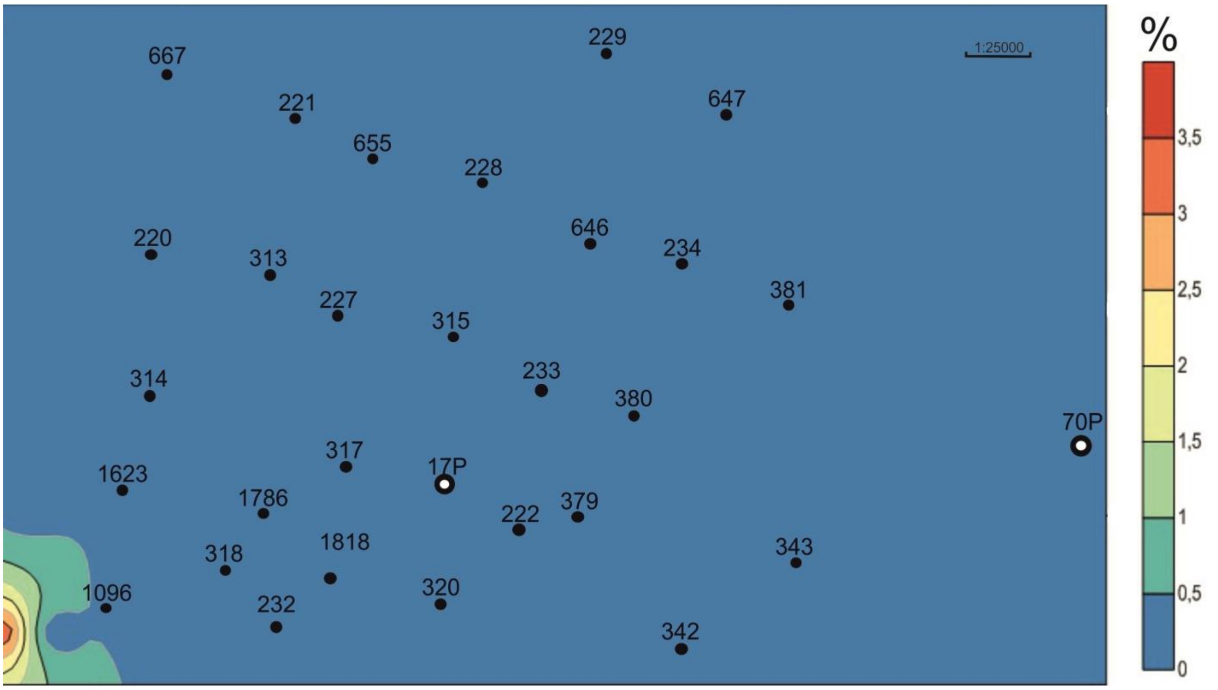

Figure 3. Porosity of the study area

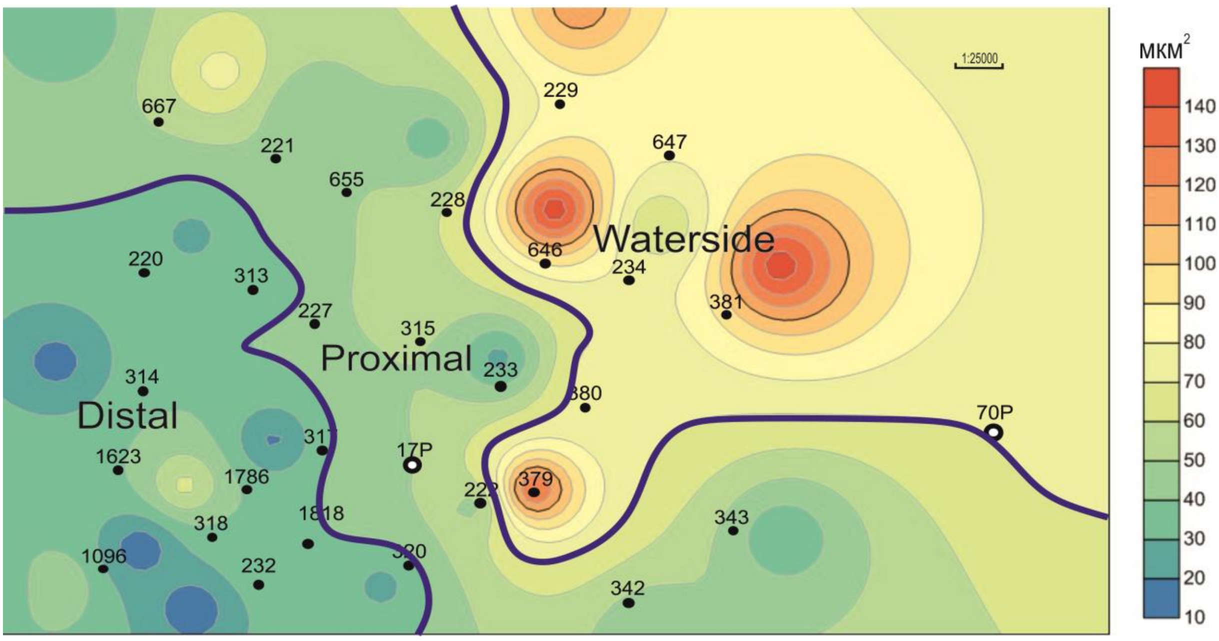

Figure 4. Permeability of the study area

4. Results

Proceeding from the considered model of AV_1 layer structure it is possible to draw a conclusion that the allocated inter-reservoir covers presented by both clay sublayers and sublayers of carbonated sandstone can serve as local hydrodynamic divisions for AV_1^1 sublayers AV_1^{2a} and AV_1^{2b}. In this regard each of the allocated sublayers should be considered as independent hydrodynamic system.

The studied AV_1 layer reserves in the Soviet field are difficult to recover. Therefore, development of the appropriate technologies allowing increasing oil recovery is required to bring these new areas into development. Well interference testing may be one of the most effective techniques. This method will allow conducting research on the unsteady mode of filtration and to define connectivity of the layer between wells.

To obtain reliable data on characteristics of layer and to reveal their heterogeneity, it is important to select the wells for the interference test correctly. For this purpose, it is necessary to consider the actual azimuth of a wellbore direction, data on special arrangement of wells, changes in vertical and radial permeability of layer.

5. Conclusion

The AV_1 layer formative conditions analysis in the Soviet field has revealed major sedimentation factors proving complex lithologic structure of the reservoir, and allowed evaluating sandy oil-saturated sublayer area.

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