https://doi.org/10.33271/nvngu/2025-5/005

D. S. Malashkevych*,
orcid.org/0000-0002-8494-2489,
V. V. Ruskykh,
orcid.org/0000-0002-5615-2797,
V. Yu. Medianyk,
orcid.org/0000-0001-5403-5338,
O. A. Haidai,
orcid.org/0000-0003-0825-0023

Dnipro University of Technology, Dnipro, Ukraine
* Corresponding author e-mail: malashkevych.d.s@nmu.one

PREDICTION OF COAL SEAM OCCURRENCE USING NUMERICAL METHODS AND A THREE-DIMENSIONAL GEOINFORMATION SYSTEM

Purpose. Development and application of a methodology for predicting the occurrence of a coal seam using numerical interpolation methods and three-dimensional geoinformation modeling.

Methodology. The study is based on geological exploration data of the c_4^2 coal seam at the "Samarska" mine. Numerical interpolation methods and three-dimensional modeling in AutoCAD 3D were used. Based on geological data, a digital terrain model of the seam's floor was constructed, and its thickness and variations across the area were determined. Using mathematical methods, an analysis of thinning and thickening zones of the seam was carried out, allowing for the estimation of coal extraction volumes, waste rock yield, and the operational ash content of coal.

Findings. As a result of the study, a three-dimensional model of the c_4^2 coal seam of the "Samarska" mine was developed and its geological thickness was determined. Areas of thinning and thickening of the seam were identified, which made it possible to optimize the location of extraction pillars and preparatory workings. Volumes of coal to be mined and waste rock to be cut were calculated. The estimated operational ash content of coal was determined to be 34.4 %, which is an important factor for controlling the quality of the extracted product. The data obtained made it possible to optimize the parameters of cleaning operations, adapting the technological process to the geological conditions of the coal seam.

Originality. The article proposes an improved approach to predicting coal seam occurrence using numerical interpolation and three-dimensional modeling, adapted to conditions with limited geological data. For the first time, a step-by-step construction with dynamic uprating of seam geometry is implemented, enhancing the accuracy of reserve estimation and the efficiency of mining design.

Practical value. The developed methodology makes it possible to minimize exploration costs, improve the reserve estimation accuracy, reduce risks, and optimize mining operations. The results can be used to design production technology for other mines in Western Donbas, contributing to increased mining efficiency.

Keywords: *prediction, coal seam, three-dimensional modeling, interpolation, geological thickness, extraction*

Introduction. In the modern world of mining, one of the most pressing tasks is to ensure the efficiency and safety of coal seams development. This is due to the constant growth in demand for energy resources and the need to reduce the negative impact on the environment [1]. In today's economy and fierce competition, mining companies are forced to look for new approaches to optimizing production processes. One of such approaches is the use of modern information technologies to predict the occurrence, qualitative and quantitative characteristics of coal deposits, which in turn ensure a reasonable choice of their development parameters and the expected technical and economic performance of mining sites [2].

Today, the mines of Western Donbas face an acute problem with insufficient exploration of coal deposits. Prospecting and exploration of coal seams in Western Donbas was carried out in 1950–1970, just before the construction of enterprises and their commissioning. The seams were predicted by drilling a grid of exploration wells and analyzing the cores in detail [3].

Currently, no exploration work is being carried out in Western Donbas to find coal deposits by drilling wells due to the high cost of such work. Due to the depletion of reserves, mines such as the "Pershotravenska" and "Stashkova" mines ceased operations and were liquidated in accordance with the closure projects. Similarly, the "Stepova" and "Yuvileina" mines will exhaust their resources in the next 2–3 years [4, 5]. Other coal mining enterprises in the Western region of Donbas are forced to cut reserves from reserve blocks and mine fields to maintain production volumes and extend their operating life. Often, these reserves are virtually unexplored, which creates significant risks and complications in the process of their development [6, 7].

In this regard, the use of modern information technologies for modeling and forecasting coal seams is becoming an important tool for solving these problems. Modern software tools allow predicting the geometry, thickness and other characteristics of coal seams with high accuracy and at a much lower financial cost, which allows for a prompt approach to mining planning, solving various geotechnical and engineering problems, including reducing the amount of waste rock accumulation on the surface [8, 9].

Literary review. One of the most important aspects of accurate and reliable reserves forecasting is the use of numerical methods for interpolating geological exploration data. Various interpolation methods are used in modern science and practice.

For example, the inverse distance method is one of the most common interpolation methods used to predict values at unknown points based on known values at neighboring points. The authors of [10, 11] note that this method allows for high accuracy in estimating the spatial distribution of rock properties, but its effectiveness may be reduced in cases of uneven distribution of the initial data. Therefore, it is often used in combination with other methods to improve the accuracy of forecasts [12, 13].

Kriging is a more complex and statistically sound interpolation method that takes into account not only the distance between points but also the spatial correlation between them. The authors of [14] note that this method can significantly improve the accuracy of predictions of geological characteristics, such as seam thickness and coal ash content, by using variograms to model the spatial variability of data. However, this method has a high computational complexity and requires a large amount of data to ensure reliable and correct modeling [15].

The spline interpolation method uses smooth curves to model the spatial distribution of geological characteristics. This method allows you to create continuous surfaces that accurately reflect geological structures, while maintaining smoothness and avoiding sudden changes in values [16]. This approach makes it possible to achieve high modeling accuracy, which is especially important for analyzing complex and variable geological environments.

The application of these methods in practice gives the opportunity for accurate estimation of coal reserves and forecasting its quality through spatial modeling [17]. The key stage of this process is the creation of three-dimensional models using advanced software tools, which allows getting a detailed picture of the geological structure of the deposit and the quality characteristics of coal [18]. The use of modern software for modeling coal seams has several advantages.

Firstly, it can significantly reduce the cost of exploration. Instead of drilling many wells, which is a costly and time-consuming process, mathematical models can be used to predict the location of coal seams. This reduces the amount of exploration work required and reduces its cost.

Secondly, the use of three-dimensional models improves the accuracy and reliability of the data obtained. Thanks to a detailed analysis of the geometry of coal seams, their boundaries, thickness and other parameters can be determined more accurately.

For example, in [19], an approach based on spatial three-dimensional modeling was presented to calculate coal reserves and predict its quality. Coal quality characteristics were assessed by ash and sodium content, total sulphur, and calorific value. Geostatistical methods, conventional kriging and sequential Gaussian modeling were used to build the models.

This approach is further applied in [20], where a comprehensive 3D modeling of coal seams was carried out, which includes the step-by-step creation of digital geoinformation models taking into account structural features such as faults and folding of the geological body of the seam. In addition, authors propose to create block models, where each block is assigned coal quality attributes, such as ash content, moisture content, volatile matter content, sulphur content and calorific value. This allows for a more detailed and accurate picture of the quality characteristics of coal within the studied deposit.

A similar modeling of a coal deposit using the specialized geoinformation software GEOVIA SURPAC was carried out in [21] and ArcGIS [22]. Such models make it possible not only to optimize production, but also to increase the overall efficiency of the deposit's resource management.

The use of three-dimensional modeling allows for better prediction of coal seams and optimization of the mining process. For example, in [23], multivariate solutions for the development of new coal mine reserves are considered using 3D modeling. Taking into account the lithological and geological structure of the rock mass in the models allows determining the rational parameters of underground mining technology [24].

There are also methods for ongoing adjustment of the models of the geological body of the seam using laser scanning of the face during coal mining [25]. The data on the position of the roof and the bottom of the seam are used in a continuous mode to adjust the three-dimensional model of the seam, allowing one to adapt the mining strategies depending on the actual geological conditions of the mine.

Problem formulation. For relatively small areas of coal seams, where there is no drilling data or geological surveys during preparatory workings within the boundaries of the contours of the mining pillars, a universal and operational method for predicting the occurrence of coal seams based on modern technologies of three-dimensional modeling and dynamic adjustment of geological data is required [26].

Such a method should use geographic information systems to continuously update the model based on new data obtained during development, taking into account possible changes in the seam. This will minimize the risks associated with the lack of drilling data and increase the efficiency of excavation planning, optimizing costs and ensuring production stability in conditions of insufficient information about the geological environment.

In this regard, using the "Samarska" mine conditions as an example, analytical studies were conducted to forecast the occurrence of a coal seam, determine the geological thickness and ash content within the mining area using numerical calculation methods, as well as to build the geological body of the seam and prepare the excavation pillar for its mining using modern automated software. The research results can be used to optimize mining processes and improve the efficiency of the enterprise.

Research methodology. According to the mining development program at the "Samarska" mine, it is planned to bring into operation longwalls within the mining contour that have not been explored by drilling wells. One of these areas is in the coal seam area in the sloping part of the block No. 3 mine field, which is bounded on the north side by a drainage ventilation drift, on the south side by a dumping drift of the c_4^2 seam, on the west side by a 4206 longwall, and the eastern side by the boundaries of the mine field. The area of coal seam c_4^2 selected for the study is shown on the extract from the mining plan and marked in green in Fig. 1. The presented section of the c_4^2 seam area will be further mined by the 4207 longwall.

The "Samarska" mine uses a horizontal method of mine field preparation to develop reserves. Longwall mining in the c_4^2 seam is carried out using longwall mining system by uplift. Usually, the longwall mining system makes it possible to further explore the deposit area before the start of face commissioning due to the preparatory workings that have been driven in advance, which

Fig. 1. Mining plan of the c_4^2 seam in the sloping part of the block No. 3 mine field:

1 – explored area of coal seam 4201-4206 longwalls; 2 – prediction area of coal seam 4207 longwall

surround the face reserves, such as the dumping and drainage drifts of the c_4^2 seam. The parameters of the c_4^2 coal seam were determined based on the available geological exploration data and the results of previous studies during the development of 4201–4206 longwalls. These include the seam thickness, dip angle, nature of faulting, mining and geological conditions affecting the development of reserves.

Research sequence. At the first stage of the research, a three-dimensional model of the coal seam is built in AutoCAD 3D software within the boundaries of the contour of the explored part of the coal seam, taking into account the data of the mining plan. High-altitude isohypse of the coal seam floor of the c_4^2 are applied to the model. A grid of points corresponding to the elevation marks of the coal seam base is constructed with a 5 m step.

At the second stage, the x and y coordinates of each isohypse are taken for each point and automatically entered into a Microsoft Excel spreadsheet. The resulting point coordinates are used to further build the reservoir surface using the triangulation method. Based on this triangulation grid, a digital model of the formation's bottom relief is created, which allows for further analysis of its geometric characteristics.

Based on the coordinates of the isohypse position, equation functions are derived that describe the spatial position of the elevation isolines and allow mathematical modeling of the coal seam topography. The obtained functions are then used to model the bottom of the seam relief in the unexplored area of the adjacent 4207 longwall.

The third step is to determine the geological thickness of the seam over the area of distribution. According to the plan, well cores, their depths, and the thickness of the coal seam are added to the model. The mining plan is used to determine the average thickness of the coal seam at the specified points. The x coordinate is the value of the thickness at each point on the isohypse. The seam thickness change function is calculated, and the y coordinate values are determined. The obtained data is also integrated into a three-dimensional model. At each point of the predicted isohypse, the found seam thickness values are marked, which allows predicting the topography of the reservoir roof.

At the fourth stage, a geological model of the coal seam is built in AutoCAD 3D. In the three-dimensional space of the software environment, a plane with a zero mark at the z coordinate is added, and isohypse of the surface relief and coal seam cover are drawn in the explored area. Then, based on the results of mathematical modeling of the determination of the height of the spread of isohypse, the contours of the coal seam surface are built on the unexplored area of the 4207 longwall pillar, which is planned for mining.

The fifth stage involves the construction of opening and developing workings to provide access to the coal seam and its further development. These workings are designed taking into account the seam's hypsometry, the accepted parameters of the development system, mining techniques and technology, and determining the optimal place for their sinking. Modeling is performed at a scale of 1:1,000.

Research results and discussion. Based on the results of the research, a three-dimensional model of the coal seam c_4^2 was built within the explored area. Isolines of the coal

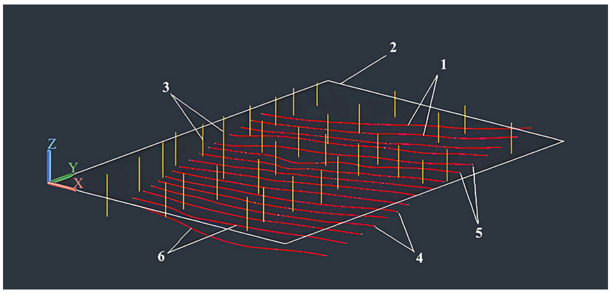

Fig. 2. Construction of a three-dimensional model of the c_4^2 coal seam area:

1 – coal seam footwall isoline; 2 – Baltic Sea level plane; 3 – exploration well cores; 4 – points on isohypses; 5 – seam thickness lines; 6 – seam footwall isohypses

seam base were constructed in accordance with the mining plan approved at the mine (Fig. 2). The isolines have the following marks: –15; –20; –25; –30; –35; –40; –45; –50; –55; –60; –65; –70; –75; –80; –85; –90 m relative to the Baltic Sea level. For a more accurate representation of the geological structure, these elevations are recalculated on the spatial model plan using the appropriate scale.

The coordinates of the points were surveyed on a grid of elevation marks of the coal seam base, which were subsequently automatically consolidated into a Microsoft Excel spreadsheet. The use of AutoCAD 3D made it possible to integrate different types of data into a single model, which greatly simplified the process of mining analysis and planning. As a result, a database of coordinates of the position of the bedding surface relief isolines on the explored area of the excavation panel was created. An example of the generated table of isohypse points of the seam c_4^2 is shown in Table 1.

Based on the determined coordinates of the seam floor, equations describing the spatial position of the heights were obtained, which allows mathematical modeling of the coal seam topography. The dependencies established as a result of this analysis are shown in Fig. 3.

The graphs in Fig. 3 shows the dependence of the coordinates of the isolines for different elevations of the coal seam. The presented curves are described by polynomial equations of the second degree where y is the value of the isoline height, x is the coordinate along the isohypse axis. The coefficients before the polynomial terms determine the shape of the curve, in particular, its curvature and slope. The constant additional part defines the curve offset along the y axis.

Further, for the unexplored area of the coal seam, the height coordinates were determined in isohypse using the established equations. This made it possible to estimate the surface relief of the seam and predict possible changes in the further development of the mine field.

The obtained coordinate values are presented in Table 2, and the equations of the coal seam thickness dependence functions are shown in Fig. 4.

The geological thickness in the explored area of the reservoir spread at each point of the triangulation grid was determined by the y coordinate of the isolation height, calculating the distance between the reservoir base and the reservoir top. To do this, we used available data from drill holes and geological sections, which allowed us to estimate the change in reservoir thickness over the explored area of the reservoir. Based on these data, we built graphs of thickness change, which allowed us to identify key zones of increased and decreased seam thickness, which will be the basis for further modeling of the seam occurrence in the unexplored area and planning of mining operations.

The geological thickness of the reservoir in the study area of the coal seam c_4^2 was determined using the established equations, substituting the corresponding x coordinates for each point of the height of the seam roof. The predicted values of the geological thickness in the studied area are summarized in Table 3.

The analysis of the data obtained showed that the average thickness of the coal seam c_4^2 in the projected area of the 4207 longwall is m = 0.74 m. The coal seam will have wavy hypsometry. Also, the results of the study in

Table 1

Coordinates of isohypse points of the seam c_4^2 floor on the explored area

	x	*y*		*x*	*y*		*x*	*y*		*x*	*y*
isohypse - 20	77.57	1,430.21	*isohypse - 40*	154.32	1,020.01	*isohypse - 60*	219.11	673.69	*isohypse - 80*	272.64	387.57
	262.05	1,483.76		340.29	1,073.6		409.84	695.7		469.34	377.3
	443.63	1,551.07		526.46	1,111.93		596.93	732.02		665.01	368.78
	622.13	1,628.58		709.04	1,168.5		781.98	777.94		856.2	378.68
	788.42	1,744.96		877.5	1,271.06		955.57	850.88		1,037.78	413.28
	1,006.88	1,848.82		1,093.45	1,389.6		1,180.27	921.73		1,264.05	480.21
	1,228.03	2,056.18		1,334.09	1,495.07		1,427.56	995.08		1,511.94	544.46
isohypse - 30	117.24	1,218.17	*isohypse - 50*	189.18	833.68	*isohypse - 70*	245.73	531.41	*isohypse - 90*	305.09	214.14
	291.18	1,334.32		375.75	879.02		440.11	537.03		503.51	192.63
	472.28	1,402.17		556.61	948.18		629.32	557.9		708.39	143.96
	655.74	1,451.75		741.13	995.54		820.55	568.35		913.33	81.23
	827.05	1,538.85		917.07	1,059.58		1,001.07	606.8		1,105.09	58.63
	1,051.12	1,613		1,137.6	1,155.83		1,225.77	681.41		1,331.66	122.02
	1,283.51	1,761.3		1,381.4	1,241.57		1,464.1	799.89		1,576.41	200.18

Table 2

Coordinates of predicted points of isohyps of the seam floor

x	y	isohypse	x	y	isohypse
–222.43	1,392.46	–20	–182.76	1,122.5	–30
–72.43	1,428.38		–32.76	1,180.4	
–80.89	626.77	–60	–54.27	583.68	–70
69.11	644.2		95.73	555.75	
–145.68	972.19	–40	–110.82	754.56	–50
4.32	991.47		39.18	791.61	
-27.36	443.4	–80	5.09	397.69	–90
122.64	411.15		155.09	311.46	

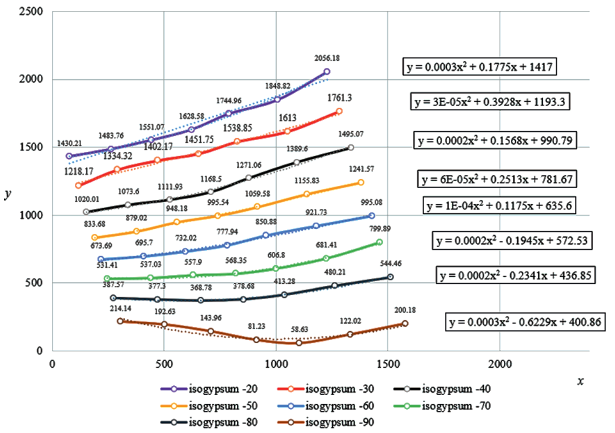

Fig. 3. Equations of functions of isohypse of the coal seam floor c_4^2

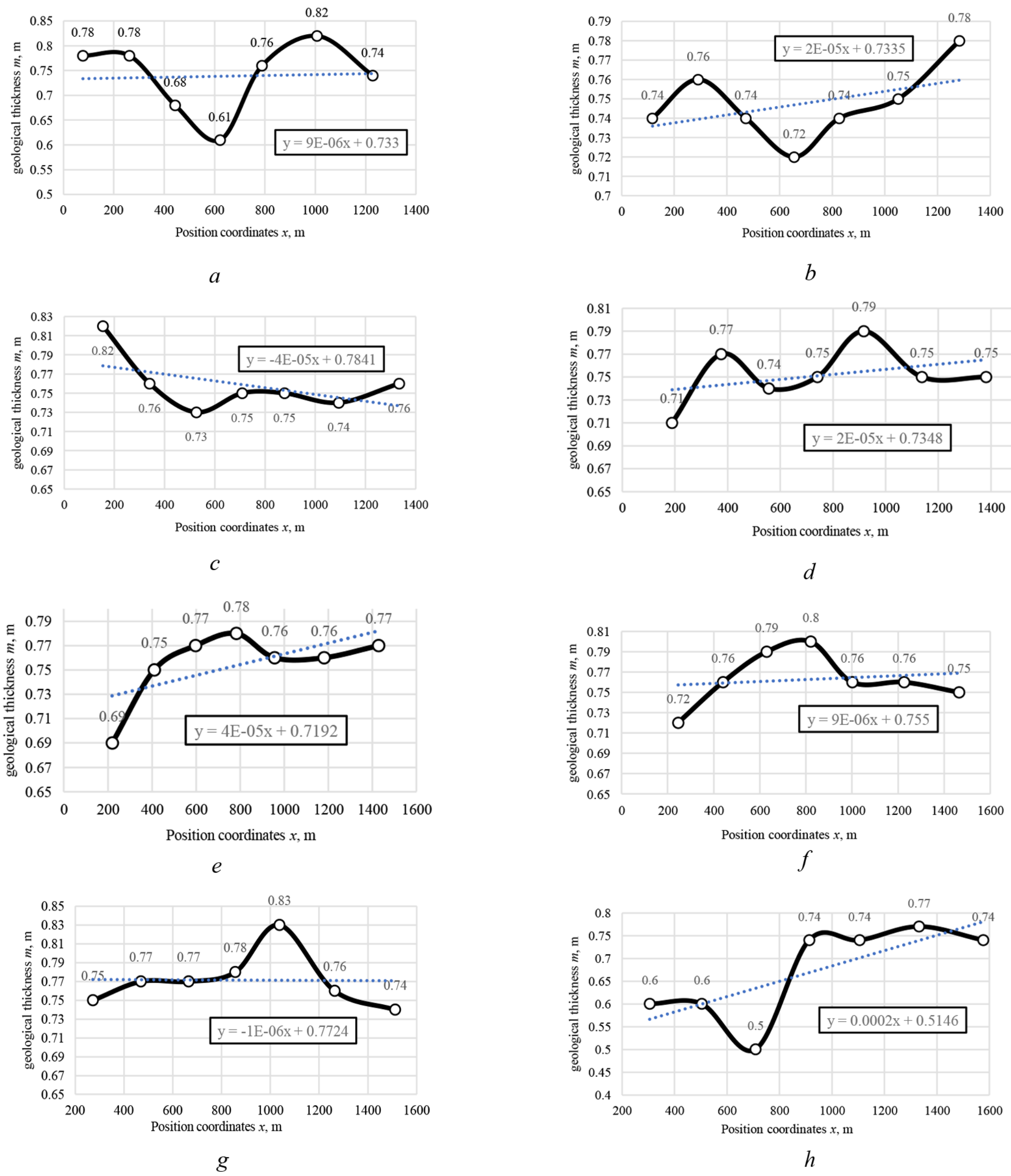

Fig. 4. Equation of geological thickness functions of the coal seam c_4^2: a – isohypse – 20 m; b – 30 m; c – 40 m; d – 50 m; e – 60 m; f – 70 m; g – 80 m; h – 90 m

Table 3

Forecasted values of coal seam c_4^2 thickness within 4207 longwall panel

isohypse	*x* coordinate	geological thickness *m*, m	isohypse	*x* coordinate	geological thickness *m*, m
–20	–222.43	0.73	–30	–182.76	0.73
	–72.43	0.73		–32.76	0.73
	77.57	0.78		117.24	0.74
	262.05	0.78		291.18	0.76
	443.63	0.68		472.28	0.74
–40	–145.68	0.77	–50	–110.82	0.73
	4.32	0.78		39.18	0.74
	154.32	0.82		189.18	0.71
	340.29	0.76		375.75	0.77
	526.46	0.73		556.61	0.74
–60	–80.89	0.72	–70	–54.27	0.75
	69.11	0.72		95.73	0.76
	219.11	0.69		245.73	0.72
	409.84	0.75		440.11	0.76
	596.93	0.77		629.32	0.79
–80	–27.36	0.77	–90	5.09	0.52
	122.64	0.77		155.09	0.55
	272.64	0.75		305.09	0.6
	469.34	0.77		503.51	0.6
	665.01	0.77		708.39	0.5

the 4207 longwall section allowed us to identify characteristic features in the distribution of this value along the excavation panel.

Thus, on a section of 290-300 m from the longwall face entry, a fairly stable width of the coal seam thickness distribution area was observed in the intervals of 0.77–0.78 m from PK150 to PK120 (along the conveyor drift).

In the section PK120-100, a relatively long area of gradual thinning of the seam from 0.78 to 0.74 m with minor fluctuations is observed. After this section, the coal seam thickness decreases and reaches 0.72 m at PK82 + 5 m.

In the area from PK70 + 7 m to PK65 + 5 m, a stable area is distinguished, where a relatively high predicted thickness of the coal seam is observed, ranging from 0.77–0.78 m. In particular, the concentration of the highest coal seam thickness is located close to the conveyor drift. In the rest of the projected mining area up to the boundary of the protective pillar of the conveyor drift, the coal seam thickness remains within 0.73 m.

Based on the results of mathematical modeling, a three-dimensional model of the explored and predicted areas of the coal seam was built (Fig. 5).

The explored part of the mine field is highlighted in black, the predicted section of the 4207 longwall is highlighted in gray, exploration wells are highlighted in yellow, the isohypses of the sole of the explored and forecasted area of the seam are red and blue lines, respectively, as well as the equation of functions of the isohypses of the seam floor.

Based on the three-dimensional model of the forecasted area of the coal seam c_4^2, taking into account the

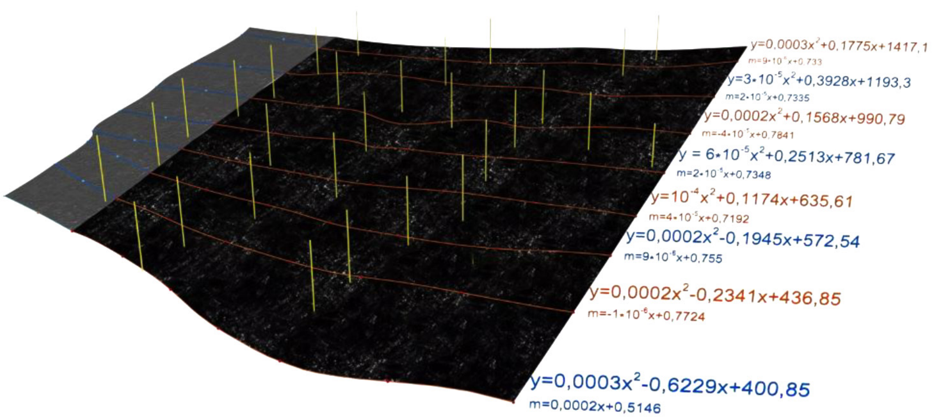

Fig. 5. Three-dimensional model of the explored and predicted areas of the coal seam c_4^2

existing mining plan for the explored area of this seam, we modeled new main workings (main dumping drift, main conveyor drift and drainage ventilation drift) to open a new longwall panel and further develop it. Taking into account the mining and geological conditions of the face, a longwall mining system was adopted. The model was used to design the tunneling workings (ventilation drift, conveyor drift, and assembly chamber), to mark the boundaries of the protective pillars, and to outline the 4207 longwall face. The boundaries of the protective pillars were marked at a distance of 50 m from the main and drainage drifts.

Based on the built model, the lengths of the extended main workings were determined, which amounted to: a dumping drift – 270 m; a conveyor face – 270 m; a drainage ventilation drift – 330 m. The lengths of the development workings of the longwall panel were as follows: ventilation drift – 1,320 m; conveyor drift – 1,100 m. The panel width is 246 m, while the panel length is 843 m.

Fig. 6 shows the three-dimensional model of the 4207 longwall panel, as well as the main and development workings.

The mine's technological solutions for the development of reserves in the c_4^2 seam include the 1MKD80 mechanized unit in combination with a shearer KA-200. However, the construction height of the mining equipment does not allow it to fit into the thickness of the seam being mined, which is less than 0.9 m. At the same time, as the practice of operating mechanized complexes in the mining and geological conditions of Western Donbas shows, the minimum mining thickness in the longwall should be at least 1.05 m. This value provides the necessary cross-section in the longwall for its ventilation, makes it possible to create fairly acceptable working conditions for workers in the face and allows for the necessary support flexibility, which makes it impossible to plant it on a "rigid base" [27]. Thus, coal extraction in the longwall will be carried out with the cutting of side rocks, which will affect the operational ash content of the extracted coal.

Given the digital model of the coal seam and the accepted parameters of the mining thickness of the mechanized roof support, the volumes of coal and rock removed in the process of mining 4207 longwall were automatically calculated in AutoCAD. The size of the cut-off rocks h_c was determined as the difference between the minimum mining thickness of the mechanized complex m_m and the actual geological thickness of the seam m. Based on the results of the study, the volumes of minerals and rocks were determined:

- coal removed – 53,450 m^3;
- rock undercut – 59,350 m^3.

The predicted operational ash content A_e of coal was calculated by a known expression using the methodology [28], taking into account the parent ash content A_p of the seam according to the available mining and geological documentation. The operational ash content of the mined coal extracted in the 4207 longwall face is 34.4 %.

Conclusions. The paper presents a comprehensive study using numerical methods and three-dimensional modeling to predict the geological parameters of the c_4^2 coal seam of the "Samarska" mine. The authors of the paper propose a methodology for applying numerical interpolation methods and three-dimensional modeling to analyze the geological thickness of the coal seam c_4^2.

The data obtained made it possible to create a three-dimensional model of the c_4^2 seam, determine its average thickness and estimate its operational ash content. Building a three-dimensional model and applying equations to describe the isolines allows us to effectively predict the topography of the reservoir surface and make prompt and informed decisions on mining operations. This approach helps to reduce drilling costs and optimize production.

In particular, the modeling made it possible to determine the geological thickness of the c_4^2 seam in the 4207 longwall development area depending on the position of the face along the panel length. The modeling of the seam thickness isolines based on the available geological data and predictive models allowed us to identify key zones of increased and decreased thickness, which makes it possible to predict the quantitative and qualitative characteristics of the extracted coal at different intervals of the face advancement.

The prospects for further research are to improve the methods of three-dimensional modeling and expand their application to other mines in Western Donbas. This will reduce the risks associated with insufficient geological exploration, improve the accuracy of forecasts and ensure stable coal production in the face of current economic challenges.

Acknowledgement. *The authors express their gratitude to the management of Mine Administration "Ternivske", PJSC "DTEK Pavlohradvuhillia" for the provided technical information, organization of mine research and active participation in the discussion of the research results.*

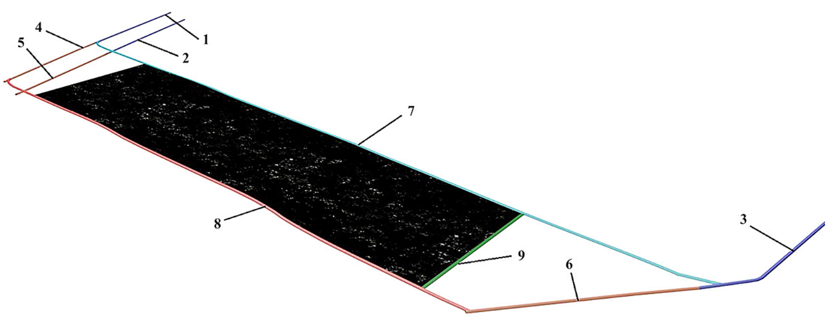

Fig. 6. Three-dimensional model of the longwall panel of the predicted coal seam area and excavations:

1 – main dumping drift; 2 – main conveyor drift; 3 – drainage ventilation drift; 4 – extended section of the main dumping drift; 5 – extended section of the main conveyor drift; 6 – extended section of the drainage ventilation drift; 7 – excavation ventilation drift; 8 – excavation conveyor drift; 9 – installation chamber

References.

1. Buzylo, V., Pavlychenko, A., & Borysovska, O. (2020). Ecological aspects of filling of worked-out area during underground coal mining. *E3S Web of Conferences*, (201), 01038. EDP Sciences. https://doi.org/10.1051/e3sconf/202020101038

2. Wang, G., Ren, H., Zhao, G., Zhang, D., Wen, Z., Meng, L., & Gong, S. (2022). Research and practice of intelligent coal mine technology systems in China. *International Journal of Coal Science & Technology*, *9*(1), 24. https://doi.org/10.1007/s40789-022-00491-3

3. Malashkevych, D., Petlovanyi, M., Sai, K., & Zubko, S. (2022). Research into the coal quality with a new selective mining technology of the waste rock accumulation in the mined-out area. *Mining of Mineral Deposits*, *16*(4), 103-114. https://doi.org/10.33271/mining16.04.103

4. Bondarenko, V., Salieiev, I., Kovalevska, I., Chervatiuk, V., Malashkevych, D., Shyshov, M., & Chernyak, V. (2023). A new concept for complex mining of mineral raw material resources from DTEK coal mines based on sustainable development and ESG strategy. *Mining of Mineral Deposits*, *17*(1), 1-16. https://doi.org/10.33271/mining17.01.001

5. Wang, L., Jia, B., & Su, G. (2025). Risk identification of coal and gas outburst based on improved CUOWGA weighting TOPSIS model. *Scientific Reports, 15*(1), 1-9. https://doi.org/10.1038/s41598-025-00266-1

6. Malashkevych, D., Poimanov, S., Shypunov, S., & Yerisov, M. (2020). Comprehensive assessment of the mined coal quality and mining conditions in the Western Donbas mines. *E3S Web of Conferences*, (201), 01013. https://doi.org/10.1051/e3sconf/202020101013

7. Salieiev, I. (2024). Organization of processes for complex mining and processing of mineral raw materials from coal mines in the context of the concept of sustainable development. *Mining of Mineral Deposits*, *18*(1), 54-66. https://doi.org/10.33271/mining18.01.054

8. Petlovanyi, M., Ruskykh, V., Sai, K., & Malashkevych, D. (2024). Prompt determination of predictive parameters for mining-technogenic landscape objects. *IOP Conference Series: Earth and Environmental Science*, *1348*(1), 012035. https://doi.org/10.1088/1755-1315/1348/1/012035

9. Bondarenko, V., Kovalevs'ka, I., & Fomychov, V. (2012). Features of carrying out experiment using finite-element method at multivariate calculation of "mine massif – combined support" system. *Geomechanical Processes During Underground Mining – Proceedings of the School of Underground Mining*, 7-13. https://doi.org/10.1201/b13157-4

10. Ljubić, A., & Petrović, M. (2024). Statistical analysis and mapping of imaginary coal layer using inverse distance interpolation, simple case study of recommended methods. *Theory and application in geomathematics 2024: 5th Croatian geomathematical scientific congress*, 173-186. Retrieved from https://hrcak.srce.hr/omp/index.php/rgn-unizg/catalog/view/81/52/5239

11. Jeuken, R., Xu, C., & Dowd, P. (2020). Improving coal quality estimations with geostatistics and geophysical logs. *Natural Resources Research*, *29*(4), 2529-2546. https://doi.org/10.1007/s11053-019-09609-y

12. Afzal, P. (2018). Comparing ordinary kriging and advanced inverse distance squared methods based on estimating coal deposits; case study: East-Parvadeh deposit, central Iran. *Journal of Mining and Environment*, *9*(3), 753-760. https://doi.org/10.22044/jme.2018.6897.1522

13. Kopacz, M., Kulpa, J., Galica, D., Dyczko, A., & Jarosz, J. (2019). Economic valuation of coal deposits – The value of geological information in the resource recognition process. *Resources Policy*, (63), 101450. https://doi.org/10.1016/j.resourpol.2019.101450

14. Zhang, J., & Guangwei, L. (2024). *Research on a Coal Seam Modeling Construction Method Based on Improved Kriging Interpolation*. https://doi.org/10.21203/rs.3.rs-4124626/v1

15. Maxwell, K., Rajabi, M., & Esterle, J. (2021). Spatial interpolation of coal properties using geographic quantile regression forest. *International Journal of Coal Geology*, (248), 103869. https://doi.org/10.1016/j.coal.2021.103869

16. Uyan, M., & Dursun, A. E. (2021). Determination and modeling of lignite reserve using geostatistical analysis and GIS. *Arabian Journal of Geosciences*, *14*(4), 312. https://doi.org/10.1007/s12517-021-06633-2

17. Zhao, X., Hao, T., Feng, H., Li, F., & Li, X. (2025). Exploration of 3D Coal Seam Geological Modeling Visualization and Gas Content Prediction Technology Based on Borehole Data. *Energy Science & Engineering, 13*(3), 1117-1131. https://doi.org/10.1002/ese3.2048

18. Che, D., & Jia, Q. (2019). Three-dimensional geological modeling of coal seams using weighted Kriging method and multi-source data. *IEEE Access, 7*, 118037-118045. https://doi.org/10.1109/ACCESS.2019.2936811

19. Olea, R. A., Luppens, J. A., & Tewalt, S. J. (2011). Methodology for quantifying uncertainty in coal assessments with an application to a Texas lignite deposit. *International Journal of Coal Geology, 85*(1), 78-90. https://doi.org/10.1016/j.coal.2010.10.001

20. Unver, B. (2018). Fundamentals of 3D modelling and resource estimation in coal mining. *Journal of Mining and Environment*, *9*(3), 623-639. https://doi.org/10.22044/jme.2018.6848.1515

21. Jiskani, I. M., Siddiqui, F. I., & Pathan, A. G. (2018). Integrated 3D geological modeling of Sonda-Jherruck coal field, Pakistan. *Journal of Sustainable Mining*, *17*(3), 111-119. https://doi.org/10.1016/j.jsm.2018.06.001

22. Dursun, A. E. (2023). Spatial coal seam modeling and reserve estimation using geostatistical methodologies by GIS technique in a selected coalfield in Ermenek Basin, Turkey. *Acta Montanistica Slovaca*, *28*(4), 863-877. https://doi.org/10.46544/ams.v28i4.06

23. Lozynskyi, V., Medianyk, V., Saik, P., Rysbekov, K., & Demydov, M. (2020). Multivariance solutions for designing new levels of coal mines. *Rudarsko Geolosko Naftni Zbornik*, *35*(2), 23-31. https://doi.org/10.17794/rgn.2020.2.3

24. Wanli, L., Xueliang, Z., & Shibo, W. (2020). Modeling and dynamic correction technology of 3D coal seam model for coal-mining face. *Journal of China Coal Society*, *45*(6). https://doi.org/10.13225/j.cnki.jccs.ZN20.0364

25. Bartoszek, S., Stankiewicz, K., Kost, G., Ćwikła, G., & Dyczko, A. (2021). Research on Ultrasonic Transducers to Accurately Determine Distances in a Coal Mine Conditions. *Energies*, *14*(9), 2532. https://doi.org/10.3390/en14092532

26. Dychkovskyi, R., Falshtynskyi, V., Ruskykh, V., Cabana, E., & Kosobokov, O. (2018). A modern vision of simulation modelling in mining and near mining activity. *E3S Web of Conferences*, (60), 00014. Retrieved from http://ir.nmu.org.ua/handle/123456789/153425

27. Yuan, J., Liu, G., & Chai, S. (2024). 3D geological fine modeling and dynamic updating method of fault slope in open-pit coal mine. *Scientific Reports*, *14*(1), 1-16. https://doi.org/10.1038/s41598-024-81872-3

28. Chen, J., He, Y., Liang, Y., Wang, W., & Duan, X. (2024). Estimation of gross calorific value of coal based on the cubist regression model. *Scientific Reports*, *14*(1), 23176. https://doi.org/10.1038/s41598-024-74469-3

Прогнозування залягання вугільного пласта з використанням чисельних методів і тривимірної геоінформаційної системи

Д. С. Малашкевич, В. В. Руських, В. Ю. Медяник, О. А. Гайдай*

Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна

* Автор-кореспондент e-mail: malashkevych.d.s@nmu.one

Мета. Розробка й застосування методики прогнозування залягання вугільного пласта з використанням чисельних методів інтерполяції та тривимірного геоінформаційного моделювання.

Методика. Дослідження виконане на основі даних геологічної розвідки вугільного пласта c_4^2 шахти «Самарська». Використані чисельні методи інтерполяції та тривимірне моделювання в AutoCAD 3D. На основі геологічних даних виконувалася побудова цифрової моделі рельєфу підошви пласта, визначалися його потужність і зміни товщини по площі. Використовуючи математичні методи, був здійснений аналіз зон потоншання й потовщення пласта, що дозволило визначити об'єми видобутку вугілля, вихід пустих порід і експлуатаційну зольність вугілля.

Результати. У результаті дослідження була побудована тривимірна модель залягання вугільного пласта c_4^2 шахти «Самарська» й визначена його геологічну потужність. Виявлені зони потоншання й потовщення пласта, що дозволило оптимізувати розташування виїмкових стовпів і підготовчих виро-

бок. Проведено розрахунок об'ємів вугілля, що підлягає видобутку, та пустих порід, що присікаються. Визначена прогнозна експлуатаційна зольність вугілля, яка склала 34,4 %, що є важливим фактором для контролю якості видобутої продукції. Отримані дані дозволили оптимізувати параметри очисних робіт, адаптуючи технологічний процес до геологічних умов залягання вугільного пласта.

Наукова новизна. У роботі запропоновано вдосконалений підхід до прогнозування параметрів залягання вугільного пласта із використанням чисельної інтерполяції та тривимірного моделювання, адаптований для умов обмежених геологічних даних. Уперше реалізована поетапна побудова з динамічним оновленням геометрії пласта, що підвищує точність оцінки запасів і ефективність проєктування гірничих робіт.

Практична значимість. Розроблена методика дає змогу мінімізувати витрати на бурові роботи, підвищити точність прогнозування залягання пластів, зменшити ризики й оптимізувати процеси видобутку. Результати можуть бути використані для проєктування технології видобутку на інших шахтах Західного Донбасу, сприяючи підвищенню ефективності гірничого виробництва.

Ключові слова: *прогнозування, вугільний пласт, тривимірне моделювання, інтерполяція, геологічна потужність, видобуток*

The manuscript was submitted 20.03.25.