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Lithological Types and Reservoir Properties of KT-II reservoir on the Eastern edge of Pre-Caspian Basin

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Abstract:

The KT-II carbonate-terrigenous stratum is the main oil and gas producing object on the eastern flank of the Pre-Caspian syneclise. Large gas fields are confined to this stratum. The structure, lithological composition and reservoir properties of stratum rocks vary in different parts of the studied region. The favorable conditions of oil and gas accumulation depend not only on the structural factors, but also on the reservoir properties of rocks. A detailed study of the lithology and reservoir properties of rocks is an important task in the organization of geological exploration and the selection of drilling points for exploration wells. This article presents a detailed description of the lithology and reservoir properties of different types of rocks of the KT-II stratum. The analysis is also carried out for the zones where the reservoir properties of rocks are most favorable for exploration wells.

Keywords: KT-II stratum, reservoir properties, lithotypes, sediments, carbonates, field, reservoirs.

I. INTRODUCTION

The eastern part of the Pre-Caspian syneclise is characterized by widely developed Paleozoic carbonate complexes, which form several isolated zones – intrabasin carbonate platforms. Carbonate strata are associated with large concentrations of hydrocarbons.

Two carbonate strata (KT-I and KT-II), separated by a unit of terrigenous rocks, with a thickness of 100 to 370 m, were cut open to study the sediments of carbonate platforms on the eastern pre-Caspian basin flank [1,2,3].

The oil deposits of Kenkiyak, Urikhtau, Kozhasai, Eastern Mortuk, Zhanazhol, Northern Truva, Alibekmola and other fields are mainly associated with the KT-II stratum. The KT-II deposits of some oil fields are in the exploration stage (Fig. 1) [4,5].

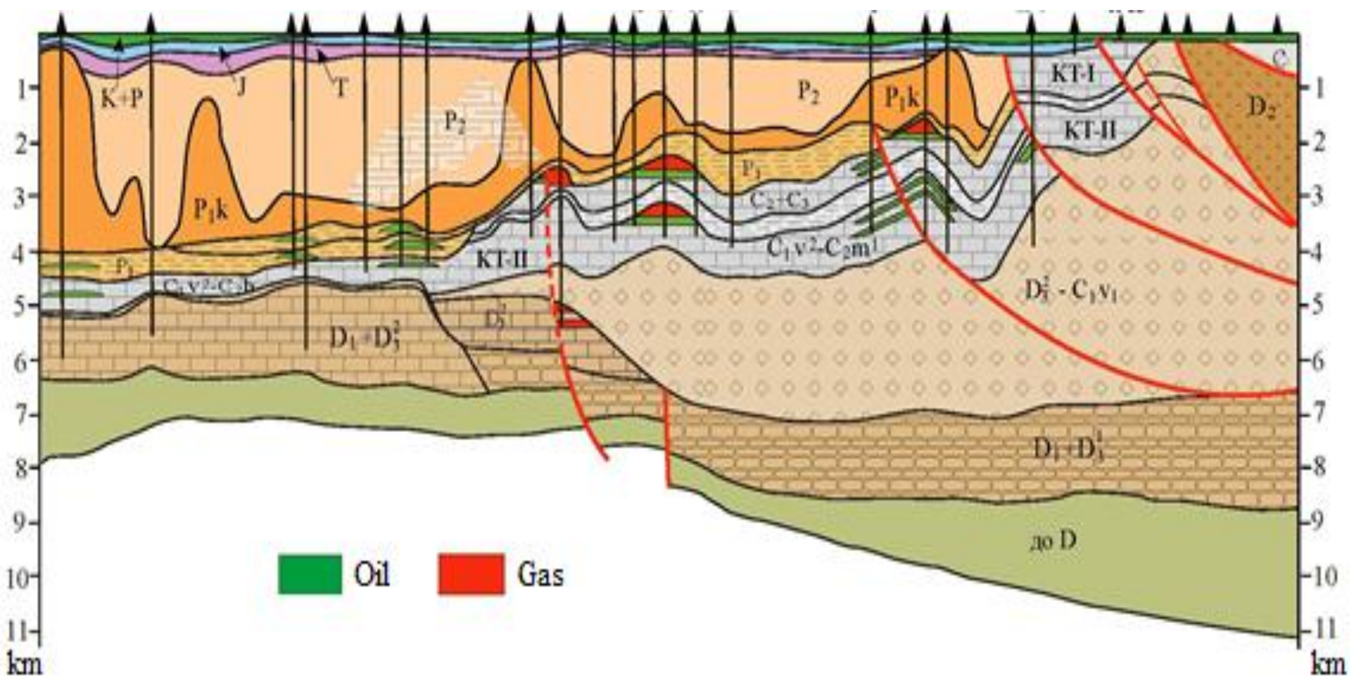

Fig. 1. Regional profile across the eastern edge of the Pre-Caspian depression

The oil-saturated part of the stratum in the fields varies over a wide range – from 50 m in Zhanazhol to 328 m in Eastern Zhagabulak and 506 m in Sinelnikovsky. The KT-II carbonate stratum is most often represented by light and light gray limestone and dolomite. The large quantities of organic residues are found in sections. The porosity value of the reservoir rocks in the lower carbonate stratum is small, varying from 0.03 to 0.1 [6-9].

II. DATA USED. THE CARBONATE-TERRIGENOUS STRATA OF THE STUDY AREA

The rocks composing the carbonate-terrigenous strata of the study area are diverse in origin, composition, structural features, and reservoir properties. These are mainly organogenic limestones, some of which have been converted to dolomites. Among the limestones of organogenic origin, biomorphic, detrital, lumpy-organogenic, lumpy-clotted and oolitic types are distinguished [10-16].

Biomorphic limestones are light gray, sometimes with a yellowish tinge, homogeneous massive rocks. Biomorphic limestones usually have many pores and cavities. Filtration is carried out through interform channels and pores themselves [17,18,4,19].

Detrital and biomorphic-detrital limestones are gray and dark gray, sometimes light gray, homogeneous massive formations. Their main component is unsorted detritus – fragments of the formed elements of foraminifera, brachiopod, crinoids, algae, ostracods, etc. The pores of detrital limestones are mainly secondary, appeared in the process of recrystallization and desalination. The capacity of such limestone is usually low. Due to desalination, the volume of the pore space is significantly increased, but the low capacity is explained by the presence of the cementing material.

The most common lithotype is lumpy-organogenic limestone. These are gray, light gray and brownish gray, homogeneous, massive, dense or porous, sometimes fractured, rocks. They are mainly composed of diverse organic residues.

Lumpy-clotted limestones are common in Serpukhovian, Moscovian and Upper Carboniferous sediments.

Oolitic limestones are characteristic of the lower Bashkirian and lower Moscovian substages. They consist of ooliths and well-rounded lumps with organic residues.

Biomorphic, less often biomorphic-detrital and detrital limestones, are found in the lower part of KT-II (Visean-Serpukhovian rocks). They are involved in the formation of organogenic structures, actively developing in the period of rising sea levels. Higher in depth, these limestones are replaced by lumpy, clotted limestones, accumulated in the highest phase of the marine transgression. Finally, in the roof of the stratum, there are oolitic and detrital limestones characteristic of the littoral and sublittoral areas as part of the coastal zone, tidal plains, saline lagoons and bays deeply embedded in the land [20].

In contrast to terrigenous, carbonate sediments undergo repeated secondary transformations because of high solubility during lithogenesis, due to which the structure of their void space and reservoir properties are very heterogeneous.

Analysis of the distribution of parameters of reservoir properties allowed characterizing individual lithogenetic types of carbonate sediments [20].

Biomorphic limestones are characterized by the highest reservoir properties – the maximum porosity of reservoirs reaches 26-28%, permeability – thousands of millidarcies and higher.

The porosity of lumpy-organogenic limestones in KT-II is 0-6%. The limestones of this type are characterized by the intensive filling of voids with secondary calcite. Their permeability is fixed at 53.8%.

Clotted and oolitic limestones have similar reservoir properties. Most of them are impermeable rocks, with porosity below 6%. The rest of the studied samples are reservoirs, which have different porosity and permeability, depending on the intensity of desalination.

Detrital limestones have the lowest reservoir properties.

III. RESULTS AND DISCUSSION

Analysis of the reservoir properties of different types of carbonate rocks composing the sediments of the eastern part of the Pre-Caspian syneclise showed that the rocks capable of containing and filtering fluids can be found among all lithotypes. These properties are due to the primary conditions of sedimentation and the features of post-sedimentation transformations. These conditions are differently reflected in the reservoir properties of different lithotypes of carbonate rocks. The most favorable combination of these factors was found in biomorphic limestones, the least favorable – in detrital ones [21,10].

Another significant factor affecting the reservoir properties of carbonate rocks is the type of reservoir. The study area is dominated by porous reservoirs. The capacity of a reservoir of this type is mainly conditioned by inherited secondary pores and cavities. The value of porosity in rocks of the pore type is 6–30%.

In addition to the porous type, there are porous-fractured and fractured reservoirs in the carbonate section.

The water-absorbing capacity of porous-fractured rocks is formed by small pores, rarely – single caverns. The capacity of cracks is insignificant, amounting to tenths of a percent. Fluids are filtered through cracks; permeability in one or several directions reaches 0.1-10-15 m2. According to the field geophysical data, porous-fractured reservoir layers are distinguished as porous reservoirs with low capacity. When testing these reservoirs, small inflows of fluids were obtained in some cases [12,18].

11% of the total number of core samples studied is accounted for fractured rocks in the KT-II stratum. The porosity of this type is less than 3%, the existing pores are filled with water, and fluids are filtered through cracks. Due to the well-developed fracturing of rocks, there is a good connection between porous reservoir layers, which contributes to the production of industrial oil and gas inflows.

The reservoir properties of reservoir rocks largely depend on the conditions of sedimentation. To fully understand and study these properties, a detailed analysis of tectonic processes and changes in conditions during different periods of sediment accumulation is required [22-25].

The carbonate sediments of the eastern flank of the Pre-Caspian depression have been entered in three structural-tectonic zones – Temir, Zharkamys and Zhanazhol-Tortkol. The conditions for the formation of carbonate sediments in the three zones differed from each other.

In the Zharkamys zone, carbonate rocks have been tapped only in the early Devonian sediments, in the Temir zone – in the lower-middle and partially upper Devonian sediments. In the early Devonian era, a large elevated crustal block was located within the Temir zone. The shallow-marine conditions prevailed here, and sediment accumulation occurred in the relatively shallow-water conditions – from the first to the first tens of meters.

Within the Zharkamys zone, a stratigraphic disagreement of considerable amplitude is currently observed. The accumulation of Devonian carbonates here occurred in the open part of the shelf at somewhat greater depths than in the Temir zone.

The results of studying the G-1 drill-hole core of the Baktigaryn area indicate the shallow-marine genesis of age sediments. Here, in the Famennian time, the bottom deepened and sediments began to accumulate in the outer part of the shelf.

The east of the Pre-Caspian depression at the turn of Devonian and Carboniferous was characterized by a tectonically active environment. An abundant removal of detrital material and the formation of a thick stratum of the terrigenous sediments of Tournaisian and Visean ages took place. At the end of the Visean age, terrigenous material ceased to flow into the sea basin, and a long period of accumulation of carbonate sediments began.

In the early Carboniferous, the Temir fold and the Zhanazhal-Tortkol zone assumed a hypsometrically elevated position.

The conditions for the accumulation of carbonate sediments were very diverse, as evidenced by the lithological and paleontological analysis of limestone rocks. The accumulation of carbonates occurred in semi-isolated sea lagoons and the tidal zone (Alibekmola), as well as in the open coastal part of the paleoshelf (Zhanazhol, Sinelnikovskaya, Kuantai, Zhanatan, Nikolaevskaya). The formation of large reef-type organogenic structures occurred in the outer part of the shelf (Kozhasai) and in the adjacent areas of the underwater slope (Bashenkol).

By analyzing GIS data, one can see that the rift body is composed of biostromes separated by layers of organogenic-detrital limestone. The capacity of individual biostromes reaches 115 m, the height of the whole array is up to 583 m. Biostromes form recrystallized algal limestones.

Such sediments accumulated at the normal or slightly increased salinity of sea water and the environment. During the shallowing periods, limestones characteristic of the tidal zone accumulated here. The traces of material drying and cracking are also observed in the rocks. Such facies of the outermost shallow water correspond not only to the upper Visean sediments, but also to the bedding rocks of the lower Serpukhovian stage.

At the beginning of the Serpukhovian time, the shelf began to be graded towards the underwater shelf. However, the greater part of its territory was dominated by the shallow-marine situation, and only carbonate rocks were accumulated.

The greatest thickness of Serpukhovian sediments is noted in the edge areas of the embedded carbonate platform – Bashenkol, Urikhtau, Zhanatan, Kozhasai, and Eastern Tortkol.

In the west, organogenic structures appear in sediments of the underwater slope. Further, to the west of the underwater slope, they are replaced by deep-water sediments of the carbonate-terrigenous composition.

The rock composition of Serpukhovian sediments within the Zharkamys zone indicates different sedimentation sources in this part of the basin. Terrigenous sediments were brought here from the coastal zone through a system of canals and submarine canyons. Carbonate sediments accumulated as a result of the periodic removal of material from the edge of the shelf.

The Ostansuk trough and the zone of the Aktobe Cisurals in the Serpukhovian time was outside the accumulation of carbonate sediments. This was confirmed by the results of drilling of G-1 and G-2 wells in the East-Mortuk area.

Thus, the shallow-marine carbonate rocks of the Temir zone are wedged in the western and eastern directions, replaced by deep-sea sediments.

The accumulation of Bashkirian sediments took place with a gradual regression of the sea, which was confirmed by the visible replacement of some lithotypes of carbonate rocks by others.

In the Zhanazhol-Tortkol and Temir zones, sediments of the coastal wave genesis prevailed. During this time, in the northern part of the Zhanazhol-Tortkol carbonate mass, algal structures were developing.

In other parts of the eastern flank, the frequent shallowing of the sea was accompanied by the destruction of the organogenic structures that existed at that time. The shallowing of the sea basin in the Bashkirian time led to the erosion of the upper Bashkirian sediments. Outside of the shallow water, the accumulation of Bashkirian sediments occurred in the context of the lack of detritus. Under these conditions, thin layer bituminous sediments accumulated.

In the early Moscovian time, there was a transgression of the sea, which led to the deepening of the sedimentation basin. The boundaries of the facies zones and the composition of sediments changed significantly. Bioherm limestones were prevalent. There were also the layers of mudstones, especially abundant in the upper part of the section. In the northern part of the Zhanazhol-Tortkol zone, there was an increase in organogenic structures. These bioherms were protected from the effects of storm waves by other structures. At present, there are no sediments of the early Moscovian time in these parts of the territory, since they were washed out. This is evidenced by the reduction in the western direction of the upper unit of the Kashirskian bedding rock from 100 m to 0 m.

The late Moscovian time was marked by a new transgression of the sea and the accumulation of terrigenous sediments. These were mainly mudstones containing the interlayers of siltstone, sandstone, gravelite and limestone.

In other areas of the eastern flank of the Pre-Caspian Basin, the Moscovian age was marked by the accumulation of sediments of the deep-water genesis. In the Aktobe-Ostansuk zone, the early Moscovian time was accompanied by the sedimentation of siliceous-clay-carbonate sediments, which in the late Moscovian time were replaced by terrigenous rocks.

In the area of the Temir fold, which was located on an elevated crustal block relative to the Ostansuk trough, the sea depth reached 300-400 m. Sedimentary material practically did not flow here, and fine clay particles and small silt grains were deposited. Argillites, siltstones and fine-grained sandstones were found in the Aransai area in the Moscovian time sediments.

The sediments of the same age within the Zharkamys stage, which was more embedded in comparison with the Zhanazhol carbonate paleoshelf, were represented by clays, argillites, siltstones and sandstones.

The upper Moscovian sediments were formed against the background of enhanced tectonic processes, which ended with the closure of the Ural paleoocean. The input of terrigenous material into the Aktobe Cisurals and the Ostansuk trough was intensified. Terrigenous material did not flow into the Temir and Zharkamys areas. The Upper Carboniferous part of the section here was represented by thin layers of fine-grained limestone.

Within this Zhanazhol-Tortkol zone, the sedimentation of shallow-marine carbonate sediments continued during this period, proceeding against the background of the regression of the sea basin and the inflow of clayey material.

The mountain-cutting processes, which intensified in the neighboring Ural zone at the end of the early Permian era, caused an increase in the input of terrigenous material into the Pre-Caspian depression. Then the development of carbonate platforms in the east-side zone was completed.

Subsequent processes influenced the reservoir properties of rocks accumulated here – in some cases, the primary pores became the main fluid containing, while in others, the pores were healed with secondary minerals.

Recrystallization has affected different types of rocks. It was most pronounced in microgranular limestones, which were recrystallized into fine-, medium- and coarse-grained. Often, recrystallization led to the formation of small intercrystalline pores. The presence of such pores contributed to the desalination of adjacent recrystallized rock areas, which significantly increased the porosity.

In addition, almost all lithotypes showed dolomitization. Extensive dolomitization contributed to the formation of voids.

The leading role among the postsedimentation processes that influenced the improvement of the reservoir properties of rocks belongs to desalination. As a result of the desalination process, the volume and number of pores increased, which enhanced the effective porosity and also had a positive effect on the increase in the permeability of carbonate rocks.

After analyzing the distribution of capacity and the quality of regional natural reservoirs, including reservoir rocks, it is possible to identify zones with different parameters of reservoir properties (Fig. 2).

According to lithological criteria, the most favorable area is the northern part of the Zhanazhol-Tortkol zone. In the fields of this zone in the sediments of the lower carbonate age, the carbonate reservoirs of pore type with maximum thickness and improved reservoir properties were entered. Mining is carried out here from the massive deposits of carbonate sediments in the Zhanazhol, Kenkiyak, Truva and Alibekmola fields.

To the south of this zone, in the area of the Kuantai, Tortkol and Zhantay fields, the reservoir properties in the KT-II stratum are not high.

In the zone extending along the eastern border of the above-described zones, the maximum effective reservoir properties and capacities are determined in the Kozhasai field. To the south of the Kozhasai field these properties may decline.

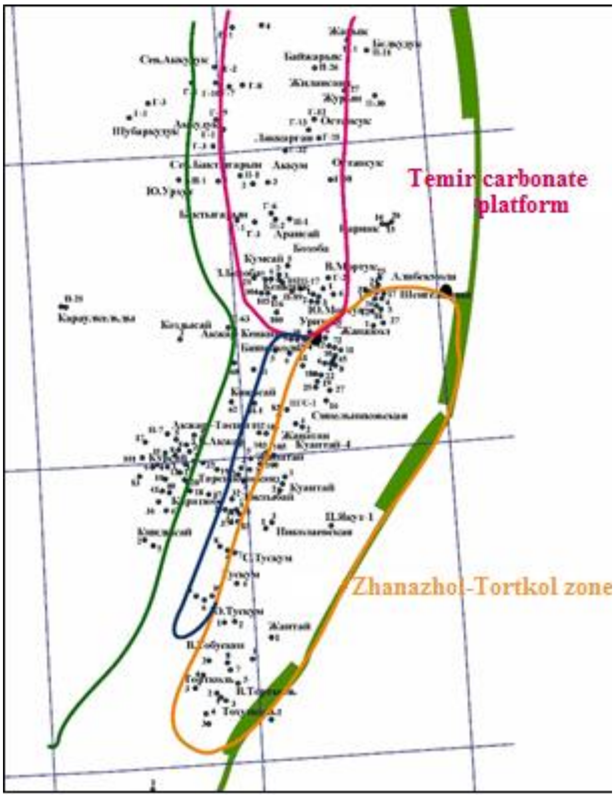

Fig. 2. Zones with different parameters of reservoir properties. The eastern flank of the Pre-Caspian syneclise

Within the Temir carbonate platform, the prospects for sedimentation in the KT-II stratum are quite high. The reservoirs here are characterized by high reservoir properties and considerable capacity.

To the west of the carbonate platforms, there is a transition zone from the shallow carbonate shelf to the basin facies. Studies of this area showed that coal sediments most often did not create powerful structures and collapsed as they grew. Therefore, the sediments of this zone are represented by dense clayey limestones as well as marls with insufficiently high porosity. However, the rocks trapped in the indicated zone, the zone of tectonic activity, cracked, which possibly increased their reservoir properties.

IV. CONCLUSION

When projecting further exploration work to detect new oil and gas objects, one should conduct a detailed study of reservoir properties. This criterion is essential, since the nature of reservoir properties is often ambiguous, and, therefore, insufficient knowledge of reservoir properties increases the risk in the process of locating exploration wells.

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