RESULTS OF DISPERSION AND SPATIAL ANALYSIS OF THE GERMANIUM DISTRIBUTION IN COAL SEAM C_8^B OF ZAHIDNO-DONBASKA MINE FIELD (UKRAINE)

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Introduction. The research actuality of studying the content of germanium 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).

The usage of germanium in different industries is quite diverse. $GeCl_4$ is used as a component for obtaining glass in optical fiber technology. Germanium oxide with a purity of up to 99.999% is used in catalysts for the polymerization of PET plastics (Poly Ethylene Terephalate or polyethylene phthalate resin), and especially pure - in the production of BGO crystals ($Bi_{14}Ge_3O_{12}$) scintillation sensors of high-energy photons. Semiconductor properties of germanium are again in demand in electronic devices and solar converters, as well as in Si-Ge connections. Night vision devices in the IR range use poly- and single-crystal windows and lenses made of Ge single crystals. Recently, germanium is beginning to be used in biogeochemistry and medicine. Its increased content in many medicinal plants, the ability to exert an antitumor, antiseptic effect was established.

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 $c_8^в$ of "Zakhidno-Donbaska" mine field were carried out.

Recent achievements. Earlier [1-20], 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 [21-22] and Krasnoarmiysk [23-30] geological and industrial regions of Donbas and some oil deposits [31-34] were investigated. At the same time, the analysis of germanium distribution in coal seam $c_8^в$ of "Zakhidno-Donbaska" mine field had not been performed before.

The purpose of the work: to establish the characteristics of germanium distribution of over the area and in the cross-section of coal seam $c_8^в$ of the "Zakhidno-Donbaska" 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 Be 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 assessing the connection of germanium with the organic or mineral part of coal, the coefficients of affinity with organic matter Fo were used, which shows the ratio of the content of elements in coal with low (<1.6) and high density (>1.7), coefficients of the given concentration Fnk, which show the ratio of the content of elements in the i(Ci) fraction to the content in the original coal, the correlation coefficients of the content of the studied elements and the ash content of the coal, and the coefficients of the indicated extraction of the element in the fraction of different density.

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 $c_8^в$ of the "Zakhidno-Donbaska" mine field were: revision of previously performed studies; formation of representative samples of analyses of its content; establishment of average concentrations of this element in coal, establishment of regularities of its distribution in the coal seam $c_8^в$ and connection with other "small elements" - coal impurities.

Research results. Administratively, the mine is located on the territory of the Pavlohrad area of the Dnipropetrovsk region of Ukraine, east direction from Pavlohrad city. From a geological and industrial point of view, Zahidno-Donbaska mine field is located within the boundaries of the Pavlohrad-Petropavlivka geological and industrial area of Western Donbas, which is located on the southwestern side of the Dnipro-Donets depression. The geological structure of the mine field is complex. Widely developed tearing and folding dislocations. The thickness of sedimentary rocks has a gentle monoclinal dip with a dip to the northeast at an angle of 2 - 5°.

On Zahidno-Donbaska mine field, the concentration of germanium in coal seam $c_8^в$ varies from 0.16 g/t to 9.48 g/t (Fig. 1a), with an average value of 5.49 g/t. The largest location of germanium is in the southern part of the mine field in the area of well No. 14336. The regional component of its content increases in the direction of the reverse dip of the formation in the southwest direction (Fig. 1b).

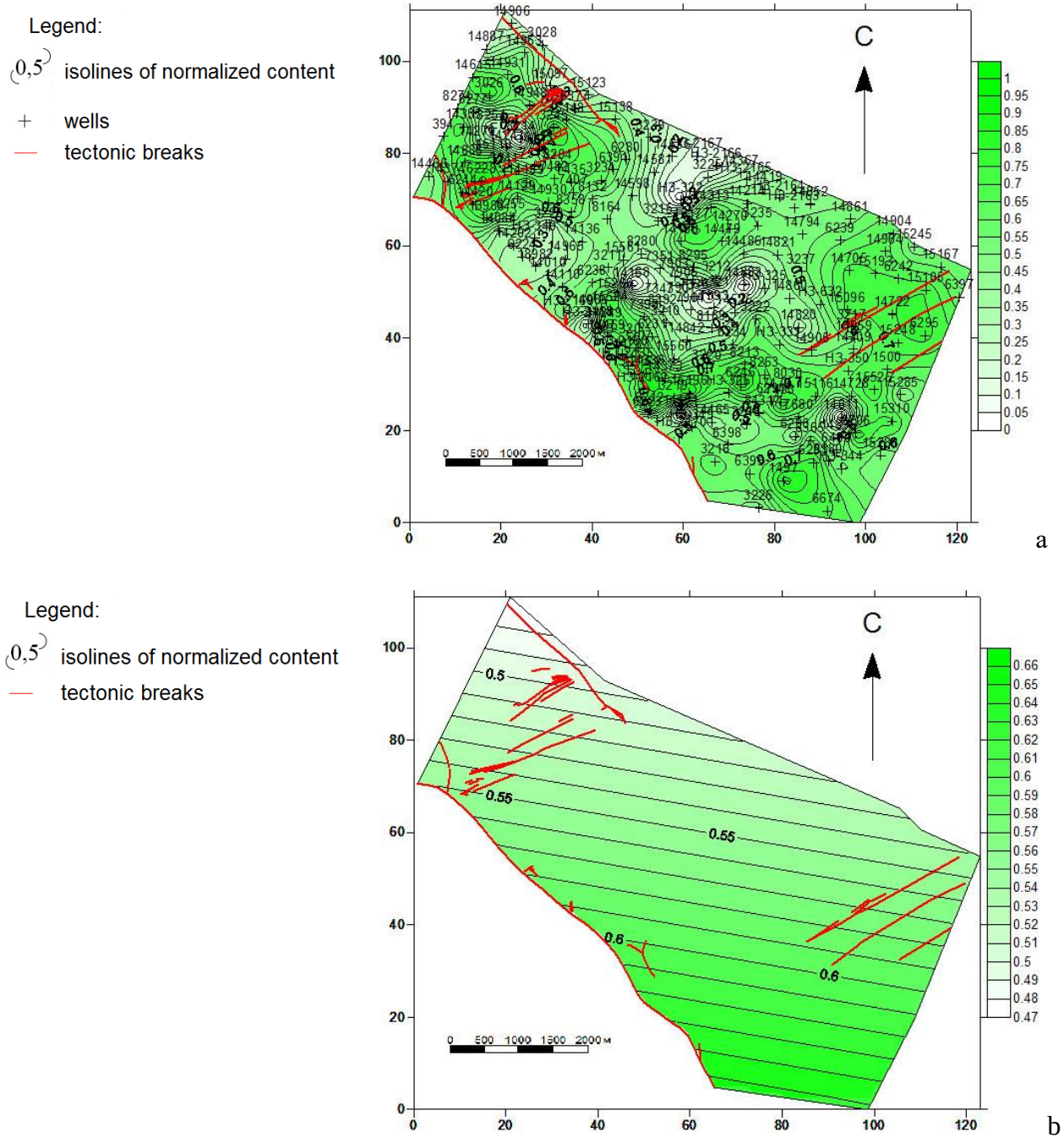

Fig. 1 Map of isoconcentrates (a) and map of regional component change (b) of the normalized content of germanium in the coal seam c_8^B (Zakhidno-Donbaska mine)

There is a close inverse statistical relationship between germanium content and ash content (r = -0.96) and fluorine (r = -0.90).

A dispersion analysis was carried out to determine the influence of variations in the strength of the coal seam, ash content and total sulfur on the concentration of germanium. The coefficients calculated using it are listed in Table 1.

Table 1 – Values of coefficients that characterize the degree of influence of each of the factors on the distribution of germanium.

Factors	Value of the coefficient
Thickness of seam	0,034
Ash content	0,960
Total sulfur content	0,006

In the cross-section of the formation, increased concentrations of germanium are observed in areas located directly near the soil and the roof and/or near low-strength intra-reservoir layers. Attention is drawn to the presence of areas of increased germanium content near zones with increased fracturing and epigenetic mineralization.

The main conclusions: 1) the regional component of the total content of germanium increases in the south-northern direction; 2) the content of germanium does not depend on the direction of fall, thickness and current depth of the coal seam, and its total sulfur in coal; 3) reverse relationship of the concentration of the studied element with the ash content of the formation, and therefore, its relationship with the organic component of coal.

The main practical value of the performed research consists in the construction of germanium content maps, which make it possible to perform a medium- and long-term forecast of the content of this element in mined rock mass and to plan the following technical and organizational measures aimed at managing its content in coal mining products and waste. The main scientific significance of the obtained results is to establish the character of germanium distribution, which probably has a polygenic and polychronic nature of accumulation.

In our opinion, the following main topical issues require further research: 1) establishing the general characteristics of germanium distribution in other main seams of the operating mines of the Pavlohrad-Petropavlivka and Krasnoarmiysk geological and industrial areas, which would take into account the features of the distribution of this element both along the plane of the distribution of mine strata and in their vertical cross-section, the peculiarities of the petrographic composition of coal, its main technological indicators (ash content, sulfur content, fractional composition, etc.). 2) identification of various tectonic factors that affect the content of germanium in the main working coal seams of the operating mines of the Pavlohrad-Petropavlivka and Krasnoarmiysk geological-industrial areas. 3) development of methods for forecasting the content of germanium in the main working coal seams of the operating mines of the Pavlohrad-Petropavlivka and Krasnoarmiysk geological and industrial areas of Donbas.

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