About the nature of gas saturation in coal rock massifs of the Donets Basin (Ukraine)

Произход на газонаситеността във въгленосните седименти на Донбас (Украйна)

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Abstract. Рассмотрено геологическое строение Карбонитской антиклинали. Проведен анализ результатов изучения газоносности угленосной толщи в сводовой части Карбонитской антиклинали, выше верхней границы метановых газов. Приведены рекомендации по оптимальной работе скважин малой глубины над угленосной толщей.

Резюме. Разгледан е геоложкият строеж на Карбонитската антиклинала и са анализирани резултатите от изследванията върху газоносността на въгленосните седименти в сводовата част на антиклиналата, над горната граница на метановия газ. Дадени са препоръки за оптимизиране на сондажните работи с малка дълбочина над въгленосния хоризонт.

Keywords: cleavage, structure, reservoir, methane, borehole.

The Donets Coal Basin (Donbas) is one of the largest geological provinces of economic minerals not only in Ukraine, but also in the world. Its recoverable reserves of coal are 56.7×10^9 t that are worth hundreds of years of production. The average depth of development at the present comes close to 1000 m. The Donbas is not only coal, but also powerful reservoir of natural gas methane. According to different estimates its resources vary from 12 to 25×10^{12} m^3. Methane of coal deposits in most cases occurs in adsorbed form in the pore structures of the coals and it is being released in the atmosphere during the coal recovery.

The Donbas is a regional-scale fold structure that represents an inverted element of the Palaeozoic Dnieper-Donets palaeorift. It is located in the southern part of the East European Platform, between the Ukrainian Shield (from the southwest) and the Voronezh Crystalline Massif (from the northeast). The cross-section of the Donbas represents a symmetrically-built orogen with large negative simple folds in the central part and smaller fault-complicated folds in the flanks. The sedimentary sequence is represented by Carboniferous terrigenous-carbonate sediments which contain thin coal seams.

The studied area includes the sediments of the Carbonite Anticline, which in depth is cut by the Maryevka Overthrust. The Carbonite Anticline is composed of Middle Carboniferous terrigenous sediments of the Bela Kalitva Group that is covered by 5–10 m thick Palaeogene and Quaternary deposits. The Middle Carboniferous consists of alternating shales, siltstones and sandstones. In the top part of the sequence (up to depth 50 m), shales and sandy-shaly sediments prevail, and in deeper levels clayey-sandy sediments become dominant. Below the depth of 200 m, three horizons of limestones occur (I_4^1, I_4 and I_3 of 0.8–3.0 m thickness). The coal seams of gas, fat coal rank i_2 and i_3, occur in the top part of the section (up to 100 m), and have small thicknesses, ranging between 0.1 and 0.2 m. The coal-bearing sequence is weakly metamorphosed. The top boundary of methane gases is at 100 m depth in the crest and down to 400 m on the limbs of the anticline. The gas content in the coal seams is typical for coals of such metamorphic grade and at 1000 m depth it reaches 20–25 m^3 of dry ash-free mass. The static level of groundwater in the Carboniferous sediments (based on the data of prospecting boreholes) is at ~100 m depth.

The Carbonite Anticline (amplitude 450–500 m) is an asymmetric fold with steeper southern limb striking to the southeast-northwest on the azimuth 300–310°. The hinge of the fold is plunged to the northwest at an angle 15–20° and to the southeast at an angle 3–5°. The prevailing dip of the rocks in the southern limb

of the anticline is 25–35°. The limb is complicated by small flexures dipping at angles varying from 12–15° in the northern flank to 38–42° in the southern one. At some places the angles of dip reach 70°, therefore the rocks are intensively fractured and unstable.

The Maryevka overthrust is the largest one in the studied area and bounds the Maryevka coalmine district from the northeast. The trust plane strikes northwest with southwest dipping at angle 15–35°. The displacement amplitude of the overthrust reaches 2400 m, and the zone of rock crushing thickness varies from 100 m up to 200 m. The general dip of the overthrust is complicated by structural waves and its amplitude decreases in depth. It cuts the Carbonite cupola at 1450 m depth.

According to the biolocation mapping and geochemical gas survey, the crest of the dome is complicated by a series of variously oriented faults confirmed by exploration boreholes. They are steep upthrusts (dipping <75–80°) and sometimes normal faults with amplitude of displacement 2–27 m, playing a role of natural degassing channels for gas dissolved in water, mainly methane (natural ways of migration of carbohydrates from depth).

The development of low-amplitude dislocations in the cupola and the periclinal parts of the anticline structures is caused by the maximum-tension forces, indicated by fold structures.

Ten boreholes were drilled down to 100–200 m in the flanks of the Carbonite Anticline. Nine of them are characterized by the gas manifestations. The distance between those boreholes is from 50 up to 80 m.

The majority of boreholes have revealed fractured zones in the Carboniferous sedimentary rocks of the Bela Kalitva Group, filled with low-mineralized water along with dissolved methane. As a rule, the gas in the boreholes was detected in fractured sandstones (free gas in small traps of granular-structural-tectonic type), as well as in the cataclastic zones of fault planes. Obviously, the upper shale sequence should be considered as a fluid screen for free gas accumulations.

The study testifies different ways of gas filtration from these zones. The formation pressure of gas in the fractured rocks did not exceed 0.1 MPa and for the majority of boreholes the initial pressure of gas in the course of time was sharply reduced down to zero, with a subsequent long period of restoration. Gas flow rates for each of these boreholes reached 300–500 m^3/day at pressure drop down to 0.06 MPa, with subsequent period of restoration no less than 10 days. The carbohydrate-gas content changed slightly in the course of time: the methane content varied from 85–89% to 93–97%; the helium content oscillated within the limits of 0.08–0.13%. Waters in the subsurface layer are low-mineralized (1.3 g/dm^3) and reach 4.0833 g/dm^3 on depth of 400–500 m. The waters are hydrocarbon-chlorine-sodium in composition that can speak in favour of methane-bearing aquifer.

Conclusions

1. The restoration of pressure in short terms and presence of helium in the structure of gases testifies to a deep nature of methane, leaking to the subsurface horizons through fault conduits.

2. The content of methane is 85–97% that makes possible its use by small enterprises as car refuelling or local heating.

3. For rational extraction of methane, it is necessary to take into account the drainage zones of each borehole, and also to apply due tubing choke to keep gas flow rates stable.