RESERVOIR TYPES OF THE KASHIRIAN HORIZON OF THE MIDDLE CARBONIFEROUS WITHIN THE MELEKESS DEPRESSION AND THE SOUTH TATAR ARCH

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Abstract. At the present stage, most of the oil fields in the central part of the Volga-Ural oil and gas province, administratively located within the Republic of Tatarstan on the structures of the Melekess Depression, the South and North Tatar Arches, are at a late stage of development. Developed fields are characterized by high depletion of the main productive horizons and increase of hard-to-recover oil reserves. In order to replenish the accumulated oil production, it is required to intensify exploration for less studied horizons, which include, inter alia, the deposits of the Kashirian horizon of the Moscow stage of the Middle Carboniferous. The low degree of study for these deposits is associated with the relative importance of their study when drilling on the Devonian, Lower Carboniferous, and Vereisko-Bashkirian Middle Carboniferous deposits.

For the purposeful conduct of geological exploration in the Kashirian horizon, the study of Kashirian oil reservoirs, features of their location, and the structure of oil-bearing rocks is of great importance. The most important direction of research for solving these problems is the typification of Kashirian reservoir rocks according to their reservoir properties, structure and genesis.

Keywords: Kashirian horizon, limestones, dolomites, porosity, permeability, porous, fractured, cavernous
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The Middle Carboniferous deposits in the studied area within the Melekess Depression and the South Tatar Arch, administratively located within the Republic of Tatarstan, are represented by rocks of the Bashkirian and Moskovian stages, developed everywhere. Bashkirian stage in the studied territory is composed mainly of carbonate deposits. The Moscovian stage is represented by terrigenous-carbonate deposits of the Vereiskian horizon and carbonate deposits of the Kashirian, Podolskian, and Myachkovskian horizons. The lower boundary of the Kashirian horizon is located at the base of carbonate rocks overlapping the mudstone of the Vereiskian horizon, the roof of which, by radioactive logging, coincides with the roof of the high gamma-ray logging zone with reduced values of neutron gamma-ray logging. The upper boundary of the Kashirian deposits is confined to the base of dense rocks in the lower part of the Podolskian horizon, characterized by elevated values of gas oil contact. The thicknesses of the Kashirian deposits vary from 45 meters in the dome of the South Tatar Arch to 95 meters on the eastern edge of the Melekess Depression.

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In the structure of the Kashirian horizon, studied at the Aksubaevo-Mokshinsky, Vishnevo-Polyansky, Pionersky, Osenny (Melekess Depression), Yamashinsky, Shegurchinsky, Yersubaykinsky, Romashkino (South Tatar Arch) and other fields, six packs are allocated of carbonate, predominantly organogenic-clastic rocks, separated by regional references of chemogenic micro-grained and pelitomorphic carbonate rocks. The packs of organogenic-clastic rocks are considered as reservoirs with proven oil content and are called from the bottom up as Cks-1, Cks-2, Cks-3, Cks-4, Cks-5 and Cks-6. All six packs can be traced in most of the fields in the territory under consideration (Vishnevo-Polyansky, Aksubaevo-Mokshinsky, Shegurchinsky, Ersubaykinsky, Novo-Elkhovsky and other fields). The reference strata are conditionally indexed from bottom to top as rp-1, rp-2, rp-3, rp-4, rp-5 and are considered as impermeable layers (Fig.1).

Reference strata separating reservoir packs are represented by dense micro-grained and pelitomorphic limestones (Fig. 2) and secondary dolomites. The thickness of the reference rocks varies from 0.5 to 4.0 m.

The reservoir packs Cks-1, Cks-2, Cks-3, Cks-4, Cks-5, Cks-6 are composed of organogenic-clastic limestones, to a lesser extent secondary dolomites. Their

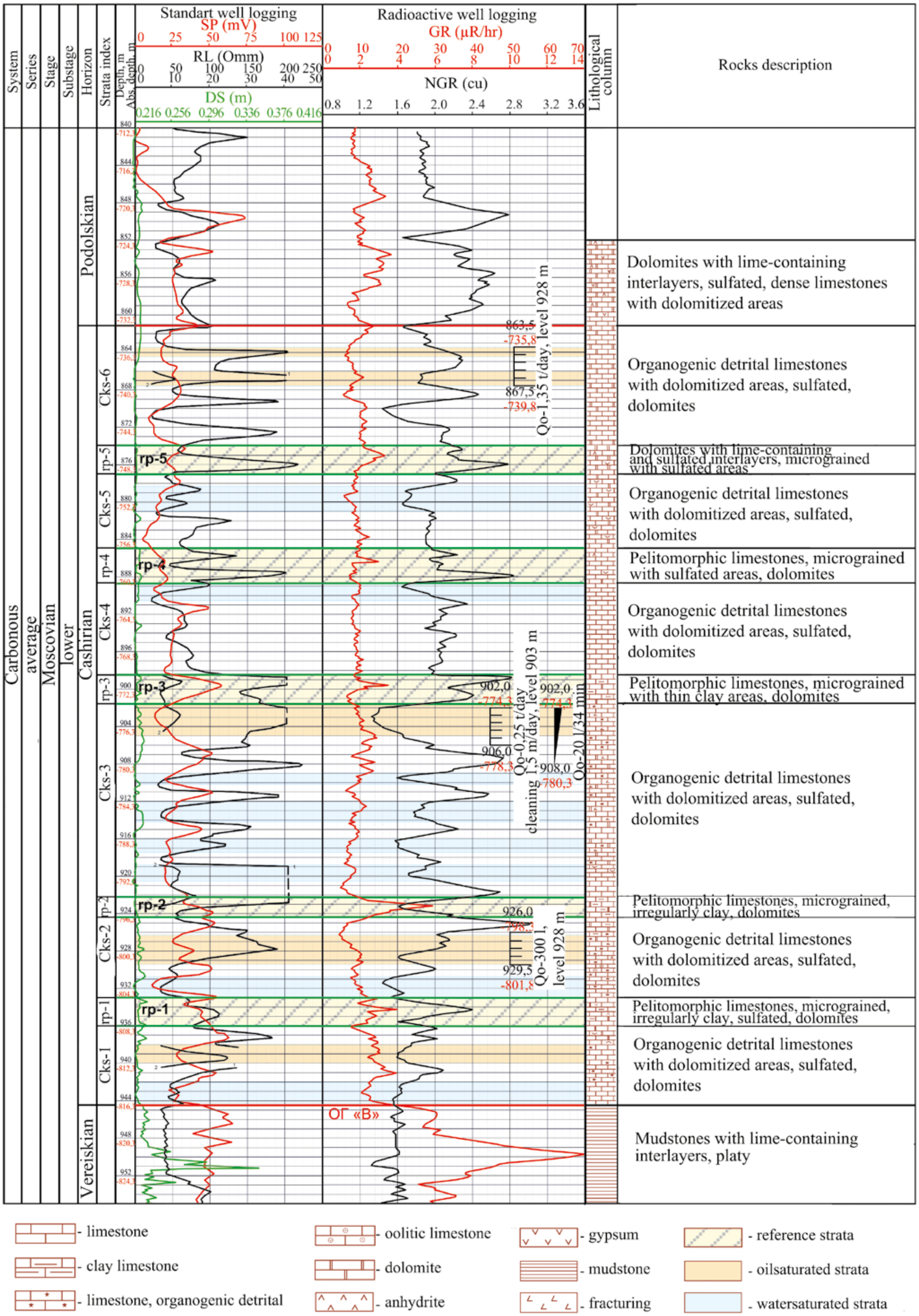

Fig. 1. Consolidated geological and geophysical section of sediments of the Kashirian horizon (eastern side of the Melekess Depression, western slope of the South Tatar Arch)

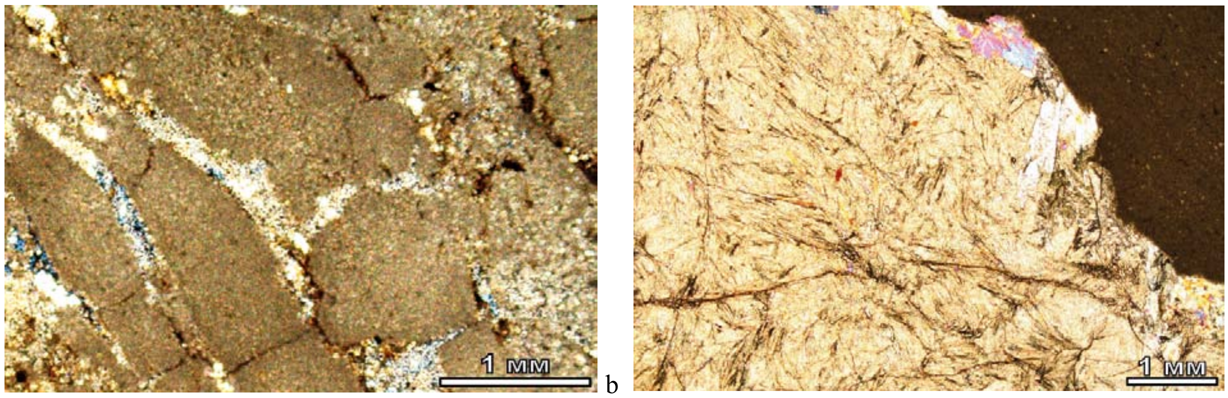

*Fig. 2. Pelitomorphic and micro-grained limestones in reference rocks. a – Pelitomorphic brecciated limestone from reference mark rp-1, well 13 of the Yamashinsky field. Void space is leached with gypsum. K_p – 1,8%, K_{per} – 0,04 * 10^{-3}μm². b – Anhydrite and micro-grained limestone from the reference mark rp-1, well 13 of the Yamashinsky field, K_p – 0,9%, K_{per} – 0,01 * 10^{-3}μm²*

thickness varies from 4.4 to 31 m. Allocated reservoir packs are heterogeneous in their composition and contain both reservoir rocks and dense, recrystallized non-reservoir rocks.

Reservoir rocks in the packs are described in Vishnevo-Polyansky, Yamashinsky, Shegurchinsky and Romashkino fields (Fig. 3, 4). The rocks are represented mainly by organogenic-clastic limestones and are composed of fragments of foraminifera, brachiopods, crinoids, algae (Fig. 3). Pore-forming elements are cemented with heterogeneous mainly calcite cement. Lumps and clots of micrograngular or pelitomorphic calcite are observed in some areas of limestone (Fig. 3a, 3b). The rocks are recrystallized to different degrees (Fig. 4a, 4c). In some sections rocks are fractured (Fig. 4c, 4d). In the dolomitized limestone differences, spots of fractured areas with leached pores, saturated with oil, are observed (Fig. 4d) (Khisamov et al., 2010). The described reservoir rocks were formed as a result of carbonate sedimentation under conditions of

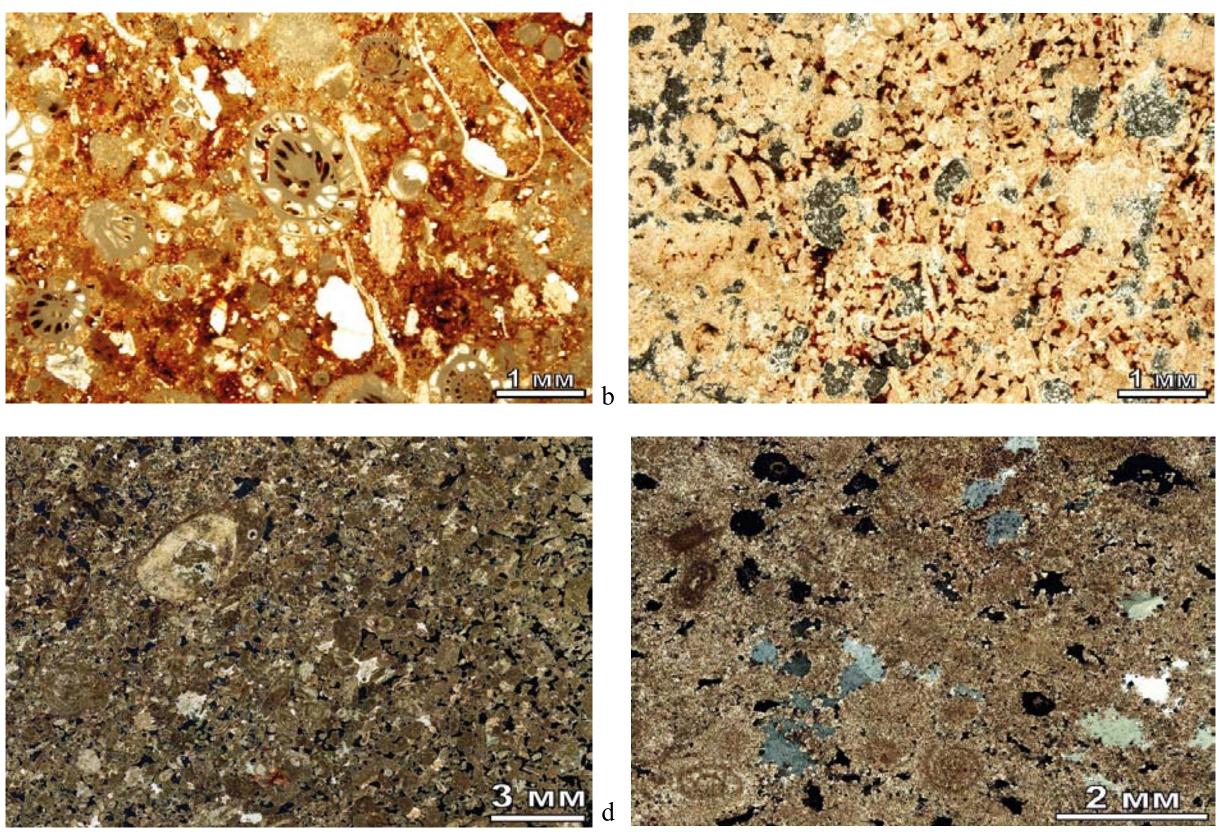

*Fig. 3. Thin sections pictures of the Kashirian reservoir rocks. a – Organogenic-clastic fusulinide limestone from the pack Cks-2, well 13 of Yamashinsky field, K_p – 11.4%, K_{per} – 2.7*10^{-3} μm², K_{rws} – 38%, type of reservoir is porous. b – Organogenic-clastic foraminiferous limestone from the pack Cks-1, well 13 of Yamashinsky field, K_p – 15.1%, K_{per} – 18.9*10^{-3} μm², K_{rws} – 31%, type of reservoir is porous. c – Organogenic-clastic thin-layered limestone from the pack Cks-3, well 2 of the Vishnevo-Polyansky field, K_p – 21%, K_{per} – 855*10^{-3} μm², K_{rws} – 18%, reservoir type-porous. d – Cavernous dolomite from the pack Cks-5, well 3P of Romashkino field, K_p – 17%, K_{per} – 42*10^{-3} μm², K_{rws} – 23%, reservoir type is cavernous-porous*

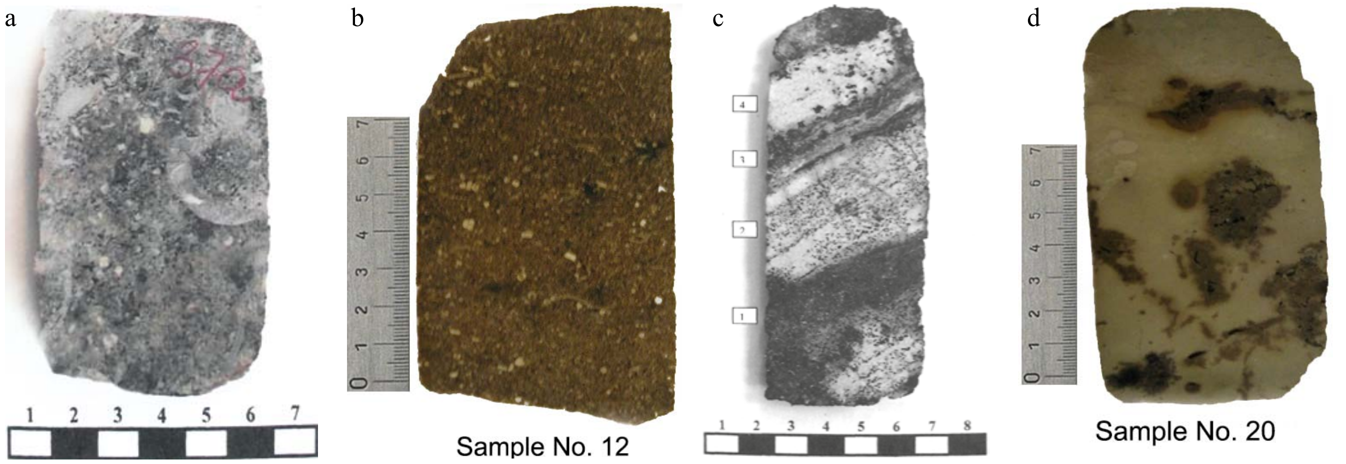

*Fig. 4. Core samples of the Kashirian reservoirs of the Vishnevo-Polyansky and Shegurchinsky field. a – Sample 37a. Organogenic-clastic recrystallized oil-saturated limestone from the pack Cks-3, well 17 of the Vishnevo-Polyansky field, K_p – 9.2%, K_{per} – 5.4*10^{-3} μm², K_{rws} – 44%, reservoir type is porous. b – Organogenic-clastic oil-saturated limestone from the pack Cks-1, well 1sh of the Shegurchinsky field, along with the pores, rare leaching cavities are noted, K_p – 12.4%, K_{per} – 6.7*10^{-3} μm², K_{rws} – 32%, type of reservoir is cavernous-porous. c – Sample 9a. Organogenic-clastic, banded-oil saturated limestone from the pack Cks-3, well 17 of Vishnevo-Polyansky field, K_p – 15.3%, K_{per} – 121.4*10^{-3} μm², K_{rws} – 28%, type of reservoir is cavernous-fissured-porous. d – Dolomitized spotted oil-saturated limestone from the pack Cks-1, well 1sh of Shegurchinsky field, K_p – 7.9%, K_{per} – 1.06*10^{-3} μm², K_{rws} – 54%, type of reservoir is fractured-porous*

an open shallow sea of normal salinity with an active hydrodynamic regime, in an environment favorable for the habitation of organisms serving as the material for the formation of organogenic limestone varieties and subsequent deposition of organogenic detrital material (Khisamov et al., 2014).

Reservoir properties were determined for reservoir rocks of the Kashirian horizon; the dependence of reservoir properties on rock types was analyzed, and the Kashirian horizon reservoir was identified and valued according to the type of void space in accordance with the genetic classification of K.I. Bagrintseva (Bagrintseva, 1999). A detailed description of the reservoir rocks and determination of their reservoir properties was carried out from the core material of Shegurchinsky, Yamashinsky, Vishnevo-Polyansky and Romashkino oil fields (Fig. 3, 4).

Most of the allocated reservoirs are of a pore type, but their capacitive space varies greatly from medium to low. Sometimes there are high-capacity pore reservoirs, which are described in detail at the Vishnevo-Polyansky field, where 80-90% of deposits are composed of debris from shells of foraminifera with a minimum content of cement (up to 5-10%), with high primary porosity, the simplest structure of void space, good voidability (Fig. 3c). Here, the processes of inherited leaching with high primary porosity, which improve reservoir properties, the secondary processes of carburization and recrystallization, which worsen the reservoir properties, are most intensively developed. Accordingly, they have the best reservoir properties – porosity (K_p) – 21%, permeability (K_{per}) – 855*10^{-3} μm², residual water saturation (K_{rws}) – 18%, and assigned to reservoirs with high reservoir properties (Fig. 3, 4).

In medium-sized reservoirs of the porous type, the primary voidness is smaller, the structure of the void space in them is more complicated, and secondary leaching processes are worse, secondary processes that worsen the reservoir properties play a big role – cementation, secondary mineral formation, recrystallization. In these rocks, clots and lumps of pelito-morphic and microgranular calcite are noted, they are more recrystallized, the content of cement is higher (up to 15-25%) (Fig. 3a, 3b). Accordingly, these porous reservoirs are characterized by lower values of reservoir properties – K_p, from 11.4 to 15.1%, K_{per} – from 2.7 to 18.9*10^{-3} μm², and K_{rws} from 31 to 38%.

The low reservoir properties of organogenic-detrital limestone in Fig. 4 a (K_p – 9,2%, K_{per} – 3,4*10^{-3} μm², K_{rws} – 44%) are associated with the presence of lumps and clots, a high degree of its recrystallization, as a result of which the primary organogenic structure is strongly altered. Such limestone is attributed to the porous reservoirs with low reservoir properties.

The Kashirian deposits are characterized by fracturing. A part of fractures is encapsulated by secondary mineral formation processes, secondary leaching processes with formation of pores and caverns are noted in the other part of fractures. Thus, in the studied rocks of the Vishnevo-Polyansky field, pores and leaching cavities are developed in the areas of inclined and horizontal microcracks, forming alternating thick and thin porous-permeable oil-saturated interlayers and strongly recrystallized dense interlayers (Fig. 4c) (Khisamov et al., 2010). Due to the system of inclined and horizontal cracks along the interlayers, along with the improvement of the capacitive properties (K_p – 15.3%), the filtration properties of the reservoirs are improved (the increase in K_{per} to 121.4*10^{-3} μm^2), ensured by the direction of filtration pathways. Such reservoirs are attributed by the author to reservoirs of cavernous-fractured-porous type with an average useful reservoir properties.

Occasionally microcrack formation in dolomitized limestones is observed, which may be due to secondary processes in the rocks. At the Shegurchinsky field, dolomitic limestone is a reservoir where microcracks and leaching pores filled with oil are noted (Fig. 4d). The formation of secondary porosity occurs due to leaching along the cracks. The reservoir properties are low – K_p – 7.9%, K_{per} – 1.06*10^{-3} μm^2, K_{rws} – 54%. Such reservoirs are attributed to the fractured reservoirs with low reservoir properties.

Conclusions

Reservoir rocks in sediments of the Kashirian horizon are confined to the packs of carbonate rocks predominantly of organogenic-detrital origin, separated by regional reference chemogenic micrograined and pelitomorphic carbonate rocks that are impermeable strata.

Reservoir rocks by the type of a void space are represented by porous, cavernous-porous, cavernous-fractured-porous, and fractured-porous type. Porous reservoirs are the most widespread, mainly associated with organogenic-clastic limestones.

Reservoir properties of reservoir rocks, depending on the primary conditions of sedimentation and secondary processes of rock transformation vary widely – from low to high. The most common are reservoirs with low and medium reservoir properties – porosity – 10-15% with permeability from the first units to tens of millidarcy. Rarely, as in the Vishnevo-Polyansky field, when the high primary porosity is significantly increased by secondary leaching processes, the reservoir has high reservoir properties – porosity is more than 15-16%, permeability is more than 100-300*10^{-3} μm^2.

In the presence of oriented microcracking in the bedding of rocks and the development of pores and leaching cavities along it, reservoirs of a cavernous-fractured-porous type are developed. In the dolomitized limestones, areas of heterogeneous microcracks with developing leaching pores are noted. Such reservoirs of the fractured-porous type are distributed, as a rule, in dense rocks and possess low reservoir properties (porosity 6-10%, permeability – the first units of millidarcy).

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