RESULTS DATA OF THE REGRESSION AND CORRELATION ANALYSIS OF THE CONCENTRATION OF GERMANIUM WITH THICKNESS AND ASHITY IN THE COAL SEAM C_8^H OF THE DNIPROVSKA MINE

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Research actuality of the studying of the germanium content in coal seams is due to the possibility of its industrial extraction and use as a valuable accompanying component. Coal is the most important source of germanium in Ukraine, in China (germanium-bearing coal deposits in China are developed near Lincang, Yunnan province and Xilinhaote, Inner Mongolia province), as well as in Russia (92.6% of the total germanium reserves in categories $A+B+C_1$ are concentrated in coal deposits, which are located mainly within the borders of the Prymorskyi Krai, Zabaikalskyi Krai, Krasnoyarskyi Krai, as well as Sakhalin and Kemerovo regions).

In coal, germanium belongs to the group of "small elements" or elements - coal impurities, which must be investigated in the process of prospecting geological works carried out in the coal deposits of Ukraine.

For an objective geological and economic assessment of the possibility of simultaneous extraction of germanium from coal, waste and products of its processing and planning of the most effective organizational and technical measures in this regard, it is first of all necessary to have information about the character of the distribution and

concentration level of this element in coal and coal-bearing rocks. In order to obtain such information, detailed studies of the distribution of germanium over the area and in the cross-section of the coal seam $c_8^н$ of "Dniprovska" mine field were carried out.

Recent achievements. Earlier [1-24], the peculiarities of the distribution of "small elements" that belong to the group of "toxic and potentially toxic elements" in coal seams of some mines of the Pavlohrad-Petropavlivka, Donetsk-Makiivka [25-26] and Krasnoarmiysk [27-41] geological and industrial regions of Donbas and some oil deposits [42-49] were investigated. At the same time, the analysis of germanium distribution in coal seam $c_8^н$ of "Dniprovska" mine field had not been performed before.

The purpose of the work: to establish a relationship between the germanium content and the thickness and ash content of the coal seam $c_8^н$ of the "Dniprovska" mine field.

Research methodology. A feature of the conducted research was the impossibility of direct observation of geological processes. In such cases, consideration of their dynamics is traditionally carried out by comparing statistical data and analyzing cartographic materials regarding the distribution of chemical elements in the objects under consideration. Then the obtained results are interpreted taking into account physico-chemical and geological features. Then, obtaining information about the distribution of chemical elements in geological objects is the first stage of research, which starts from the generalization of the actual material, through its theoretical understanding to the verification of the revealed regularities by research.

Samples were taken from mining operations (seam samples taken by the furrow method and from core duplicates personally by the authors with the participation of employees of geological services of coal mining enterprises and production geological exploration organizations in the period from 1981 to 2013. The volume of the control test was 5% of the total volume of samples. All analytical work was performed in the central certified laboratories of industrial geological exploration organizations. The content of germanium was determined by quantitative emission spectral analysis. 7% of duplicate samples were sent to internal laboratory control. 10% of duplicate samples were subjected to external laboratory control. The quality of the analysis results (correctness and reproducibility) was evaluated as the significance of the average systematic error, tested using Student's criterion, and the significance of the mean random error, tested using Fisher's criterion. Since the above errors are not significant at the 0.95 significance level, the quality of the analyses was recognized as satisfactory. With the help of Excel 2016 and Statistica 11.0 programs, at the initial stage of processing primary geochemical information, the values of the main descriptive statistical indicators were calculated, frequency histograms of the content were constructed and the germanium distribution law was established. When constructing all maps, the Surfer 11 program was used. During the construction of maps, graphs and calculation of correlation coefficients, all values of germanium concentrations and technological parameters of coal were normalized according to the formula: $X_{norm} = (X_i - X_{min}) / (X_{max} - X_{min})$, where: X_i is the result of a single value of element concentration; X_{max} is the result of the maximum concentration value of the element; X_{min} is the result of the minimum concentration value of the element. Normalization was carried out to bring the sample to the same scale regardless of the units of measurement and the scope of the samples.

In this work, the main tasks of studying the features of germanium distribution in coal seam $c_8^н$ of the "Dniprovska" mine field were: revision of previously performed studies; formation of representative samples of analyses of its content; establishing the relationship between the germanium content on one side and the thickness and ash content of the coal seam $c_{10}^в$ in the "Dniprovska" mine field on the other side.

Research results. Administratively, the coal mine is located on the territory of the Pavlohrad district of the Dnipropetrovsk region of Ukraine. In geological and industrial terms, the Dniprovska mine field is located within the Pavlohrad-Petropavlivka geological and industrial aref of Western Donbas, which is located on the southwestern side of the Dnipro-Donets depression. The geological structure of the mine field is complicated. Widely developed discontinuous and folding dislocations. The thickness of sedimentary rocks has a gentle monoclinal occurrence with a fall to the northeast at an angle of 2 - 5°.

The relationship between the content of germanium and the ash content of coal according to the results of the analyzes of the general sample according to the Chedok scale, taking into account the data of correlation (linear Pearson -0.12 and non-parametric Spearman -0.07, Kendel -0.05 and gamma -0.05) and regression analyzes is inverse and moderate, but it should be taken into account that it is statistically significant at a confidence interval of 0.99. In fig. 1 shows the graph of the result of the regression analysis of the modeling of the linear relationship between the content of germanium and the ash content of coal. The regression equation in this model is $Ge = 0{,}3747 – 0{,}1437 \cdot Ad$, but in our opinion, the quadratic model is more adequate, its graph is shown in Fig. 2, and the calculated regression equation $Ge = 0{,}3376 + 0{,}1597 \cdot Ad – 0{,}4258 \cdot Ad^2$. The analysis of the result of the regression analysis of the modeling of the quadratic relationship of germanium with the ash content of coal clearly indicates the presence of a relationship between the maximum values of germanium content in coal and the ash content interval within 5-10%. That is, with the so-called "sorption optimum" [50-51]. The relationship between the content of germanium and the thickness of coal seam according to the results of the analyzes of the general sample according to the Chedok scale, taking into account the data of correlation (linear Pearson -0.94 and non-parametric Spearman -0.95, Kendel -0.84 and gamma -0.86) and regression of analyzes is inverse and very high, at a confidence interval of 0.99 it is statistically significant.

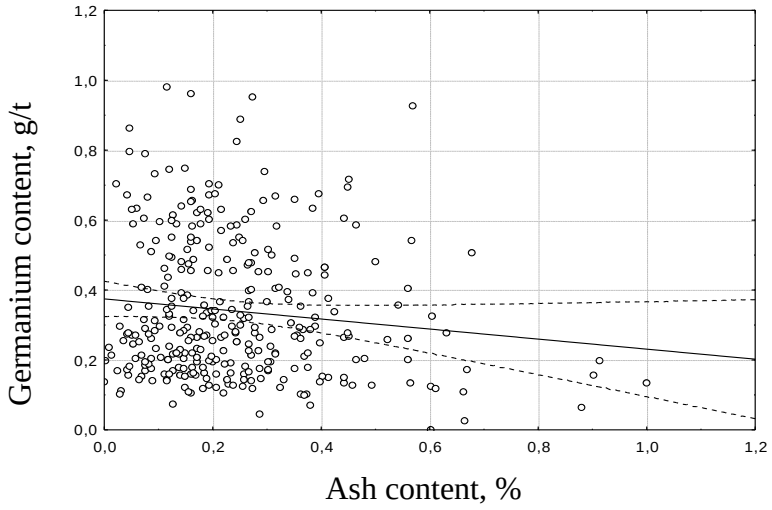

Fig. 1. The result of the regression analysis of modeling the linear relationship between germanium and coal ash content

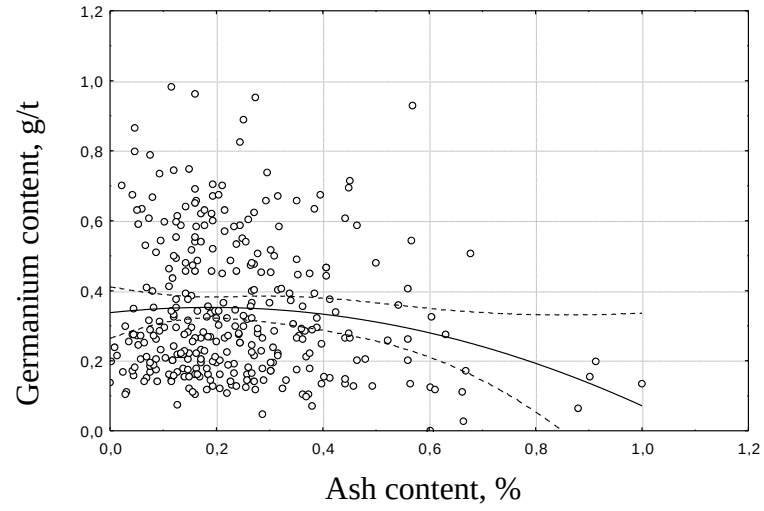

Fig. 2. The result of the regression analysis of the modeling of the quadratic relationship of germanium with coal ash content

Figure 3 shows the graph of the result of the regression analysis of the modeling of the linear relationship between the germanium content and the thickness of the coal seam. The regression equation for this model is Ge = 1,0835 - 1,1614·m , but in our opinion, the polynomial cubic model is more suitable for interpretation in geological terms, its graph is shown in Figure 4, and the calculated regression equation is Ge = 0,987 + 0,1291·m – 3,3477·m^2 + 2,357·m^3. When analyzing this regression model while simultaneously taking into account the initial data of both germanium content values and thickness of coal seam values and ash content, as well as the results of previous studies [1-49], it is possible to formulate preliminary conclusions about the relationship between these indicators.

The fact is that Ge is distributed extremely unevenly in the vertical profile of the coal seam. The main influence on the germanium content of the formation thickness is a consequence of the manifestation of the so-called "Zilbermints law" - the empirical regularity of the enrichment of some elements (primarily germanium) in the near-contact zones of coal seams. The thickness of such layers usually does not exceed 0.2 m. It should be noted that manifestations of the "Zilbermints law" are noted in every

coal basin of the world. They find a rather satisfactory interpretation within the framework of the concept of post-sedimentary diagenetic accumulation of germanium in the contact zone by diffusion and partly by filtration mechanisms during the period of peat accumulation [1-41]. Thereby, all other things being equal, with a decrease of coal thickness as a whole, the contribution of germanium-enriched areas to the total content of this metal in the coal seam will increase. At the same time, in some cases, these enriched layers will join and the entire coal seam will represent a continuous zone of enrichment. This can explain the connection of almost all abnormally high values of germanium content to areas of the seam with a thickness of no more than 0.4 m.

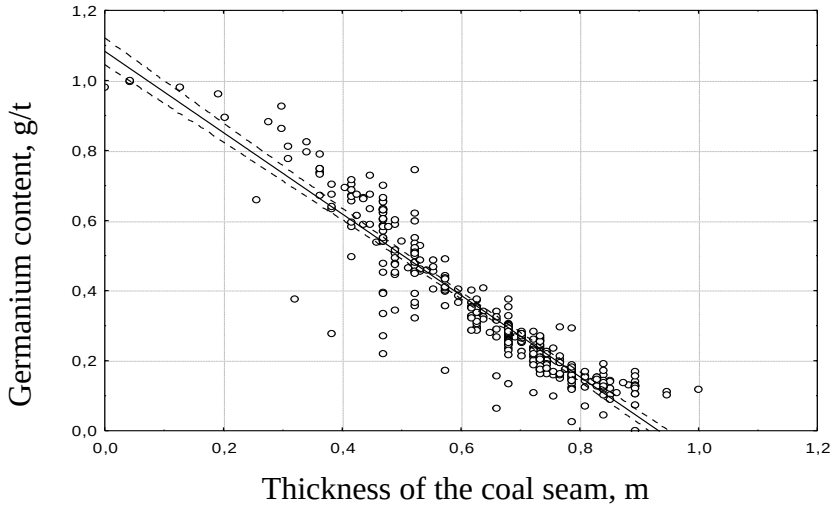

Fig. 3. The result of the regression analysis of the modeling of the linear relationship between the content of germanium and the thickness of the coal seam

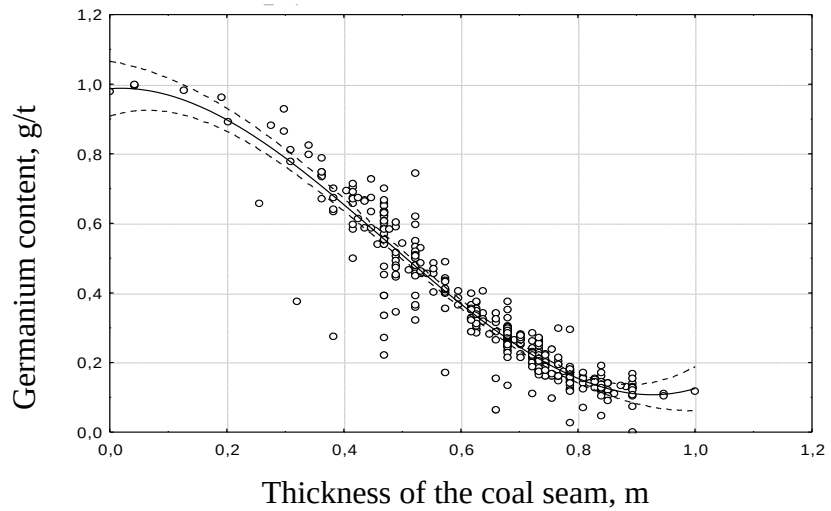

Fig. 4. The result of the regression analysis of the modeling of the polynomial cubic relationship of the germanium content with the thickness of the coal seam

Conclusions. The conducted research allows us to formulate the following main conclusions: 1. The analysis of the result of the regression analysis of the modeling of the quadratic relationship of germanium with the ash content of the coal seam c_8^H of the "Dniprovska" mine clearly indicates the existence of a relationship between the maximum values of the germanium content in coal and the ash content interval within 5-10 %, which reflects the so-called "sorption optimum".

2. It was established that, all other conditions being equal, with a decrease in the thickness of the formation as a whole, the contribution of its areas enriched in germanium to the total content of this metal in the considered formation will increase. At the same time, in some cases, these enriched layers will be join and the entire coal seam will be a continuous zone of enrichment. This explains the limitation of almost all abnormally high values of germanium content to areas of the seam with a thickness of no more than 0.4 m.

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