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# GEOLOGICAL PREREQUISITES TO EVALUATE GAS-BEARINGNESS OF THE KRASNOARMIYSK COALMINE DISTRICT, DONBAS

Tectonic movements that were developed during four stages from Permian to Neogene time have influenced the present-day gas occurrence in the coal rock massif. Gas concentration and component composition of coal seams in disturbed and undisturbed massifs differ. Heavy disturbances of a coal rock massif may drastically change its gas regime regardless of the tectonic structure and coal bed deep.

*Keywords:* Donets basin, Krasnoarmiysk coalmine district, coalbed methane, faults, coal rock massif, coal beds, tectonics.

**Introduction.** The Donets basin is one the most explored geological regions in Ukraine and its main as coal-producing basin. Commercial coal reserves of the Donets basin are confined to the $C_2^7$-$C_2^5$ suites of Middle Carboniferous age and to single coal seams of operating thickness of the $C_3^1$ suite in the Upper Carboniferous. The Carboniferous sedimentary sequence is represented by alternation of sandstones, siltstones and shales of variable thickness and rather thin beds of limestones, coal and coal shales. Recently a lot of attention is paid to study and solve the issue of integrated development of coal and coalbed methane fields in the Donbas.

Gas content of coal seams in different coal-bearing suites differs. Many factors stipulate gas occurrence in the coal-bearing formations, namely the type of geological structure in the first instance, the rock type of coal seams overburden, presence of brittle and plicate deformations, coal composition and its thermal maturity, hydrogeological and hydrogeochemical conditions.

During the decades a considerable input into the knowledge of geological, tectonic-magmatic, litho-facies, coal gas content and its spatial distribution, and coal petrographic characteristics of the region was made by M.L. Levenshtein, A.Ya. Radzivill, V.F. Shulga, I.O. Maydanovich,V.V. Lukinov, L.I. Pimonenko, V.F. Baranov, V.F.Prykhodchenko, Ch. Dzamalova, K.I. Bagrintseva, A.M. Bryzhanyov, V.Yu. Zabigaylo, Yu.M. Nagorny, S.Yu. Prykhodchenko, M.V. Zhykalyak and many others.

The possibilities to reveal a dependence of the coal rock massifs gas potential on deep-seated structures in the Krasnoarmiysk coalmine district are steadily increasing due to the move of coal mine working faces towards tectonically complicated peripheral parts of mine fields coupled with increasing depth of the mining as well. Till this century the mines of Krasnoarmiysk coalmine district were characterized by rather quiet mining conditions. Nowadays, the gas regime of the mines becomes more complicated that is clearly seen while producing coal from $l_3$ seam. Last time a lot of attenintion is paid to study and solve the problem of combined exploitation of coal-gas fields. The investigation of tectonic processes impact on natural gas content of $m_4^2$ and $l_3$ coal seams due to post-sedimentary transformations during Hercynian (partly), Cimmerian and Alpine stages of tectonimagmatic reactivations is of top priority fundamental and practical issue.

**The methodology and research methods.** This study is based on analysis of the coals and host rocks sampled in the mines of SE Krasnolimanska Coal Co. (Fig. 1) during 2007–2014. During this period it was conducted macro- and micropetrographic studies of coals from seams $m_4^2$, $l_1^c$, $l_2$, $l_3$ and $l_4^a$, host rocks and inclusions and measured residual gas content in coal samples. Also, it was made generalization and analysis of previosly collected data. Recognition of stadial (of different level) dislocations within the coal seams $m_4^2$ and $l_3$ under production of the North-Rodinska-2 license permit allow prediction of local zones containing gas accumulations within the studied area of SE Krasnolimanska Coal Co.

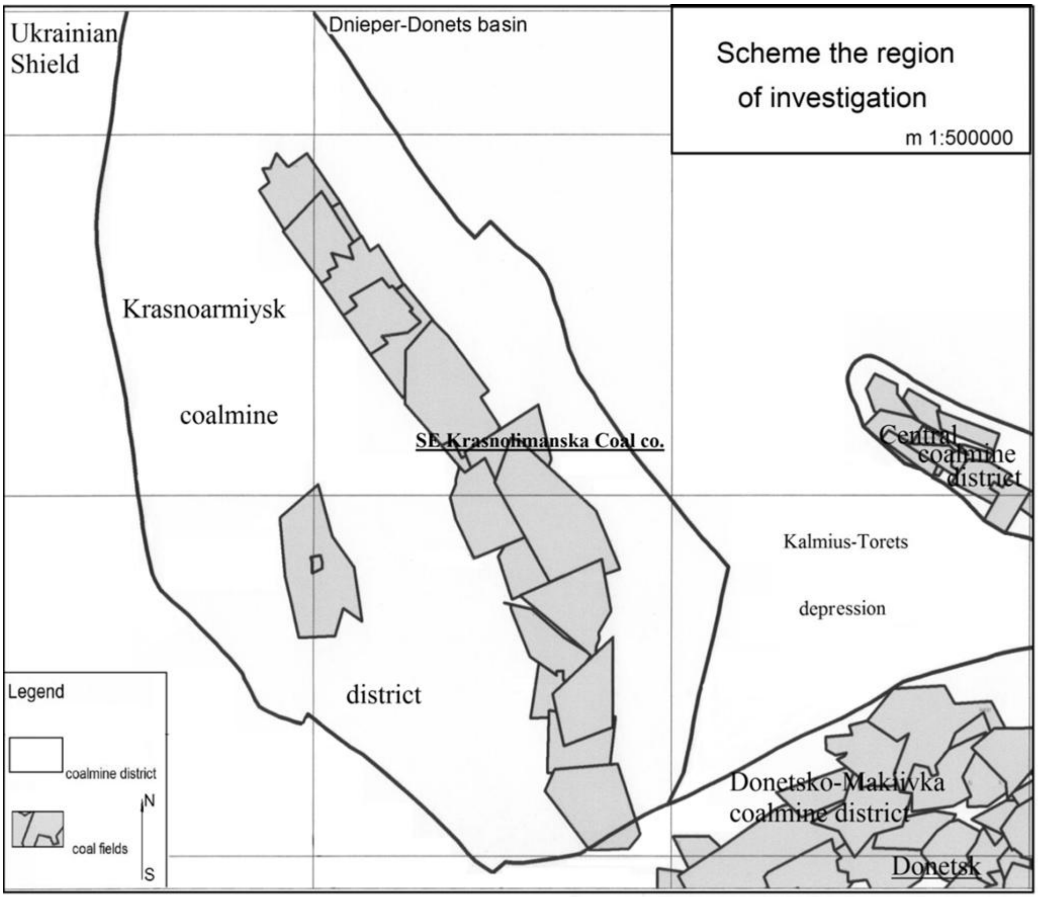


Fig. 1 Krasnoarmiysk coalmine district

**Research results.** *Geology of the Krasnoarmiysk coalmine district.* In the Donbas basin the Carboniferous stratigraphy has been divided into suites by Popov (1965): four in the Mississippian, nine in the Middle Carboniferous (or Bashkirian and Moscovian) and two in the Upper Carboniferous. The coal rock massif of the Krasnoarmiysk coalmine district is represented by Mississippian and Pennsylvanian strata of Carboniferous period. These suites have been defined on the base of lithological characteristics.

Rock occurrence is complicated by faults like thrusts, normal and reverse faults. While mining of the coal seems it is found that faults can ramify on branches and have a stepwise structure in the mimes producing coal from the Kamenska *(k),* Almazna *(l)* and Gorlivka *(m)* suites, but their impact onto bulk fracturing and gas content is different. Gas distribution in coal rock massif both in coals and host rocks are tightly linked to the structural fractures of coal fields and tectonic structures of higher rank. The strata of anticline folds as well as zones of some faults (Main Anticline, Central, Italian, French thrusts, and Glybokoyarsky, Fedorivsky and other normal faults (Figs. 2, 3) are gas-bearing [1, 2, 5].

The coal seams $\boldsymbol{m_4^2}$ and $\boldsymbol{l_3}$ have as similar as different features that can be referred to the accumulation time (sedimentation) and overprinting (post-sedimentary) processes [1, 2, 7].

The studied area is located within the Krasnoarmiysk coalmine district. The Carboniferous rocks form a monocline dipping to the east and northeast at angle 3°–14°. At the central part of the area studied it is observed a gentle dipping flexure with elevated northwest flank. The host rocks strikes northwest on the flanks and proximal to meridional one within the fold closure. Vertical height of the flexural bend is about 100 m. The stratal inclination at the flanks and the closure is practically unchanged. The occurrence of rocks is complicated by faults (14 normal ones and 7 thrusts). During extraction of $\boldsymbol{l_3}$ and $\boldsymbol{m_4^2}$ coal seams it had been documented that these faults are ramified into subordinate branches or have staircase array governing higher population density of fractures and gas content of the coals (Figs. 2, 3).

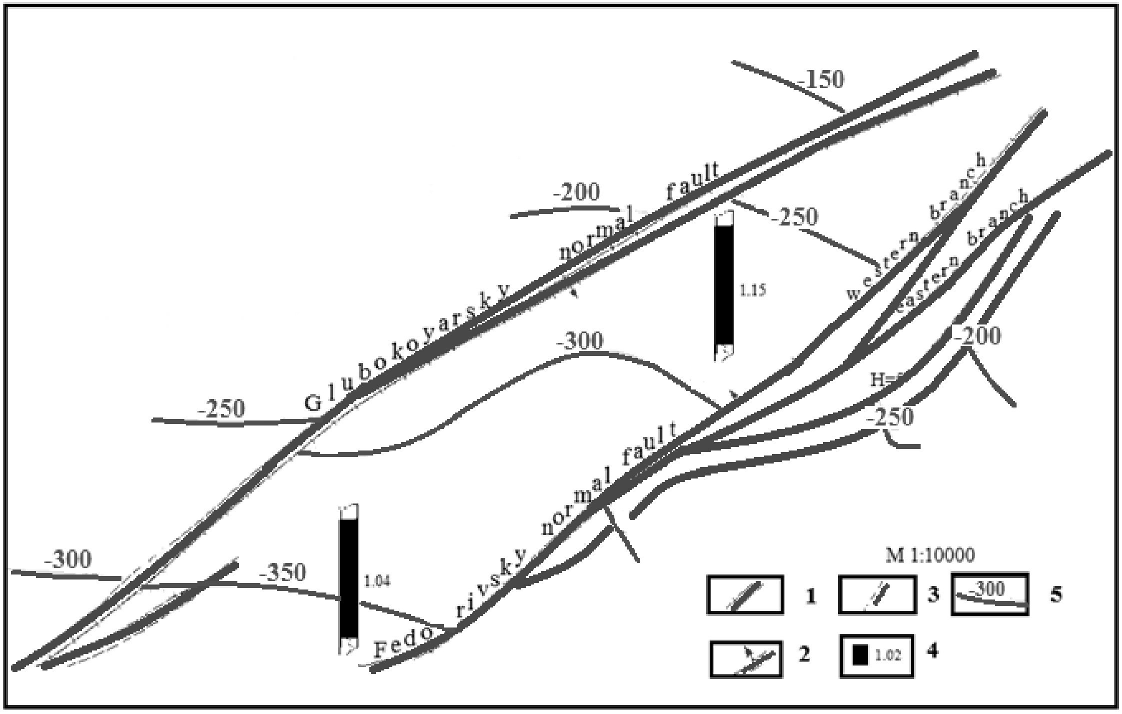


Fig. 2 Coal seam $\boldsymbol{m_4^2}$ cross-section
1. normal fault, 2. dip direction, 3. tectonic fault, 4. coal bed, 5. depth contour line

The coal seams $\boldsymbol{m_4^2}$ (Fig. 2) has rather simple geometry complicated by splitting of it into two members of 1.10–1.38 m (up to 1.5 m) total net thickness and it is continious along the axis of splitting. The top of the coal seam $\boldsymbol{m_4^2}$ is locally composed by shale (0.05–0.1 m), limestone of 1.0–2.0 m thick (carbonates substitute upper part of coal seam in some places) that overlaid by sandy or limy shales of 9 m total thickness. It is caracteristic of most coal seams of series ***m*** that their covering rocks gradually transfer from shales and sandy shales into shaly sands and sandstones up to 20 m thick [1, 2].

The coal seam $\boldsymbol{l_3}$ in the first western mining face consists of two members separated with thin (3–10 cm) interlayer. Within the second western face the seam consists of 3 members due to splitting of the upper coal member onto two sub-members. In the third mining face the coal seam consists of 4 coal members combining into two main units differing on coal quality. The interlayer is found within the western faces 1 and 3 and reaches 25–36 cm in the face 2. The thickness of the coal seam is changed accordingly: 2.2 m for the face 1.2–2.8 m for face 2, and more than 3.6 m for the third one. It should be mentioned that thickening of the seam and its members occurs towards the Central thrust. The coal seam is cut by many faults with small amplitudes of 0.16–0.5 to 3.0–5.0 m, sometimes up to 25 m as well as significant number of faults without visible displacement. Slickensides are typical for many collected coal and host rock samples as well crused coal zones of 0.5–1.0 cm thick [1, 2].

A smart few minor faults have been mapped during detail exploration, however, their number for $\boldsymbol{m_4^2}$ coal seam is much less then for $\boldsymbol{l_3}$ one. Extended fractured zones and fault amplidutes of the coal rock massif in $\boldsymbol{l_3}$ coal seam are significantly levelled in $\boldsymbol{m_4^2}$ coal seam during next stage of sedimentation (Fig. 2, 3).

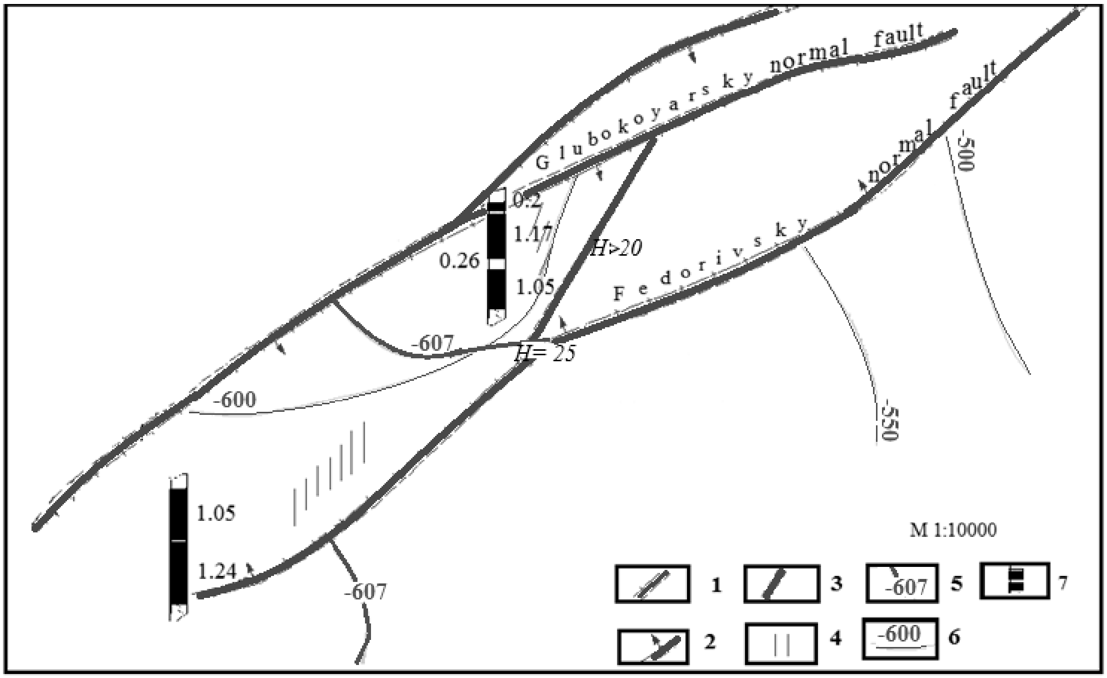


Fig. 3 Coal seam $l_3$ cross-section
1. normal fault, 2. dip direction, 3. tectonic fault, 4. small-scale tectonics, 5. depth to potential outburst zone, 6. depth contour line, 7. coal bed.

The tectonic faulting of the coal rock massif within the North-Rodinska-2 license area of the SE Krasnolimanska Coal Co. is different for coal seams $m_4^2$ and $l_3$. The zones of rock damage and fracturing are built by the post-formation tectonic processes in the coal seam $l_3$ while such disturbances are minor or decay in the $m_4^2$ coal seam.

Tectonic movements that were developed during four stages from Permian to Neogene time have influenced the present-day gas occurrence in the coal rock massif. The late Hercynian folding phase was the most prominent one. Substantial tectonic movements took place during the Laramian phase of Alpine cycle at the boundary of Cretaceous and Paleogene periods. As to these and later tectonic movements the systematization is not completed yet [7].

**Gas characteristics.** The coal seams of that area are characterized as low gas-bearing ones up to 16.3 $m^3$/t of gas content [3]. Coal samples selected for the analysis of the residual gas component testifies that their component composition changes depending on the distance from the fault plane. Methane is characteristic constituent for all of residual gas samples varying from 22.22 to 77.4 vol. %. Adsorbed hydrogen is also typical for all coal samples (the highest concentration is about $3.97 \times 10^{-2}$ vol. %, the lowest is $1.21 \times 10^{-3}$ vol. %). The unsaturated hydrocarbons are represented by ethylene (the highest content is about $0.845 \times 10^{-3}$ vol. %, and the lowest one is $2.7 \times 10^{-6}$ vol. %) and propylene (traces). Their concentrations increase while approaching the fault plane [2].

The gas content of the sandstones (host rock) at favorable conditions range from 0.01 to 0.27 $m^3$/t and closely related to the presence of dissolved gas in formation waters. The sandstones have different permeability [3, 6]. Theirs higher permeability is caused by weak metamorphism of the rock massif and stipulates active degassing of coal seams and even accumulation of gas in them at favorable conditions [2, 3]. It is identified helium in those samples besides of methane homologues helium. This may point out at present-day gas inflow from deeper sources viathe damage zones to the coal rock massif.

The gas potential of the Almazna and Gorlivska coal-bearing suites is different. The highest gas content is characteristic of Almazna formation ($C_2^6$), which is confirmed by previous, exploration studies, observations at the mine and gas saturation of the collected samples [1, 3].

An elevation of the methane zone reacted to anticline uplift is one of the features speaking in favor of increased gas saturation of a coal rock massif. At the depth of 500-700 m the coal seams are gas-containing in synclines as well. Tectonic faults redistribute gaseous hydrocarbons in spite of the structural form of a coal rock massif.

Thus, the faults and fracture density have a significant impact of gas potential of a coal rock massif as whole and coal seams in particular. Depending of the sealing properties the faults can prevent or favor degassing of a coal rock formation. Overburden rocks of a coal seams usually seal free, absorbed and adsorbed gases confined in a rock coal [4].

Free gas occupies porous space (intergranular and fractured ones) where its concentration depends on porosity of coal or rocks, formation pressure and temperature of the rock massif. Under saturation of pores with water their gas content is properly decreased. Total amount of free and occluded methane in coal seams and host rocks is increased with the depth.

A volumetric ratio between free and fixes gases depends on thermobaric conditions of the rock massif, sorption properties of coals, reservoir properties of coal-bearing rocks, degree of water influx, etc. An equilibrium in the system gas – host medium is changed due to lithogenesis, tectonic movements, and also while mining.

Gas concentration and component composition of coal seams in disturbed and undisturbed massifs differ. Concentration of hydrogen, helium and heavier hydrocarbons is significantly increases in a disturbed massif. Presence of hydrogen and helium in relatively undisturbed massifs may be explained by upward migration of gases updip the beds of coal. Drastic decrease of the gas concentration in the thinnest part of a coal seams can be interpreted as the result of additional compaction of a coal matter comparing to its average density. Heavy disturbance of a coal rock massif drastically change its gas regime regardless of tectonic type of the structure. Most of faults favor degassing of the coal formation, however, while crossing different structural forms these ones can produce traps for gas accumulation in some places along the strike.

**Conclusions.** Coal seams have an increased gas saturation in the vicinity of oblique faults as well. A spontaneous ignition of coal seams (like at SE CC “Krasnolymanska mine”) is probably related to high gas-saturation of the coal rock massif and typical for tectonic fault zones.

Gas content of the coal seams in the Kamyanska, Almazna and Gorlivka suites are different. The highest gas content is characteristic of the Almazna suite ($C_2^6$) that proved by exploration mapping, subsurface observations and analysis of gas samples.

Considerable fracturing of the coal rock mass testifies to reorganization of the coal seam ***l*** rock massif followed by considerably quiet tectonic regime. Inherited faults typical for the Almazna and Gorlivka suites, for example Glubokoyarsky or Fedorivsky normal faults have different influence on dislocation of the coal seams and formation of fractures. The Glubokoyarsky fault is inherited from older tectonic disturbance and distinctly traced in the seams $\boldsymbol{l_3}$ and $\boldsymbol{m_4^2}$. At the same time the amplitude of the Fedorivsky fault (25 m) taken upon seam $\boldsymbol{l_3}$ almost completely attenuates in $\boldsymbol{m_4^2}$ seam.

Due to re-structuring of the existed coal rock massif the hydrocarbon content and zonation is also changed.

While studying residual gas content in the coal seams it was found that the volume and variety of gases is increased toward the fault planes and fracturd zones.

The gas content of the coal seams in the area studied is correlated with depth: the deeper their occurrence the higher is their gas content.

Tectonic movements change hypsometric levels of structures in the coal-bearing series. Under tectonic reactivation of coal rock massifs it was formed new structures and gas traps that can explain its irregular occurrence in the local forms.


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## ГЕОЛОГІЧНІ ПЕРЕДУМОВИ ГАЗОНОСНОСТІ КРАСНОАРМІЙСЬКОГО ВУГЛЕПРОМИСЛОВОГО РАЙОНУ, ДОНБАС


Тектонічні рухи, що розвивалися протягом чотирьох стадій від пермі до неогену, впливали на формування сучасного газового стану вуглепородного масиву. Концентрація газу та якісний склад відрізняються в тектонічно порушених і непорушених частинах масиву. Значні тектонічні порушення можуть кардинально змінювати газовий стан гірського масиву незалежно від тектонічної структури і глибини залягання вугільного пласта.



*Ключові слова:* Донецький басейн, Красноармійський вуглепромисловий район, метан вугільних пластів, розломи, вуглепородний масив, вугільні пласти, тектоніка.



**Н.В. Вергельская**


## ГЕОЛОГИЧЕСКИЕ ПРЕДПОСЫЛКИ ГАЗОНОСНОСТИ КРАСНОАРМЕЙСКОГО УГЛЕПРОМЫШЛЕННОГО РАЙОНА, ДОНБАСС


Тектонические движения, которые развивались в течение четырех стадий от перми до неогена, повлияли на формирование современного газового состояния углепородного массива. Концентрация газа и качественная составляющая отличаются в тектонически нарушенных и ненарушенных частях массива. Значительные тектонические нарушения могут кардинально изменять газовое состояние горного массива независимо от тектонической структуры и глубины залегания угольного пласта.



*Ключевые слова*: Донецкий бассейн, Красноармейский углепромышленный район, метан угольных пластов, разломы, углепородный массив, угольные пласты, тектоника.



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