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ON THE ISSUE OF SCIENTIFIC SUBSTANTIATION OF THE METHOD FOR FORECASTING THE HAZARDOUS PROPERTIES OF COAL SEAMS

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ДО ПИТАННЯ НАУКОВОГО ОБГРУНТУВАННЯ МЕТОДУ ПРОГНОЗУ НЕБЕЗПЕЧНИХ ВЛАСТИВОСТЕЙ ВУГІЛЬНИХ ШАХТОПЛАСТІВ

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К ВОПРОСУ НАУЧНОГО ОБОСНОВАНИЯ МЕТОДА ПРОГНОЗА ОПАСНЫХ СВОЙСТВ УГОЛЬНЫХ ШАХТОПЛАСТОВ

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Abstract. The dependence of the manifestation of any dangerous property of coal mines during mining operations on the influencing factors of the three blocks is considered. In the general case, the most dangerous properties of coal seams include the release of explosive and flammable gases, sudden emissions of coal and gas, the tendency to spontaneous combustion and the occurrence of endogenous fires, increased dust formation, explosiveness of coal dust and other negative phenomena. To prevent emergencies during mining operations, it is necessary to take into account the influence of factors of all three blocks.

Factors of the first block determine the genetic trend of the mine formation to manifest dangerous properties under the influence of geological processes and metamorphic transformation of the source material. The factors of the second block include mining and geological conditions of coal mines. On the basis of data on parameters of the first two blocks at stages of designing and operation of the coal enterprise mining indicators of the third block of factors are set.

In contrast to the mining, geological and technical conditions conditions of the second block, the factors of the first block are the least studied and not always reliably established. They must be determined under the influence of metamorphic changes in the chemical composition, structure and physical properties of coal in the bowels of the Earth, mainly under the influence of elevated temperature and pressure.

Currently, more than thirty factors are known, which in different ways characterize the metamorphic transformations of the starting material. There is a practice when in normative documents for the characteristic of degree of metamorphic transformations of layers in the vast majority of cases one indicator is used - an exit of volatile substances at thermal decomposition of coal without access of air. One indicator cannot simultaneously and comprehensively characterize the content, structure, chemical and physical and mechanical properties of the organic mass of coal and mineral impurities. It is necessary to proceed from the position that each dangerous property of mine layers depends on a certain influence of several factors of metamorphism.

Studies have shown that the carbon content and the reflection index of vitrinite in the ranking of coal by their degree of metamorphic transformations have a reliable quantitative definition, which allows their use in establishing the dangerous properties of mines as the main classification indicators. In this case, the carbon content directly controls the overall change in the sum of the main components of the organic mass (hydrogen, nitrogen, sulfur, oxygen), and the reflection index of vitrinite - reflects structural changes in the petrographic composition. The chemical activity of coal is also affected by the presence of moisture in different states, composition and properties of mineral impurities. The use of each auxiliary indicator must be justified with taking into account the purpose of application and the method of its determination. This allows to develop general principles of scientific substantiation of the method of forecasting dangerous properties of coal mine layers in combination with mining-geological and mining conditions of works on the basis of carbon content and vitrinite reflection index.

Keywords: properties, coal mine layers, emergencies, influencing factors, geological processes, metamorphism, conditions, mining-geological, mining-technical, regulatory framework, indicators, carbon content, reflection of vitrinite, moisture, mineral impurities, method, forecast.

The problem formulation. For a reliable forecast of the manifestation of one of the many hazardous properties of coal seams during mining operations and the development of effective preventive measures to escape it, it is necessary to consider three blocks of influencing factors [1].

In the first block it is proposed to consider and establish stages of the metamorphic transformations of coal seams under which conditions for the occurrence of hazardous properties are formed. In general, the most dangerous properties of coal seams include the release of explosive and flammable gases, sudden outbursts of coal and gas, a tendency to spontaneous combustion and endogenous fires, increased dust formation, explosiveness of coal dust and other negative phenomena.

The factors of the second block include the mining and geological conditions of the occurrence of coal seams: the depth of mining, the thickness of the developed seams, the angles of their occurrence, the presence of geological disturbances and adjacent satellite coal seams, the properties of the enclosing rocks, the value of the geothermal gradient, etc.

Based on the data on the parameters of the factors of the first two blocks at the stages of design and operation of the coal enterprise, the mining technical indicators of the third block of factors are laid. They are associated with schemes of opening and preparing a mine field, development systems, methods for controlling rock pressure, ventilation schemes for a mine, excavation areas and individual mine workings, the technology of breaking coal in working faces, the method of breaking rocks during the construction of workings and other technical solutions.

The operational efficiency of a mining enterprise ultimately depends on successful engineering decisions made on the basis of the factors of the third block and their parameters. The optimality of such solutions depends on the reliability of determining both the list of influencing factors of the first two blocks and their quantitative indicators characterizing the conditions for the possible occurrence of hazardous phenomena.

The influencing factors of the second block, characterizing the mining and geological conditions of mining are reliably established when justifying the feasibility of developing a coal deposit.

In contrast to the mining-geological and mining-technical conditions of the second block, the factors of the first block are the least studied and not always reliably established. The indicators of this block determine the genetic propensity of coal seams to develop hazardous properties under the influence of geological processes and metamorphic transformation of the initial substance. The generally accepted concept of metamorphism means changes in the chemical composition, structure and physical properties of coal in the bowels of the Earth, mainly under the influence of elevated temperature and pressure [2]. The degree of coal metamorphization characterizes the change in composition and properties achieved during coal formation and determines it in the genetic row: brown coal - coal - anthracite.

At present, the practice has developed when in the normative documents [3-10] regulating the safety of mining operations, to characterize the degree of metamorphic transformations of seams in the overwhelming majority of cases, one indicator is used - the release of volatiles during the thermal decomposition of coal without air access (V^{daf}). Sometimes coal grades are used as a criterion for the degree of metamorphic transformations in parallel with V^{daf}. Coal grade is a conventional designation of varieties of coals that are similar in genetic characteristics and basic energy and technological characteristics [2]. In essence, both of these indicators do not directly characterize either the composition or properties of fossil coals. Despite this, their parallel using presupposes an unambiguous assessment by them of the degree of metamorphic transformations associated with changes in the composition and properties of coals.

This assumption is not confirmed by the qualitative indicators for coal and anthracite seams [11]. According to the V^{daf} factor, a part of semi-anthracite (ПА) is considered together with hard coals. The second part of semi-anthracite coal seams and coal seams containing coal of T grades, is classified according to their consumer properties in one section with anthracite coal seams. This indicates that there are no clear boundaries between coal grades according to the V^{daf} factor and they reflect different properties of fossil coals that appeared in the process of metamorphic transformations.

The maximum number of classification indicators of the degree of metamorphism was simultaneously used to establish the outburst hazard of seams [3]. The outburst hazard of hard coal seams is set separately according to the V^{daf} factor in the ranges of its variation 9÷29% and more than 29%. In addition to V^{daf}, the values of the thickness of the plastic layer (y) are used for the indicated purposes.

The outburst hazard of anthracite seams is predicted [3] by using indicators of the volumetric yield of volatile matter during thermal decomposition of coal $\left(V_{\mathrm{V}}^{\mathrm{daf}}\right)$ and electrical resistivity $(\lg\rho)$. The additional use of indicators $V_{\mathrm{V}}^{\mathrm{daf}}$ and $\lg\rho$ is due to the high relative error in determining V^{daf} at its small values.

When predicting gas release, the V^{daf} value is used in conjunction with $V_{\mathrm{V}}^{\mathrm{daf}}$ [4], and when compiling the "Catalog of the USSR coal mines by the dust factor" V^{daf} is considered [6] together with moisture (W^t). Dust-generating capacity is associated with the coal crushing, and it, in turn, determines the endogenous fire hazard of coal seams [12]. The probability of an endogenous fire is calculated [5] with taking into account the content of total sulfur in coal (S^t) and diffusion resistance (H_g).

The above analysis shows that at present there are no methods of scientific substantiation of the use of classification indicators of the degree of metamorphism for predicting a specific hazardous property of a coal seam.

In all regulatory documents [3-10] there is no systematic approach to the use of indicators of direct change, first of all, the composition of organic and mineral parts, as well as structural transformation and physical and mechanical properties of the original substance. For this reason, the scientific substantiation of general approaches to the development of a method for forecast of manifestation of various hazardous properties of coal seams during mining is an urgent problem. Its solution will allow combining the scientifically grounded use of the factors of the three blocks, determining the safety of mining operations, in a single logical chain.

The idea is that each hazardous property of a coal seam corresponds to a certain combination of several criteria for assessing the degree of metamorphism, and different hazardous properties, in some cases, can be characterized by the same indicators of the composition and properties of coals.

The method is based on the study of the interdependence between the indicators of the degree of metamorphism of coals, which characterize different aspects of their transformation during geological processes

Results. If we adhere to the principle that one indicator of the composition or property of coals characterizes one of the sides of metamorphic transformations, then there can be more than thirty such criteria. The most perfect at present is the classification of coals by genetic and technological parameters [13], in which ten classification indicators are used: the heat of combustion for a wet ash-free state $\left(Q_S^{af}\right)$, the thickness of the plastic layer (y), the yield of semi-coking resin $\left(T_{sk}^{daf}\right)$, the mass yield of volatile matter (V^{daf}), volumetric yield of volatile matter $\left(V_V^{daf}\right)$, maximum moisture content (W_{max}), index of Roga (RI), content of fusinized components per clean coal (ΣOK), vitrinite reflectance index (R_{or}), vitrinite reflectance anisotropy (A_R), free swelling index (SI). This choice of a combination of classification indicators is explained by the goal set: to produce a gradation of coals according to their consumer properties.

All qualification indicators [13], except for the reflection of vitrinite (R_{or}), in the range of ranking coals according to their degree of metamorphic transformations, have a reliable quantitative determination only in some of its ranges. They serve to clarify the characteristic properties of coals in these ranges. For example, when additional indicators Q_S^{af} and V^{daf} were used, coals were graded into their types (Table 1). When principle of a different combination of indicators according to [13] is used, all coals are divided into sorts, grades, groups, subgroups, types and subtypes. Eighty one varieties of fossil coals have been identified according to their consumer properties.

Table 1 - Division of fossil coals into types according to [13]

Coal type	Average Vitrinite Reflection, R_{or}, %	Higher heat of combustion for a wet ash-free state Q_S^{af}, M·J/kg	The release of volatile substances to a dry ash-free state V^{daf}, %
Brown coal	less than 0,60	less than 24	–
Hard coal	from 0,40 to 2,59 inclusive	24 and more	8 and more
Anthracite	from 2,20 and more	–	less than 8

It follows from these data that the universal indicator R_{or}, which has a reliable quantitative determination in the entire series of metamorphism, cannot sufficiently reliably characterize the individual consumer properties of coals without auxiliary indicators. This can be seen from the absence of unambiguous boundaries between coal grades according to the R_{or} factor. According to the factor V^{daf} , the boundaries between coal grades, according to [13], are even more blurred. This indicates a high probability of obtaining significant errors in determining the grade of coals by factor V^{daf} in regulatory documents [3-10] when developing measures for the safe conduction of mining operations.

Table 2 - Ranges of variation of average vitrinite reflectance (R_{or}) and carbon content (C_o) for coal grades, respectively, according to [13] and [10]

No	Coal grade according to [13]		Range of change	Range of change	Coal grade according to [11]		Range of change	Ranges of change in the sum of organic mass components
	name	designation	R_{or}, %	V^{daf}, %	name	designation	C_o, %	H_o, S_o, N_o, O_o, 100- C_o, %
1	Brown	Б	0,20÷0,59	–	–	–	–	–
2	Long Flame	Д	0,40÷0,79	more than 40	Long Flame	Д	75,0÷81,8	25,0÷18,2
3	Long Flame gas	ДГ	0,50÷0,79	30 and higher	–	–	–	–
4	Gas	Г	0,50÷0,99	30÷38 and higher	Gas	Г	77,1÷88,9	22,9÷11,1
5	Gas fat semi-lean	ГЖО	0,60÷0,99	30÷38 and higher	Fat gas	ЖГ	81,2÷85,2	18,2÷14,8
6	Gas fat	ГЖ	0,50÷1,19	30÷36 and higher	Gas fat	ГЖ	83,0÷85,5	17,0÷14,5
7	Fat	Ж	0,80÷1,19	28÷36 and higher	Fat	Ж	81,6÷89,5	18,4÷10,5
8	Coking fat	КЖ	0,90÷1,29	24÷30	–	–	–	–
9	Coking	К	1,00÷1,69	24÷30 and below	Coking	К	85,3÷90,4	14,7÷9,6
10	Coking semi-lean	КО	0,80÷1,39	16÷30	–	–	–	–
11	Coking low-caking low meta-morphosed	КСН	0,80÷1,09	28 and higher	–	–	–	–
12	Coking low-caking	КС	1,19÷1,69	24÷28 and higher	–	–	–	–
13	Semi-lean sintered	ОС	1,30÷1,70 and higher	20 and below	Semi-lean sintered	ОС	86,1÷91,6	13,9÷8,4
14	Thin sintered	ТС	1,40÷1,99	16÷20 and below	–	–	–	–
15	Low-caking	СС	0,70÷1,79	16-30	–	–	–	–
16	Lean	Т	1,50÷2,59	8÷18	Lean	Т	88,2÷92,2	11,8÷7,8
17	Anthracite	А	2,20÷4,50 and higher	less than 8	Anthracite *	А	91,4÷96,9	8,6÷3,1

Note: * - for semi-anthracites (grade ПА) the range of C_o variation according to [11] is 89,4-95,5%. Such a brand is not provided by GOST [13].

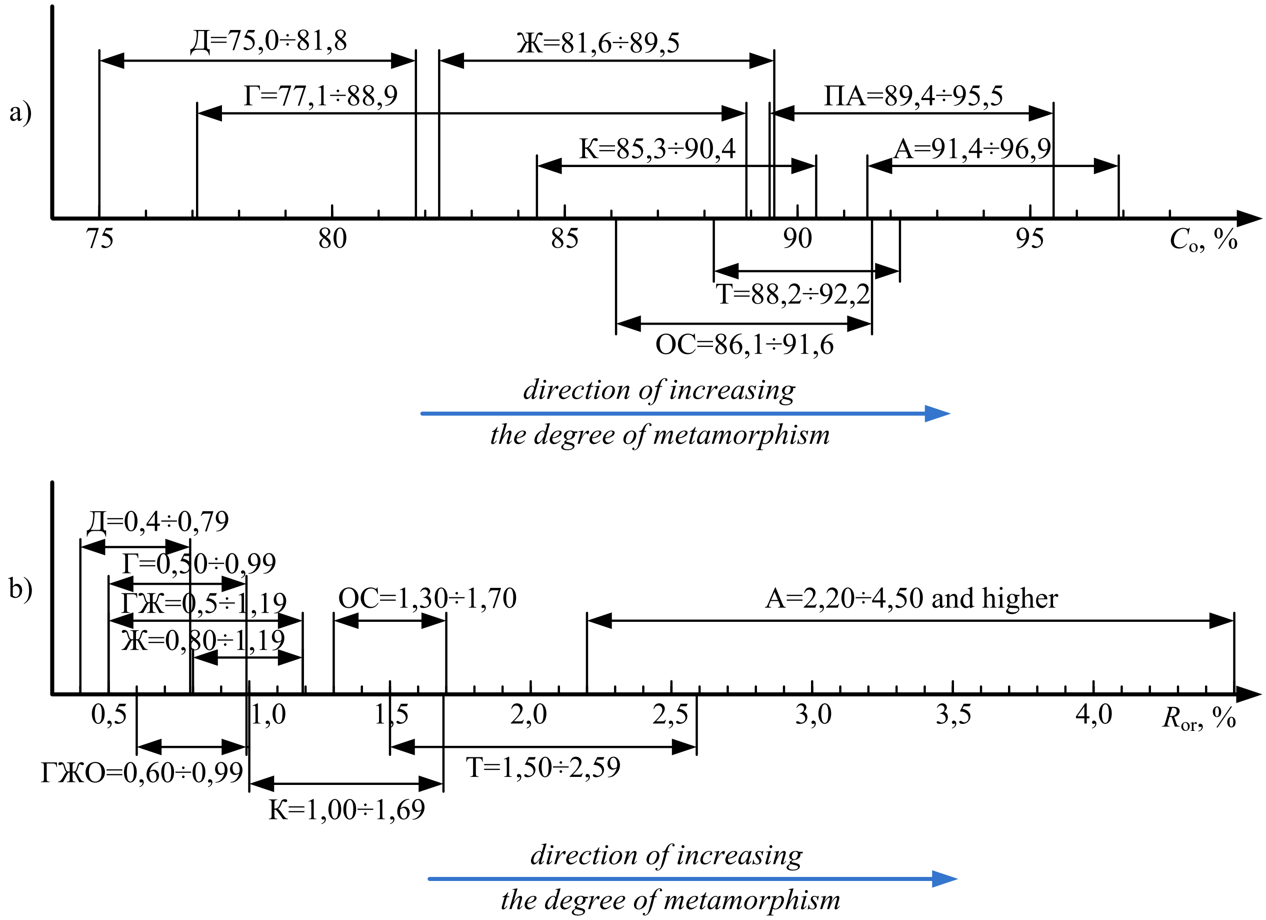
To obtain a more accurate assessment of the degree of metamorphic transformations, when the elemental composition of the initial substance changes, the carbon content in the organic (combustible) mass (C_o) is suitable. The C_o index directly controls the change in the sum of the remaining components of the organic mass of hydrogen (H_o), sulfur (S_o), nitrogen (N_o) and oxygen (O_o). With an error of about one percent Σ H_o, S_o, N_o, O_o = 100 - C_o,% (Table 2). This accuracy is quite satisfactory when predicting the hazardous properties of coal seams.

The C_o index, like R_{or}, has a high accuracy of quantitative determination in the entire range of coal rankings according to the degree of their metamorphic transformations. In the industrial classification [13], the C_o indicator is not used to identify consumer properties, including for establishing the grade composition of coals. C_o values and coal grades for the mines of the Donetsk and Lviv-Volyn basins are given in the reference book [11]. Before the development of the industrial classification [13], all hard coals and anthracites by their consumer properties were divided into ten grades Д, Г, ЖГ, ГР, Ж, К, ОС, Т, ПА, А. Such their gradation is also given in the reference book [11]. The number of grades in the classification [13] was increased to 17 due to the use of auxiliary indicators, and the intermediate grade ПА was replaced by others. On the whole, in both sources [11, 13], the main grades remained the same (Table 2).

This made it possible to compare the ranges of change in C_o and R_{or} indices for grades as the degree of metamorphism increased (Fig. 1). In all cases, according to the factor of the C_o index, as well as according to the R_{or} criterion, there are no specific boundaries between individual grades. In addition, the sizes of the ranges of variation of C_o and R_{or} with the intensification of the degree of metamorphism do not coincide in any case. This indicates, on the one hand, that the C_o and R_{or} indicators characterize different sides of the metamorphic transformations of coals, and on the other hand, using different indicators to establish coal grades. For these reasons, there is no reason to use the grade composition of coals to predict the hazardous properties of coal seams in the regulations for the safe conduct of mining operations.

According to [11, 13-16], there is a close correlation between the indicators C_o and R_{or} (Fig. 2). It is characterized by a high correlation ratio (R=0,94), which allows C_o and R_{or} to be used in determining the hazardous properties of coal seams as the main classification indicators. In this case, C_o directly characterizes the overall change in the elemental composition of coals, and R_{or} reflects their structural changes in the process of metamorphic transformations.

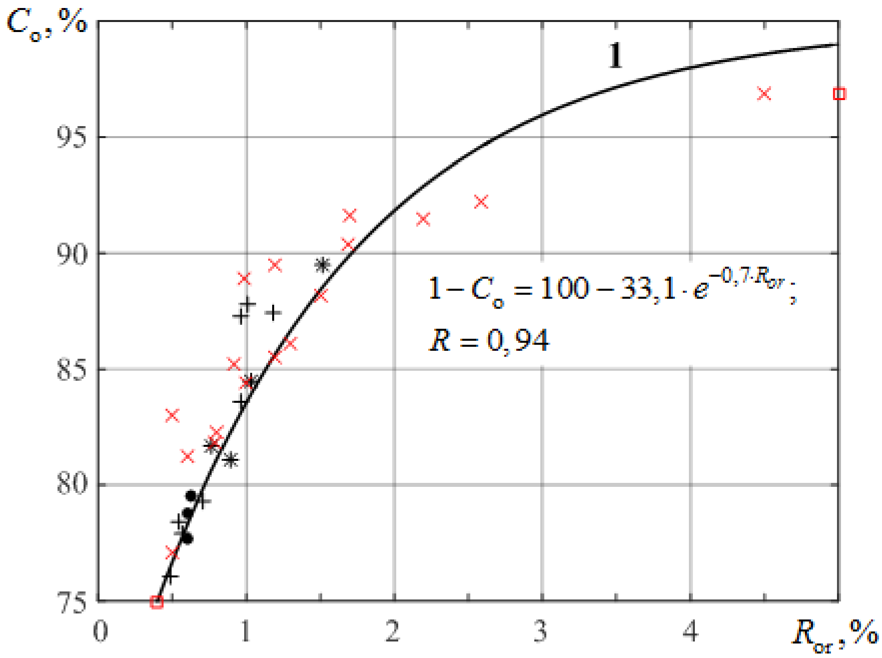
For a more accurate determination of changes in carbon in the composition of the organic matter of each coal seam, in addition to C_o, it is necessary to consider the individual ratio between the other components H_o, S_o, N_o and O_o. Their sum is practically functionally controlled by the C_o value. The ratio between H_o, S_o, N_o and O_o determines the reactivity of the organic component at a carbon content of C_o. The chemical activity is also influenced by the presence of moisture in different states, the composition and properties of mineral impurities. The influence of these factors on the manifestation of the hazardous properties of coal seams requires additional study.



C_o - carbon content in organic matter,%; R_{or} - average vitrinite reflectance,%;
Д, Г, ГЖО, ГР, Ж, К, ОС, Т, А - coal grades and quantitative values of C_o and R_{or} parameters in the ranking series as the degree of metamorphism increases (see table 2)

Figure 1 - Ranges of change in classification indicators the degree of metamorphism of coals and anthracites when determining grades coal by carbon content (a) and average reflections of vitrinite (b), respectively, according to [10] and [13]

The predominant use of one of any classification indicators, including C_o and R_{or}, is unjustified from the standpoint of the classical definition of metamorphism. One indicator cannot simultaneously and comprehensively characterize the composition, structure, chemical and physical-mechanical properties of the organic mass of coals and their mineral impurities. When predicting the hazardous properties of coal seams, interchangeability of classification indicators is inadmissible, even with a high correlation between them [17]. Different methods for determining the classification indicators also reflect the different properties of coals that appeared in the process of metamorphic transformations. The use of each indicator should be justified with taking into account the purpose of the application and the methodology for its determination. For example, in the industrial classification [13], grades are used to conventionally designate types of coal. The use of V^{daf} is limited by the characteristics of only hard coals, the maximum moisture capacity W_{max} and the external heat of combustion Q_S^{af} serve to distinguish between hard and brown coals, the volumetric yield of volatile matter V_V^{daf} to distinguish anthracites into groups, subgroups, types and subtypes, etc.

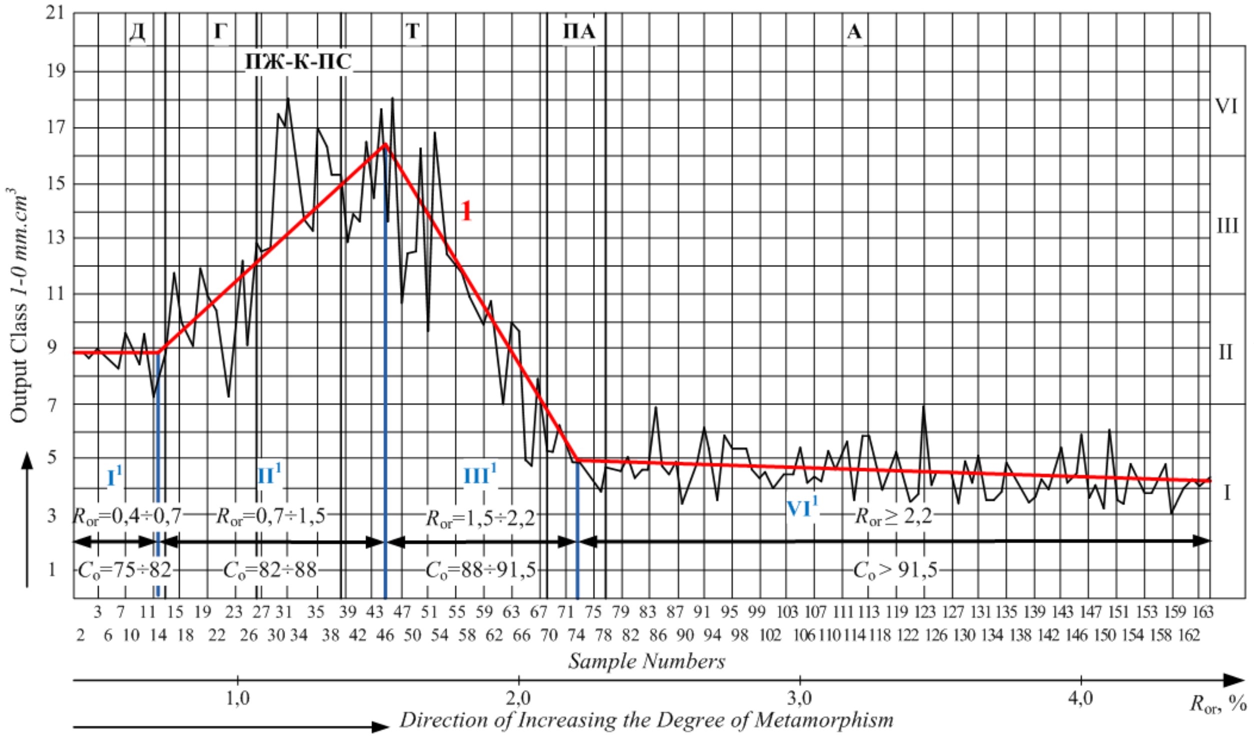


1 - averaging curve; R - correlation ratio; +, •, * - experimental data according to [14, 15, 16];
□ - points, the position of which is determined by the minimum and maximum values of C_o (75,0 and 96,9%) according to [11] and similar indicators R_{or} (0,4 and 5,0%) according to [13];
× - points, the position of which is determined by the boundaries of the ranges of C_o change [10] and the vitrinite reflectance R_{or} [13] for specific grades of coal (table 2)

Figure 2 - Interdependence of the carbon (C_o) content in the organic mass of coals and the average reflectance of vitrinite (R_{or})

The hazardous properties of coal seams are largely determined by the physical and mechanical characteristics of coals, therefore, they must be considered depending on the corresponding indicators. These include structure, density, strength, hardness, plasticity, elasticity, fragility, coal crushing. The physical and mechanical properties of coals are also interrelated and are determined by the chemical composition and structural features of the organic and mineral parts [18]. Such indicators to an insignificant extent characterize the consumer properties of coals, therefore they are not considered in the industrial classification [13]. It is unacceptable to ignore them when assessing the hazardous properties of coal seams, since they refer to direct classification indicators of the degree of metamorphism. This is proved by the determination of the mechanical strength of hard coal and anthracite by the test in a pile driver. The output class 1-0 mm characterizes the brittleness of the test material, i.e. gives values inverse to the mechanical strength and, consequently, the stronger the coals, the lower their yield of this class, and vice versa [19]. The output of the 1-0 mm class, taken by volume, differentiates hard coal and anthracite rather well as the influence of metamorphism increases (Fig. 3). It is quite suitable for characterizing the dust-generating ability of coal seams.

It should be noted that none of the indicators characterizing the physical and mechanical properties were used in the compilation of the "Catalog ..." [6] for the gradation of coal seams according to their dust-generating capacity, as well as for predicting other hazardous properties of coal seams in other regulatory documents. The use of R_{or} and C_o instead of coal grades makes it possible to quantify both the dust yield and the fragility of the coal (Table 3). These indicators, with strict scientific justification, can characterize several hazardous properties of coal seams at once. Preliminarily, these include the dust-generating ability, the explosiveness of coal dust, the tendency to the emergence of foci of endogenous fires and emissions of coal and gas.



Д, Г, ПЖ, К, ПС, Т, ПА, А and I, II, III, IV - respectively coal grades and fragility groups according to [19]; R_{or} - values of the average reflection index of vitrinite in the entire range of the degree of metamorphism of hard coal and anthracite [13]; C_o - carbon content corresponding to its interdependence with the R_{or} index (Fig. 2);
1 - averaging broken line of change in the output of dust class 1-0 mm.cm^3 according to [19] as the degree of metamorphism increases in the entire range of ranking using the R_{or} index [13];
I^1, II^1, III^1, IV^1 - ranges of R_{or} and C_o values, in which the nature of the dependence of the dust yield on the degree of intensification of metamorphism changes in different ways

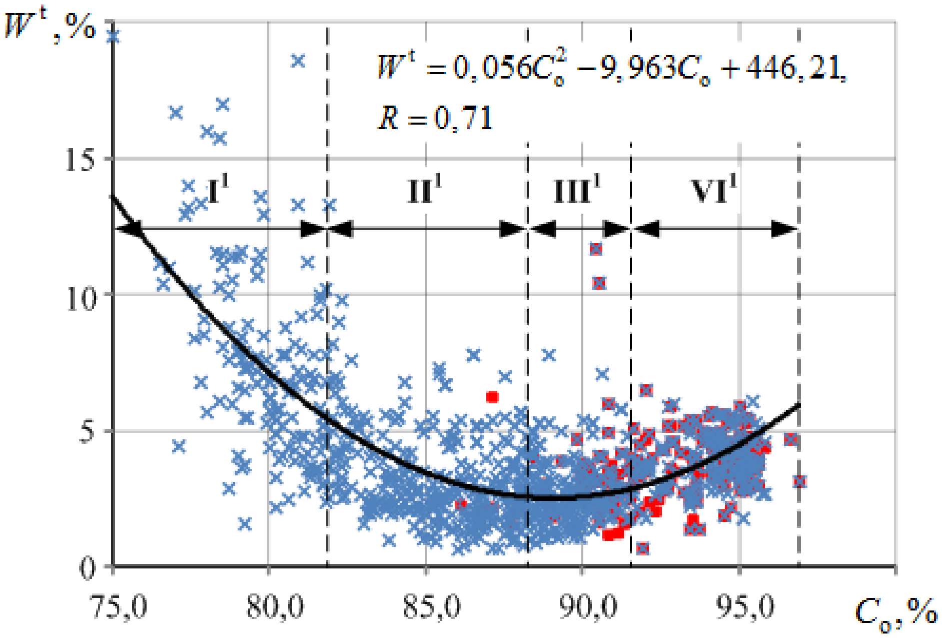
Figure 3 - Distribution of hard coal and anthracite by brittleness (yield of dust of class 1÷0 mm.cm^3) according to [19] and its correspondence to the increase in the degree of metamorphism in terms of R_{or} [13] and C_o [10]

The broken character of the averaging line (1) and the ambiguous change in the dust yield as the degree of metamorphism increases (R_{or} and C_o increases) indicates a significant effect on the dust-generating ability of other factors that differ from each other (Fig. 3). At the early stages of metamorphism (range I^1), the influence of other factors, like R_{or} and C_o, did not significantly affect the dust yield. Fluctuations in the dust yield were insignificant (7,3÷9,5 cm^3) and averaged about 8,8 cm^3 (Table 3). With an increase in the degree of metamorphism (range II^1), an increase in dust output from 8,8 to 16,3 cm³ was observed. At the same time, there was a simultaneous increase in the content of C_o to about 88% and a decrease in the sum of other components in the organic mass (H_o, S_o, N_o and O_o) to 12%. In parallel with such changes in the elemental composition of organic matter, the formation moisture decreases to minimum values (Fig. 4). It is believed [11] that the formation moisture does not significantly affect the quality of the consumer properties of anthracites. For this reason, this reference and regulatory document does not provide information on moisture for anthracite seams, and for hard coals, such information is partially indicated.

Table 3 - Gradation of coal seams according to the output of dust of class 1-0 mm (brittleness) and classification indicators (coal grades R_{or} and C_o)

Totality of coal seams by metamorphic signs of coal transformation								
Fragility groups [19]			By values R_{or} и C_o					
№ group	Dust output, cm³	Coal grades	№ group	by samples	by averaging broken line	R_{or}, % [13]	C_o, % [11]	Σ H_o, S_o, N_o, O_o= =100- C_o, %
I	3,2÷2,0	А, ПА	I¹	7,3÷9,5	8,8	0,4÷0,7	75÷82	25÷18
II	7,0÷11,0	Т, ПЖ, ГД	II¹	7,2÷18,0	8,8÷16,3	0,7÷1,5	82÷88	18÷12
III	11,0÷16,0	Т, ПС, К, Г	III¹	18,0÷4,9	16,3÷5,0	1,5÷2,2	88÷91,5	12÷8,5
IV	16,0÷20,0	Т, ПС, К, ПЖ	VI¹	7,0÷3,2	5,0÷4,5	2,2÷4,5	91,5÷96,9	8,5÷3,1

In the "Catalog ..." [6], for the majority of coals and anthracite seams, there is data on the formation moisture, therefore, when plotting the graph (Fig. 4), they were used together with the data on C_o from the reference book [11].



×, ■ - experimental data for hard coal and anthracite seams, respectively; R - correlation ratio; I¹, II¹, III¹, IV¹ - ranges of values of C_o, according to the output of dust class 1-0 mm [19]

Figure 4 - Dependence of formation moisture W^t [6] on the carbon content of C_o [10]

In the range of carbon content 82÷88%, there is an increase in dust output (Fig. 3) and a decrease in formation moisture (Fig. 4). This indicates that the growth of dust formation is facilitated by both an increase in carbon content in the range of 82÷88% and a decrease in formation moisture in this interval to minimum values.

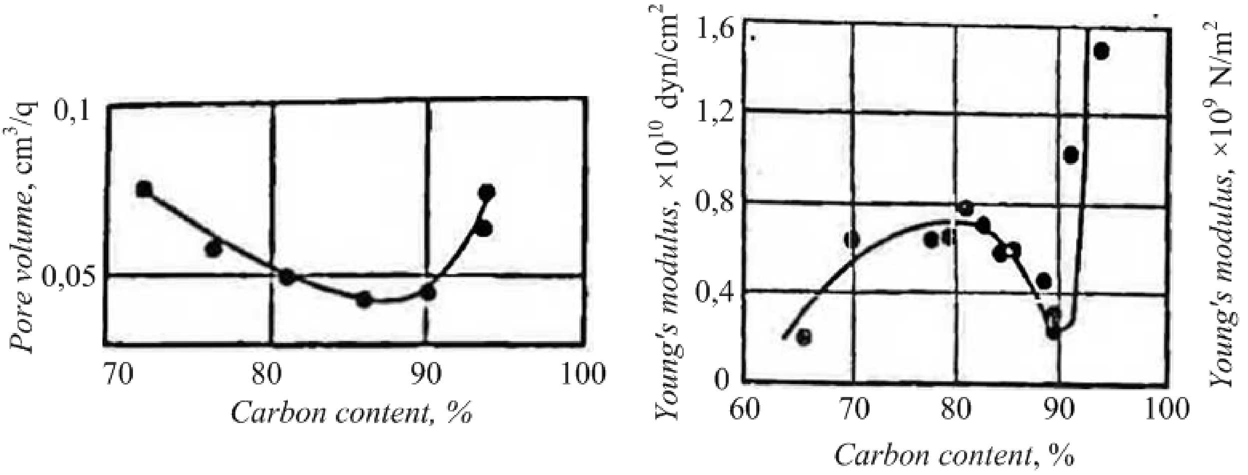
After reaching the maximum value of the dust yield (18 cm^3) in the II^1 range (Fig. 3), an ambiguous decrease in dust formation is observed with a further increase in the degree of metamorphism. In the range III^1 (C_o=88÷91,5%), there is a sharp decrease in the dust yield from 18 to 5 cm^3, and in the range IV^1 (C_o=91,5÷96,9%), the reduction occurs more smoothly from 5 to 4,5 cm^3.

The given example of an ambiguous change in dust emission with an increase in metamorphism in its entire row (R_{or}=0,4÷4,5%, C_o=75÷96,9%) indicates the presence of both influencing factors and changes in their degree of influence in certain ranges (I1, II1, III1, IV1) of metamorphic transformations. It is logical to assume that similar ranges of changing factors can be observed when considering other properties of coal seams. When predicting the hazardous properties of coal seams, the use of carbon (C_o) content as a classification indicator makes it possible to establish the level of influence of the remaining components of the organic mass (H_o, S_o, N_o and O_o), as well as their separate influence.

The composition of the organic mass also includes the moisture content W^t, but the developed modern methods for its determination [20] do not provide for the joint consideration of W^t in combination with the rest of the main components C_o, H_o, S_o, N_o, O_o of the organic mass. This situation arose due to the determination of the main components of organic matter for the dry ash-free state of the fuel. When predicting the hazardous properties of coal seams, it is necessary to bring the content of the main components (C_o, H_o, S_o, N_o, O_o) of coal to its natural state. For such calculations, a special GOST has been developed [21]. After bringing the proportion of the content of all components of organic matter to one (close to natural) state, the carbon content, practically functionally (with an error of 1÷2%), will control the sum of the main components (C_o, H_o, S_o, N_o, O_o) in combination with moisture. In order to bring the condition of coal as close as possible to production conditions, it is also necessary to take into account mineral inclusions and their composition. In all cases, a certain amount of mineral impurities is contained that are closely related to the organic mass and cannot be mechanically separated from the organic matter. The solution to this problem is possible by using the method for determining the petrographic composition of coals. The essence of the method lies in the determination of macerals and mineral inclusions in coals under a microscope in reflected light in polished briquettes and in the quantitative determination of their content. According to [22], macerals (varieties of minerals) are grouped according to their reflection index, color, structure, and microrelief, which are revealed by comparing individual macerals with each other. Macerals of the vitrinite group (R_o) are taken as the standard of reflection and relief in each angle. All macerals are grouped into separate groups: vitrinite (V^t), semivitrinite (S_V), inerginite (I), liptinite (L) and mineral impurities (M).

Mineral inclusions in coals and anthracites are represented by clay minerals, iron sulfides, carbonate silicon oxides and other minerals. In addition to the petrographic composition, the vitrinite reflectance (R_o) also characterizes some of the physical and mechanical properties of coals. These, for example, when establishing the hazardous properties of coal seams, include the pore volume in coals of different stages of metamorphism [18].

The carbon content, in addition to controlling the sum of the components of organic matter, also characterizes some of the physical and mechanical properties of coals (Fig. 5).



а) б)

Figure 5 - Change in the volume of micropores (a) and Young's modulus (b) depending on the carbon content [18]

From the above analysis, it follows that the C_o and R_{or} indicators taken together fairly reliably characterize the elemental composition of hard coal and anthracite and some physical and mechanical properties. This allows, on the basis of the classification indicators C_o and R_{or}, to develop general principles for the scientific substantiation of the method for predicting the hazardous properties of coal seams. They should take into account the influence of factors from all three blocks.

Conclusions.

When identifying the factors of metamorphic transformation of coal seams (first block) on the basis of the studies carried out, the following features must be taken into account:

− the classification indicators of the grade composition and yield of volatile matter do not directly reflect the elemental and petrographic composition of fossil coals. Methods for their determination were developed for the classification of coals by their consumer properties based on the analysis of samples reduced to dry and ash-free state of organic matter (daf). Such a determination of the indicators of the grade composition and the yield of volatile matter does not correspond to the state of coals in the seams during mining works and leads to significant errors in assessing the degree of metamorphic transformations. The use of indicators of coal grades and the yield of volatile matter in regulatory documents is not sufficiently scientifically substantiated to predict the hazardous properties of coal seams;

– the carbon content in the organic mass, reduced to a dry ash-free state, reliably controls the amount of the remaining main components. The methods of modern GOST allow you to calculate the ratio between the main components of organic matter with taking into account the actual moisture content and mineral impurities. This makes it possible to analyze the results of coal samples cutting, reduced to conditions close to production;

– average reflectance of vitrinite characterizes the petrographic composition of coals, including the presence of mineral impurities;

– indicators of carbon content and average reflection of vitrinite control, respectively, the elemental and petrographic compositions of fossil coals. Their values are reliably determined in the entire series of metamorphic transformations of hard coal and anthracite. In addition, they characterize the chemical activity and physical and mechanical properties of coals. These features of the indicators of carbon content and reflection of vitrinite allow them to be recommended as the main indicators for predicting the hazardous properties of coal seams;

– at present, more than thirty indicators are known that characterize one of the specific aspects of metamorphic transformations of coal seams. Each of these indicators or their complex, in combination with the main ones, can fairly reliably characterize a specific hazardous property of an individual coal seam. The selection of auxiliary indicators should be justified by the appropriate methods for their determination and the nature of the predicted hazardous properties of the coal seam.

The proposed scheme for determining the degree of metamorphic transformations makes it possible to comprehensively characterize the elemental and petrographic composition of coals, the chemical, physicomechanical and technological properties of coals for almost every coal seam in the Donbass and Lviv-Volyn basin on the basis of the corresponding catalogs. In due time, they were compiled on the basis of the experience and data of geological exploration and operation of coal enterprises, the establishment of the quality of products after coal enrichment at factories, etc.

The complex of such information about the factors of the first block for each coal seam and reliable knowledge of the factors of the second block about the mining and geological conditions of occurrence and properties of the enclosing rocks make it possible to design optimal technological processes associated with mining and ensuring their safety. The properties of a coal seam that affect the manifestation of hazardous properties can change even within a small area, therefore, all rational measures to ensure safe conditions for mining operations should be developed for a specific coal seam within its boundaries.

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Анотація. Розглянуто залежність прояви будь якої небезпечної властивості вугільних шахтопластів при веденні гірничих робіт від впливаючих факторів трьох блоків. У загальному випадку до найбільш небезпечних властивостей вугільних пластів відносяться виділення вибухових та легкозаймистих газів, раптові викиди вугілля і газу, схильність до самозаймання і виникнення ендогенних пожеж, підвищене пилоутворення, вибуховість вугільного пилу та інші негативні явища. Для запобігання виникнення аварійних ситуацій при веденні гірничих робіт необхідно в комплексі враховувати вплив факторів всіх трьох блоків.

Фактори першого блоку визначають генетичну схильність шахтопластів до появи небезпечних властивостей під впливом геологічних процесів і метаморфічного перетворення вихідної речовини. До факторів другого блоку належать гірничо-геологічні умови залягання вугільних шахтопластів. На підставі даних про параметри перших двох блоків на стадіях проектування і експлуатації вугільного підприємства закладаються гірничотехнічні показники третього блоку чинників.

На відміну від гірничо-геологічних і гірничотехнічних умов другого блоку найменш вивченими і не завжди достовірно встановленими є чинники першого блоку. Вони повинні визначати під впливом метаморфізму зміни хімічного складу, структури і фізичних властивостей вугілля в надрах Землі, переважно під впливом підвищеної температури та тиску.

На даний час відомо більш тридцяти факторів, які з різних боків характеризують метаморфічні перетворювання вихідної речовини. Склалася практика коли у нормативних документах для характеристики ступеня метаморфічних перетворень пластів в переважній більшості випадків використовується один показник - вихід летких речовин при термічному розкладанні вугілля без доступу повітря. Один показник не може одночасно і з усіх боків характеризувати вміст, структуру, хімічні і фізико-механічні властивості органічної маси вугілля і мінеральних домішок. Необхідно виходити з положення, що кожна небезпечна властивість шахтопласта залежить від певного впливу декількох чинників метаморфізму.

Дослідження показали, що вміст вуглецю та показник відбиття вітриніту в ряду ранжирування вугілля по їх ступеню метаморфічних перетворень мають достовірне кількісне визначення, що дозволяє використовувати їх при встановленні небезпечних властивостей шахтопластів в якості основних класифікаційних показників. В цьому випадку вміст вуглецю безпосередньо контролює в цілому зміну суми основних складових органічної маси (водень, азот, сірка, кисень), а показник відбиття вітриніту - відображає структурні зміни у петрографічному складі. На хімічну активність вугілля також впливають присутність вологи в різному стані, склад і властивості мінеральних домішок. Застосування кожного допоміжного показника повинно бути обґрунтовано з урахуванням мети застосування і методики його визначення. Це дозволяє на основі вмісту вуглецю та показника відбиття вітриніту розробити загальні принципи наукового обґрунтування методу прогнозу небезпечних властивостей вугільних шахтопластів у сукупності з гірничо-геологічними та гірничотехнічними умовами ведення робіт.

Ключові слова: властивості, шахтопласти, аварійні ситуації, впливаючі фактори, геологічні процеси, метаморфізм, умови, гірничо-геологічні, гірничотехнічні, нормативна база, показники, вміст вуглецю, відбиття вітриніту, волога, мінеральні домішки, метод, прогноз.

Аннотация. Рассмотрена зависимость проявления разнообразных опасных свойств шахтопластов при ведении горных работ от влияющих факторов трех блоков. В общем случае к наиболее опасным свойствам угольных пластов относятся выделение взрывчатых и легковоспламеняющихся газов, внезапные выбросы угля и газа, склонность к самовозгоранию и возникновению эндогенных пожаров, повышенное пылеобразование, взрывчатость угольной пыли и другие негативные явления. Для предотвращения возникновения аварийных ситуаций при ведении горных работ необходимо в комплексе учитывать влияние факторов всех трех блоков.

Факторы первого блока определяют генетическую склонность шахтопластов к появлению опасных свойств под влиянием геологических процессов и метаморфического преобразования исходного вещества. К факторам второго блока относятся горно-геологические условия залегания угольных шахтопластов. На основании данных о параметрах факторов первых двух блоков на стадиях проектирования и эксплуатации угольного предприятия закладываются горнотехнические показатели третьего блока факторов.

В отличие от горно-геологических и горнотехнических условий второго блока наименее изученными и не всегда достоверно установленными являются факторы первого блока. Они должны определять под влиянием метаморфизма изменения химического состава, структуры и физических свойств угля в недрах Земли, преимущественно под влиянием повышенной температуры и давления.

В настоящее время известно более тридцати критериев, с разных сторон характеризующие метаморфические преобразования исходного вещества. Сложилась практика, когда в нормативных документах для характеристики степени метаморфических преобразований пластов в подавляющем большинстве случаев используется один показатель - выход летучих веществ при термическом разложении углей без доступа воздуха. Один показатель не может одновременно и всесторонне характеризовать состав, структуру, химические и физико-механические свойства органической массы углей и их минеральных примесей. Необходимо исходить из положения, что каждому опасному свойству шахтопласта соответствует определенное сочетание нескольких критериев оценки степени метаморфизма.

Исследования показали, что содержание углерода и показатель отражения витринита в ряду ранжирования угля по их степени метаморфических преобразований имеют достоверное количественное определение, что позволяет использовать их при установлении опасных свойств шахтопластов в качестве основных классификационных показателей. В этом случае содержание углерода непосредственно контролирует в целом изменение суммы основных составляющих органической массы (водород, азот, сера, кислород), а показатель отражения витринита - отражает структурные изменения в петрографическом составе. На химическую активность угля также влияет присутствие влаги в разном состоянии, состав и свойства минеральных примесей. Применение каждого вспомогательного показателя должно быть обосновано с учетом цели применения и методики его определения. Это позволяет на основе содержания углерода и показателя отражения витринита разработать общие принципы научного обоснования метода прогноза опасных свойств угольных шахтопластов в совокупности с горно-геологическими и горнотехническими условиями ведения работ.

Ключевые слова: свойства, шахтопластов, аварийные ситуации, влияющие факторы, геологические процессы, метаморфизм, условия, горно-геологические, горнотехнические, нормативная база, показатели, содержание углерода, отражения витринита, влага, минеральные примеси, метод, прогноз.

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