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INFLUENCE OF ROCK SHEAR PROCESSES ON THE METHANE CONTENT OF LONGWALL FACES

Purpose. To establish patterns of change in methane content during formation of zones of unloading of rock mass caused by a longwall face progression.

Methodology. Determination of gas content (methane content) of coal seams, ash content of Karaganda basin coals, methane content of mine workings was made on the basis of taking and cutting samples from the coal massif in the laboratory of "Management of special maintenance and gasification" of the Coal Department of JSC "Qarmet" according to the DMT methodology (Germany). The chemical structure of gases of k_{10} seam was determined in the laboratory of Scientific Research Center "Ugol" (Karaganda), as well as by samples of air-gas mixture of degassing wells and in the working area of Saranskaya mine.

Findings. A model of geomechanical structurization of rock massif was developed, patterns of methane content changes were established, obtained in specific mining-technological conditions of the mine, which were used for productive and safe work on coal excavation.

Originality. For the first time a model of geomechanical structurization of the coal-rock massif in the conditions of longwall faces was developed; a parametric model determining the intervals of the mining pillar to increased methane flows into the mined-out space was developed; a connection between the dynamics of geomechanical processes in the mined-out coal-rock massif and the methane content of the mine face was established.

Practical value. The established regularities of change in methane content of mining pillar areas arising at rock shear make it possible to plan degassing of mining area, to provide safe working conditions for miners on gas factor, to forecast the moment of formation of the main roof vaults of different levels and methane emission into the mine face to control mining, which were tested at Saranskaya mine Coal Department of JSC "Qarmet".

Keywords: *methane, longwall, unloading zone, coal seam, gas content, rock massif, dynamics of methane content*

Introduction. The Karaganda coal basin of Central Kazakhstan contains 41.4 billion tons of coal to a depth of 1,800 meters. The gas content of coal seams increases from 0 m^3/t in the oxidized zone (60–250 m depth from the surface) to 15–20 m^3/t at a depth of 400–500 m, then reaches 22–27 m^3/t at depths of 500–700 m. The average density of resources (reserves) is 400–700 million m^3/km^2 of methane [1].

The highly explosive nature of firedamp is a major problem in underground coal mining operations [2, 3]. Our research demonstrated that the limitation of productivity of stoping equipment due to the gas factor in operating longwall faces is 13–15 %, and at loads of 1,200–1,500 tons per day this value increases to 35 %. The problem of out-gassing is even more acute in advance workings. As a result of the increasing difference between the rates of advance and mine development works, the technical and economic indicators of mining worsened significantly [4, 5].

Annual increase in the depth of mining operations by 10–12 m is associated with the growth of gas content of coal seams. Depth of mining at a number of mines in the Karaganda basin exceeded 600–700 m. At the same time, the gas content of coal seams is 25–30 m^3/t. The contribution to the formation of the gas balance is made by the adjacent strata, whose gas content in some cases reaches 4–6 m^3/t [6].

The cost price of coal mining in mines deeper than 700 m increases due to the influence of gas and heat factors by 5–6 % for every 100 m of deepening of mining works. In order to increase the level of usage of mining equipment, degassing of coal-bearing thickness is carried out [7]. Degasification costs in the mines of the basin reach 8–10 % of the cost of coal mining. The analysis of mines using degassing showed that in this case the increase in coal production due to reduction of gas factor limitation is 20–50 % [7, 8].

Modern equipment and technology of coal mining allow providing the load on the longwall up to 5,000 tons/day, but considering the possibilities of ventilation, such productivity is achievable only if the gas content of coal seams is not more than 6–8 m^3/t [9, 10]. Currently, almost all mines in the Karaganda coal basin are classified as super category and hazardous in terms of sudden coal and gas emissions [1, 10].

A characteristic feature of modern degassing is the growth of gas emission, on the one hand, and, on the other hand, the complication of application conditions and reduction of efficiency of degassing methods [9]. Thus, the increase in the depth of development from 300–400 to 600–700 m reduced the efficiency of pre-degassing of formations in the Karaganda basin by 1.5–2 times. Methane bleeding emissions, which are usually confined to the zones of geological disturbances and are associated with natural fractures, and less often with fractures created in the course of mining works, significantly limit the pace of cleaning and preparatory works [11, 12]. As the depth of mining operations increases, their frequency and intensity increase significantly. The possibilities of ventilation without their reconstruction are practically used up, and various complexes of degassing methods are used to remove the emitted methane bypassing the atmosphere of mine workings [10, 13].

Increase in the gas content of coal seams with depth, along with a decrease in gas permeability of the latter, leads to a decrease in the efficiency of pre-degassing of seams. Especially, it strongly affects the state of mining and preparation works. The development of seams is considerably complicated by their emission hazard, which increases with depth [14]. Under such conditions, preparatory workings are carried out with the use of local anti-emissions measures, such as hydropressing, moistening of coal and drilling of advance wells. This leads to a significant deterioration of technical and economic indicators of excavation: the rate is reduced by 1.5–2 times, the labor productivity of miners is reduced by 1.2–1.4 times compared to the indicators achieved when conducting mine workings in seams safe for sudden coal and gas emissions. Therefore, solving problems related to coal methane is highly relevant and timely [15, 16].

Characterization of the object of research. The Karaganda formation (Fig. 1) is the second and main productive formation of the basin. It is bounded at the bottom by the soil of the k_1 seam and at the top by the roof of the k_{20} seam. The capacity of the series varies from 630 to 800 meters, increasing in the southern and western directions. The series is subdivided into three sub- series: the lower, middle and upper series [10, 17].

The lower sub-series, 130 to 180 meters thick, is bounded by the roof of the k_5 seam and consists of mudstones, siltstones with plant remains and coal seams. It contains six coal seams characterized by complex structure, significant thickness and high ash content.

The middle sub-series, located between seams k_6 and k_{14}, has a thickness of 340 to 440 meters and is distinguished within the limits from the roof of the k_3 formation to the soil of the k_{15} formation. This sub-series contains the main k_7, k_{10}, k_{12}, k_{13}, k_{14} and several thin formations and interbeds.

The upper sub-series, 160 to 200 meters thick, is isolated between seams k_{15} and k_{20} and is characterized by a decreasing role of sandy sediments. The lower part is dominated by mudstones and siltstones. This sub-series contains several coal seams and interlayers, of which only the k_{18} seam is of industrial significance.

The k_{10} seam is one of the main productive coal seams of the Karaganda series (Fig. 1, *b*). In the field of Saranskaya mine the seam has a sustained structure and thickness of 4.6–4.8 m.

The direct roof is represented by an unconfined coal pack with a capacity of 0.35 m, as well as an interlayer of argillite and siltstone – 2.2 m. The roof is overlain by sandstones up to 25 m capacity.

The soil of the seam is represented by mudstones up to 1.5 m, which are replaced by gray sandstone up to 27.7 m capacity. Seam k_{10} itself consists of coal with interlayering of low thickness (up to 0.01–0.23 m) mudstone interlayers, which can number up to 15 (Fig. 1, *b*) [18].

According to the unified classification of force interaction, the rocks of the main roof take part in the force interaction with the support, but are not tightly caving [10, 19]. The roof control method is full caving. At Saranskaya mine in 2016, the western block of the k_{10} seam was mined by longwall face 72 k_{10}-*z* with a design daily production of 3,000 tons and absolute methane content rate of 95.46 m^3/min. The longwall face length is 180 m, the length of the mining pillar is 890 m. The average mining depth is 724 m. Excavated capacity – 3.8 m.

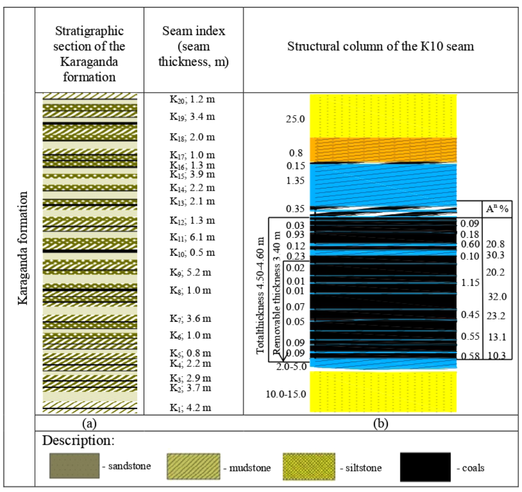

Fig. 1. Geology: stratigraphic section of the Karaganda series (a), structural column of the k_{10} seam (b)

Methods. The methane content of a coal seam is one of the main characteristics of a coal seam in underground mining operations. The chemical structure of coal seam gases was studied using samples of air-gas mixture from exploration, degasification (vertical and formation) wells for seams k_{10}, k_{12}, k_{13}, k_{14}, d_6 in the laboratory of Scientific Research Center "Ugol" (Karaganda), as well as at the "Management of special maintenance and gasification" department of Coal Department of JSC "Qarmet". The same laboratory analyzed samples taken from the excavated area of Saranskaya mine. Determination of coal gas content using the equipment and apparatus of the German company DMT, is the main parameter for predicting methane emission in active mining workings. Gas pressure was determined based on sorption isotherms, using the DMT technique, and is the main characteristic of different coal grades. The ash content of the coals was also determined using DMT equipment. The work to determine gas content was carried out using a special tool for drilling boreholes through the coal seam. Coal rocks were sampled at two-meter intervals using a special ejector and placed in a sealed container. The amount of released gas from one vessel was determined using Ratemount catalyst. Xstream (DMT package). The length of the well was 20 m. Ash content and adsorbed gas content on dry ash-free mass was determined in a special furnace. Moisture content, volatile yields were determined in the laboratory [18].

Results and discussions. The following degassing methods were used to ensure the required level of methane reduction in the mine workings of the mine site:

- the developed formation – uprising formation wells;
- the mined-out space – methane drip from the dead end of the ventilation drift (frontal drainage) and methane drip from the gas-drainage drift jumper 72 k_{11}-*z*.

Changes in the methane content of the longwall face during mining. The main factors determining the methane content of mining sites are:

- degree of development of mine development;
- movement processes of mined rock;
- gas desorption from mined coal seams and adjacent rocks.

Fig. 2 shows the curve describing the change in the relative methane content of the 72 k_{10}-*z* longwall face during the initial mining period. The derivative of the function $q = f(L)$ allows us to find the minimum extremum $q_{\min}$, which is located at 97 m.

The main factors determining the methane content of mining sites are:

- degree of mine development;
- processes for moving mined rock;
- methane desorption from mined coal seams and adjacent strata.

The obtained value of the first step of main roof caving is confirmed by the methane production data of gas-drainage

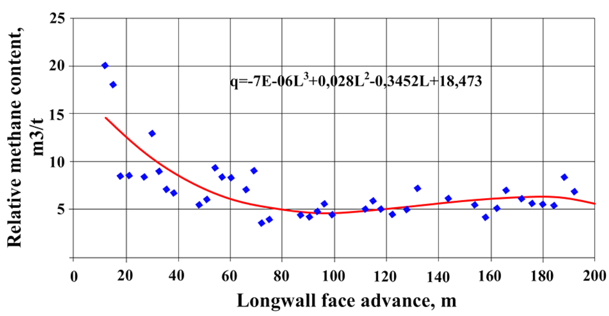

Fig. 2. Relative methane content graph: longwall face 72 k_{10}-z in the initial mining period

drift 72 k_{11}-z (Fig. 3). In the considered longwall advance interval, two areas with different trend are clearly distinguished. Achievement of the first maximum of methane extraction in the gas-drainage drift indicates that the maximum length of the main roof cantilever (96 m) was reached before its caving.

To interpret the methane content data of the mining area 72 k_{10}-z of Saranskaya mine, we used the approach developed by G. Ya. Polevshchikov [16], according to which wave-like changes in methane content of the excavated area during the movement of the longwall face is associated with the periodicity of the process of shearing of the underlying rock massif. At the same time, its parameters reflect the reaction of the coal-bearing massif to the seam mining and correspond to the contours of full shear, and the dynamics of methane content of the excavated area is due to the nonlinearity of geomechanical processes in the rock massif [12, 20]. The use of these features allows us to accept that gas-bearing strata in the area of geomechanical influence of the coal-face operation are plates-indicators of changes in the geomechanical state of the environment [21, 22]. On the basis of these provisions a semi-empirical (parametric) model of the development of nonlinear geomechanical processes in the rock massif during underground mining of coal seams with long columns was substantiated and developed [23, 24].

Parametric model of rock massif. Consider the rock massif within the block as a model with the following geometric parameters. The section of the block in the horizontal plane corresponds to the contour of the excavation area under consideration. Upper (mined-out) part of the block – from the mined-out layer to the day surface. Lower part (overworked) – from the developed formation to the boundary of the unloading zone. In this block, the rock massif is represented as a set of geomechanical layers, which are formed during the movement of the mine face. At technogenic change in external conditions the massif reduces its energy potential (realization of elastic energy) by formation of volumetric surfaces and rejection of corresponding masses of the rock massif [24]. The bodies of rejection have the shape of shear vaults in the form of paraboloids. The formation of such a shape of bodies corresponds to the principle of minimum energy expenditure to create a new surface at uniaxial unloading. The height of vaults-paraboloids is equal to the capacity of geomechanical layers of different levels of the structural hierarchy and depends on the depth of occurrence of the produced layer. The bases of the "vaults-paraboloids" in the formation plane are multiples of the length of the mine face [25, 26].

The minimum (critical) dimensions are the parameters of the "vault-paraboloid" l_0 and h_0 in the geomechanical layer closest to the produced layer (critical). l_0 is the diameter of the base of the critical vault which is assumed to be close to the secondary collapse step or calculated

$$l_0 = l_{och} \cdot 2^{-n} \approx 0.25 \cdot r_1 \approx r_2, \quad (1)$$

where l_{och} is a face length; n – a level of structural hierarchy (integer number); r_1, r_2 – steps of primary and secondary caving of the main roof; h_0 – the height of the critical vault or critical layer.

$$h_0 = 0.5 \cdot l_0 \cdot \mathrm{tg}\,\psi. \quad (2)$$

The frequency of formation of shear vaults under conditions of equal geostatic stresses is determined by the rule of doubling the capacity of geomechanical layers of the n^{th} level of the structural hierarchy

$$h_n = h_0 \cdot 2^n, \quad (3)$$

here h_n is the height of the geomechanical layer of the n^{th} level of the structural hierarchy without considering the elastic energy of the massif.

The diameter of the vault base in the geomechanical layer of the n^{th} level of the structural hierarchy is

$$l_n = l_0 \cdot 2^n. \quad (4)$$

The dominant in the development of processes in the contour zone of the massif is the layer with thickness $h_d = 0.5 \cdot l_0$. It corresponds to the dominant arch with the diameter of the base $l_d = l_{och} \cdot 2^{0.5.}$

Thus, at the stage of considering the process of self-organization of homogeneous isotropic geosphere in the field of equal stresses under its uniaxial unloading, the array is represented as a set of geomechanical layers (Fig. 4), the capacities of which correspond to the principle of superposition with a multiplicity of two [21, 22].

To improve the model adequacy in terms of considering the massif heterogeneity and stresses variable in depth from the day surface, the model was supplemented with the energy assessment [15, 24].

The elastic energy of rocks of the critical layer is calculated by the formula

$$E_0 = k^2 \cdot (6E_0)^{-1} \cdot [H_p^3 - (H_p - 0.5l_0)^3], \quad (5)$$

where E_0 is modulus of elasticity of critical layer rocks, MPa; $k = 0.025$ – the lithologic pressure coefficient; H_p – the depth of the mined layer, m.

The elastic energy distribution increases nonlinearly with layer depth. For vault base sizes that are uniquely related to the length of the face, this nonlinearity can only appear through the vault height.

The capacity of the geomechanical layer of the n^{th} level of the structural hierarchy is calculated as

$$h_{l.n} = H_p - [H_p^3 - 6E_n \cdot 2n \cdot E_0 \cdot k^{-2}]^{0.333}, \quad (6)$$

where E_n is the weighted average modulus of elasticity of rocks of the geomechanical layer of the n^{th} level of the structural hierarchy, MPa.

The position of the unloading front in each layer can be described by sinusoids of the form

$$H_{\sin.n} = A_n \cdot [\sin(L_x \cdot 2\pi/T_n) + 0.5\pi] + h_{c.n-1}, \quad (7)$$

where A_n, T_n are amplitude and period of sinusoid, m; L_x – distance of the face from the installation chamber, m; $h_{c.n-1}$ – thickness of geomechanical layer of (n – 1)-level of structural hierarchy, m.

The parameters of the sinusoid are directly related to the geometric dimensions, depth of occurrence of the worked-out

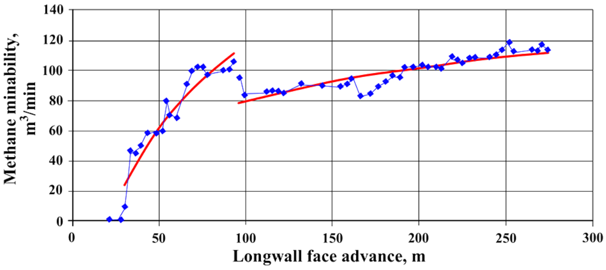

Fig. 3. Methane production schedule of gas drainage drift: longwall face 72k$_{10}$-z at Saranskaya mine

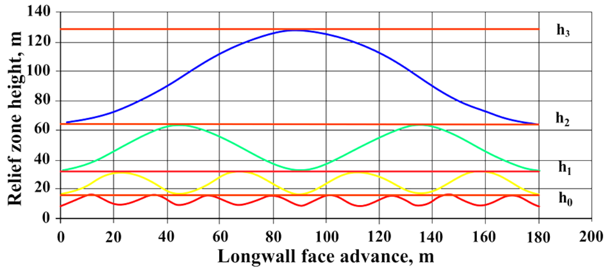

Fig. 4. Graph of dependence of unloading zone height on longwall progress of different geomechanical layers

part of the excavation pillar and weighted average modulus of elasticity of rocks in the considered layer.

Sinusoid amplitudes

$$A_n = 0.5(h_n - h_{c.n-1}). \qquad (8)$$

Periods of change are

$$T_n = l_{och} \cdot 2^{N-n}. \qquad (9)$$

The use of sinusoids as approximating functions is convenient for the algorithmization of this geomechanical model when the length of the excavation pillar is significant.

Similar processes occur in the overworked massif, but the peculiarities of nonlinear changes in the elastic energy of rocks here lead to a decrease in the height of vaults (thickness of geomechanical layers) [27].

Table 1 shows the vertical scheme of geomechanical structurization, where the bases of vaults of the n^{th} level of hierarchy are shown in different colors ($n = 0$ – red, $n = 1$ – yellow, $n = 2$ – green, $n = 3$ – blue, $n = 4$ – black).

Parameters of geomechanical structurization of a rock massif. Approbation of the model in specific mining-technological conditions allows calculating the parameters of geomechanical structurization of rock mass both along the length of the excavation pillar and along the mining face line.

Figs. 5, 6 show the contours of the nested unloading zones. They contain coal-methane strata – satellites of the: k_{11}, k_{12}, k_1/k_{12}, k_2/k_{12}, k_3/k_{12}, k_{13}, k_{14}, k_{15}, k_{16}. They are sources of gas emission into the mined-out space, the unloading of which leads to a corresponding decrease in gas-bearing capacity, causing the inflow of methane into the mined-out space. The dynamics of gas-kinetic processes is determined by the amplitude of unloading in the corresponding zone

Table 2 shows the sequence of development of the vaults and connection of the undercutting satellite formations as the face moves away from the assembly chamber according to the geomechanical model. It shows that the methane content of the site at the initial moment is determined by gas emission of the developed k_{10} seam (L_{dist} = 22.5 m, J = 16–20 m^3/min). After the integration of 2 critical level vaults and the formation of the level 1 vault, the methane content of the site increases due to the connection of the satellite seam k_{11} (L_{dist} = 45 m, J = 65–110 m^3/min).

Integration of the level 1 vaults leads to the formation of the level 2 vault, which is the dominant vault, and methane inflow into the mined-out space from the k_{12} seam (L_{dist} = 90 m, J = 110–160 m^3/min). Usually, the value of the reached methane emission caused by the primary settlement of the main roof characterizes the possible maximum level of gas emission during further operation of the mine site.

The formation of the 3^{rd} level of the hierarchy is due to the integration of two 2^{nd} level vaults (L_{dist} = 180 m, J = 150–170 m^3/min). Stabilization of methane emission indicates that the advancement of the mine face for a certain period of time does not cause the emergence of significant new volumes of converging formations and gas-bearing rocks in the unloading zone.

Formation of the vault of the 4^{th} level involves the overlying formations up to k_{16} in the degassing process. This leads to an increase in methane emission from the processed massif and achievement of maximum gas content of the mining area (L_{dist} = 360 m, J = 170–210 m^3/min). In practice, cases of exceeding of gas emission at the primary seeding of the main

Table 1

Parameterization of geomechanical layers of the working massif

Level of structural hierarchy	Vault base diameter in the geomechanical layer of the n^{th} level layer, m		Elastic energy of critical layer rocks layer, MJ	Capacity of geomechanical layer of the n^{th} level	
Critical	l_0	22.5	428	h_0	16
1	l_1	45		h_1	32
2	l_2	90		h_2	64
3	l_3	180		h_3	128
4	l_4	360		h_4	256

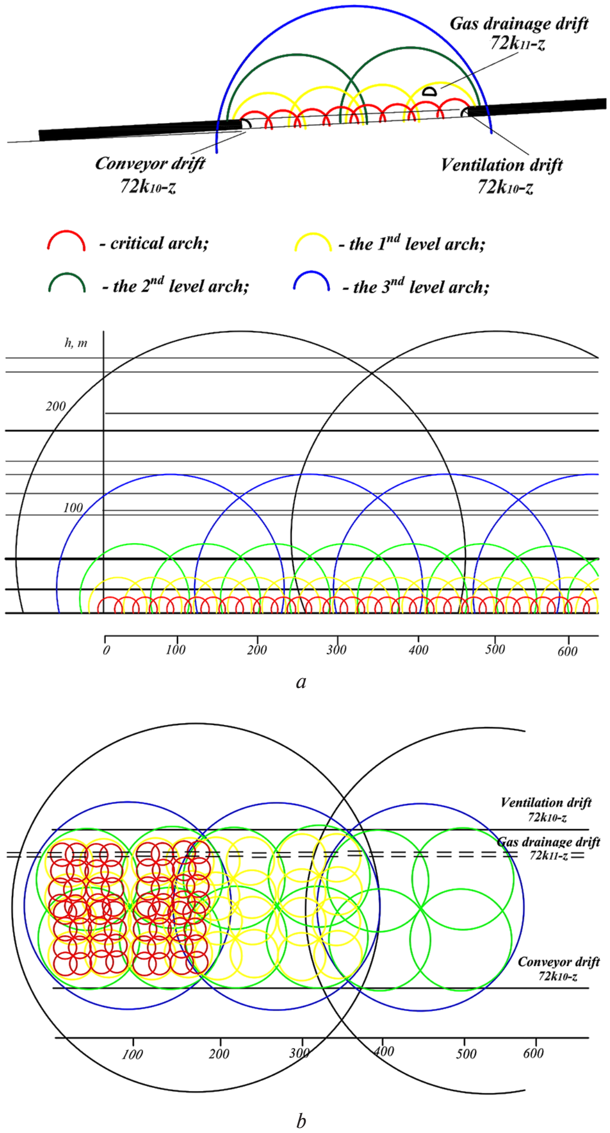

Fig. 5. Formation of unloading vaults in geomechanical layers for the conditions of face 72k_{10}-*z of Saranskaya mine along the length of the excavation pillar:*

fragments of vertical (a) and horizontal (b) schemes of geo-mechanical structurization of rock massifs

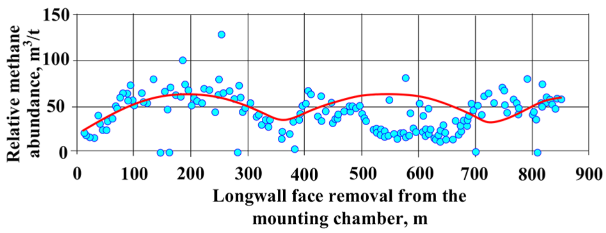

Fig. 6. Relative methane content graph: predicted and actual relative methane content of mining area 72k_{10}-*z of Saranskaya mine*

Table 2

Sequence of connection of methane emission sources in the mined-out massif of mining area 72 k_{10}-z

Level of structural hierarchy	Formations that are sources of methane emission	Distance from the installation chamber L_{dist}, m	
		According to the geomechanical model	Actual state
0	k_{10}	0–22.5	0–30
$0 + 0 \to 1$	$k_{10} + k_{11}$	22.5–45	30–60
$1 + 1 \to 2$	$k_{10} + k_{11} + k_{12}$	45–90	60–96
$2 + 2 \to 3$	$k_{10} + k_{11} + k_{12}$	90–180	96–180
$3 + 3 \to 4$	$k_{10} + k_{11} + k_{12} + k_1/k_{12} + k_2/k_{12} + k_3/k_{12}, k_{13} + k_{14} + k_{15} + k_{16}$	180–360	180–360

roof by subsequent maxima are quite rare; on the opposite, as a rule, they are somewhat less than the first one. This is most often associated with increased intensity of coal mining and increased gas potential of the mined massif.

Influence of rock shear processes on methane content. Coal seams release methane only when the stresses are reduced. The outer contour of the area of gas depletion of coal-bearing rocks is the surface of their anthropogenic unloading from the acting stresses [5, 28]. To understand the dynamics of the anthropogenic geomechanical process, it is necessary to study one of the final parameters – for example, the change in the relative methane content of the excavated area during the movement of the mine face (Fig. 6).

Fig. 7 shows two curves of approximation of relative methane content of the 72k_{10}-z mining area at the 0–360 m section. It can be seen that the black curve characterizes the vault of level 4 of the hierarchy with a maximum located at 180 m and a period (base of the vault) of 360 m. The blue curve considers two maxima at 90 and 260 m and a deflection with a minimum at 180 m. This curve reflects the parameters of two vaults of the *3rd* level of the hierarchy with a period of 180 m. Thus, the connection between the dynamics of geomechanical processes occurring in the mined coal and gas-bearing massif and the dynamics of methane content of the excavated area is clearly confirmed. The density of measurements is important for the detailing of shear processes. The high density of these measurements allows for the identification of smaller vaults.

Similar results were obtained when approximating the data of the actual absolute methane content of the excavation site at different distances from the installation chamber (Fig. 8). This also shows the discharge vaults of level 4 of the hierarchy (solid line).

It should be noted that the dynamics of methane emission of the mining area is predicted quite accurately by the parametric model up to the formation of the first vault of the *4th* level of the hierarchy. With further mining of the excavation pillar, the cyclic formation of vaults is destroyed. An analogy

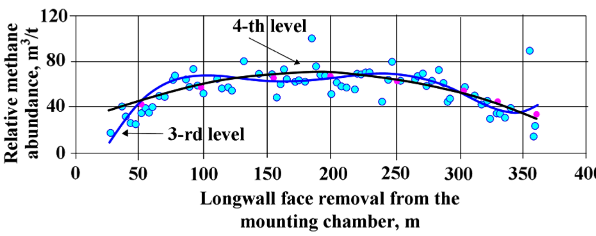

Fig. 7. Approximation of relative gas content data of mining section 72k_{10}-z of Saranskaya mine

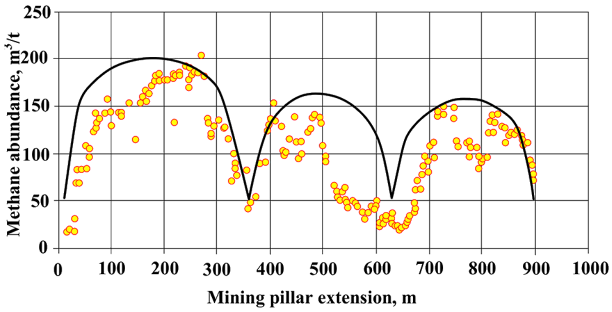

Fig. 8. Graph of actual absolute methane content in the mine area: longwall 72k_{10}-z and unloading vaults of the 4th level of hierarchy

with the reduction of the secondary caving pitch of the main roof compared to the primary one is suggested. However, the distortion of the dynamics of methane emission of the mine site was caused by the loss of operability of the gas drainage drift 72 k_{11}-z and subsequent alluvial water inflow into the mined-out face space, which for some time practically excluded methane inflow therefrom. The loss of throughput capacity of gas drainage drift 72k_{11}-z coincided with the moment of formation of the third vault of unloading level 3.

Water inflow into the mined-out massif, considering practically single location of 72k_{10}-z excavation area, is caused by water-conducting fractures penetration to the water-bearing horizon. A possible cause could be that a degassing or geological exploration well has crossed these zones.

The change in methane content of longwall faces has a wavy character along the length of the excavation pillar. The parameters of the wave are determined by the shear processes of the mined rocks and depend on the depth of coal seam development, the length and speed of movement of the face, its departure from the installation chamber.

The developed parametric model makes it possible to identify the intervals of the mine pillar where increased methane inflow from the mined-out space is expected to occur.

One of the ways to solve the problems of gas emission control is to clarify the knowledge about the peculiarities of geomechanical and, as a consequence, gas-dynamic processes in the adjacent massif in the zone of influence of mining operations. The Coal Department of ArseLorMittal Temirtau Joint Stock Company has introduced electronic systems of mine aerogas control everywhere. The use of research results and methods of assessment of model parameters (speed of face movement, methane content of workings that measured in the ventilation network), as well as data of degassing installations, their processing will give continuous mode to develop a unified automated system of forecasting and control of gas eruptions in coal mines.

At large mining depths and the use of high-performance mining equipment, objective knowledge of the natural gas content of coal seams and host rocks and their gas-kinetic properties, as well as methods for maintaining mine workings, become important for safe operation [27–29].

Increase in the depth of mining operations, decrease in the permeability of coal seams, increase in the natural gas content, decrease in the efficiency of preliminary extraction of methane from the seam by means of seam degassing wells, increase in the rate of coal production up to 3500–4000 t/d cause an increase in the rate of change in the distribution of rock pressure in the coal massif under development. These factors lead to the fact that methane from the seam enters the bottom-hole space only when the coal is destroyed, and the fast rate of movement of the face contributes to the intensification of methane emission into the mined-out space, and its share reaches 80–85 % in the gas balance of the mine site. All these factors required new approaches to the problem of assessing the methane content of longwall faces [4].

Conclusions. A comprehensive study of mining processes and actual materials obtained during mining of longwall face $72k_{10}$-z at Saranskaya mine of the Coal Department of JSC "Qarmet" allow us to draw the following conclusions:

- for the first time a model of geomechanical structurization of rock massif was developed, which was tested in specific mining-technological conditions of the mine for productive and safe work on coal excavation;

- a parametric model has been developed, which allows one to identify the intervals of the mine pillar, in which an increased inflow of methane from the mined-out space is expected; this makes it possible to plan the degassing of the mine site to avoid gasification of the mine faces, to increase the safety of miners' work on the gas factor;

- the connection between the dynamics of geomechanical processes occurring in the mined coal-rock massif and the dynamics of methane content of the excavated area has been established;

- the obtained parametric model and the established regularities of methane content changes in the data of mine faces were used at other mining sites of the mine and can be recommended at other mines and coal basins.

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References.

1. Drizhd, N.A., Sharipov, N.H., & Lee, K.D. (2013). Methane content and factors influencing degassing efficiency. *Proceedings of the University, KSTU, Karaganda,* (2), 74-77.
2. Chen, S., Zhang, C., Li, X., Zhang, Y., & Wang, X. (2021). Simulation of methane adsorption in diverse organic pores in shale reservoirs with multi-period geological evolution. *International Journal of Coal Science and Technology, 8*(5), 844-855. https://doi.org/10.1007/s40789-021-00431-7.
3. Kamarov, R.K., Akhmatnurov, D.R., Mussin, R.A., & Zamaliyev, N.M. (2018). Setting the volume and location of the gas collectors of abandoned coal mines. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu,* (2) 5-11.
4. Maussymbayeva, A.D., Yurov, V.M., Rabatuly, M., & Rakhimova, G.M. (2024). Assessment of the Influence of the Surface Layer of Coals on Gas-Dynamic Phenomena in the Coal Seam. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (2). https://doi.org/10.33271/nvngu/2024-2/005.
5. Zhang, C., Tu, Sh., Chen, M., & Zhang, L. (2019). Pressure-relief and methane production performance of pressure relief gas extraction technology in the longwall mining. *Journal of Geophysics and Engineering, 14*(1), 77-89. https://doi.org/10.1088/1742-2140/14/1/77.
6. Ma, Y., Nie, B., He, X., Li, X., Meng, J., & Song, D. (2020). Mechanism investigation on coal and gas outburst: An overview. *International Journal of Minerals, Metallurgy and Materials, 27*(7), 872-887. https://doi.org/10.1007/s12613-019-1956-9.
7. Clarkson, C.R., & Bustin, R.M. (2010). Coalbed Methane: Current Evaluation Methods, Future Technical Challenges. *SPE Unconventional Gas Conference*. Pittsburgh, Pennsylvania, USA. https://doi.org/10.2118/131791-MS.
8. Sasmito, A.P., Birgersson, E., Ly, H.C., & Mujumdar, A.S. (2013). Some approaches to improve ventilation system in underground coal mines environment – A computational fluid dynamic study. *Tunnelling and Underground Space Technology, 34*, 82-95. https://doi.org/10.1016/j.tust.2012.09.006.
9. Sidorenko, S.A., & Ivanov, V.V. (2017). Improving the efficiency underground mining of coal beds in difficult mining and geological conditions. *ARPN. Journal of Engineering and Applied Sciences, 3*(12), 882-888.
10. Kenetayeva, A.A., Kenetayeva, Zh.K., Tokusheva, Zh.T., & Rabatuly, M. (2019). Methane content of coal seams of Karaganda basin. *IOP Conference Series: Materials Science and Engineering, 516*(1). https://doi.org/10.1088/1757-899X/516/1/012020.
11. Karacan, C.Ö. (2015). Analysis of gob gas venthole production performances for strata gas control in longwall mining. *International Journal of Rock Mechanics and Mining Sciences, 79*, 9-18. https://doi.org/10.1016/j.ijrmms.2015.08.001.
12. Buzylo, V., Pavlychenko, A., Borysovska, O., & Saveliev, D. (2019). Investigation of processes of rocks deformation and the earth's surface subsidence during underground coal mining. *E3S Web of Conferences, 123*, 01050. https://doi.org/10.1051/e3sconf/201912301050.
13. Gray, I. (2012). Mining gassy coals. Proceedings of the 12th Coal Operators' Conference. *Mining Engineering, University of Wollongong*, 249-259. Retrieved from https://ro.uow.edu.au/coal/414.
14. Wang, W., Li, H., Liu, Y., Liu, M., Wang, H., & Li, W. (2020). Addressing the gas emission problem of the world's largest coal producer and consumer. Lessons from the Sihe Coalfield, China. *Energy Reports, 6*, 3264-3277. https://doi.org/10.1016/j.egyr.2020.11.199.
15. Xueliang Li, Yu Wang, Shuo Xu, Haonan Yang, & Bo Li (2021). Research on Fracture and Energy Evolution of Rock Containing Natural Fractures under Cyclic Loading Condition. *Geofluids, 2*, 9980378. https://doi.org/10.1155/2021/9980378.
16. Bodden, W.R., & Ehrlichb, R. (1998). Permeability of coals and characteristics of desorption tests: Implications for coalbed methane production. *International Journal of Coal Geology*, 333-347. https://doi.org/10.1016/S0166-5162(97)00039-6.
17. Imashev, A., Suimbayeva, A., Zhunusbekova, G., Zeitinova, Sh., Kuttybayev, A., & Mussin, A. (2022). Research into stress-strain state of the mass under open pit with a change in the open-pit bottom width. *Mining of Mineral Deposits, 16*(3), 61-66. https://doi.org/10.33271/mining16.03.061.
18. Kenetayeva, A.A., Usupayev, S.E., Kryazheva, T.V., & Rabatuly, M. (2021). Demethanization of coal seams in the Karaganda basin. *IOP Conference Series: Earth and Environmental Science, 677*(4). https://doi.org/0.1088/1755-1315/677/4/042118.
19. Li, B., Li, J., Yang, K., Ren, C., Xu, J., & Zhang, M. (2019). Deformation and permeability model of coal and rock considering moisture content Meitan Xuebao. *Journal of the China Coal Society, 44*(4), 1076-1083. https://doi.org/10.13225/j.cnki.jccs.2018.0608.
20. Ren, F., Zhang, D., Cao, J., Yu, M., & Li, S. (2018). Study on the Rock Mass Caving and Surface Subsidence Mechanism Based on an In Situ Geological Investigation and Numerical Analysis. *Mathematical Problems in Engineering*, 1-18. https://doi.org/10.1155/2018/6054145.
21. Karacan, C.Ö. (2011). Probabilistic modeling using bivariate normal distributions for identification of flow and displacement intervals in longwall overburden. Goodman GVR. *International Journal of Rock Mechanics and Mining Sciences*, 27-41. https://doi.org/10.1016/j.ijrmms.2010.08.006.
22. Makarov, V.V., Guzev, M.A., Odintsev, V.N., & Ksendzenko, L.S. (2016). Periodical zonal character of damage near the openings in highly-stressed rock mass conditions. *Journal of Rock Mechanics and Geotechnical Engineering, 8*(2), 164-169. https://doi.org/10.1016/j.jrmge.2015.09.010.
23. Demin, V., Khalikova, E., & Rabatuly, M. (2024). Research into mine working fastening technology in the zones of increased rock pressure behind the longwall face to ensure safe mining operations. *Mining of Mineral Deposits, 18*(1) https://doi.org/10.33271/mining18.01.027.
24. Rabatuly, M., Musin, R.A., Demin, V.F., Usupaev, Sh.E., & Kenetaeva, A.A. (2023). Improving the efficiency of methane extraction from coal seams. *Kompleksnoe Ispolzovanie Mineralnogo Syria, 324*(1). https://doi.org/10.31643/2023/6445.01.
25. Schatzel, S.J., Krog, R.B., & Dougherty, H. (2017). Methane emissions and airflow patterns on a longwall face: Potential influences from longwall gob permeability distributions on a bleederless longwall panel. *Transactions of Society for Mining, Metallurgy, and Exploration, 342*(1), 51-61. https://doi.org/10.19150/trans.8108.
26. Adhikary, D.P., & Guo, H. (2014). Measurement of Longwall Mining Induced Strata Permeability. *Geotechnical and Geological Engineering, 32*, 617-626. https://doi.org/10.1007/s10706-014-9737-8.
27. Zhang, S., Tang, S., Zhang, D., Fan, G., & Wang, Z. (2017). Determination of the Height of the Water-Conducting Fractured Zone in Difficult Geological Structures: A Case Study in Zhao Gu No. 1 Coal Seam. *Sustainability, 9*(7), 1077. https://doi.org/10.3390/su9071077.
28. Tutak, M., & Brodny, J. (2019). Predicting Methane Concentration in Longwall Regions Using Artificial Neural Networks. *International Journal of Environmental Research and Public Health, 16*(8), 1406. https://doi.org/10.3390/ijerph16081406.
29. Pan, Z., Connell, L.D., Camilleri, M., & Connelly, L. (2010). Effects of matrix moisture on gas diffusion and flow in coal. *Fuel, 89*(11), 3207-3217. https://doi.org/10.1016/j.fuel.2010.05.038.

Вплив процесів зсуву гірських порід на вміст метану в забоях лави

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Мета. Встановити закономірності зміни вмісту метану при формуванні зон розвантаження гірського масиву, викликаних просуванням очисного забою.

Методика. Визначення вмісту метану у вугільних пластах, зольності вугілля Карагандинського басейну, вмісту метану в гірничих виробках проводилося на підставі відбору й вирізки проб з вугільного масиву в лабораторії «Управління спеціального обслуговування і газифікації» вугільного департаменту АТ «Карм» відповідно до Методика ДМТ (Німеччина). Хімічний склад газів пласта k_{10} був визначений в лабораторії «Науково-дослідного центру вугілля» (м. Караганда), а також за пробами газоповітряної суміші з дегазаційних свердловин і в робочій зоні шахти «Саранська».

Результати. Була розроблена модель геомеханічного структурування гірського масиву, встановлені закономірності зміни вмісту метану, отримані в конкретних гірничо-технологічних умовах шахти, що використовувалися для продуктивних і безпечних робіт із виїмки вугілля.

Наукова новизна. Уперше розроблена модель геомеханічного структурування вугільно-породного масиву в умовах очисних вибоїв; розроблена параметрична модель, що визначає інтервали проходження гірського цілика до підвищених надходжень метану у вироблений простір; встановлено зв'язок між динамікою геомеханічних процесів у виробленому просторі. Був встановлений масив вугільних порід і вміст метану у вибої шахти.

Практична значимість. Встановлені закономірності зміни вмісту метану в ціликах гірничих виробок, що виникають при зсуві гірських порід, дозволяють планувати дегазацію гірського масиву, забезпечувати безпечні умови праці шахтарів по газовому фактору, прогнозувати момент утворення основних склепінь покрівлі різного рівня й контролювати викид метану в забій, що були випробувані на шахті «Саранська» вугільного управління АТ «Карм».

Ключові слова: *метан, лава, зона розвантаження, вугільний пласт, газоносність, гірський масив, динаміка вмісту метану*

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