The prospects of oil deposits of the Vereyian horizon of the marginal part of the Melekess-Abdulin oil and gas region of the Tatarstan Republic

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Abstract. The paper presents the results of a study of oil-bearing sections of the Vereyian horizon of low-amplitude uplifts in the western marginal part of the Melekess-Abdulin oil and gas region of Tatarstan. It has been established that the main reservoir rocks are algal-peloid packstones, fusulinide grainstones and greywacke fine-grained sandstones. Carbonate reservoirs of the lower part of the section of the Vereyian horizon and sandstones of the upper part of the section are watered to varying degrees, most of them are not promising for development. The productivity of the sections is associated with fusulinide grainstones and underlying algal-peloid packstones that have not experienced intensive waterflooding. As a rule, such lithotypes of carbonate reservoir rocks are in the middle parts of sections of Vereyian age. A feature of the fusulinide limestone layers is their areal inconsistency in thickness, which is due to the facies conditions of the sedimentation basin. Due to this, on some small oil-bearing structures they give good oil inflows, on others they show relatively small debits.

1 Introduction

The Tatarstan Republic is one of the oldest oil-producing regions of the Volga-Ural anteclise [1]. According to rough estimates, from 2.6 to 6 billion tons of oil reserves are concentrated here [2]. Most of the oil fields are localized within the South Tatar arch and the Melekess depression [3-7]. Currently, unique and large oil fields in terms of reserves are at the late stages of development [8-12]. Therefore, further oil production is associated with the search and development of small oil-bearing structures and previously unpromising structural subdivisions [13]. In recent years, small oil companies have begun to actively develop the marginal part of the Melekess-Abdulin oil and gas region, having discovered several small oil fields. Prospects for development are associated with deposits of the Bashkirian (C_2b) and Moscowian (C_2m) stages. If the geology of the oil-bearing sections of the Bashkirian stage is more or less clear, then the deposits of the Moscowian stage raise numerous questions. Since even with the oil content visible in the core of the intervals of the Vereyian (C_2vr) and Kashirian (C_2ks) horizons, the proportion of oil

extracted from them is relatively small [14-16]. This is due either to the complexity of the geological structure of the sections of the lower part of the Moscowian stage, or to passed reservoir flooding processes. Taking this into account, the study of oil-bearing sections of the Vereyian horizon of low-amplitude uplifts of the western marginal part of the Melekess-Abdulin oil and gas region was carried out deposits.

2 Materials and methods

The main research methods were optical microscopic, X-ray diffraction analysis was used as an auxiliary method.

Optical-microscopic analysis of the rocks was carried out on a polarizing microscope Carl Zeiss AXIO Imager A2. Before research, thin sections were made from samples of carbonate and terrigenous rocks - thin sections with a thickness of about 0.03 mm. This thickness of the plates makes it possible for polarized and transmitted light to pass through the analyzed samples. The study determined the mineral composition of rocks, associations of organic residues, secondary transformations: leaching, calcitization, dolomitization.

X-ray analysis was carried out to clarify the mineral composition of the rocks of the Vereyian horizon. X-ray survey was carried out on powder preparations. X-ray diffraction analysis was carried out on a D2 Phaser diffractometer (Bruker, Germany). Analysis mode: X-ray tube voltage - 30 kV, current - 30 mA, scanning step - 0.02°, speed - 1 deg/min. The range of scanning angles in the Bragg-Brentano geometry was from 3 to 40°.

3 Results

In total, 4 sections of low-amplitude uplifts with obvious oil content were studied in Vereyian -Bashkirian deposits. Reservoir layer-uplifted type with regional oil-water contact in the middle part of the Bashkirian horizon. Reservoir oil deposits in the sediments of the Vereyian horizon do not have their own contact with bottom waters. In the sections of the Vereyian horizon, alternation of carbonate rocks of different facies with sandstones, siltstones, and clays is observed. From bottom to top along the sections, there is a gradual increase in the share of the terrigenous component with a decrease in carbonate rocks. Conventionally, the sections can be divided into two parts: lower carbonate and upper terrigenous (figure 1).

Within the carbonate part of the section, interbedding of dense and decompressed oil-saturated limestones is noted. The cap rocks are represented by dense varieties of micro-grained mudstone-wackstone limestones and recrystallized packstone limestones, according to the R.J. Dunham [17]. The dense composition of structural elements in limestones and the predominance of capillary intergranular pores in them, containing practically immobile pore solutions, determine the good fluid-resistant properties of carbonate rocks. Due to this, hydrodynamically separated oil reservoirs formed between them, often differing both in the fractional composition of oil and in the intensity of watering [18]. The reservoir rocks are mainly represented by two limestone lithotypes: algal-peloid packstones and fusulinide grainstones.

Algal-peloid packstone limestones (figure 1B,D) are developed in the lower and upper parts of the carbonate section of the Vereyian horizon. For the most part, they are characterized by uniform oil saturation, dark brown color, and massive texture. Only at the bottom of the section, some reservoir rocks have spotted-banded oil saturation due to the development of nest-like and banded light gray aggregates of diagenetic calcite in them. Limestones are composed of 80-85% organic remains 0.1-0.25 mm in size, represented by spheroidal microgranular lumpy aggregates (70-75%), fragments of algae (15-20%), segments of crinoids (5-10%), rare brachiopod valves. Bioclasts come into contact with

each other at the edges, forming a dense structural pack. Organic residues are cemented with calcite cement, porous type with a microgranular structure. Most of the cement is leached from the interform space of the rock. Clear-grained diagenetic calcite develops in the formed pores in the form of large grains. In some oil reservoirs, rhombohedral grains of diagenetic dolomite (up to 0.25 mm) are found in the pores. In patchy-banded oil-saturated limestones, the share of diagenetic calcite is 20-30%, a large amount of heavy fractions of hydrocarbons appears. Heavy hydrocarbons form thick dark brown films along the walls of pore-caverns. Limestones with uniform oil saturation contain 15-20% pores. Interform pores communicating, form winding intersecting channels up to 0.25 mm in diameter, filled with oil. Limestones with patchy-banded oil saturation contain 10-15% pores. The pores are unevenly distributed, healed to varying degrees by clear-grained calcite aggregates, and contain films of oxidized oil.

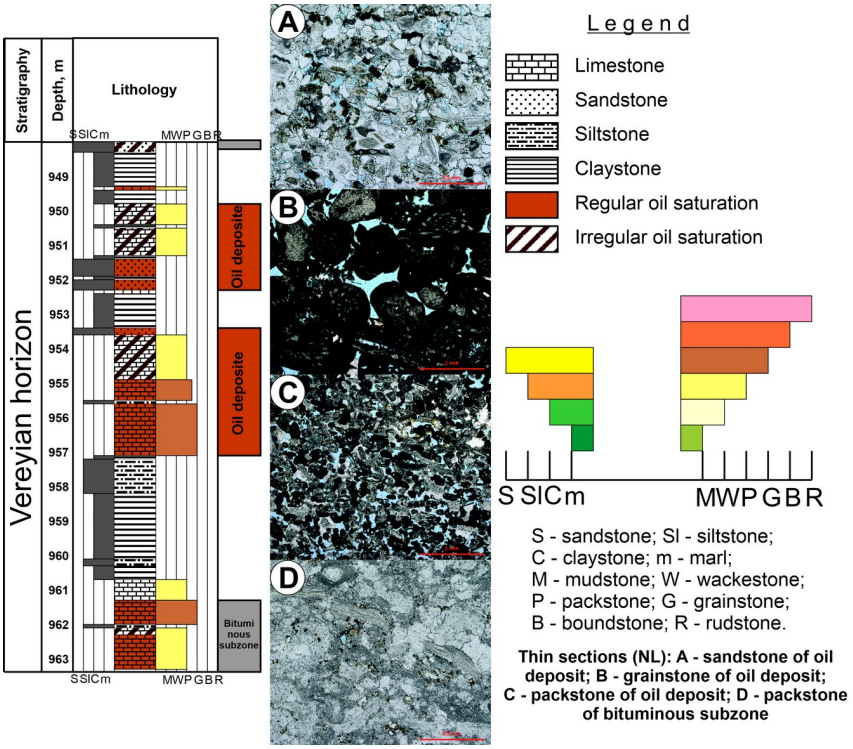

Fig. 1. Lithological section of the Vereyian horizon oil-bearing strata with photographs of the main sedimentary rocks types.

Fusulinide grainstones (figure 1B) occur in the middle part of the section of the Vereyian horizon, forming layers with a thickness of 1.8 to 4.5 m. In all wells, the rocks are uniformly oil-saturated, dark brown, massive, with numerous caverns up to 1.0 mm. Limestones are 80-85% composed of organic remains with a predominant size of 0.25-0.5 mm. Bioclasts are represented by whole, weakly granulated fusulinid shells (85%), segments of crinoids (10%), shell fragments of bivalve mollusks (3%), and rare fragments of algae (2%). In separate layers, in addition to organic remains, there are 5-10% angular fragments of quartz grains and feldspars of silt-sand size. Angular quartz grains grow into fusulinid shells, which is a consequence of the lithostatic pressure of the overlying layers. The shaped elements are cemented with porous-type calcite cement, with a microgranular structure. The cement is mostly leached from the interform space of the rock, fixed in the

form of thin rims along the edges of the organic residue. Grains of diagenetic fine-medium-grained calcite are noted in the formed cavities of the caverns. In some areas, single aggregates of chalcedony up to 1.0 mm in size are noted, filling the pore space of the rock. Limestone contains 15-20% pore-caverns. Interform pores communicating, form winding intersecting channels up to 1.0 mm in diameter, filled with oil.

Within the terrigenous part of the section, interbedding of dense greenish-gray calcareous marls, greenish-gray and reddish-brown mudstones and siltstones with rare interlayers of dense dark gray wackstone and packstone limestones is noted. The reservoir rocks are represented by layers of sandstones with a thickness of 0.8 to 1.6 m. Terrigenous reservoirs are enclosed between layers of dense rocks, they are isolated oil deposits. They usually have a higher degree of water cut compared to the underlying carbonate reservoirs.

Sandstones according to the classification of V.D. Shutov belong to the graywackes (figure 1A) [19]. The rocks are characterized by a polymineral composition, fine-grained structure, uniform oil saturation, dark brown color, massive or indistinctly layered texture. Sandstones are 80-85% composed of a clastic component with a predominant size of 0.1-0.25 mm. They contain semi-rounded quartz grains (40%), rounded fragments of siliceous rocks (35%), fragments of organic remains (15%), angular grains of feldspars (10%), and rare flakes of muscovite and chlorite. The organic remains are dominated by fragments of crinoids, algae, microgranular lumpy spheroidal aggregates, and fragments of brachiopod shells. Fragments of minerals and organic remains are cemented with carbonate-argillaceous cement. Pore-type cement, fine-grained in structure, predominantly calcite in composition. In the intergranular space of calcite cement, there are dark brown inclusions of clay aggregates represented by illite and chlorite with an admixture of kaolinite. Lime cement is partially leached from the interform space of the rock with the formation of pore-caverns. Sandstone contains 10-15% pores. The leaching pores, interform type, communicating, form winding intersecting channels with a diameter of up to 0.1 mm, filled with oxidized oil.

4 Discussion

The analysis of the core material showed that the structure of the sections of the Vereyian horizon of the marginal western part of the Melekess-Abdulin oil and gas region of the Tatarstan is distinguished from 4 to 5 oil reservoirs. The most promising for development are carbonate reservoirs in the lower part of the sections. Sandy reservoirs of the upper part of the section, despite the oil saturation visible in the core, are often waterlogged, heavy hydrocarbons of oxidized oil predominate in them. The first oil-bearing layers from below, which lie at the base of the sections of the Vereyian horizon, bear traces of the penetration of marginal waters. In terms of lithology and mineralogy, this is expressed by an increased content of light gray nested-veinlet aggregates of diagenetic calcite in carbonate reservoirs. Filling the void-pore space in previously leached algal-peloid packstones, diagenetic calcites create dense areas within oil-bearing reservoirs (figure1D). Intensive calcitization is accompanied by oil oxidation. Therefore, in most cases, the lower limestone reservoirs are not of interest for development. The most promising are the fusulinide grainstones occurring in the middle part of the sections of the Vereyian horizon. Due to their high porosity (15-20%) and a branched system of intertwining channels up to 1.0 mm in diameter, they have good potential for industrial development. In most sections, fusulinide limestones bear only minor traces of natural flooding in the form of diagenetic sparite grains of calcite and dolomite filling the void-pore space of the rocks.

The nature of the location of oil-saturated rocks in the sections and the patterns of their interbedding with dense rocks as fluid seals show that all potential carbonate and terrigenous reservoirs were formed at the stage of low standing of the sea sedimentation basin of normal salinity [20]. Obviously, sandstones accumulated in the coastal part of the

beach zone with active hydrodynamics of the aquatic environment. Due to sea water waves, detrital material of the same size accumulated with a constant supply of bioclast fragments from the open shelf. The algal-peloid and fusulinide limestones were formed at some distance from the shoreline within flat-topped uplifts of a gently sloping shelf bordering the coast of an epicontinental marine basin. Judging by their areal distribution, they can be identified as organogenic banks in the photic region of the sea basin, where intensive accumulation of biogenic material occurs: fragments of algae, microgranular lumpy aggregates, shells of fusulinids, crinoids, brachiopods, and bivalve mollusks. The addition of detrital material was weak or absent. The areal discontinuity of the underwater flat-top uplifts determined the variability of the lateral thicknesses of the organogenic banks. Therefore, even in neighboring sections of the Vereyian horizon, different thicknesses of layers of algal-peloid and fusulinide limestones are noted. Due to this, within each oil-productive structure, even with close uplift amplitudes, various oil inflows can be expected.

5 Conclusion

Considering the above, the following conclusions can be drawn:

- In the sections of the Vereyian horizon of small oil-bearing structures of the marginal western part of the Melekess-Abdulin oil and gas region of the Tatarstan, from 4 to 5 oil reservoirs are distinguished.
- Reservoir rocks are represented by algal-peloid packstone, fusulinide grainstone, and greywacke fine-grained sandstones enriched in bioclasts. The porosity of carbonate reservoir rocks is 15-20%, sandy - 10-15%. Interform pores, communicating, form tortuous leaching channels with a diameter of 0.1 to 1.0 mm.
- Carbonate reservoirs in the lower part of the section and sandy reservoirs in the upper part of the section are watered to varying degrees, the pore-caverns are partially healed by diagenetic grains of calcite and dolomite, medium and heavy fractions of hydrocarbons predominate in the composition of the oil fluid. In most of the oil-bearing structures, these reservoir rocks are not promising for development.
- The most promising for oil production are the oil strata in the middle part of the section - fusulinide grainstones and underlying algal-peloid packstones that have not experienced intensive flooding. They can be traced in almost all sections of the Vereisk horizon within the contours of the structures of small oil fields. A feature of the layers of fusulinide limestones is the inconsistency of their thickness over the area. As a result, on some structures they give good oil inflows, on others they show relatively small debits.

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