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ESTIMATION OF COAL RESERVES IN LOWER HORIZONS OF OPERATING MINES TO INVOLVE THEM INTO MINING

Purpose. To assess coal reserves using modern geoinformation technologies to improve the accuracy of quantitative analysis, optimize mining processes, and minimize losses.

Methodology. The study employs computer modeling and geostatistical methods. The research was carried out in several stages to prepare cartographic and factual materials for reserve estimation. All stages were implemented using specialized Micromine software, which is widely used for geological data analysis and field modeling. 3D models of the coal seam were created to analyze its geometric parameters, such as thickness, dip angle, and spatial distribution.

Findings. It was established that the balance coal reserves of the studied area amount to 585.2 thousand tons, of which 493.7 thousand tons are recoverable. Reserve assessment by categories revealed that 355 thousand tons belong to category A (first group of geological complexity), while 230.2 thousand tons fall under category B (second group of geological complexity). 3D models significantly improved the accuracy of coal seam parameter estimation and reduced potential industrial losses of the mineral resource.

Originality. An integrated approach to coal reserve estimation has been developed, considering spatial variations in seam geometry, ash content, and technological parameters. Zones with the highest industrial potential were identified, enabling increased coal extraction efficiency by prioritizing the development of blocks with the highest concentration of recoverable reserves.

Practical value. The proposed solutions reduce coal losses and enhance extraction efficiency through detailed area segmentation block-by-block coal quality forecasting and seam characteristics analysis. The results can be utilized to optimize mining planning, reduce industrial losses, and improve the economic efficiency of coal extraction.

Keywords: *coal reserves, geoinformation technologies, 3D modeling, geostatistics, mining*

Introduction. Globally, the mining and metallurgy industry is experiencing complex changes due to economic and environmental factors [1, 2]. Coal mining, which has long been the mainstay of the energy sector in many countries, faces challenges posed by the global transition to cleaner energy sources [3]. Despite these trends, coal continues to play a significant role in the economies of several countries, particularly those where coal reserves remain extensive, and the use of coal in industry and power generation remains in high demand [4]. Traditional and new coal fields continue to be exploited using underground and open-pit mining methods, while technologies are constantly being improved to increase efficiency and reduce environmental risks [5].

International coal mining projects often focus on implementing innovative resource management methods and optimizing production processes. Significant trends in this area include automation of production operations [6], improved safety systems, and developed resource reserve prediction methods based on modern geological data [7, 8]. At the same time, issues related to coal reserve management and minimizing losses in the mining process are particularly relevant since they directly affect the economic feasibility of field mining and business in general [9].

In recent years, the government in Kyrgyzstan has had to pay great attention to the problem of efficient mining of mineral deposits. Coal exhaustibility requires adopting such design and technological solutions that will ensure maximum extraction from the subsoil, and due to the increase in the cost of capital investments and the growth of current expenses, the issue arises of creating the prerequisites for their reduction. In mining coal deposits with complex conditions of coal occurrence, subsoil users prefer to write off a part of reserves, arguing that it is not economically viable [10]. Such reserves can be categorized as irreplaceable losses of part of the national wealth. It is known that during the construction and operation of the field, especially using the underground mining method, significant capital investments take place. The research objective is to ensure the interests of society, on the one hand, and the subsoil user, on the other hand, that is, to make a decision in which it would be profitable for the latter to mine completely the previously abandoned reserves and reserves classified previously as off-balance reserves [11].

The technical and economic assessment, generally conducted to substantiate the technical and technological solutions applicable in the process of field mining and the feasibility of involving the field reserves in mining, affects the interests of both the subsoil user and the potential investor. Reduction of subsoil losses brings certain benefits to the state in the form of additional tax revenues to different levels of budgets. In case of refusal to continue further mining, license renewal, or bankruptcy of a subsoil user, the state assumes the costs of liquidation [12].

The feasibility of involving the reserves in mining is relevant for existing and planned enterprises. However, the approaches and methods of such assessment have several differences related to the degree of exploration of reserves and technical and technological decisions taken at the planning and exploitation stages [13]. Estimating reserves necessitates assessing the field from the time of planning until its closure, which is associated with complete mining, including post-exploitation activities.

In summary, the coal mining industry is undergoing significant transformations driven by economic pressures and the global transition towards cleaner energy sources. Despite these challenges, coal remains a critical resource for several economies, necessitating the development and implementation of innovative approaches to optimize resource utilization and minimize environmental impacts. The unique conditions in Kyrgyzstan highlight the importance of ensuring efficient resource management and reducing losses during mining operations, particularly for reserves previously classified as economically unviable. Addressing these issues requires a comprehensive technical and economic assessment of coal reserves throughout the lifecycle of mining operations, from planning to closure. By integrating advanced technological solutions and adopting sustainable mining practices, it is possible to balance the interests of subsoil users, the state, and society, ultimately promoting the efficient use of coal reserves and minimizing their irreplaceable losses.

Literature review. Current scientific research is focused on several key issues related to the mining of coal reserves. They include:

- studies aimed at hydro- and geological-technological assessment of fields and substantiation of their mining, based on the methodology of feasibility study of conditions [14, 15];
- studies on economic assessment of fields in the process of their exploitation, including analysis of the economic feasibility of mining separate local areas using the geomechanical assessment methodology [16, 17];
- studies on the potential of coal-mining regions and their adaptation to actual conditions [18];
- studies on the feasibility of rational schemes for stripping, preparing, and mining new horizons of active mines, taking into account the complex conditions of seam occurrence, applying the methodology for calculating the efficiency of investment projects [19, 20];
- studies aimed at assessing the efficiency of introducing new types of equipment and technology [21, 22].

The problems were either related to the technological aspects of coal mining or to the economic aspects of coal mining. Accurate quantification of coal reserves when assessing reserves to substantiate the feasibility of involving them in mining and the feasibility study of exploration and operational conditions could have significant errors. Thus, the principle of comparability of assessment results for different purposes was violated, resulting in unreliable estimates.

This necessitates the creation of an approach based on unified criteria for assessing coal reserves of fields, which can solve these problems. There is a need for tools that would link mining-geological conditions of occurrence, mining-technological parameters of stripping, preparing and mining schemes, and parameters of technological processes through the use of modern geoinformation technologies, that is, the construction of a 3D geometric model of the field based on drilling data and geophysical surveys.

Unsolved aspects of the problem. While the presented 3D models and reserve estimations provide detailed insights into the geometry, categorization, and spatial distribution of coal reserves in the "F" seam, several significant challenges remain unresolved, limiting the entire understanding of the seam's potential. One of the key issues is the presence of geological uncertainties that may affect mining efficiency. Despite the high resolution of the constructed models, minor faults, discontinuities, and other heterogeneities that may not have been detected during geological exploration could impact reserve accessibility and operational safety. Advanced geophysical methods, such as seismic or electromagnetic surveys, could provide a more detailed understanding of the seam structure and enhance the accuracy of reserve estimation.

Another unresolved aspect is the dynamic behavior of groundwater within the mining area. While the study identifies the presence of Jurassic aquifers and estimates water inflows to be up to 25 m^3/hour, the models do not simulate how groundwater might behave over time during active mining. This omission could hinder the development of an effective drainage system and increase operational risks. Developing a hydrogeological model incorporating temporal changes in water inflow would allow for better planning of drainage measures and ensure safer working conditions. Additionally, the broader environmental impacts of mining the "F" seam require further investigation. The study focuses primarily on resource quantification and operational planning; however, potential issues such as land subsidence, groundwater contamination, and air pollution due to the spontaneous combustion of coal remain insufficiently addressed. These environmental considerations are critical for developing sustainable mining practices, especially in light of growing regulatory pressures and societal concerns.

Finally, while the models assume the use of conventional mining technologies, the integration of advanced systems such as automation and real-time monitoring has not been explored. Such innovations could improve operational safety and efficiency and reduce losses and environmental risks. Furthermore, incorporating economic simulations into the analysis could provide a more comprehensive understanding of the financial viability of mining under different market conditions, particularly in the face of fluctuating coal prices and evolving energy policies.

Addressing these challenges will enhance the reliability and applicability of the proposed methods while contributing to the development of safer, more efficient, and environmentally sustainable mining operations for the "F" seam. These unresolved aspects highlight the need for future research to refine current methodologies and incorporate innovative technologies into the planning and operational processes.

This research aims to develop a unified methodological approach to accurately quantify coal reserves, taking into account the geological conditions of coal seam occurrence, such as thickness and inclination angle.

Study area. The research object, considered for subsequent underground mining, is the "F" seam coal reserves located in the local area of the south-western flank of site No. 12 of the Sulukta lignite deposit [23]. This site has been selected due to its potential economic significance and geological conditions favorable to underground mining. Coal reserves within this site have significant industrial potential and require detailed analysis to determine the feasibility of their further mining.

The boundaries of the stripped area were delineated as follows:

1. The northern boundary of the local area runs along estimated block B-41-1, located near exploration well No. 1189.
2. The western boundary runs along the seam hypsometry on a horizon of 1,220 m and is close to exploration well No. 1251.
3. The area's eastern boundary is set by seam hypsometry on a horizon of 1,280 m, next to exploration well No. 1209.
4. The southern boundary passes through estimated blocks A-39-2 and A-39-1.

The length of the area planned for mining along the strike of the seam is 283 m. The width of the dip of the seam is 192 m, indicating that significant coal reserves are available for underground mining.

The "F" seam occurrence within the study mining area ranges from 190 to 260 m, with an average depth of about 225 m. The seam is characterized by stability and consistency of occurrence, with a dip angle varying from 10 to 18º. The average seam thickness is 8.76 m, indicating its significant industrial potential. According to the results of geological additional exploration, the seam does not show any disturbance, confirming its stability and endurance.

The coal is characterized by its tendency to spontaneously combust, requiring increased attention to safety measures during its mining. The mine is additionally classified as hazardous by coal dust explosion, which necessitates strict compliance with anti-explosion measures and control of the state of the atmosphere in mine workings.

Geological surveys have also revealed the presence of groundwater in Jurassic sediments, which requires consideration of hydrogeological conditions when designing drainage systems and ensuring safe working conditions at depth.

In the mines of the field located at a depth of 200–300 m, the water inflow into the mine workings did not exceed 25 m^3/hour. Water inflows within this mining area are also expected to be within the same limits, requiring a sustainable drainage system to be organized to maintain safe working conditions.

Seam "F" within the mining allotment has a medium complex structure. This is expressed in the dip angle variability, which gives the seam an irregular shape. The seam has an average thickness of 8.76 m, which is of interest for further mining despite the complex geometric conditions. Depleting preparatory drifts will conduct stope operations in the area with an inclination angle of up to 1°. This will be achieved by driving a face entry to the seam rise and then depleting it on the return drive. It is calculated that the operational losses at this stage will be 13.98 %. Seam "F" will be mined in stages. Each seam block will be mined separately, which will optimize the mining process and ensure safe operations. The initial block is mined first, and then the next block is mined with a 15–20 m lag. This staged approach to mining ensures gradual and safe exploitation of coal reserves, minimizing losses and reducing the risks of emergencies.

Methods. Modern methods such as computer modeling and geostatistical analyses are used to estimate coal reserves accurately and in detail, which significantly improves the accuracy of estimates and optimizes the calculation process [24, 25]. These innovative approaches provide in-depth analysis of large data sets and reveal complex relationships specific to coal fields. They allow modeling spatial changes in the coal seam geometry, which is especially important when its thickness and dip angle are varied.

Coal reserve estimation relies on fundamental volumetric calculations refined by integrating geometric and density parameters. The formula for coal reserve estimation for a specific block is given by

$$R_i = A_i \cdot T_i \cdot \rho \cdot (1 - L),$$

where R_i is reserves of block, tons; A_i is the true plan area of block i, m^2; T_i is seam thickness for block i, m; P is Unit specific gravity, tons/m^3; L is operational losses (fraction, e.g., 0.1398 for 13.98 %).

This approach allows the integration of variable seam thickness and losses due to mining inefficiencies.

Geostatistical methods such as variogram modeling and kriging are applied to account for seam thickness variability and ash content variability. The spatial structure of seam thickness, $T(x, y)$, is modeled using a variogram

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[T(x_i) - T(x_i + h) \right]^2,$$

where $\gamma(h)$ is variogram value for lag h; $N(h)$ is the number of data pairs separated by h; $T(x_i)$ is the thickness value at location x_i; $T(x_i + h)$ is thickness value at location $x_i + h$.

The variogram provides insights into the spatial continuity of seam parameters and is used for kriging interpolation.

The coal seam thickness at an unknown location, $T^*(x)$, is estimated using ordinary kriging interpolation

$$T^*(x) = \sum_{i=1}^{N} \lambda_i \cdot T(x_i).$$

Subject to the condition

$$\sum_{i=1}^{N} \lambda_i = 1,$$

where $T^*(x)$ is the estimated thickness at location x; λ_i is kriging weights for each sample point i; $T^*(x_i)$ is the measured thickness at sample point i.

The weights λ_i are derived by solving the kriging system based on the variogram model.

To improve the precision of reserve estimation, the coal seam is segmented based on thickness and ash content. Each segment, j, is categorized using the following formula

$$R_j = \sum_{i=1}^{N} (A_{ij} \cdot T_{ij} \cdot \rho \cdot (1 - L)),$$

where R_j is reserved for segment j; A_{ij} is an actual plan area of block i within segment j; T_{ij} is the thickness of block i within segment j.

Ash content (A_c) is classified into intervals using a step of 5 %

$$A_c \in \{[0, 5], [5, 10], ..., [40, 45],\}.$$

This segmentation ensures that reserves are classified by their suitability for industrial use.

The 3D modeling process uses geometric and geostatistical parameters to create a block model. The reserve volume (V) for each block is calculated as

$$V = \int_A \int_T f(x, y, z) dxdydz,$$

where $f(x, y, z)$ represents the coal seam thickness over the spatial domain A.

The integration is performed numerically within Micromine using block-modeling techniques, which automate the process of spatial segmentation and volume calculation.

To quantify uncertainty, a range of possible reserve values is calculated using Monte Carlo simulation

$$R_{sim} = R \cdot (1 + \varepsilon),$$

where R_{sim} is simulated reserve; $\varepsilon \sim N(0, \sigma^2)$ is a random error modeled as a normal distribution with mean zero and variance σ^2.

This approach provides a confidence interval for reserve estimates, enhancing the reliability of results.

The following key stages have been accomplished in the course of the research process:

1. Modeling spatial variations in dip angle and seam thickness to more accurately reflect seam characteristics.
2. Quantitative assessment of errors: determining the range of possible reserve values, considering uncertainties in the input data and models constructed.
3. Consideration of risks associated with data uncertainty has allowed for more informed decisions in mining the field and managing its reserves.

The initial data for coal reserve modeling and estimation was provided by a catalog of drilling-mining operations, which contains detailed information on the geological characteristics of the seam, including data on thicknesses, dip angles, and geometry of coal seams obtained during drilling-mining operations. Data from the catalog of drilling-mining operations were used to construct 3D field models, which provided a more accurate assessment of the change in seam parameters and estimation of coal reserves, considering all spatial peculiarities.

The research objective is to estimate coal reserves accurately by blocking coal seam reserves by category. Each block was divided into segments with coal seam thickness intervals every 0.5 m, accounting for 100 % blockage by rock interlayers. This allows for a more accurate estimation of coal volumes suitable for mining. For each of the obtained segments, the division was made by ash content intervals from 0 to 45 % with a step of 5 %, which is essential for assessing coal quality since ash content directly influences its suitability for industrial use. The resulting isohypsum map, which previously represented a block of reserve estimates, has been divided into technical coal grades based on coal characteristics and composition. This division allows coal to be classified according to its industrial value and purpose.

After all these operations, a separate estimation of coal seam reserves was made for each category, considering all the above-mentioned parameters. Such a detailed approach makes it possible to significantly improve the accuracy of coal reserve assessment and make informed decisions on further field mining.

The stages of cartographic and factual material preparation for reserve estimation were performed using Micromine software, which provides a wide range of tools for working with geological data and field modeling. Micromine automates the reserve estimation process using various modeling and calculation methods, thereby increasing accuracy and reducing error probability.

In addition to the segmentation based on coal seam thickness and ash content, using geostatistical methods in Micromine further enhances the precision of the reserve estimation process. By applying variogram modeling and kriging techniques, spatial relationships between coal seam properties, such as thickness and ash distribution, can be accurately represented. This advanced spatial analysis provides a more detailed understanding of coal deposit variability and helps identify areas with higher industrial potential and lower extraction costs. Such geostatistical methods ensure that the estimation is grounded in a robust statistical framework, contributing to more reliable resource management and strategic mine planning.

Results and discussion. Micromine software has automated and simplified many processes, providing high accuracy of coal reserve estimation and the possibility to analyze further and use them.

The methods described in the previous section have resulted in highly detailed 3D models of the coal seam, which not only improve the accuracy of reserve estimation but also allow better prediction of changes in thickness and inclination of the seam in space, which is critical for planning practical mining. The approach makes it possible to reduce operational losses and improve the quality of mining planning, making it an essential tool in today's mining environment.

The conducted modeling and analysis of the spatial change in the dip angle and seam thickness made it possible to create 3D models that demonstrate the peculiarities of coal seam occurrence (Figs. 1 and 2). These models show that the coal seam has a complex structure with changing geometric parameters, confirming the need for an individual approach to each blocking and interval.

The 3D model of the seam surface shown in Fig. 1 highlights the spatial geometry and variability of the "F" seam, which is critical in planning mining operations. The seam exhibits a dip angle ranging from 10 to 18°, indicating moderate structural complexity. This variability requires tailored mining strategies to ensure stability and efficiency during extraction. Additionally, the seam thickness is consistent across the area, averaging 8.76 m, which is favorable for industrial-scale mining. These characteristics emphasize the potential for economically viable extraction with minimal operational adjustments.

Fig. 2 demonstrates the estimated blocks within the "F" seam, providing a detailed breakdown of coal reserves. The segmentation of the seam into distinct blocks enables precise categorization of reserves, with 355 thousand tons classified as category *A* (fully explored and reliable) and 230.2 thousand tons as category *B* (preliminarily explored). The spatial distribution of these reserves identifies key areas with higher resource concentrations, such as block A-42, which contains approximately 164.5 thousand tons. These insights are essential for prioritizing mining activities in blocks with the most significant economic potential.

The 3D models presented in Figs. 1 and 2 also reveal the operational efficiency of the proposed mining approach. Replying reserves constitute 84.3 % of the balance reserves, confirming that the detailed modeling minimizes operational losses and optimizes the utilization of available resources. The visualized block segmentation further enables the design of a stepwise extraction process, which ensures safety and stability by minimizing disruption to the seam's structure.

In addition to supporting efficient resource extraction, the models address critical safety and hydrogeological considerations. Jurassic aquifers within the mining area are indirectly reflected in the seam geometry, underscoring the need for sustainable drainage systems to handle anticipated water inflows of up to 25 m^3/hour. Furthermore, risks of areas prone to spontaneous combustion or coal dust explosion are identified through the models, reinforcing the necessity of robust safety protocols. Overall, the 3D modeling approach demonstrates its value in improving coal reserve estimation, enhancing the precision of mine planning, and ensuring safer and more efficient mining operations.

As a result of the conducted research and preparatory work on coal reserve estimation in the "F" seam of the south-western flank of site No. 12 of the Sulukta lignite deposit, significant results have been obtained, allowing essential conclusions to be drawn on the state of reserves and their feasibility for further mining.

The balance reserves of the seam, planned for involvement in mining, amounted to 585.2 thousand tons, of which 355.0 thousand tons belong to category *A* and 230.2 thousand tons – to category *B*. Recoverable reserves in categories *A* and *B* amount to 493.7 thousand tons, which confirms the availability of significant resources for economically efficient mining. The reserve recovery efficiency (K_r) is 84.3 %. Data on estimated balance reserves are presented in Table.

The data presented in Table 1 reflects the distribution of reserves by blocks and categories and considers geometric parameters such as dip angle, seam thickness, volume, and unit-specific gravity. Reserves and seam thickness by block are presented in Fig. 3.

The chart in Fig. 3 illustrates each block's reserves and seam thickness. The blue bars represent the coal reserves in each block, while the orange line with markers indicates the seam thickness. This dual visualization highlights how seam thickness correlates with the quantity of reserves, enabling a deeper understanding of the resource distribution and prioritization of blocks for mining operations.

The appropriate categories were identified after a detailed analysis and categorization of the reserves. Category *A* coal reserves (355.0 thousand tons) are thoroughly explored mineral resources where the bodies' boundaries, shape, and structure are entirely determined. The types and industrial grades of raw materials

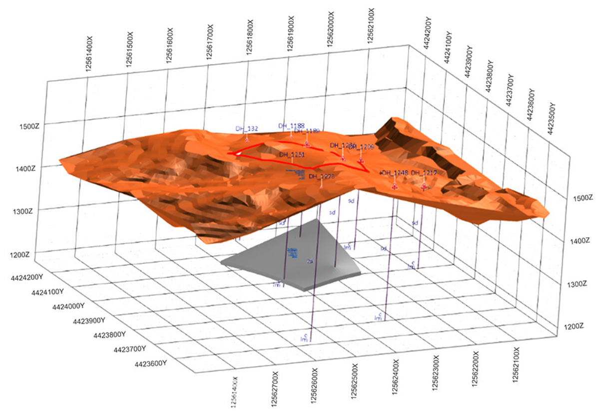

Fig. 1. 3D model of the seam surface involved in mining

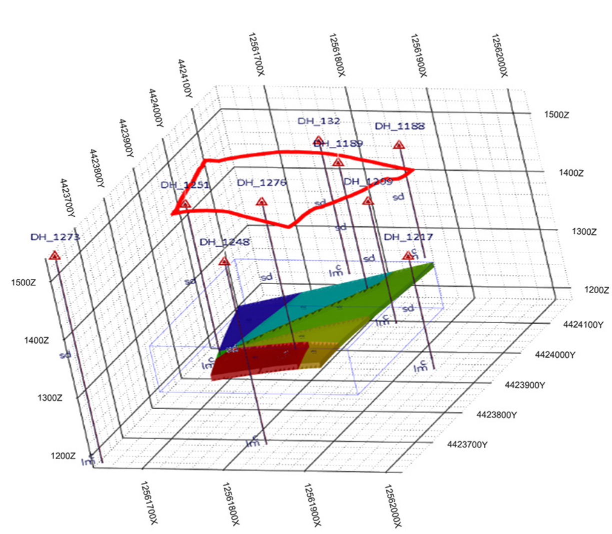

Fig. 2. 3D model of estimated blocks in "F" seam

Table

Estimation of balance reserves of the south-western flank of minefield No. 12, planned for involvement in mining by blocks and categories

Block No.	Area in plan, m^2	Dip angle (secant)	True area, m^2	Seam thickness, m	Volume, m^3	Specific gravity, tons/m^3	Reserves, tons
A-39-1	8,432.50	1.03	8,725.87	9.37	81,761.44	1.25	102,201.80
A-39-2	1,952.24	1.02	1,986.60	9.37	18,614.44		23,268.05
A-40	6,160.65	1.02	6,300.42	8.26	52,041.46		65,051.82
A-42	15,844.70	1.03	16,366.11	8.04	131,583.54		164,479.42
B-25	220.12	1.03	226.84	9.95	2,257.10		2,821.37
B-41-1	12,543.04	1.04	12,994.76	8.16	106,037.23		132,546.54
B-41-2	8,980.24	1.04	9,303.04	8.16	75,912.81		94,891.01
Total							585,260.01
Including *A* Category							355,001.09
Including *B* category							230,258.92

and the geologic factors influencing their mining conditions are also known. Category *B* coal reserves (230.25 thousand tons) are preliminarily explored reserves where the contours of mineral bodies are approximately determined. Still, the exact spatial position of natural types of raw materials is not shown.

The industrial coal reserves in the study area were determined using two different methods, which allows for a more accurate assessment of their volume and characteristics.

The first method analyzes the area where the reserves amount to 475.8 thousand tons. This approach includes measurements and calculations related to the geometric parameters of the area, which provides a sufficiently accurate estimate of reserves. However, there may be errors in this method due to simplifications in the consideration of geological-technological factors.

The second method, which uses horizons for mining, shows a slightly higher reserve value of 476.3 thousand tons. This approach considers the area and the spatial location of coal layers, their thickness, and other parameters, which increases calculation accuracy.

A comparative analysis of the results obtained by the two methods shows that the difference between them is 512.7 tons, equivalent to a 0.1 % discrepancy. This minimal discrepancy indicates the high reliability of both methods, which makes it possible to confidently assume that the value of industrial reserves calculated by the

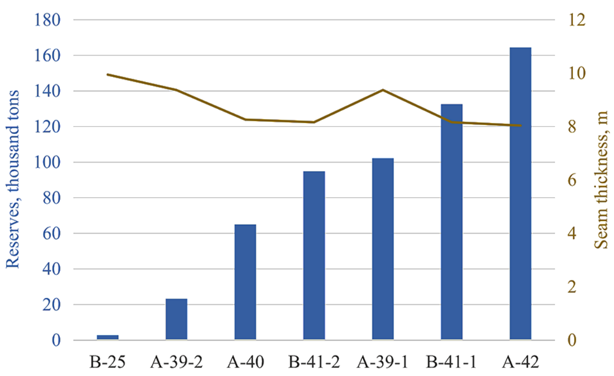

Fig. 3. Reserves and seam thickness by block

second method equals 476.3 thousand tons. Thus, the selected reserve volume will be used for further planning of the field mining, which includes assessment of economic feasibility, selection of mining technologies, and design of mine workings.

Comparing the data with the results of other researchers, it can be noted that coal reserves estimated using similar methods range from 500 to 600 thousand tons for coal fields with comparable geological conditions. For example, studies conducted in the fields of Ukraine show similar volumes of reserves, and the quality of coal is also high. It is also worth noting that the applied reserve estimation and analysis methods, such as computer modeling and geostatistical approaches, reflect trends in the mining industry [26]. The studies [27] emphasize using 3D modeling to identify reserves better and develop efficient mining schemes. For example, research conducted in Poland demonstrates that using geoinformation technologies has increased the accuracy of reserve estimation by 15–20 % compared to traditional methods.

The results confirmed compliance with modern methods and trends in the coal mining field. The comparisons not only strengthen the reliability of calculations but also serve as a basis for further research and optimization of coal mining processes, which, in turn, will contribute to improving the efficiency and safety of the coal mining industry.

Using innovative technologies such as remote sensing [28] and unmanned aerial vehicles [29] can significantly improve the quality of geological exploration and make it possible to obtain more detailed data on the geological structure of fields. It is also important to consider recent advances in computer engineering [30, 31]. This, in turn, can lead to more accurate models that help improve planning processes [32]. Thus, the integration of the results of this research with existing data from other researchers, as well as the application of modern technologies, creates a foundation for improving coal mining processes.

Conclusions. The obtained results confirm the expediency of involving coal reserves of "F" seam into mining. The use of modern methods for reserve estimation and analysis, as well as detailed blocking by categories, allows one not only to reliably quantify available resources, but also to create a theoretical basis for effective management of their mining processes. These methods contribute to a better understanding of geologic conditions, which can minimize the risks associated with coal mining and increase the safety and sustainability of mine operations.

Further research and implementation of innovative technologies can significantly optimize mining processes and improve the overall efficiency of the coal mining industry. The creation of computer models for predicting reserves and developing optimal mining schemes provides an opportunity to make informed decisions on further development of the mine. This will make it possible to select the most adequate mining schemes, reduce production costs, and assess the long-term prospects of the field development.

Estimating coal reserves is a dynamic and iterative process that requires regular updating of data to reflect new geological studies and changes in the mining-geological and mining-engineering environment. This approach ensures the relevance and reliability of information, which is critical for efficient coal field operation.

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Оцінка запасів вугілля на нижніх горизонтах діючих шахт для їх залучення у процес видобутку

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Мета. Оцінка запасів вугілля з використанням сучасних геоінформаційних технологій для підвищення точності кількісного аналізу, оптимізації процесів видобутку й мінімізації втрат.

Методика. У роботі застосоване комп'ютерне моделювання й геостатистичні методи дослідження. Дослідження виконувалось у декілька етапів, що були спрямовані на підготовку картографічного й фактичного матеріалу для оцінки запасів. Усі етапи реалізовані із використанням спеціалізованого програмного забезпечення Micromine, що широко застосовується для роботи з геологічними даними та моделювання родовищ. 3D-моделі пласта були створені для аналізу геометричних параметрів пласта, таких як потужність, кут падіння та просторовий розподіл.

Результати. Встановлено, що балансові запаси вугілля досліджуваної ділянки становлять 585,2 тис. тон, із яких 493,7 тис. тон придатні до видобування. Оцінка запасів за категоріями показала, що 355 тис. тон належать до категорії А (перша група складності геологічної будови), а 230,2 тис. тон – до категорії В (другої група складності геологічної будови). Використання 3D-моделей дозволило значно підвищити точність оцінки параметрів пласта й знизити можливі промислові втрати корисної копалини.

Наукова новизна. Розроблено інтегрований підхід до оцінки запасів вугілля, що враховує просторові варіації геометрії пласта, зольності й технологічних параметрів. Визначені зони з найвищим промисловим потенціалом, що дозволяє підвищити ефективність видобутку вугілля шляхом пріоритетного розроблення блоків із найбільшою концентрацією видобувних запасів.

Практична значимість. Запропоновані рішення дозволяють знизити втрати вугілля й підвищити ефективність його видобутку за рахунок детального блокування ділянки та аналізу характеристик пласта. Результати можуть бути використані для оптимізації процесів планування видобутку, зменшення промислових втрат і покращення економічної ефективності видобутку вугілля.

Ключові слова: *запаси вугілля, геоінформаційні технології, 3D-моделювання, геостатистика, видобуток*

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