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Geothermobaric criteria for oil-and-gas bearing in the Dnieper-Donets Graben

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To evaluate exploration areas and forecast individual productive horizons of exploration for oil and gas, it is necessary to establish patterns in the location of the already explored hydrocarbon deposits. The analysis has to consider the structural and tectonic build, lithological and stratigraphic features, and hydrogeological and geothermobaric conditions of the oil and gas region. The relationship of geothermobaric parameters with the phase state of hydrocarbons in a vertical section should serve as an important factor for solving the problem. Within the Eastern oil and gas region of Ukraine, gas, oil, and gas condensate deposits are zoned. Vertical zoning of the location of hydrocarbon deposits of oil and gas horizons follows the geothermobaric criteria for the Monastyryshchensko-Sofiyivskyi and Talalaivsko-Rybalskyi oil-and-gas bearing, Hlynsko-Solokhivskyi gas-and-oil bearing and Mashivsko-Shebelinskyi gas-bearing, Rudenkivsko-Proletarskyi oil-and-gas bearing deposits of the Eastern oil and gas region of Ukraine.

Key words: geothermobaric criteria, thermobaric parameters, oil, gas, gas condensate deposits.

Introduction. For the evaluation of exploration areas of the Eastern oil and gas region of Ukraine, as well as separate forecasting of individual productive horizons of exploration areas for oil and gas, it is necessary to establish patterns in the location of already explored hydrocarbon deposits, taking into account the structural and tectonic structure, lithological and stratigraphic features, and hydrogeological and geothermobaric conditions.

The solution of the problem. The pressure and temperature regime of the Dnieper-Donets Graben is determined by the magnitude of the deep heat flow coming from the subsoil, the structural and tectonic features of the region, the lithology of the sedimentary complex, the development of a powerful

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complex of chemogenic and volcanic rocks, hydrogeological and other factors, and the presence of hydrocarbon deposits.

The research established the relationship between the geothermal activity of the subsoil and the placement of hydrocarbon deposits [Hrytsyk et al., 1999; Prykhodko et al., 2005; Kurovets et al., 2019]. Within the Eastern oil and gas region of Ukraine, spatial zoning in the location of gas, oil and gas condensate deposits has been established. The northwestern part, the least submerged, contains mainly oil; the southeastern, the most submerged, is mainly gas-bearing; the central oil-and-gas part has a complex ratio of oil-and-gas bearing floors in the section. Similar patterns are observed in other oil-and-gas bearing provinces of the world.

Main results of the study. Analyzing the geothermobaric parameters of the region, we developed vertical zoning and established patterns in the locations of hydrocarbon deposits of the Monastyryshchensko-Sofiyivskyiand Talalayivsko-Rybalskyi oil-and-gas bearing regions, the Hlynsko-Solokhivskyi gas-and-oil bearing region, the Mashivskogo-Shebelinskyi gas-bearing region, the Rudenkivsko-Proletarskyi oil-and-gas bearing region [Prykhodko et al., 2019a, b].

Monastyryshchensko-Sofiyivskyi oil-bearing region. The explored oil deposits in the vertical section are located in the depth range from 1500.0 to 4921.5 m. The reservoir temperatures vary from 409.0 to 323.0 K, reservoir pressures — from 14.20 to 52.48 MPa, thermobaric coefficient — from 7.50 to 22.75, hydrostatic coefficient — from 1.02 to 1.14.

Talalaivsko-Rybalskyi oil-and-gas bearing region. Based on the values of reservoir temperatures, reservoir pressures, thermobaric and hydrostatic coefficients in the vertical section of the studied region, such zones of the phase state of hydrocarbons were identified:

– upper (oil-and-gas condensate deposits): reservoir temperatures vary from 312.0 to 366.0 K, reservoir pressures — from 13.6 to 31.0 MPa, thermobaric coefficient — from 11.42 to 22.94, zone depth — from 1312.0 to 2996.0 m;

– middle (oil, gas condensate, gas and oil-and-gas deposits) — reservoir temperatures vary from 345.0 to 417.0 K, reservoir pressures — from 31.1 to 53.4 MPa, thermobaric coefficient — from 7.47 to 12.07, depth of the zone — from 2998.0 to 4690.0 m;

– lower (gas condensate deposits) — for this zone, the typical values of reservoir temperatures are more than404.0 K; reservoir pressures more than 57.47 MPa, thermobaric coefficient — from 8.02 to 4.97 at depths greater than 4709.0 m.

According to the hydrostatic coefficient, hydrocarbon deposits in the section of the studied area are located as follows: oil — within the range from 1.00 to 1.20 at depths of productive horizons from 1472.0 to 5088.0 m; gas condensate — from 1.0 to 1.6 at depths greater than 1312.0 m; gas — 1.05—1.14 at depths from 3271.0 to 4261.0; oil and gas — 1.05—1.06 at depths from 2998.0 to 3152.0 m.

The explored oil deposits (48.1 %) are characterized by the following geothermobaric parameters: reservoir temperatures vary from 313.0 to 397.0 K, reservoir pressures — from 14.20 to 56.15 MPa, thermobaric coefficient — from 6.86 to 22.39, hydrostatic coefficient — from 1.0 to 1.20. The depths of the explored oil deposits vary from 1472.0 to 5088.0 m. Gas deposits (3.4 %) were discovered in the depth range from 3271.0 to 4261.0 m and are characterized by reservoir temperatures from 359.0 to 385.0 K, reservoir pressures — from 35.38 to 47.65 MPa, thermobaric coefficient values— from 8.0 to 10.15, hydrostatic coefficient — from 1.05 to 1.14.

For gas condensate deposits (48.5 %) the following geothermobaric parameters have been established: range of reservoir temperatures — from 314.0 to 418.0 K, reservoir pressures — from 13.80 to 83.90 MPa, thermobaric coefficient — from 5.01 to 22.94, hydrostatic coefficient — from 1.00 to 1.23. It is worth noting that gas condensate deposits C_{1v2} Karaikozivka and C_{1v2} Berezivka gas condensate fields at depths from 4800.0 to 5412.0 m have relatively high values of hydrostatic coefficient — from 1.43 to 1.60 at investigated depths from 1312.0 to 5690.7 m.

According to the thermobaric parameters, the following zones are distinguished in the vertical section of the sedimentary cover of

the ***Hlynsko-Solokhivsky gas-and-oil bearing region***:

– upper (oil and gas deposits): reservoir temperatures vary from 291.0 to 345.0 K, reservoir pressures — from 8.3 to 23.8 MPa; thermobaric coefficient — from 13.96 to 35.06; zone depth — from 346.0 to 2322.0 m;

– middle (oil, gas condensate, gas, and oil-and-gas deposits) — reservoir temperatures vary from 336.0 to 400.0 K, reservoir pressures — from 23.8 to 50.7 MPa, thermobaric coefficient — from 6.17 to 15.20, depth of the zone — from 2320.0 to 4720.0 m;

– lower (gas condensate and gas deposits) — for this zone, the typical values of reservoir temperatures are >388.0 K, reservoir pressures >50.7 MPa, thermobaric coefficient — from 7.02 to 3.67 at depths greater than 4720.0 m.

Hydrocarbon deposits in this area are characterized by the following parameters:

Oil deposits (10.3 %) are characterized by reservoir temperatures ranging from 317.0 to 399.0 K, reservoir pressures ranging from 10.40 to 51.90 MPa, thermobaric coefficient ranging from 7.61 to 24.86, hydrostatic coefficient ranging from 1.0 to 1.18. Theyare located in the depth range from 1256.0 to 4896.0 m.

Gas deposits (7.6 %) are characterized by the following geothermobaric parameters in a vertical section: reservoir temperatures ranging from 291.0 to 417.0 K, reservoir pressures ranging from 8.30 to 64.50 MPa, thermobaric coefficient ranging from 6.47 to 35.06, hydrostatic coefficient — from 1.0 to 1.27 within the depth range from 840.0 to 5593.0 m.

The explored gas condensate deposits (80.5 %) are located at depths from 1500 to 6222.0 m at reservoir temperatures from 336.0 to 419.0 K, reservoir pressures from 23.50 to 113.50 MPa, thermobaric coefficient values from 3.67 to 14.68, and hydrostatic coefficient values from 1.0 to 1.24 (the exception is the high values of the hydrostatic coefficient of gas condensate deposits in the C_{1t} deposits on the Rudivska area, C_{1t} Vasylivka oil and gas condensate, C_{1v2} Komyshnyansky, C_{1v2} Zakhidno-Koshoviyskiy, Gogolivka gas condensate fields, where at depths from 4713.0 to 5795.0 m they reach from 1.35 to 1.65). In this oil-and-gas bearing region of the Eastern oil-and-gas bearing region of Ukraine, the deepest gas condensate deposit C_{1v2} has been discovered at the Perevozovskyi gas condensate field (6300 m).

Oil and gas deposits (1.6 %) are located in the depth range from 2338.0 to 3642.0 m and are characterized by the following geothermobaric parameters: reservoir temperatures vary from 339.0 to 368.0 K, reservoir pressures — from 23.50 to 40.90 MPa, thermobaric coefficient — from 9.00 to 14.68, and hydrostatic coefficient — from 1.02 to 1.28. The large capacities of potentially oil-and-gas bearing deposits of the Lower Carboniferous, which lie at depths of up to 7000 m, open up significant prospects for the search for new hydrocarbon deposits.

The Mashiv-Shebelinskyi gas-bearing region is located in the submerged part of the depression, where the largest gas condensate deposits have been explored and are being developed. The degree of exploration is 88.2 %. The explored gas condensate deposits are discovered in the depth range from 1200.0 to 4290.0 m and are characterized by the following geothermobaric parameters: reservoir temperatures — from 318.0 to 365.0 K, reservoir pressures — from 23.14 to 47.15 MPa, thermobaric coefficient — from 6.73 to 11.17, hydrostatic coefficient — from 1.12 to 1.35. The exceptions are the C_{3ar} and C_{3ar}-P_{kt} deposits of the Melekhivskyi gas condensate field, where at depths from 2780.0 to 3120.0 m it varies from 1.40 to 1.49.

In the vertical section of the ***Rudenkivsko-Proletarskyi oil-and-gas bearing region***, two zones of the phase state of hydrocarbons are distinguished by thermobaric parameters:

– upper (oil, gas condensate and gas deposits), characterized by the following parameters: reservoir temperatures vary from 295.0 to 382.0 K, reservoir pressures — from 4.5 to 40.4 MPa, thermobaric coefficient — from 9.2 to 43.5; zone depths — from 295.0 to 3700.0 m;

– lower (gas condensate and gas deposits) — for this zone, the following values are typical: reservoir temperatures morethan 380.0 K, reservoir pressures more than 40.4 MPa, and thermobaric coefficient —

less than 9.2 at depths greater than 3700.0 m.

The values of hydrostatic coefficients for hydrocarbon deposits of the upper zone are from 1.0 to 1.2; lower — less than 1.1.

Oil deposits have been explored at depths from 500.0 to 3810.0 m and are characterized by geothermobaric parameters: reservoir temperatures — from 297.0 to 380.0 K, reservoir pressures — from 4.50 to 41.13 MPa, thermobaric coefficient — from 9.31 to 33.43, hydrostatic coefficient — from 1.01 to 1.12. The exception is the C_{1s2} oil deposits of the Zachepylivka oil and gas condensate field, where at depths of 750.0 m the hydrostatic coefficient is 1.23.

The area of gas deposits (19.0 %) in the vertical section is traced at depths from 709.0 to 4875.0 m and is characterized by the following thermobaric characteristics: reservoir temperatures vary from 295.0 to 403.0 K, reservoir pressures — from 7.13 to 71.83 MPa, thermobaric coefficient — from 5.61 to 41.37, hydrostatic coefficient — from 1.01 to 1.22. The exceptions are the deposits of C_{1s} Reshetnekivske gas and oil at a depth of 2360.0 m and C_{1v1} Gorobtsivske gas condensate at a depth of 4875.0 m of the fields, where the coefficient values are 1.29 and 1.50, respectively.

Gas condensate deposits have been explored at depths from 709.0 to 5208.0 m and are characterized by the following geothermobaric parameters: reservoir temperatures vary from 295.0 to 410.0 K; reservoir pressures — from 6.83 to 94.50 MPa; thermobaric coefficient — from 4.60 to 43.48; hydrostatic coefficient — from 1.00 to 1.17. (The exceptions are the C_{1v1} and C_{1t} deposits of the Rudenkiv gas condensate field, where at depths from 2510.0 to 5120.0 m its values vary from 1.22 to 1.73).

Conclusions. Based on the results of the analysis of the geothermal material, geothermal and geothermobaric parameters were determined, which characterize the temperature state of rocks and fluids of various tectonic zones of the Eastern oil and gas region of Ukraine. Lateral and vertical zonation of hydrocarbon deposits was developed. Taking into account the peculiarities of the tectonic structure of the Dnieper-Donets Graben, as the sedimentary complex sinks, oil deposits are gradually replaced by oil and gas deposits, and then by gas deposits from the northwest to the southeast. The determined parameters characterize the geothermal baric activity of the region's subsoil. It should be noted that the temperature and pressure of the studied region are combined in various combinations, which causes the differentiation of hydrocarbon deposits according to their phase state.

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Геотермобаричні критерії нафтогазоносності Дніпровсько-Донецької западини

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Для прогнозної оцінки перспективних пошуково-розвідувальних територій, а також роздільного прогнозування окремих продуктивних горизонтів пошуково-розвідувальних площ на нафту та газ необхідно встановлення закономірностей в розміщенні вже розвіданих покладів вуглеводнів з урахуванням структурно-тектонічної будови, літолого-стратиграфічних особливостей, гідрогеологічних та геотермобаричних умов нафтогазоносного регіону. Взаємозв'язок геотермобаричних параметрів з фазовим станом вуглеводнів у вертикальному розрізі має слугувати важливим фактором для вирішення поставленої задачі. У межах Східного нафтогазоносного регіону України встановлена просторова зональність в розміщенні газових, нафтових і газоконденсатних покладів. Розроблена вертикальна зональність розміщення покладів вуглеводнів нафтогазоносних горизонтів за геотермобаричними критеріями Монастирищенсько-Софіївського і Талалаївсько-Рибальського нафтогазоносних, Глинсько-Солохівського газонафтоносного і Машівсько-Шебелинського газоносних, Руденківсько-Пролетарського нафтогазоносного району Східного нафтогазоносного регіону України.

Ключові слова: геотермобаричні критерії, термобаричні параметри, нафтові, газові, газоконденсатні поклади.