The conditions of forming and the prospects of oil-and-gas potential of the Cretaceous-Palaeogene reservoir rocks of the northwestern part of the Carpathian foredeep basin

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Abstract

The article describes the schemes of the effective thickness distribution of Paleogene sediments within the first and the second structure stages of the northwestern Inner zone of the Carpathian foredeep basin.

The character of reservoir rocks distribution is studied; the conditions of their formation and the main patterns of their spatial distribution, features of filtration and capacitance properties are clarified.

The results have been the basis for the allocation of oil and gas objects within the chosen area of study.

There are distinguished 9 new oil and gas perspective objects; their spatial position is confirmed by the presence of gas geochemical anomalies.

The amount of total prospective resources in allocated objects at the depths of 2 to 5 km are 4,200,000 tons of oil.

The main ranking criteria of the objects have been the depth, size and prospective resources of the object as they determine the economic feasibility of drilling.

Keywords: *effective thickness, filtration and capacitance properties, oil and gas bearing object, prospective resources.*

Introduction

The strategy of increasing the resource base as the basis of the national economy stabilization involves expanding of oil and gas activities, which are associated with the identification of new and perspective trends based on a comprehensive assessment of oil and gas presence. As the efficiency of exploration operations depends not only on technical means of implementation but also on the methods of their implementation and the correct choice of activities, the solution of this problem requires a systematic analysis of comprehensive material on the geological structure of the area of study, the conditions of formation, oil and gas presence and exploration data for the discovery of new oil and gas objects in the old cultivated areas which include the Carpathian Foredeep Basin.

A comprehensive analysis of a wide range of factual materials shows that Carpathian Foredeep is characterized by virtually stagnant hydrodynamic conditions. Major oil deposits in flysch sediments thrust and in the platform part of the Carpathians were forming simultaneously and associated with the most intensive development of tectonic and fluid processes of the final alpine tectonogenesis. This is also showen by genetic affinity of oil and associated gases in platform autochthon (Lopushna field) and flysch allochthon of the Carpathians [1].

Analysis of current research and publications

The flow of hydrothermal ores (pyrite, sphalerite, sulfur, mercury, galena), which are in close association with Boryslav, Truskavets, Dzvyniach and Starunia ozocerites and fill the cracks and fractures in rocks, are shown on intervention of steam gas-liquid fluids that include hydrocarbons and ore components [2]. There are also revealed the silver, cobalt, cadmium, molybdenum, nickel, tellurium, arsenic and other components in ores.

The inteconnection of ore and oil-gas presence in the Carpathian foredeep basin is confirmed by metallogenic studies of oil deposits – distribution of trace impurities and their associations in oil. Uniformity of associated trace elements structure (Pb, Bi, Cu, Zn, Ag, Hg, Sb, As) indicates the regional genetic affinity of oils. A unique feature of the Pre-Carpathian oil and gas fields is the presence of silver and bismuth. Regional Clarkes for Ag (1/8 g / t) and Bi (0.1 g / t) in oils exceed the concentration of specified elements in sedimentary rocks respectively at one and two orders of magnitude. The maximum concentration of Ag at the level of 4.6 g /t is found in some samples of oils in Boryslav anticline and Bi at the level of 0.6–1.0 g/t – in oil deposits of Skhidnytsya-Urych (on average in deposits) [3].

The genetic affinity of oil and associated gases of Carpathian flysch allohton and platform autochthon (Lopushna field) indicates that the major deposits of petroleum hydrocarbons in Precarpathians were formed during the completion of the Carpathian orogen by

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means of vertical (subvertical) migration on tectonic faults.

On the basis of generalization of large amount of data on temperature measurements in many boreholes in the Inner zone of the Carpathian foredeep there is for the first time set the geothermal gradient increasing from the bottom cover (1.98°C/100 m) to the upper (2.36°C/100 m) for the pulled over oil and gas structures with molasses and flysch. In this direction the average temperatures of oil and gas structures are increasing in the cut – 2,000 m (from 63.6°C up to 65.5°C and 66.8°C). This character of distribution of geothermal gradients and temperatures confirms the formation of deposits in the inner zone of the Carpathian foredeep as a result of vertical migration [4]. The process of their formation could not begin before the end of folding and orogenesis tectonic movements. The deposits of ozokerite were also formed due to the vertical migration of deep ore steam fluids.

Truskavets-Boryslav ore and ozokerite field is located in the area of Ivanykiv condensate field, Starunya and Dzvynyach – between Kosmach, Rosilna and Bytkiv gas and condensate fields. It is known that there must be converted more than 250 million tons of light paraffin oil for formation of Boryslav ozokeryt deposit; it is significantly more than all oil reserves discovered in this field. Therefore, the physical conditions of the ozocerites forming process, can be explained by the effect of retrograde condensation of fluid during its migration through the gap to the surface, combined with a significant cooling due to adiabatic expansion of gas and paraffin deposition in the surface conditions.

Various hydrothermal ore manifestations indicate the repeated receipt of deep high-temperature fluids with hydrocarbons and ore components. Isotopic and geochemical data (after V. V. Naumenko and S. A. Galliy, 1989) indicate that mineral formation at Truskavets field occurred in the interaction with highly mineralized thermal solutions with infiltration waters and hydrocarbons [1].

There were found low-mineralization condensing waters, the salt composition of which differentiated from hydrochemical background in many areas of Boryslav Oil and Gas District (OGD). Their formation was associated with the jet vertical migration of hydrocarbons through fractures and transfer of water in the vapor state, followed by condensation in favorable thermobaric conditions.

According to geochemical research in the field of Boryslav it was found that high concentrations of helium (0.2 vol. %) in some gas samples with the highest coefficient of elasticity were associated to the zones of transverse lineaments.

The relationship between gas hydrocarbons systems and great depth are also proved by elevated CO_2 content that is dissolved in petroleum gas. Thus, the content of carbon dioxide is 10–62% in Oriv–Ulychno, Semyhyniv and Tanyava oil fields. In our opinion the presence of sour gases at depths, where processes of oxidation are virtually eliminated, can be explained by the overall migration in oil and gas mixture from deep areas of the earth's crust, where they may have polygenic source of formation (metamorfogenous, endogenous or mixed).

The deep nature of ore oil and gas fluids that are saturating Cretaceous-Paleogene allohton indicates the possibility of formation of ore and hydrocarbon accumulations at different depths of the Carpathian region. Their attachment to places of crossection of tectonic faults must be taken into consideration during planning of explorations.

The possibility of presence of oil deposits in deep horizons (5–8 km) of the Carpathian foredeep is indicated by the absence of regular changes of petroleum geochemical parameters with the depth of their occurrence.

The geological scrutiny of the Carpathian region was studied a lot. The main features of the region's structure were clarified in the second half of the last century. Two complexes of sediments have become parties in geological structure of Boryslav–Pokuttya area: the Cretaceous–Paleogene flysch and Miocene molasses, the first of which has been a major regional oil and gas complex.

Flysch strata of the Carpathian basin according to A.P. Lisitsyn [5] are gravity streams sediments that characterize the certain types of continental margins and can emerge both in the foot of the continental slope and in the deep trenches.

The main sources of terrigenous sediment in the Carpathian sedimentary basin were the Central European and Scandinavian dry lands that consisted of sedimentary and crystalline rocks. Intense erosion of these structures in various epochs of the Late Cretaceous and Paleogene predetermined the receipt of a large mass of terrigenous material that was settled at the bottom of the northern segment of the continental margin of the Tethys Ocean [6].

According to many scientists the nature of reservoir rocks distribution is controlled by ancient rivers, namely paleorivers that delivered clastic material in the Cretaceous and Paleogene periods.

Two complexes are regionally productive in Paleogene sediments: the Oligocene – menilitova suite, Palaeocene–Eocene – Vygodska, Manyavska and Yamnenska suites. Reservoir-rocks in flysch complex are layers of sandstones and siltstones that are sometimes interbedded with mudstones. They are characterized by medium and low reservoir properties. Low values of reservoir properties are caused by both bad sediments sorting and the processes of secondary cementation.

Oil and gas bearing Cretaceous sediments, namely Stryiskyi sediments, have been known for a long time. The upper part of this suite has oil and gas deposits in Skhidnytsya and Urytsko fields. There have been discovered oil deposits in Striyska suite sediments of Verhnomaslovetske oil field several years ago. The Cretaceous sediments are widespread within the Skybova zone of the Carpathians and Boryslav–Pokutstka area of the Carpathian foredeep, they form cores of folds and the Stryiskyi suite. This terrigenous

flysch sediments are composed of mudstones, siltstones and sandstones.

In order to determine the nature of reservoir rocks spread and to clarify the conditions of formation of Paleogene deposits in the northwestern part of the Carpathian foredeep we have built the schemes of effective thickness of two structural layers (Fig. 1–5) and geological crossections (Fig. 6). We have used the results of previously known, new geological and geophysical data, the results of lab core tests and wells drilling for the schemes building.

The schemes show certain distribution regularities of Paleogene reservoir rocks of the structural layers I and II. Sand-siltstone rocks for each of the chosen layers are grouped mainly in linearly elongated bodies transversely to the Carpathians. Based on these data we can conclude that the main zones of distribution of sand bodies in Boryslav OGD are associated with two large alluvial fans. Main oil and gas fields are associated with these bodies. There is also traced clear connection between local maximum of the effective thickness of Menilitova, Yamnenska, Manyavska and Vygodska suites and their oil and gas potential.

Based on microscopic studies it has been revealed that mainly lithogenetic fractures have been formed in areas, characterized by schistose tight sandstones, siltstones and mudstonesand. The lithogenetic fractures have resulted in uneven saturation of reservoir rocks [7].

Uneven capacitive and filtration properties of reservoir rocks are predetermined by secondary sedimentation transformations during katagenesis changes and geodynamic movements.

During the investigation of reservoir rocks of the Stryiska suite L.S. Monchak et.al. [8] found that the reservoir rocks were broken by cracks of various orientations, well observed in outcrops. Mudstones and marls have a clearly expressed fissility. Sometimes there appear curved shape cracks, which may be caused by the forces of compression. Among the total mass of gray colored rocks there are sometimes found layers of dark colors of shale argillites, rich in organic matter. They are very similar to menilit Paleogene shale. The thickness of these layers varies from a few centimeters to several meters. These shales have a clear layered texture. The opening of the cracks, which are clearly visible in the photos, is significantly less at depths but it is enough to improve the filtration properties of reservoirs.

The studies of secondary transformations of reservoir rocks are essential for predicting the capacitive and filtration properties of deep deposits. The cracks of different genesis are the most important among the secondary origin cavities. The cracks are usually combined with primary pore space into a filtration system, which leads to a significant increase of permeability.

To evaluate the changes of reservoir properties (open porosity, permeability) and density of Paleogene reservoir rocks influenced by katagenesis transformations we have analyzed laboratory tests of the core material from wells at depths ranging from 1,000 to 6,000 meters [9]. The authors established that geodynamic evolution of the region and postsedimentation transformation at great depths affect the formation of pore-fractured and fractured reservoir rocks. The maximum number of high-capacity reservoirs is confined to areas of early, middle and partially late katagenesis, while secondary porosity in areas of middle and late katagenesis causes the development of commercial value reservoir rocks.

B.Y. Mayevskyy et. al. [10] have determined that zones of lithogenetic fissility have been important for the formation of filtration properties of reservoir rocks at great depths, and their presence has led to uneven oil and gas saturation. It is related to the fact that hydrocarbons are concentrated mainly in the cracks and near the cracks zones. In other words, determination the dominant type of void space and its oil and gas saturation should be a necessary precondition for rationale exploration and taken into consideration during the development of oil and gas deposits at great depths.

To confirm the opinion of the prevailing pore-fracture reservoir type, we [11] have calculated flow rates of oil wells of Oriv–Ulychna field according to the Dupuis formula. Comparison of the calculated and actual debits wells indicates that the actual initial flow rates in wells far exceed the settlement. The difference between the calculated theoretical values and actual wells debits, in our opinion, may be due to fractures in Oligocene reservoir rocks, as evidenced by our studies of thin sections of these wells. However, there are wells where the actual initial flow rates are lower than the calculated ones. This may be due to many technical and geological factors, such as deformation of reservoir rocks and closing of cracks due to improper choice of initial depression.

We have built a graph of the initial flow of oil from the effective oil saturation thickness and stimulation for depression in Oriv–Ulychna field, and found that the most effective filtration occurs with depression stimulation up to 7.5 MPa. In this case oil flows through cracks from the adjacent porous reservoir matrix that provides sustainable flow rates and rational oil withdrawal regardless the effective thickness of deposits.

From the above we can say that a decisive role in forming the capacitive-filtration properties of reservoir rocks have zones of fractures distribution. For marking the new oil and gas objects we have used the schemes of distribution of effective thickness (Fig. 1–5), the studies results of Paleogene reservoir rocks fracturing and the results of geochemical researches carried out in these areas by D. I. Aronskyy, L. S. Monchak et. al. in recent years.

Within Boryslav Oil and Gas District in the first and second structural layers of folds there are identified nine oil and gas objects (Fig. 1–3). For a better choice of priority sites in order to find oil and gas deposits we have calculated perspective resources in category C_3 (Table 1). Perspective oil and gas areas within the regions are identified by proven methods of geological and geophysical studies for this area. The resources of C_3 category are associated with layers, the productivity

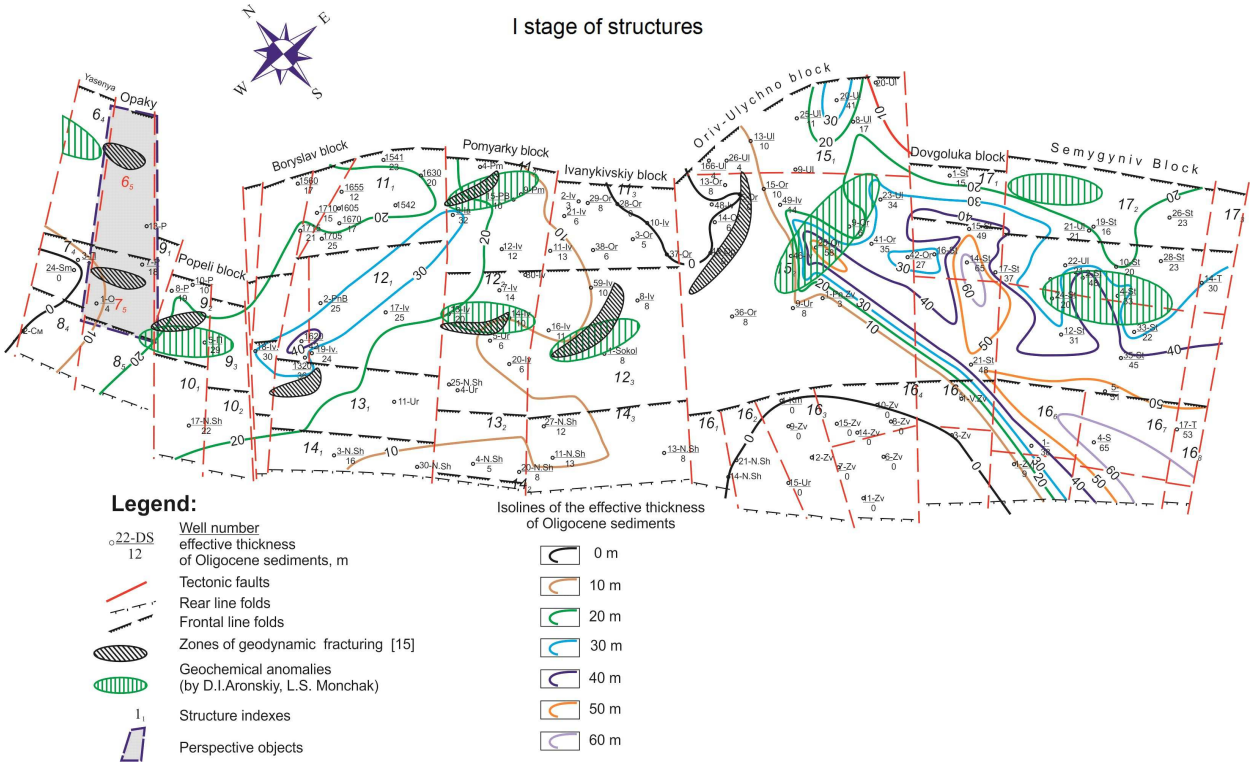

Figure 1 – Schematic fragments of oil and gas objects related to Oligocene sediments of I stage of structures (by B.Y.Mayevskyy, A.V.Yarema, 2013)

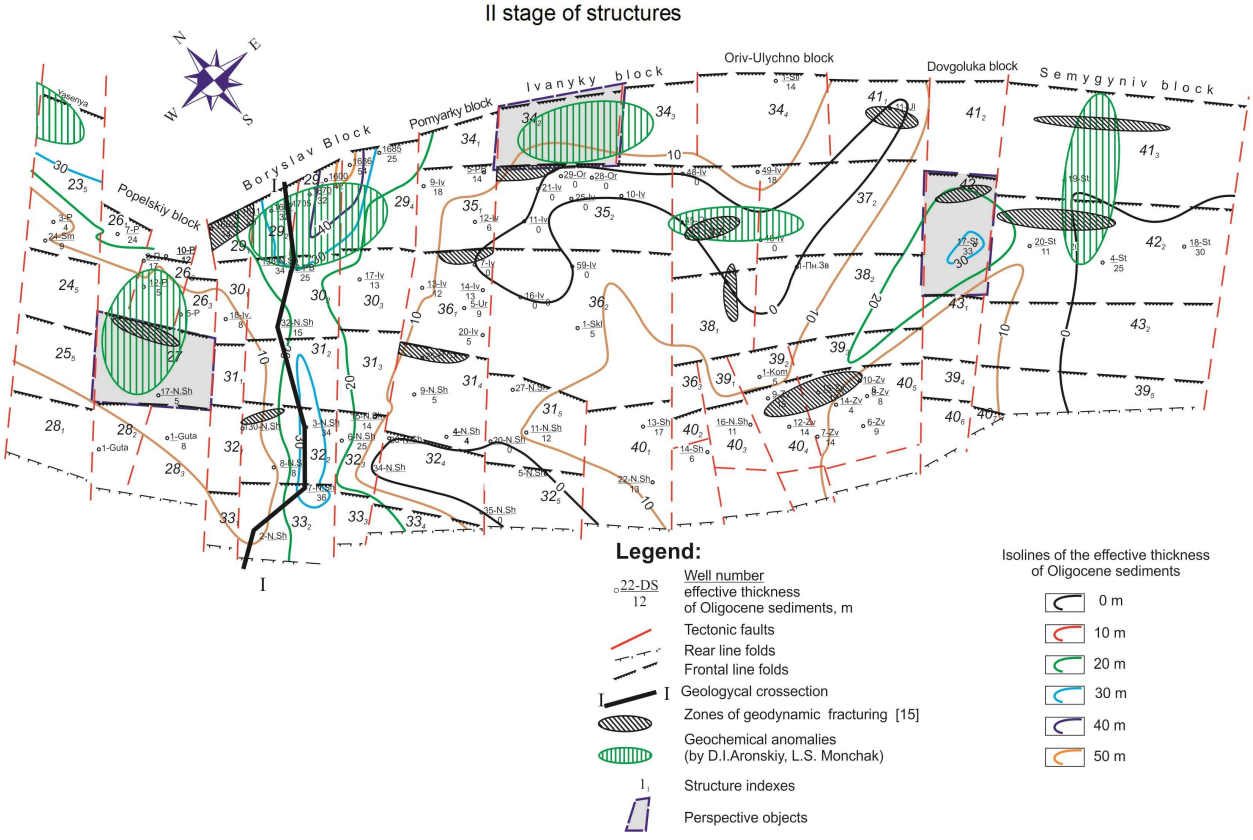

Figure 2 – Schematic fragments of oil and gas objects related to Oligocene sediments of II stage of structures (by B.Y.Mayevskyy, A.V.Yarema, 2013)

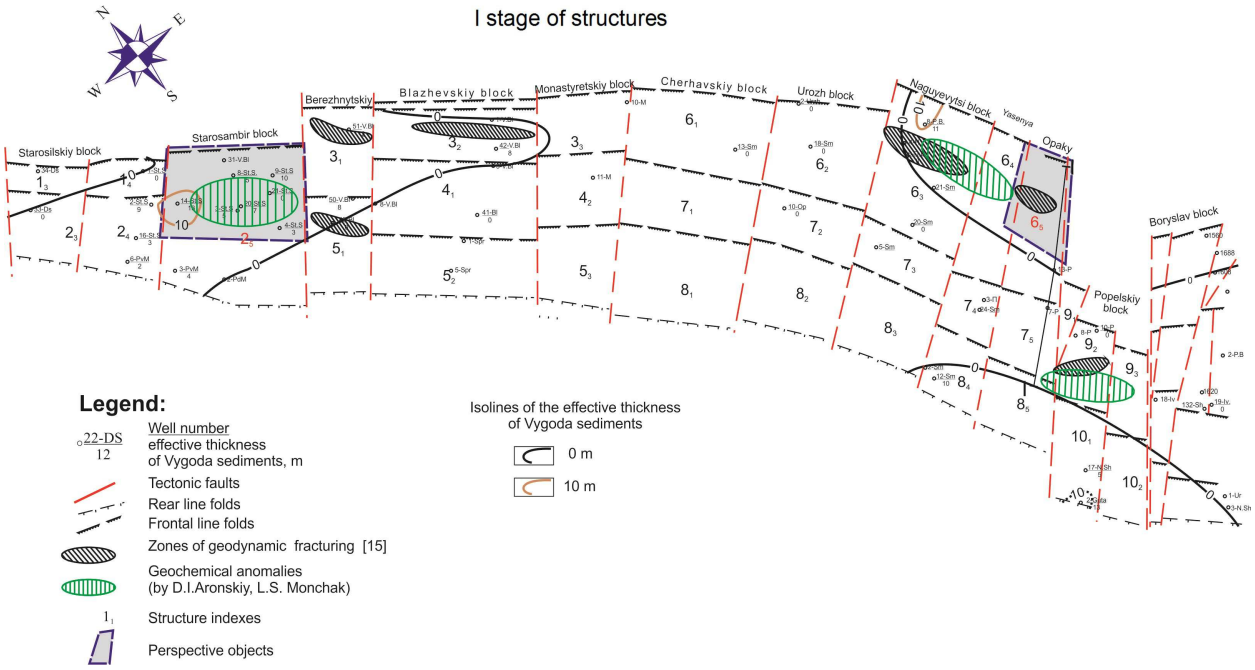

Figure 3 – Schematic fragments of oil and gas objects related to Eocene sediments of I stage of structures (by B.Y.Mayevskyy, A.V.Yarema, 2013)

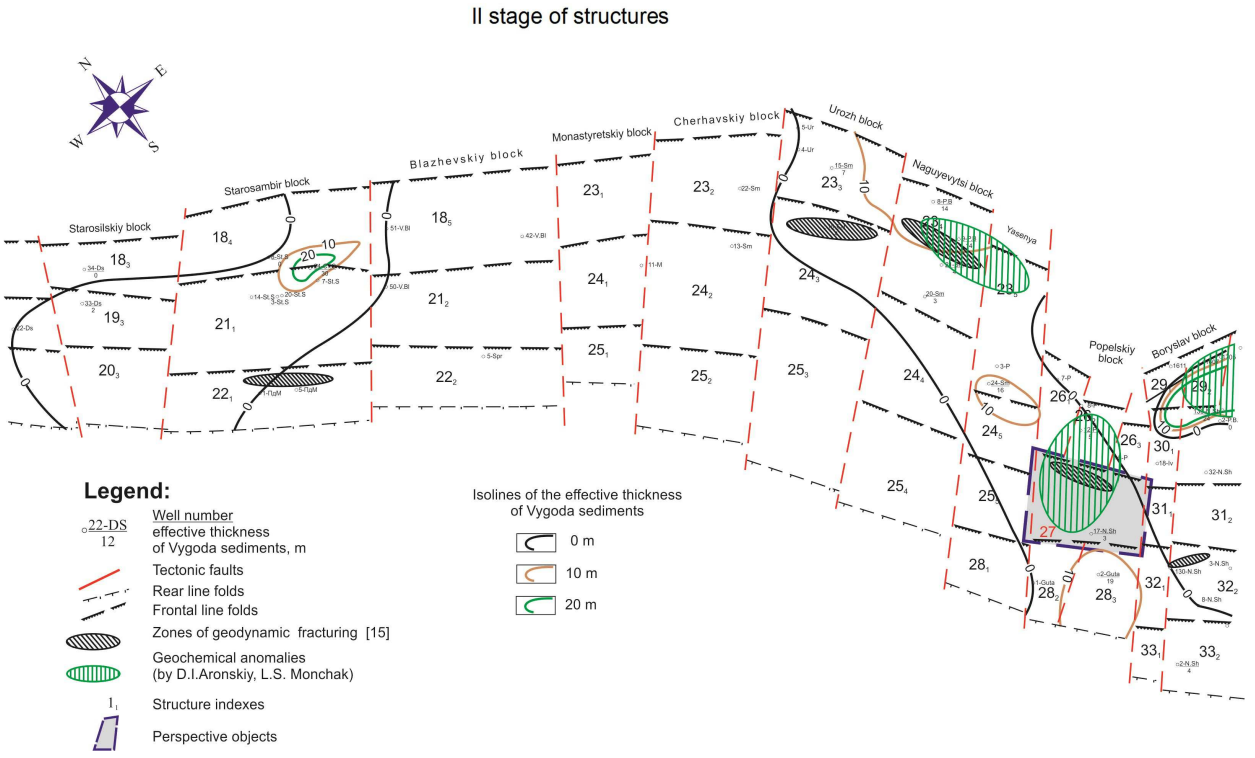

Figure 4 – Schematic fragments of oil and gas objects related to Eocene sediments of II structures stage (by B.Y.Mayevskyy, A.V.Yarema, 2013)

of which is determined in the certain deposits of the area. Counting was performed by volumetric method for the three productive horizons: menilit suite of Oligocene, Vygoda suite of Eocene and Yamna suite of Paleocene.

The resources of Paleogene perspective objects that lie at the depths of 2 to 5 km are 4,200,000 tons. To determine the priority of objects we have used the following criteria – the depth of the object and the value of prospective resources that determine the economic feasibility of drilling. The primary targets are Opaky (Oligocene, Eocene and Paleocene) and Starosambir (Eocene) blocks.

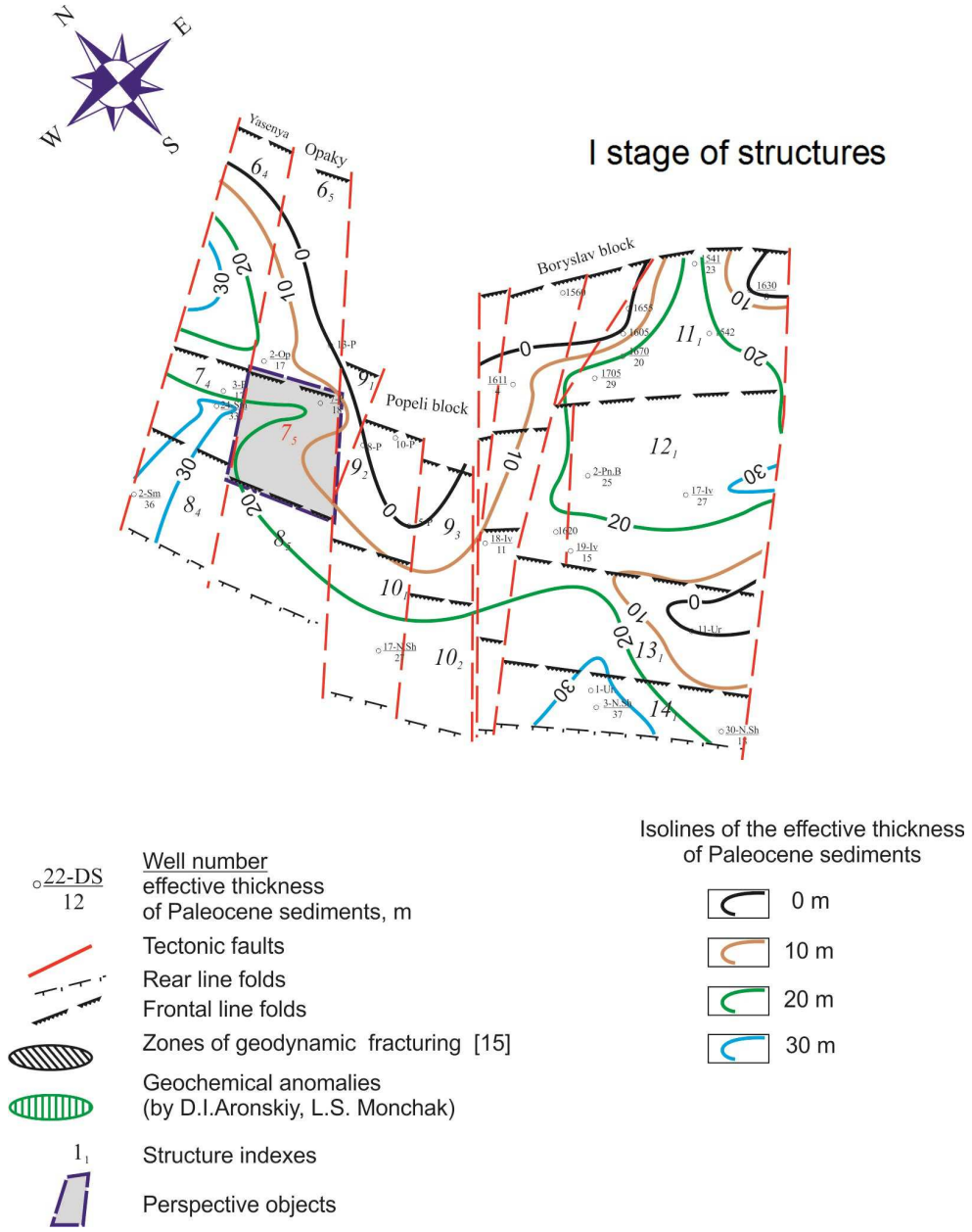

Figure 5 – Schematic fragments of oil and gas objects related to Paleocene sediments of I stage of structures (by B.Y.Mayevskyy, A.V.Yarema, 2013)

Discussion and concluding remarks

Significant hydrocarbon potential of Boryslav OGD is definitely related to Paleogene flysch sediments of the third stage, which lies at depths greater than 5 km. According to the character of distribution and thickness of Paleogene sediments in the first and second structural layers we can assume that the distribution of reservoir rocks in the third layer is of inherited nature. Thus, the search for oil and gas objects for further exploration in the third structural stage must be focused within the area of distribution of reservoir rocks.

For studying and planning the researches for oil and gas, and increasing resources of the third structures stage the authors estimated the predicted resources of category D_1 for specific densities per area unit. Within Boryslav OGD they make up 107 million tons of oil. Within this structural stage the authors have chosen four prior oil and gas objects (Boryslav 47_1, Pomyarkyi 48_1, Oriv 49_1, Ulychno 49_1).

According to the authors [12], it is important to identify the most vault-type traps and tectonically screened traps for predicting oil and gas presence of the Lower Cretaceous sediments. Regarding the latter, now there aren't determined the shielding properties of the Upper rocks, as they contain packs of semi permeable rocks. There are traps for oil and gas both at greater depths and at shallow depth (2–3 km).

Thus, these results clearly indicate the hydrocarbon potential of the investigated area. Therefore, it is necessary to extend the geological and geophysical study of the occurrence conditions and lithofacies composition of Paleogene and Cretaceous sediments with the aim to start exploration operations.

Table 1 – Perspective hydrocarbon resources of the chosen areas

Depth, m	Perspective objects, index	Resources, thousand tons		
		P_3ml_1	P_2vg	P_1jm
2100	Opakivskyi, 6_5	750	–	–
2200	Opakivskyi, 6_5	–	100	–
2750	Opakivskyi, 7_5	300	–	–
3150	Opakivskyi, 7_5	–	–	400
3150	Starosambirskyi, 2_5	–	350	–
4400	Popelskyi, 27	300	–	–
4500	Ivanykivskyi, 34_2	800	–	–
4700	Dovholutskyi, 42_1	1000	–	–
4700	Popelskyi, 27	–	200	–
		3150	650	400
	Total	4200		

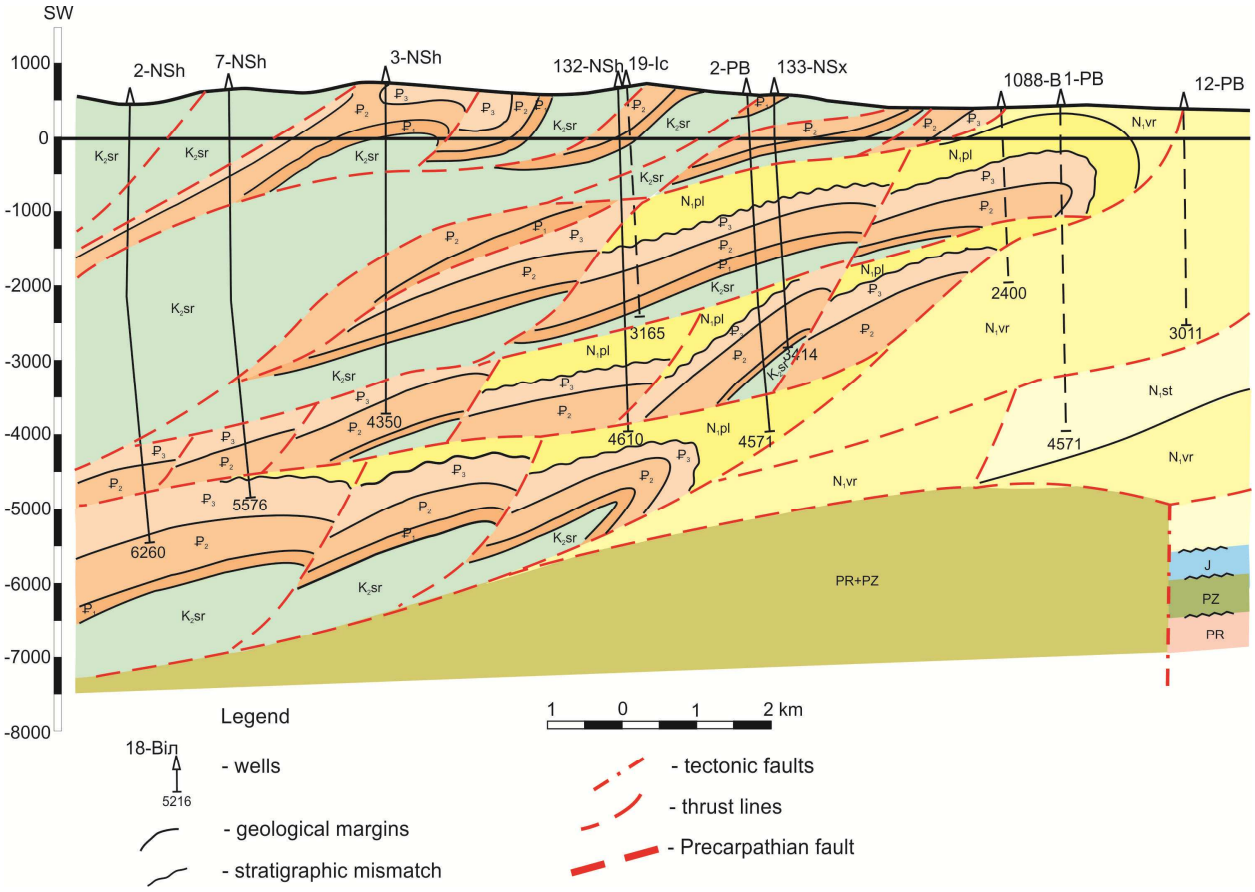

Figure 6 – Geological crossection through the study area

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УДК 553.98

Умови формування та перспективи нафтогазоносності крейдово-палеогенових порід-колекторів північно-західної частини Передкарпатського прогину

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У статті побудовано схеми поширення ефективних товщин палеогенових відкладів у межах I та II ярусів структур північно-західної частини Внутрішньої зони Передкарпатського прогину.

Вивчено характер поширення порід-колекторів, уточнено умови їх формування та встановлено основні закономірності їх просторового поширення, а також особливості фільтраційно-ємнісних властивостей.

Одержані результати стали основою для виділення нафтогазоперспективних об'єктів у межах обраного району досліджень.

Виділено 9 нафтогазоперспективних об'єктів, просторове положення яких підтверджується наявністю газогеохімічних аномалій.

Обсяг сумарних перспективних ресурсів виділених об'єктів, які залягають на глибинах від 2 до 5 км, становлять 4200 тис. т нафти.

Основними критеріями під час ранжування об'єктів були глибина залягання об'єкта і величина перспективних ресурсів, оскільки вони визначають економічну доцільність буріння свердловин.

Ключові слова: *ефективна товщина, нафтогазоперспективний об'єкт, перспективні ресурси, фільтраційно-ємнісні властивості.*