Construction of geological model of a shallow super-viscous oil deposit based on core analyses and geophysical monitoring data

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Abstract. Deficiency of fossil minerals, limited reserves of conventional hydrocarbon raw materials indicates the need to involve in the fuel and energy complex of other sources of hydrocarbons. Fields of super-viscous oil are one of the sources. Development of super-viscous oil deposits opens new challenges in the field of building geological models associated with the shallow occurrence of these deposits. This article is devoted to the study of sediments of the Permian sedimentary complex containing super-viscous oil deposits. Study object is Sheshmian sandstone pack of the Ufimian stage. The pack is composed of sands and sandstones with different degree of carbonate cementation with small interlayers of siltstones. Cementation is the main factor which affect reservoir quality. In the process of analysis and preparation of the initial data and, subsequently, the geological model construction, the main features of the super-viscous oil deposits were revealed.

1. Introduction, general information about deposit

In this paper, the Lower Karmalsky uplift of the Cheremshansky oil field, is considered. The uplift controls super-viscous oil deposit and territorially confined to the western Zakamye. In tectonic terms, it is located on the western slope of the South Tatar arch, which is a sloping monocline, step-wise submerging in the direction of the Melekess depression.

The Lower Karmalsky positive structural form is an integral part in the ridge of elongated sand bodies of the northwest strike. Sand bodies are paleobars; they have the form of local sedimentary domes of the brachiantical type. The chains of the uplifts are separated from each other by sections of reduced thickness of the sand pack [1-2].

The Sheshmian sandstone pack of the Ufimian stage is the main stratum containing hydrocarbons. The pack is composed of sands and sandstones with different degree of carbonate cementation with small interlayers of siltstones. Cementation is the main factor which affect reservoir quality [3]. The thickness of the pack varies from 3 to 10 meters on the wings and up to 45 meters in the arch of the structure.

Deposits of Sheshmian sandstone pack of the Ufimian stage are overburden by the lower pack of the Baytuganskian horizon, composed of clays, dark gray, with a bluish tinge and is a reliable impermeable layer (reference horizon – “lingula clays”). The sections with the
maximum thickness of the Sheshmian sandstones correspond to the minimum thickness of the “lingula clays” pack.

The upper pack of the Baytuganskian horizon, lying over the “lingula clays”, is composed of limestones, bluish-gray, dark gray, steel-gray, porous, cavernous, fractured, with a mass of brachiopod and spirifer residues, in the bottom with frequent remains of bryozoans with inclusions of pyrite (reference horizon – “Medium-spirifer limestone”). Its thickness is from 2 to 4 meters [4-5].

2. Correlating core analysis and well logging

The accuracy of geological modeling depends on the correct determination of the depth of rocks samples, therefore core analysis data should be correlated with well logging curves.

The study of well sections and refinement of core sampling depths begin with the identification of reference horizons - spatially and lithologically continuous rock strata that have a clear and explicit well logging characteristic – and an accurate correlation of core, collected from these horizons. The reference horizons on the studied deposit are (from top to bottom) “Medium-spirifer limestone”, “Lingula clay” and a shaly sand pack of the Ufimian stage, underburden on the main productive strata.

Correlating core analysis and well logging was done by comparing the values of porosity, saturation, permeability, density, carbonate content and other characteristics determined on core samples with well logging curves. As a result, separate continuous formations were identified.

For correlating core analysis and well logging a well logging complex was used, including: GR, NGL, PZ, SP, density gamma-gamma logging. In addition, Caliper, LLD, etc. were used (Fig. 1).

3. Building of the structural framework

Building of the structural framework of the three-dimensional model is the next step after the completion of the detailed correlation.

A peculiarity in structural constructions of a shallow deposit is the specificity of processing and interpretation of seismic data in the upper part of the section, which does not allow obtaining sufficiently accurate data about structures in the inter-well space. This is due to the low speed zone and, consequently, the poor resolving capacity of seismic exploration in the upper part of the section (~ 300 m). Exploration wells in the investigated deposit have been drilled with a close spacing, and therefore structural constructions based on well data are more accurate.

When constructing a grid model, a smaller grid should be defined than in traditional models in order to characterize the heterogeneity of a closely drilled reservoir and also to describe the process of steam-assisted gravity drainage (SAGD) in reservoir modeling, if the SAGD method is planned to be used during the deposit development. Rotation of the grid should be chosen from the calculation of its orientation, not only along the strike of the geological structures, but also in the cross of the main mass of the horizontal boreholes.
4. Geometrization of deposit, sandstone lithotypes classification based on carbonate content and density properties

While the geometrization of deposits the main difference from the work with traditional model is presence of a large volume of core material, selected from prospecting, exploration, structural wells.

Based on the correlating core analysis and well logging the following sedimentation concept was adopted for further building of the geological model:

- the upper sandstone (productive) part of the deposit has undergone erosion, “Lingula clays” pack overburden this part with unconformity;
- layering of the upper sandstone pack was carried out by follow base method;
• shaly sand pack, lying at the base of the upper sandstone pack, is rather sustained in thickness, and, therefore for this zone were choose proportional layering between top and bottom.

After the layering process of 3D grid, the reservoir/non-reservoir parameter was calculated from normalized GR value. It should be noted that the upper (sandstone) pack of the Ufa stage throughout the section is represented by a reservoir of different quality (depending on carbonate content and density), and the lower (shaly sand) pack is largely represented by a non-reservoir with interlayers of reservoirs.

In the obtained reservoir volume on the basis of carbonate content property (according to core studies) and density property (according to core studies and well logging) lithological types were divided. In total, 2 lithologic types of sandstones were distinguished - loose sandstone and firm sandstone with carbonate cementation. (Fig. 2).

Further, to determine the reservoir saturation behavior, the strata with mass bitumen saturation above and below 4.5% were distinguished (according to oil producing company condition criteria). For this, cells with mass bitumen saturation above conditioned were assigned the value 1, cells with saturation below conditional - 0, after which this parameter was interpolated in the reservoir volume using the Kriging method. The final discrete property of the reservoir saturation behavior (Fig. 3) was calculated using a cutoff of 0.5 (more than 0.5 — an interval with a bitumen saturation higher than the conditioned one).

![Fig. 2 Lithological types of sandstones slice.](image-url)
5. **Building a petrophysical model**

As a basis for the distribution of porosity in the model core analysis data correlated with well logging were used.

The methods of porosity distribution do not differ from the work with the traditional model. Porosity distribution in the reservoirs was carried out using the Gaussian random function simulation method for each lithological type of sandstone separately.

The permeability property also was distributed on a basis of core analysis data (horizontal absolute permeability). The porosity property was used as a trend in the permeability distribution, since the number of porosity measurements is greater than the permeability measurements.

6. **Building a saturation model**

For the distribution of bitumen saturation, the dependence of volumetric bitumen saturation on mass is obtained, since the measurements of mass bitumen saturation are more accurate for super-viscous oil. After recalculation, the obtained values of volumetric bitumen saturation were distributed separately in the zones with bitumen saturation above and below 30% (according to oil producing company standards).

7. **Geophysical monitoring, optical fiber thermograms analysis**

When developing a shallow super-viscous oil deposit by the SAGD method the temperature is periodically measured [6-7]. Using of thermograms in complex with well logging and production data allows us to determine the correct position of the horizontal wellbores in a 3D model and to clarify the surface of the oil water contact which is not horizontal in a shallow super-viscous oil deposits.
Fig. 4 shows an example of a thermogram. The lowest temperature in the toe of the production well is due to the presence of a large amount of produced water. It is worth noting that such an analysis should be carried out in conjunction with the development analysis, if the salinity of the produced water is significantly lower than the reservoir water, then the assumption of the proximity of the conditional oil water contact is not correct - more likely steam has break through from the injection well.

8. Conclusions

On the basis of correlated core analysis data lithological types of sandstones and the reservoir saturation behavior models was constructed, the following features of the construction of geological models of a shallow super-viscous oil deposit was distinguished:

- The presence of a large volume of core material can serve as a source of data allowing to build detailed geological model core analysis data should be correlated with well logging data.
- The complexity, and often the impossibility of processing and interpreting seismic data in the upper part of the section do not allow us to obtain sufficiently accurate data on structures in the inter-well space. In the case of close spacing of drilled wells, structural constructions for well data will be more accurate.
When building a bitumen saturation model, it is necessary to allocate conditioned and substandard zones of saturation (according to oil producing company standards), since there may be layers with high porosity and low saturation within the deposit. Measurements of mass bitumen saturation, as a rule, are presented in a larger volume and more reliable than measurements of volumetric bitumen saturation.

Geophysical monitoring based on analysis of thermograms in production wells allows to clarify the position of the conditional OWC.

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