About oil and gas content potential of deeply embedded horizons of the Ukrainian Carpathians

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SUMMARY

There were reservoir properties of sand and silt rocks of Lower Cretaceous on the central part of Skybova zone of the Carpathians and the Precarpathian foredeep predicted according to the dependencies of the open porosity and permeability from complex of geological parameters. It was determined that at a depth of more than 5 km there may exist the reservoir rocks with high capacitive-filtration indicators, which are capable to hold the industrial accumulations of hydrocarbons and give them back while development. There was also a research on the secondary changes in a hollow space of deeply embedded reservoir rocks of the Precarpathian foredeep made. It was found that the main criteria for the prospective prediction of the secondary porosity at a great depths is the presence of rocks in the section of the individual zones with high porosity, permeability and deconsolidation at the background of a regular deterioration of reservoir properties with depth.

Introduction

The problem of hydrocarbon potential of the deep deposits of the Carpathian oil and gas province, especially Carpathian basin and Skybova zone of the Carpathians, is more relevant nowadays and is a matter of debate. A particular object of study is the Lower Cretaceous section of the central part of Skybova zone which has been disclosed recently by the drilled wells 1-Shevchenkovo, 1-Luhy, 1-Mizun under the complex of Paleogene rocks that made it possible to expand the notion of the geological structure, oil and gas content, compound and reservoir deep-drawn properties of these sediments.

The absence of the industrial inflows of the Lower Cretaceous of Skybova zone of the Carpathians and the Carpathian Foredeep cannot definitely indicate the absence of the industrial accumulations. For example, in Poland in the wells Kuzmin-1, and then Kuzmin-2, there were revealed deposits of the Lower Cretaceous (Spaska suite) and the presence of good reservoirs and hydrocarbon dissolved gases have been proved in the stratal water.

Accordingly, the study of patterns of changes in filtration-capacitive properties of the reservoir rocks, predictions of possible anomalies in their properties, their ability to predict and anticipate the depth of the areas of the development of reservoir rocks with improved capacitive-filtration properties is an important prerequisite for the successful conduct of the geological prospecting and the development of hydrocarbon deposits.

Method

It is known that the nature of filtration-capacitive properties of Cretaceous-Paleogene aleurite-sandy rocks of the Carpathian Foredeep is caused by their structural, textural and mineralogical features that are determined by sedimentation (primary sedimentological factors) and the nature post-sedimental processes (secondary changes). Undoubtedly, the influence of sedimentary factors to aleurite-sandy reservoir rocks of the Carpathian Foredeep at a depth is largely eliminated by secondary changes. On the one hand, the processes of diagenesis and catagenesis cause the changes in the primary porosity, such as compaction, cementation, authigenic mineralization that induce a decrease in the free pore space of collectors, and on the other hand, such secondary changes in pore space as leaching, recrystallization and crack-forming improve filtration-capacitive properties of reservoir rocks.

It was carried out the laboratory study of core samples from deep and ultradeep wells of the Foredeep and was established the nature of the change of filtration-capacitive parameters (open porosity, permeability and volumetric density) of Paleogene sandy-aleurite reservoir rocks at the range of depth from 200 meters to 6.5 km in order to assess the impact of catagenetic change on physical properties of reservoir rocks.

As a result of the research it was found that with increasing of the depth of rocks open porosity decreases from 32 to 0.6%, the maximum values were fixed at the intervals of 200-1500 m (9 to 28%), 2450-2900 m (13%) and deconsolidation zones were observed at depths exceeding 4,000 m, where there are horizons with much higher open porosity reaching 10-12% among the sandstones with total porosity of 5-7% and open porosity of 3-5%. The areas with low (0.2 to 6%) values of open porosity with a significant decrease at a depth of 4,000 m can be traced between these intervals . It was established that rocks with an open porosity of 7-13% dominate in the range of 200-4000 m and at a depth of 4000-6500 m - 0,3-4% with some deconsolidation horizons with high-capacitive filtering parameters of reservoir rocks. Capacitive gradient was calculated for Paleocene reservoirs in the depth interval 200-4000 m, which is 0.65% per 100 m, and is 0.12% per 100 m in the depth interval 4000-6500 m.

The results of the research of the permeability of reservoirs showed that permeability decreases from 81 to 0.01 x 10-15 m^2 with the depth of sandy-aleurite rocks. It was found that rocks with a maximum value of permeability are fixed in the range of 200-1500 m and 2450-2900 m (81 x 10-15 m^2), zones of rocks with low filtration properties (0.01 - 8x10-15 m^2) are observed between these intervals. A significant decrease of filtration properties was fixed at a depth of 4000m. We calculated the total filtration gradient for sandy-aleurite rocks of the Foredeep, which is 0.5 x 10-15 m^2 for 100 m in depth intervals 200-4000 m, and is 0.3 x 10-15 m^2 for 100 m in the depth interval 4000-6500 m.

Considering that mountain or litostatic pressure is defined by the rocks density, the next parameter which we explored was volumetric density of Paleogene rocks. It is explored in the range of 200-6500 m deep and varies widely. As a result it was revealed that the density of rocks increases naturally with increasing depth. Its values rise from 2320 kh/m^3 at 200m depth and to a maximum of 2700 kg/m^3 at a depth of 6500 m. The largest amount of reservoir rocks with minimal volumetric density values is developed in a range of depths 200-1500 m, 2450-2900 m (up to 2460 kg/m^3). The tight gradient of granular reservoir rocks is 19 kg/m^3 for 100 m in the range of 200-6500 m.
The exploration of sandy-siltstone rocks helped to clarify the catagenetical changes of reservoirs at different depth in order to assess the extension of the development of the structure of sandy-siltstone rocks transformation with depth. It was concluded about the strengthening of the role of three types of structures with increasing depth of rocks: uncollegiate, regenerative, mickostylolit and reducing the role of conformal structures considering the development dynamics of catagenetical structures down the cut of wells (fig. 1).

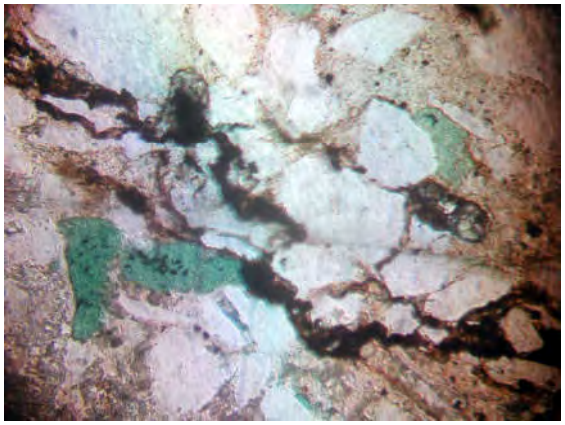

Figure 1 *Conformal-uncollegiate structure on the contacts of quartz grains. Well 100-Tanyava, menilit suite, the interval 3819-3824 m. Nick II x 80, quartz medium granular sandstone with microsteolit surfaces with dentate shapes. Stylolit similar microcrack filled with dark brown bitumen*

It was established that the conversion of clastic material reaches its highest development at a depth of over 4000 meters in conditions of high pressure and temperature. This reflects in the appearance of sandy rocks and gives it quartzite character.
The thin sections study revealed that conformal structure predominate in the structure of sand-alevrytovyh Paleogene rocks at the depth of 4000 m and single tuberous microstylolits are existing. This zone is assigned to the medium catagenesis zone. There are already numerous tuberous- jagged microstylolit surfaces at a depth greater than 4000 m accompanied by a change in detrital grains and cement resulting in microgranule porosity decreasing and causing very low reservoir parameters. In turn, this indicates the transition to the area that differs by the complex changes in the structure of the pore space - the late catagenesis area.
The strained state of catagenetically transformed rocks of massive drainage texture promotes the formation of numerous cracks at the partial violation of the matrix integrity in this area in the conditions of greater depths, which leads to the formation of zones of the rocks deconsolidation with better capacitive-filtration parameters at depths exceeding 4000m.
Due to the importance of the problem and the necessity to solve tasks of the predicting reservoir properties of Lower Cretaceous rocks at great depth by the method of (*Reznikov, 1998)*, which is to study the correlation dependencies of open porosity and permeability terrigenous rocks from the complex indicators taking into account the peculiarities of geothermal, geobaric and tectonically dynamic history of the sedimentary basins development, it was studied the dependence of the open porosity and the permeability of low-spasky sandstones of Orivska chunk of the Carpathians from the complex geological settings: exponential geochronoterm (EGCT) E_t, exponential chronogradient sealing pressure (ECGSP) E_b and conditional indicator dynamocatagenesis (CIDC) D. In accordance

exponential geochronoterm (EGCT) E_t was calculated by the method (*Reznikov, 1982*), the conventional indicator dynamocatagenesis (CIDC) D was determined according to (*Reznikov, 1998*).
The predicted values of porosity and permeability sandstone of low-spaska zone of Orivska chunk of the Carpathian prospective oil and gas horizon and Paleogene sediments of the Inner Carpathians are listed in the Table 1. It can be seen that reservoir rocks with high capacitive-filtration indicators, which are able to maintain itself the industrial accumulation of hydrocarbons and give them in the development process may be even at a depth of 6000 m.

Table 1 *Projected values of porosity and permeability sandstone of low-spaska zone of Orivska chunk of the Carpathians and Paleogene reservoirs of the area of Inner Carpathian Foredeep*

Prospective oil and gas complex	The average depth, km	EGCT (E_t)	ECGSP (E_B)	(CIDC) D	Porosity (m_o), %	Perme-ability Kpr, 10^{-3} mkm^2
Low-spaska suite (lower Cretaceous)	6,0	1,85	1,60	0,72	11 ± 0.23	15,5 ±2,5
Cretaceous-Paleogene sediments of the Inner Carpathian foredeep zone		1,98	1,72	0,65	13 ± 0.23	20,5 ±2,5

The determination of the impact of each complex geological parameter on the values of porosity and permeability of sandstones of low-spaska suite of Skybova zone of the Carpathians area at a depth of 6 km revealed that CIDC factor has primary role (-64.5%) for the porosity conversion, the second one is EGCT (26.8%) and the third is ECGSP (-8.6%). It means that affect tectonic-dynamic movements and sealing pressure affect negatively the porosity of sandstones in the area of catagenesis, while overexposure to high temperatures has positive effect. CIDC factor (-50.2%) is the first one to affect the permeability, followed by factors ECGSP (-30.9%) and EGCT (-18.9%). This corresponds to modern ideas about the conditions of formation of terrigenous reservoirs at significant depths.
However, unlike the equation of background values evaluation of open porosity, there was established the permeability of sandstones in the catagenesis area rising and stimulating effect of complex factor ECGSP (-8.6% to -18.9%), and reducing the impact of complex factor CIDC (-64, 5% to -50.2%). The main features of fissure-type collectors, the main filtration ways in which are cracks, are well reflected by all those features.
The analysis of core material from deep and ultradeep wells of Inner zone of the Precarpathian foredeep showed that intervals with anomalous improving of filtration-capacitive reservoir properties are observed on the background of regular deteriorating of the properties of aleurite-sandy reservoir with depth. There are numerous horizons with significantly higher total porosity reaching 10 - 12% in some cases, the open porosity reaching 8-11%, the permeability - 20-65 • 10-15 m^2 among sandstones of the total porosity of 5-7%, the open porosity of 3-5%, the permeability of 0,1 • 10-15 m^2 and density of 2450-2630 kg/m^3. Such zones are well correlated with low density fine-grained sandstone. For example, in the well 100-Tanyava there was the oil debit of 9.7 m^3/day received during the test of menilite sediments of Oligocene in the interval 3800-3920 m (low menilite highsuite), the deconsolidation interval was 3820-3824 m and 3910-3920 m according to the laboratory study of core samples. The oil fountain was received with the debit 2 m^3/day and deconsolidation interval 3650-5650 m in the same well during the testing of the interval 5515-5560 m (Manyavsky deposits), (Fig. 2).
There was oil inflow 3.46 m^3/day, deconsolidation interval 4885-4900 m according to the laboratory study of core samples received during the excavation of the interval 4860-4909 in the well 4-Novoskhidnytsya which has opened the low-menilite sediments of Kropivnitska fold.
There was oil debit 10.5 m^3/day at periodic flowing, deconsolidation interval according to the laboratory study of core samples 4530-4565 m obtained in a borehole 4-Zavoda during the test of

yamnensky Eocene sediments in the interval 4533-4560 m A similar phenomenon was also observed in the borehole 103-Yankivska, the oil inflow with periodic flowing was 2 m^3/day, deconsolidation interval was 5265-5282 m from the testing interval 5235-5292 m (Menilite deposits). There was oil inflow 57 m^3/day, deconsolidation interval 4350-4378 m according to the laboratory study of core samples received during the trial of low-menilite sediments in the borehole 4-Semyhynivska in the interval 4290-4396 m. While studying Paleogene sediments in the well 1-Dovholutska (the third tier of allochthon structures of Borislav-Pokutska zone of the Precarpathian foredeep) in the interval 5770-5804 m (menilite suite) that are evaluated as oil and gas rich as the results of a complex interpretation of the data of petroleum geophysics and mud logging there is deconsolidation interval at a depth of 5790-5800 m with a relatively higher total porosity fixed among small capacitive sandstone reservoirs with total porosity 1-3,5%. In some cases, the porosity of oil and gas rich core samples reaches 8-9,9%.

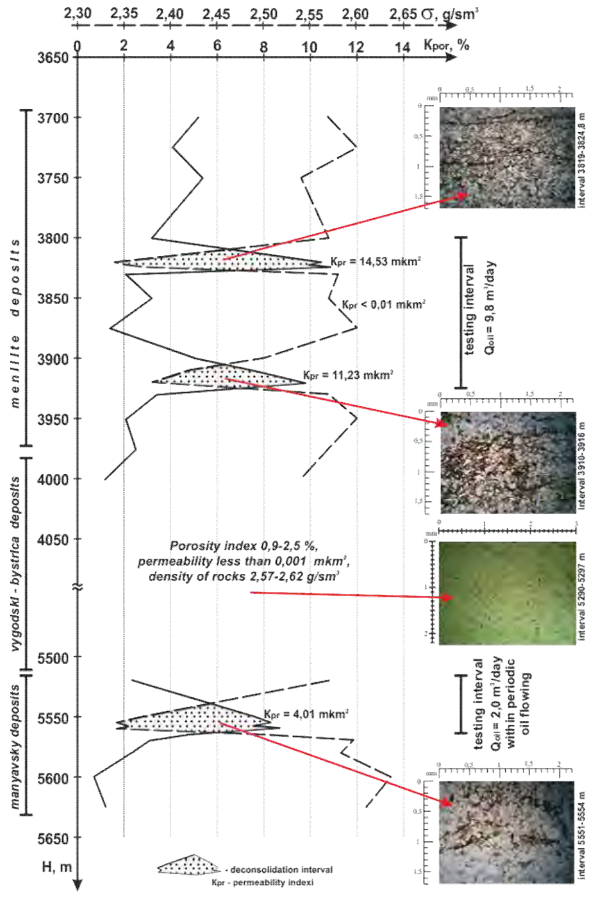

Figure 2 *Change of the density and open porosity of Paleogene sandstones, borehole 100-Tanyava, interval 3650-5650 m*

Conclusion

To sum up the results it was determined that the maximum number of high-capacity reservoirs is confined to the early, middle and partially late catagenesis, while industrial reservoirs are confined to the zone of the development of secondary porosity and rocks fracturing (deconsolidation zones) in the late catagenesis zone.

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