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## HYDROCARBON POTENTIAL OF THE DEVONIAN SEDIMENTS OF CHERNIHIVSKO-BRAHYNNSKOHO PERSPECTIVE DISTRICT

(Представлено членом редакційної колегії д-ром геол. наук, проф. С.А. Вижвою)

As a result of the analysis of wells that revealed Devonian sediments, lithostratigraphic complexes were described and the geological structure and oil and gas potential of Chernihivsko-Bragynskogo perspective district of the Eastern oil and gas region of Ukraine were compared with the Pripyat depression of the Republic of Belarus.

The list of wells which gave non-industrial inflows of hydrocarbons at test is made and their main characteristics at test are described. Hrybovorudniansko-Sednivska and Olishevsko-Losynivska fields are considered from the point of view of potential prospects for hydrocarbons from compacted carbonate reservoirs of Devonian deposits. Stock data related to the results of drilling and testing of wells №655 and №217 Hrybovo-Rudnyanska square, which confirm the prospects of Hrybovorudniansko-Sednivska area, were analyzed.

The issue of realization of the Chernihivsko-Bragynskyi perspective district as a site for signing a production sharing agreement is considered.

The geological, methodological and technological reasons of the negative results of oil and gas exploration works in the Devonian deposits of the Chernihivsko-Bragynskyi perspective district are analyzed.

**Keywords:** Chernihivsko-Bragynskyi perspective district, Devonian deposits, saline deposits, carbonate rocks, hydrocarbons.

**Problem statement.** In the Dnieper-Donetsk oil and gas region (DDOGR) there are 15 oil and gas areas with different levels of explored reserves, promising resources, exploration and development of subsoil. The least researched area is the Chernihivsko-Bragynskyi Perspective District (CBPD) located on the north-western part of the DDOGR. According to the density of unexplored hydrocarbon resources, most of the district belongs to VIII-VII categories (less than 5 thousand tons of hydrocarbons per 1 km<sup>2</sup>, partly – Yadutivsko-Kinashivska zone – up to 10 thousand tons per 1 km<sup>2</sup>). The depth of the basement in the district varies from 1000 m to 6000 m. The total area of the district is 8200 km<sup>2</sup>, on 1.01.2021, the industrial productivity of any set of deposits in the CBPD has not been proven, and the prospects of the area remain uncertain.

**Recent publications review.** Despite the large area of CBPD, potential prospects and about 150 deep wells that have discovered Devonian sediments (Pryharina, 2007) – studies of the area were actually in the early 90's for a number of economic reasons, and publications of the last 30 years, as a consequence, are retrospective (Strizhak and Korzhnev, 2012) or consider methodologically theoretical aspects of the negative result of exploration of hydrocarbons (explosives) in Devonian sediments (Lebid, 2015). The main works covering the north-western part of DDOGR and carried out in recent years are analytical reports on the review and generalization of geological and geophysical materials performed by SE "UKRGEOFIZYKA" (Beztelesnyi et al., 2008; Baranova and Voitsytskyi, 2018), also detailed the results of lithological-stratigraphic, facies, structural-tectonic, petrophysical, geochemical and geological-industrial studies in carbonate sediments of the Devonian complex within different structural-facies zones of DDOGR (Vakarchuk, 2016).

**Highlighting previously unselected parts of the overall problem.** During the more than 60-year history of studying the oil and gas potential of Devonian CBPD

sediments, three main parts of the general problem were formed – industrial oil and gas issues, namely: 1) geological, 2) methodological, 3) technological, each with its unresolved issues. However, the issue of the economic perspective of the CBPD has not been identified yet and there are no strategies for an economic approach to one of the biggest white spots of the DDOGR.

**Article aims.** The aims of the article are to consider lithostratigraphic complexes of Devonian sediments, analyze the results of tests of CBPD wells and identify those that gave inflows, consider the potential of hydrocarbon CBPD in terms of licensing and economic prospects for development.

**Main research material.** Interest in the study of Devonian sediments in DDOGR is clearly recurrent – interest is growing with the depletion of upper structural floor resources, and each new discovery related to the main Lower Devonian oil and gas complex sharply reduces this interest.

The most intensive development of Devonian exploration work was observed in the second half of the 60's and early 70's (Strizhak and Korzhnev, 2012), when seismic surveys covered almost the entire north-western part of DDOGR, where their depths do not exceed 4–5 km. The discovery of industrial oil deposits in subsalt and intersalt Devonian sediments within the neighboring Pripyat Basin (Belarus), as well as the discovery of a number of deposits in the middle part of the DDOGR showed that in the Dnieper-Donetsk basin Devonian sediments are worse than in all Pripyat depression. In the Dnieper-Donetsk basin there are slightly different conditions of oil and gas, although the regions have many similar features of the structure and history of formation, namely:

- belonging of both to oil and gas objects of continental reefs according to geodynamic classification;
- satisfactory spatial and stratigraphic correlation of Devonian sediments, the presence of five lithological complexes;

• a similar history of the development of adjacent parts of the regions – the Pripyat depression and the north-western part of DDOG;

• oil and gas properties of Devonian sediments.

87 oil fields have been discovered in the Pripyat basin on the territory of the Republic of Belarus (according to the official website of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus) (Fig. 1).

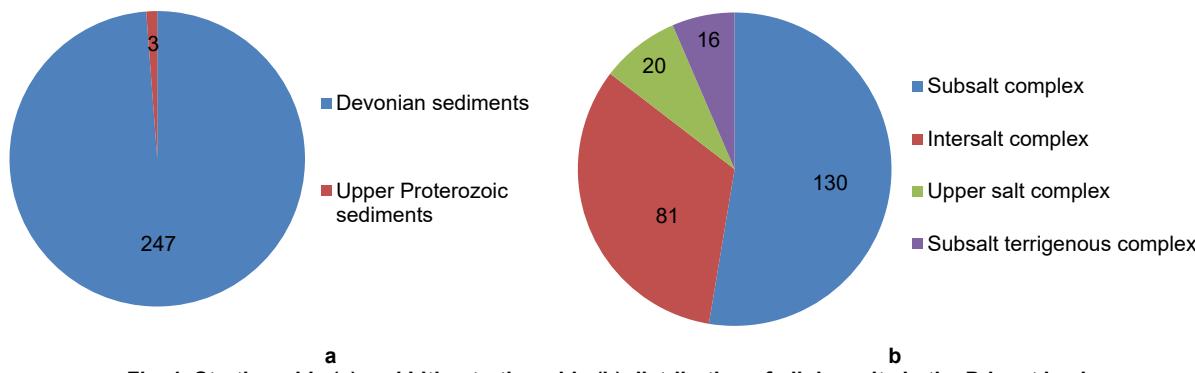


Fig. 1. Stratigraphic (a) and Lithostratigraphic (b) distribution of oil deposits in the Pripyat basin

Devonian sediments in the north-western part of the DDOG as well as in the Pripyat depression are represented stratigraphically by a single stratum of the Middle Devonian and Upper Devonian ages and are divided into five lithologic stratigraphic complexes according to lithological features: subsalt, lower salt, intersalt, upper salt and supersalt.

Stratigraphically, the **Subsalt complex** is represented by the Alatyr and Voronezh horizons of the Frasnian age, which lie directly on the bedrock. Sediments of the Alatyr horizon are represented by the thickness of effusive rocks of different composition. Above the section there are small carbonate-clay rocks (marls, limestones, dolomites) of the Voronezh horizon. The subsalt part of the Yevlan horizon is composed of argillites alternating with sulphate-carbonate rocks. Volcanic formations (tufolavas, tufoaleurolites, tuff sandstones, tuffs), which may occupy different stratigraphic levels and have different thicknesses, also take part in the section of subsalt Devonian. The **Lower Salt complex**, which corresponds to the salt formations of the Eulanov-Livno horizon of the Frasnian age, lies below the salt complex. There are cases of Voronezh age of the lower salt. Lithological composition – rock salt with layers of dolomite, anhydrite, clay limestone and marl. Salt sediments are sometimes replaced by sulfate-carbonate with layers of clayey, often saline rocks, siltstones and sandstones. The **Intersalt complex** is represented by the Zadonsk-Yelets horizon, from which the sedimentary accumulation of the Famennian age begins. In the intersalt complex there is a lower clay-carbonate stratum (Zadonsk horizon) and an upper terrigenous stratum (Yelets horizon). The clay-carbonate stratum of the Zadonsk horizon in the study area is practically absent, sometimes standing out in small thicknesses. The terrigenous stratum of the intersalt complex is represented by a fine-rhythmic layering of clayey sandstones, argillites, siltstones with layers of limestone. The **Upper Salt Complex** corresponds to the Yelets-Lebedyan horizon of the Famennian age, composed of salt deposits or their salt-free analogues, which may include sulfate formations, carbonates of various modifications, including limestones, dolomitized limestones, Merbofite-Dolomite. **Supersalt complex**, Dankiv-Lebedyan horizon of the Famennian tier, composed of effusive-terrigenous and

Their search began in 1952, and development in 1965. 250 oil deposits were discovered in these fields, 247 of them in Devonian sediments and 3 in Upper Proterozoic sediments. The largest number of oil deposits (130) is confined to the subsalt carbonate complex; in the intersalt complex – 81, in the upper salt complex – 20, in the subsalt terrigenous complex – 16. Oil production in 2020 amounted to 1.7 million tons of oil.

effusive rocks (Beztelesnyi et al., 2008; Baranova and Voitsytskyi, 2018; Kochev, 1970; Khmel et al., 1969).

Reflecting on the negative effects of exploratory drilling on Devonian sediments, analyzing previous forecasts, Yu.O. Arsiriy, B.P. Kabyshev and others tried to compare and contrast the Devonian intersalt and subsalt sediments of the northwestern part of the DDOG to the Pripyat depression. As a result of their work, they came to the conclusion that the conditions of oil and gas formation and oil and gas accumulation in the Pripyat depression are unequal, so the prospects for the north-west of DDOG are clearly worse. However, the authors insist that this is not evidence of the futility of this segment in DDNGO. The authors consider intersalt Famennian deposits to be promising; less significant, in their opinion, are the Frasnian saline deposits. In structural terms, preference is given to the peripheral areas of large depressive structures (Malodivitska, Borznyanska, Viktorivska, Velykozagorivska, Burivska squares), the slopes of the basement (Northern Khreshchatytska, Pishkivska), the axial part of the DDOG (Nizhynska). Instead, the vaulted parts of the highly elevated protrusions of the basement, composed of effusive-terrigenous deposits, are considered unpromising (Arsirii et al., 1981).

Confirmation of these considerations was obtained in the year of publication of the article (Arsirii et al., 1981) during the testing of the Ladutivska structure in the Ladutivska well 1.

In total, according to the results of 60 years of study and drilling of about 150 deep drilling wells, the most significant oil manifestations and non-industrial oil inflows within the CBPD were recorded in terrigenous deposits of intersalt Devonian (Table 1) in wells Kinashivska 3, 1, Hrybovorudnianska 1, Ladutivska 1 (Beztelesnyi et al., 2008; Baranova and Voitsytskyi, 2018).

However, the availability of promising data for only 4 tested wells, of which 3 are located on the border with Monastyryshche-Sofiyivskyi oil-bearing area, for more than 60 years of CBPD drilling is not evidence of the futility of further study and testing of Devonian deposits. For example, a detailed analysis of stock materials (Kochev, 1970; Khmel et al., 1969) concerning the results of drilling and testing of well № 217 and structural exploration well № 655 on Hrybovo-Rudnyanska square shows a number of indirect

additional features, prospects of the site. In the process of drilling the interval 2300–2344 m of the well № 217 was characterized by a drop in the specific gravity of the drilling fluid and its foaming, which may indicate the presence of gas-saturated rocks in this range. In the core material of the Voronezh horizon of Devonian subsalt deposits (2619–2643 m), which is represented by dense limestones, the presence of drip-liquid oil was observed in the cracks. The presence of oil series fluids in Devonian subsalt sediments is confirmed by luminescent-bituminous analysis. In the process of drilling in samples of drilling mud from a depth of

2615 m there is a change in the component composition of the gas, the qualitative characteristics of which are characteristic of the oil type saturation (at a depth of 2630 m there is a maximum gas saturation of the section up to  $0.44 \text{ cm}^3/\text{l}$ ). In addition, it should be noted that the section of Hrybovo-Rudnyanska Square (Fig. 2) is characterized by endurance of the Voronezh horizon of Devonian subsalt sediments and according to laboratory studies of the core material has the following average characteristics: porosity  $-2.78\text{--}3.05\%$ , permeability  $0.1 \text{ mD}$ .

Table 1

| Test results of Devonian sediments by wells within the CBPD |        |                             |                   |                   |   |
|---|--------|-----------------------------|-------------------|-------------------|---|
| Area  | № well | Year of drilling completion | Test interval (m) | Age               | Test results  |
| Hrybovo-rudnianska  | 1      | 1970                        | 2500–2550         | D <sub>3</sub> vr | Received non-industrial oil inflow  |
| Kinashivska   | 3      | 1979                        | 2038–2300         | D <sub>3</sub> el | When testing the objects obtained: int. 2038–2205 m – low oil inflow, $Q = 3.0 \text{ m}^3/\text{d}$ ; int. 2038–2268 m – oil inflow, $Q = 6.0 \text{ m}^3/\text{d}$ ; 2038–2274 m – oil inflow, $Q = 3.0 \text{ m}^3/\text{d}$ ; int. 2060–2065 m – oil inflow, $Q$ up to $7.0 \text{ m}^3/\text{d}$   |
| Kinashivska   | 5      | 1980                        | 2102–2300         | D <sub>3</sub> el | int. 2071–2161 m – oil inflow, $Q = 1.2 \text{ m}^3/\text{d}$ ; int. 2071–2199 m – inflow of filtrate with oil film; int. 2071–2207 m – inflow of filtrate with oil film; int. 2071–2277 m – inflow of mineralized water with oil film; int. 2106.5–2110 m – oil inflow; int. 2138–2149 m – oil inflow, $Q = 3.4 \text{ m}^3/\text{d}$ ; int. 2248–2261 m – oil inflow; int. 2283–2290 m – oil inflow, $Q = 1.0 \text{ m}^3/\text{d}$ |
| Iadutivska  | 1      | 1981                        | 2872–2971         | D <sub>3</sub> el | int. 2872–2971 m – oil inflow, $Q = 1.4 \text{ m}^3/\text{d}$ ; int. 2872–2971 m (after repeated perforation) – oil inflow, $Q = 8.5 \text{ m}^3/\text{d}$ ; int. 2872–2955 m – oil inflow, $Q = 3.05 \text{ m}^3/\text{d}$ ; int. 2956–2971 m – oil inflow, $Q = 3.0 \text{ m}^3/\text{d}$   |

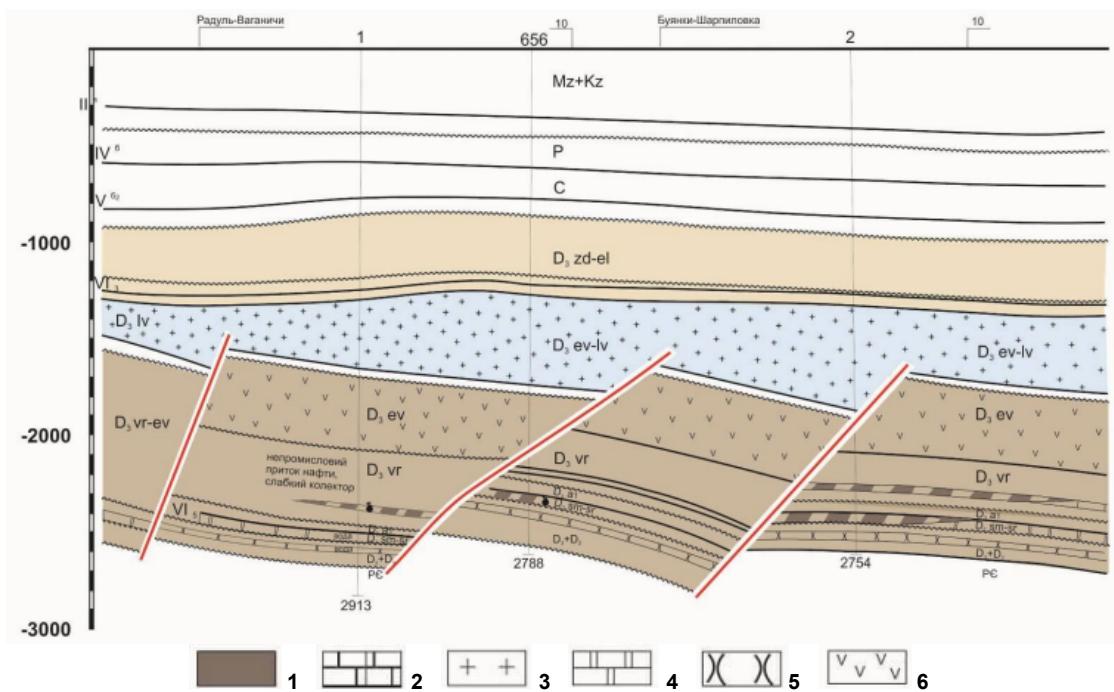


Fig. 2. Hrybovorudnianska structure. Seismogeological section along the profile 3 4 76 (Baranova and Voitsytskyi, 2018):  
1 – oil; 2 – limestones; 3 – salt; 4 – dolomites; 5 – sandstones; 6 – effusive-tuffogenic thickness

In the scientific publication "Estimation of oil and gas potential of compacted rocks of the Devonian complex of the Dnieper-Donetsk basin" S.G. Vakarchuk singles out the Hrybovo-Rudnianska area (Hrybovorudniansko-Sednivska area) as promising for the search for unconventional oil in carbonate reservoirs. The average depth of promising strata within the site is 3000 m. The area of the site is  $795 \text{ km}^2$ . Within the western part of the Hrybovorudniansko-Sednivska section, from the point of view of searching for unconventional hydrocarbons, compacted carbonate

formations of the Voronezh horizon of the Upper Frasnian sublayer, which increase the Sargaevo-Semilutsk carbonate section, are of interest. The thickness of carbonate packs of the Voronezh horizon is up to 50–60 m. The average depth of promising formations of the Voronezh horizon is 2500 m. Compacted carbonate rocks of the Voronezh horizon are promising only for unconventional oil. The geological resources of the Hrybovorudniansko-Sednivska gas section of the compacted carbonate rocks of the Voronezh, Sargaevo and Semilutsk horizons are estimated at 71.1 billion  $\text{m}^3$

(production – 24.6 billion m<sup>3</sup>). Geological resources of unconventional oil – 1144.0 million tons (extractive – 85.9 million tons) (Vakarchuk, 2016).

The second promising area for the search for unconventional oil and unconventional gas (Vakarchuk, 2016), which is partly within the CBPD, is Olishevsko-Losynivska. The average depth of promising strata within the site is 3800 m. The area of the site is 560 km<sup>2</sup>. Geological resources of unconventional gas of compacted carbonate rocks of the Olishevsko-Losynivska section are estimated at 94.3 billion m<sup>3</sup> (extractive 33 billion m<sup>3</sup>), geological resources of unconventional oil – 224 million tons (extractive – 16.8 million tons).

From the point of view of economic prospects, CBPD remains unattractive to investors, primarily due to the lack of precedent for establishing the viability of any Devonian complex.

At the end of 2020 and the beginning of 2021, 8 production sharing agreements (PSA) were signed in Ukraine, of which 7 agreements relate to the Eastern Oil and Gas Region of Ukraine and 1 agreement to the Western Oil and Gas Region of Ukraine. All areas of the PSA cover areas well studied by drilling and seismic research, within which the winning companies will study and develop traditional for Ukraine reservoirs and look for low-amplitude hydrocarbon traps that have not been discovered or missed by previous studies in contrast to CBPD which remains one of the largest white spots of DDOGR.

The total area of the CBPD is 8,200 km<sup>2</sup>, of which only three plots are covered by licenses (Fig. 3). The field of the Slavytch scientific landfill with the area of 496.19 km<sup>2</sup>, the field of the Yadutivsko-Borznyanskyi scientific landfill with the

area of 471.82 km<sup>2</sup> and the Prachivska field with the area of 24.8 km<sup>2</sup>. Thus, more than 7,000 km<sup>2</sup> of unlicensed area remains. Since there are no significant promising facilities that will be of interest to potential investors on the territory of the CBPD, and thematic studies conducted for the state budget and aimed at generalizing or reinterpreting existing data do not open new fields, the only option is to prepare the site for implementation under a product sharing agreement. If the work is successful, the state will be able to receive additional taxes to the budget and improve the socio-economic situation of the research area.

**Conclusions.** Analyzing the reasons for the negative results of exploration for oil and gas in the Devonian deposits of the CBPD, they can be divided into three groups that are closely related: 1) geological, 2) methodological, 3) technological.

Geological reasons include the complex geological structure of Devonian sediments, which include, along with the development of terrigenous and carbonate sediments, widespread volcanics (vein, outflow, pyroclastic), salt tectonogenesis and significant tectonic disturbance of both subsalt and intersalt sediments. In such conditions the lithological-stratigraphic correlation becomes very complicated and the reliability of geophysical research decreases. The intensification of tectonic processes associated with Devonian salt after the formation of intersalt and supersalt Devonian sediments led to the fact that the best reservoir varieties of these strata were not always associated with the apical parts of anticline structures, with mainly exploratory and parametric wells.

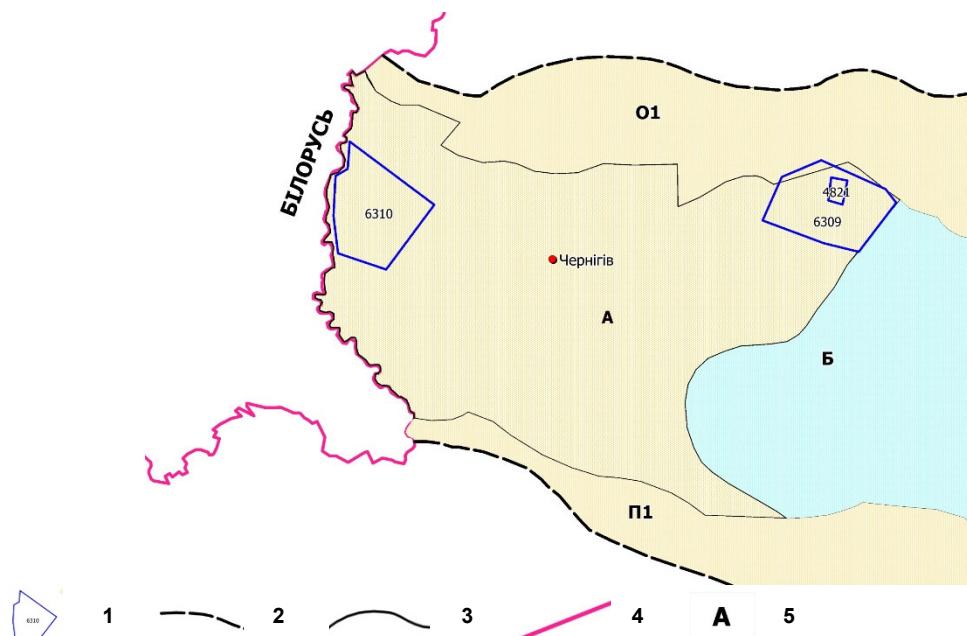


Fig. 3. Layout of special subsoil use permits on the territory of Chernihivsko-Brahynskyi Perspective District:

- 1 – contour of special permits;
- 2 – borders of the Dnieper-Donetsk oil and gas region;
- 3 – boundaries of oil and gas areas;
- 4 – the state border of Ukraine;
- 5 – index of oil and gas region (A – Chernihivsko-Brahynskyi promising area, Б – Monastyryshche-Sofiyiv oil-bearing area, O1 – oil and gas area of the North side, П1 – perspective area of the South side)

The second (methodological) reason for the negative results is the methodologically incorrect approach to drilling in the mid-60s of the last century on Devonian deposits. After the discovery of oil fields in the Pripyat depression, the study of this complex in the northwest of the DDOGR was carried out based on the analogy of the geological structure of these regions. However, this thesis was not confirmed in

many aspects in the future. Next exploration and discovery of a number of hydrocarbon deposits in the DDOGR have shown that there are other conditions for the formation of hydrocarbon deposits in the Pripyat depression.

Technological reasons include the imperfect technology of discovery during drilling and testing of promising objects. This technology requires a radical change in the direction of

opening the layers on the facilitated washing liquids, causing the inflow by a gradual change of depressions and the development of effective methods of intensification of the inflow through fracturing. One of the potential opportunities for successful completion of wells is the completion of a horizontal well.

CBPD is the least studied oil and gas area of DDOGR, in which the industrial productivity of any set of deposits has not been proven, the prospects of the area remain uncertain and geological exploration work is minimized. At the same time, the CBPD, having a fairly large area, remains one of the most interesting areas from a geological point of view for further exploration and exploration for hydrocarbons in the near future.

In order to achieve new results on the territory of the CBPD, it is proposed to prepare it as a site for implementation within the PSA.

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## ВУГЛЕВОДНЕВИЙ ПОТЕНЦІАЛ ДЕВОНСЬКИХ ВІДКЛАДІВ ЧЕРНІГІВСЬКО-БРАГІНСЬКОГО ПЕРСПЕКТИВНОГО РАЙОНУ

У результаті проведеного аналізу по свердловинах, що розкрили відклади девону, було проведено опис літостратиграфічних комплексів та виконано порівняння геологічної будови та нафтогазоносності Чернігівсько-Брагінського перспективного району Східного нафтогазоносного регіону України з При'ятським прогином Республіки Білорусь.

Складено список свердловин, які дали непромислові припливи вуглеводнів під час випробування та описано їхні основні характеристики.

Розглянуто Грибоворуднянсько-Седнівська та Олішевсько-Лосинівська ділянки з погляду потенційних перспектив на вуглеводні з ущільнених карбонатних колекторів відкладів девону. Проаналізовано фондові дані, що стосуються результатів буріння та випробування по свердловинах № 655 та № 217 Грибово-Руднянської площи, що підтверджують перспективи Грибоворуднянсько-Седнівської ділянки.

Піднято питання реалізації Чернігівсько-Брагінського перспективного району як ділянки для підписання угоди про розподіл продукції.

Проаналізовано геологічні, методичні та технологічні причини негативних результатів геологорозвідувальних робіт на нафту і газ у девонських відкладах Чернігівсько-Брагінського перспективного району.

Ключові слова: Чернігівсько-Брагінський перспективний район, девонські відклади, підсольові відклади, карбонатні породи, вуглеводні.