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CHANGES IN THE GEOLOGICAL ENVIRONMENT IN THE TERRITORIES OF MINING ACTIVITIES WITHIN PAVLOHRAD-PETROPAVLIVKA GEOLOGICAL AND INDUSTRIAL AREA

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ЗМІНИ ГЕОЛОГІЧНОГО СЕРЕДОВИЩА НА ПІДРОБЛЮВАНИХ ТЕРИТОРІЯХ В МЕЖАХ ПАВЛОГРАДСЬКО-ПЕТРОПАВЛІВСЬКОГО ГЕОЛОГО-ПРОМИСЛОВОГО РАЙОНУ

Purpose. The aim of the study is to determine the most vulnerable mine of DTEK PAVLOHRADCOAL PRJSC to hazardous processes based on the analysis of existing processes caused by coal mining activities in the Pavlohrad-Petropavlivka geological-industrial area, with the goal of comparing it to mines with similar technical parameters that have experience in analyzing hazardous geological processes.

The methods. A combined approach has been applied to forecast changes in the geological environment of mine fields, incorporating methods like scientific research analysis, technical documentation, and comparative analysis. This approach identifies recurring patterns in similar geological and technical conditions, drawing from past events. The final stage, comparative analysis, helps develop typical scenarios for geological process evolution, enhancing the accuracy of forecasts regarding potential changes in the geological environment.

Findings. The analysis of common features in mine field studies has made it possible to form typical scenarios for the development of geological processes, improving the accuracy of forecasts of possible changes in the geological environment. Based on this, the dependence of mine parameters on the area and intensity of the development of hazardous engineering-geological processes on the earth's surface has been determined.

The originality. A systematic approach is proposed for the first time, which evaluates recurring patterns in similar conditions, using the experience of past events to forecast hazardous changes in the geological environment within coal mining activities. The relationship between mine parameters and the development of hazardous engineering-geological processes above the mine fields has been determined.

Practical implementation. The obtained data can be used for developing risk management strategies at mining enterprises, as well as for environmental and geotechnical studies on the impact of mining activities on the surrounding environment. It can also help in developing measures to minimize their impact and planning safe mining operations while considering potential risks that threaten public safety.

Keywords: *coal mine, geological environment, engineering-geological processes, negative impact, subsidence.*

Introduction. Coal mining gives rise to changes in the geological environment, which increases the risk of engineering and geological processes in the uppermost layer of soil caused by coal mining. It is a fairly common problem in many coal mining areas of different countries, namely, in South Wales in Great Britain, Beipiao in China, northwestern Poland, the Greater Region of Luxembourg situated along the French-German border and the Ruhr Region in western Germany [1–6].

The most frequently occurred engineering and geological process that develops due to coal mining is the subsidence of the ground surface, which takes place in several stages: primary, secondary and residual. The primary subsidence occurs during coal mining operations, which are the result of the mining of long coal faces. Secondary subsidence includes weathering, destruction, cracking of the rock mass under the impact of underground water, which can lead to a gradual decrease in the strength of fastening in the mine workings, which occurs after the completion of mining operations due to the destruction of solid blocks. The destruction of one block leads to overloading, and subsequently to the destruction of neighboring solid blocks, which progresses until coal mining stops [7]. Deformation of the hanging wall occurs starting from the level of mine workings up to the surface. Subsidence in mine workings is not a fixed process, as it varies depending on the mining area and its environment. The last process is a residual slumping, which make occur over time in locations with subsidence previously observed, which was the result of deformation and the action of prolonged loading on the mined area [8–9].

Subsidence of soil in disturbed rock mass in the area of slopes leads to the development of a high speed in landslides, which occur mainly due to loss of strength. In most cases, landslide development was observed in loess soils, due to their loose structure, which was manifesting mainly on slopes. The underlying cause of this instability is often related to the physical properties of the soil and external factors like weather changes. Due to a decrease in adhesion and the angle of internal friction, the stability of the rock mass deteriorates, with a slide of bedrock gradually developing on the slope surface, and under the impact of heavy precipitation, landslides may be caused by four basic mechanisms, such as loosening of soil, heavy precipitation, riverbed rise and flooding of reservoirs [10]. The stability of loess soils and the tendency to collapse under the impact of water infiltration is significantly affected by the chemical dissolution of particles during internal erosion [11].

A map of the study area with existing hazardous engineering-geological processes and the technogenic environment was created using the geoinformation software (GIS) ArcMap, along with a geological environment boundaries cut-line A–B generated in AutoCAD based on materials processed from the Ukrainian State Geological Survey Institute, the Department of Ecology and Natural Resources of the Dnipropetrovsk Regional Military Administration, Ecological passport of the Dnipropetrovsk region for 2022 of the Dnipropetrovsk regional military administration and the State Scientific-Industrial Enterprise “Geoinform of Ukraine.” Specifically, geological maps at a scale of 1:200,000 and a map of exogenous geological processes within the Dnipropetrovsk oblast were utilized [12–17].

For the comparative analysis, data from technical documentation and departmental research on the activities of the Zakhidno-Donbaska Mine of DTEK PAVLOHRADCOAL PRJSC, as well as Mine №5, western part of the Illinois Basin, Sangamon County, the Central Illinois, the United States and mine №11 of Nord-Pas de Calais Mining Basin, Lens [18–22].

Results. DTEK PAVLOHRADCOAL PRJSC is one of the largest coal mining enterprises in Ukraine, engaged in the coal mining of the Donets Basin (Dnipropetrovsk Oblast) on the territory of the Pavlohrad-Petropavlivka coal field of the eastern part of the Western Donbas. The association consists of 10 mines, with five mine administrations and structural subdivisions as follows: Ternivske including Zakhidno-Donbaska and Samarska mines; Dniprovske including Dniprovska and M.I. Stashkova mines; Pavlohradske including Pavlohradska and Ternivska mines; Heroiv Kosmosu including Heroiv Kosmosu and Blahodatna mines; Pershotravenske including Yuvileina and Stepova mines (fig. 1).

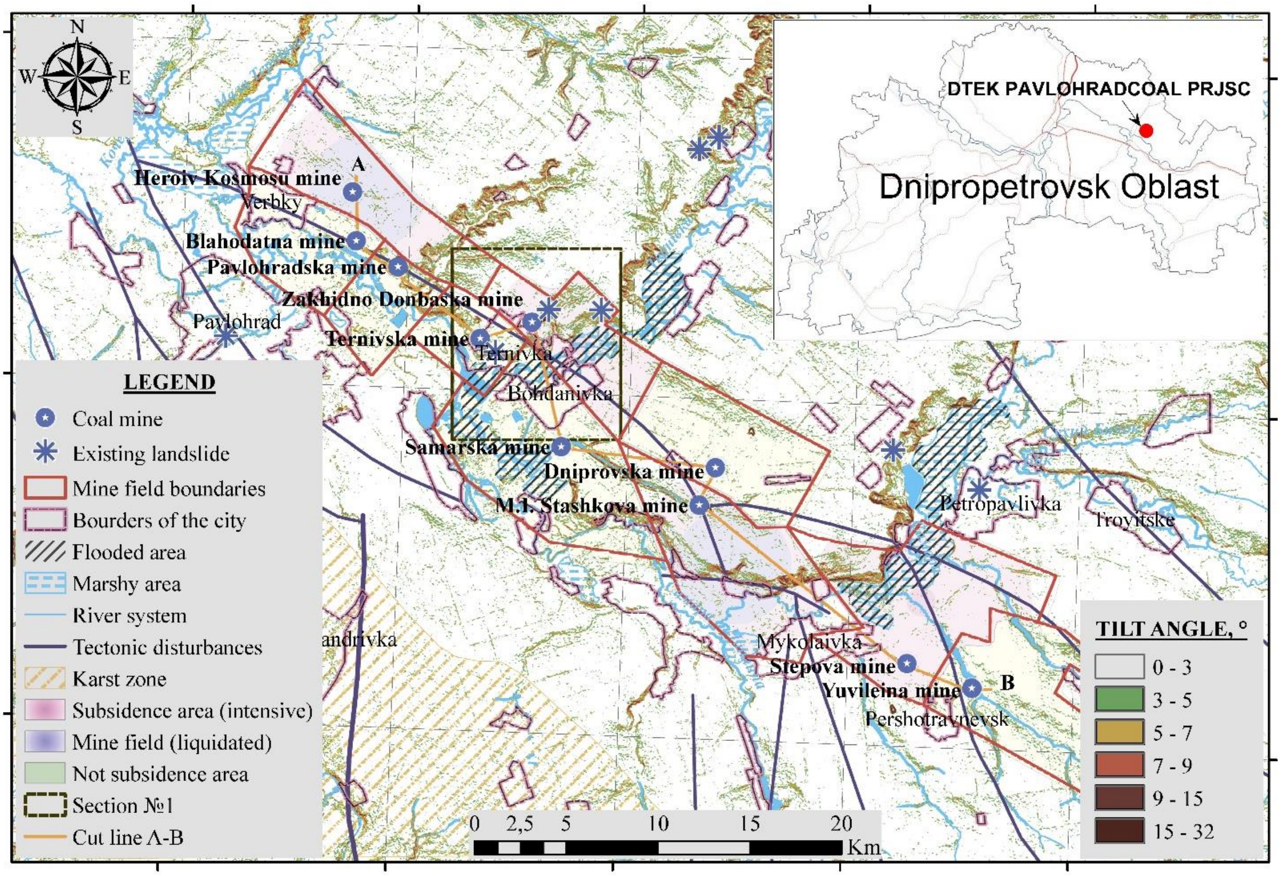

Fig. 1. Diagram of the territory under research,
Pavlohrad-Petropavlivka geological and industrial area

On waste rock dumps formed due to coal mining, the slope varies between 20–49°. If the slope of the surface ground, which is composed of loess soils, exceeds 5°40’, it is necessary to take into consideration the risks of shears [23]. The territory is divided by a dense system of rivers, gullies and ravines. There are forests and swamps in the valleys of Samara and Ternovska rivers, with a strip of sand up to 8 km wide running along Vovcha River.

The area of urbanised territories makes up 264.65 km^2 (it includes 76 localities), the largest town within the area is Pavlohrad, which has rather heavy man-made burden, due to the presence of industrial sites, such as a chemical plant, an airport and railway junctions. Industrial reserves of DTEK PAVLOHRADCOAL PRJSC amount to 699.2 mln tons with mine fields covering the area of 495.4 km^2, taking into account the average daily capacity of coal mining enterprises, the average estimated life of mines is 59 years (fig. 2).

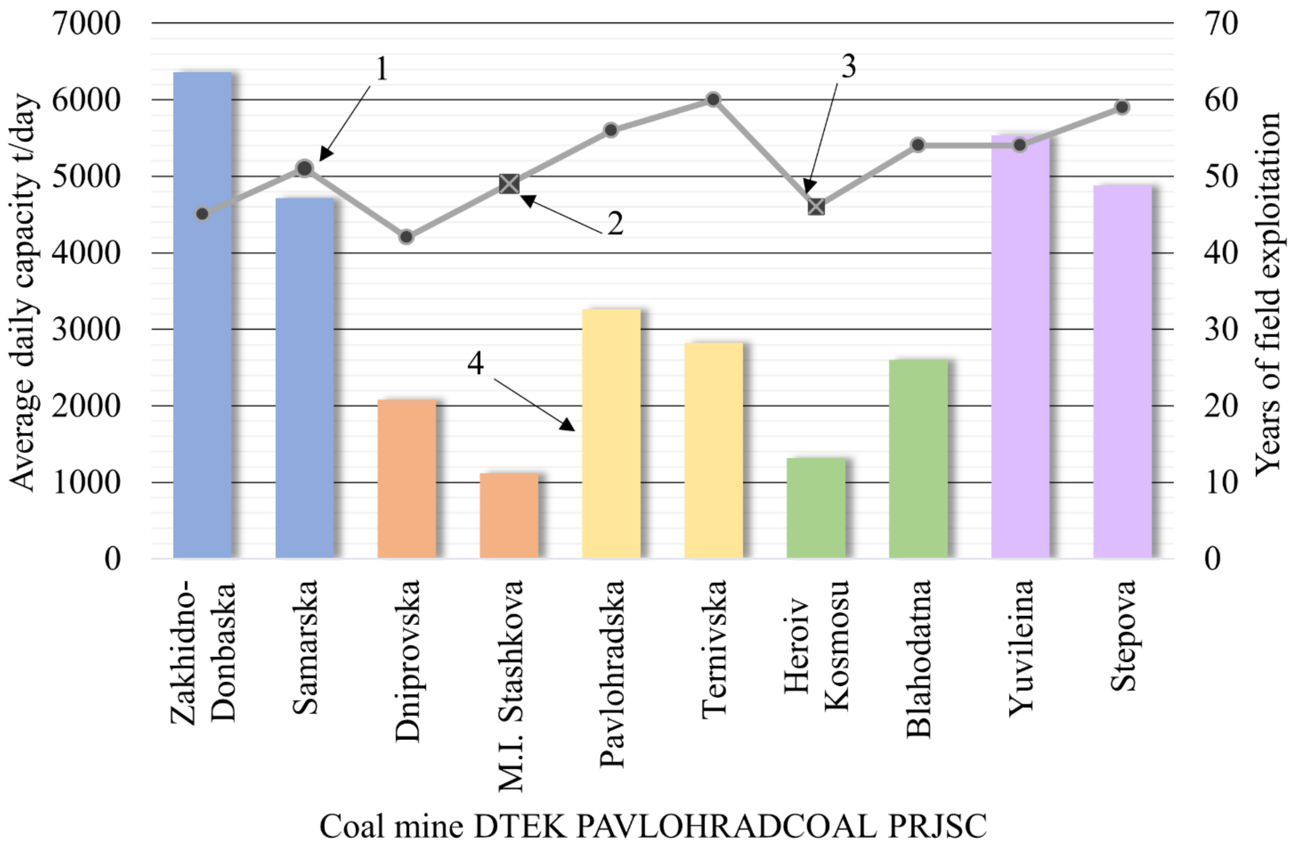

Fig. 2. Analysis of mining dynamics in the territory under research: 1 – active mines; 2 – abandoned mines; 3 – diagram of operation duration (years); 4 – average daily capacity, mines of one structural subdivision are denoted by the same colour (Ternivske is blue, Dniprovske is orange, Pavlohradske is yellow, Heroiv Kosmosu is green, Pershotravnevske is purple)

Coal extraction causes a disturbance of the rock mass stability, the formation of extra cavities (robbed-out space) in the volume of 1.4–1.8 million m^3 annually, which are being filled naturally due to subsidence and solidification above the layer.

According to the reference yearbook on the activation of dangerous exogenous geological processes for 2020, the area of the site that is prone to subsidence due to intense coal mining makes up 109 m^2, which is equal to the area of the mine fields of Zakhidno-Donbaska and Yuvileina coal mining enterprises.

We have found out that not far from the mine field of Zakhidno-Donbaska Mine the intensification of landslides is observed, therefore, for a more detailed overview, we have built a section of the development of engineering and geological processes within the framework of activities of coal mining (fig. 3) [24].

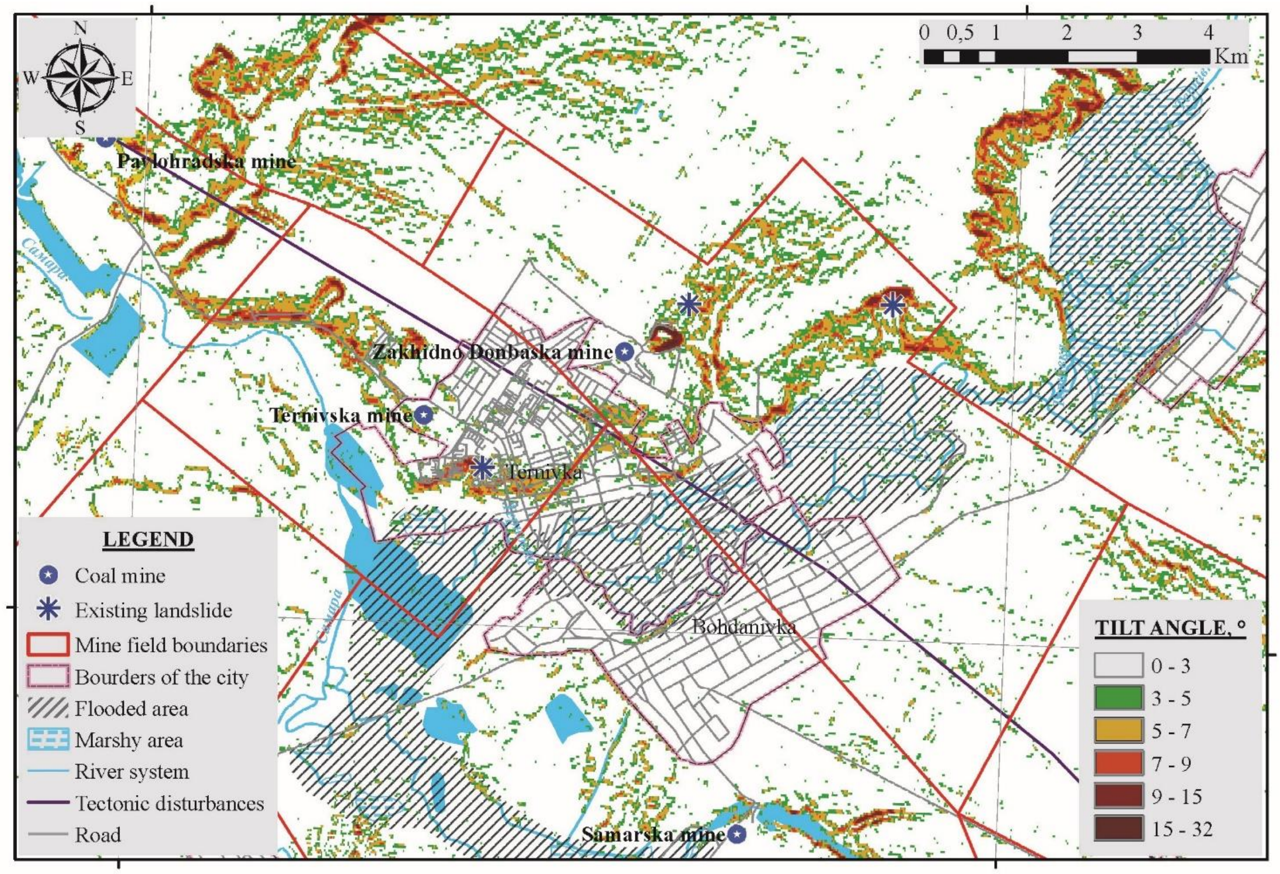

Fig. 3. Section № 1. Development of engineering and geological processes within the framework of coal mining enterprises

In Pavlohrad Region, in the section of Ternivka Town – Bohdanivka Village, flooding is caused by mining operations and the discharge of water from Ternivska and Zakhidno-Donbaska mines, site development carried out on the floodplain of the Ternivka River and siltation of its channel. Due to the subsidence of the ground where mining operations had been carried out, the ground water level rose, with wetlands formed in some places.

The section within Ternivka Village and Bohdanivka Village is prone to the development of engineering and geological processes, as it is the location of Ternivska and Zakhidno-Donbaska mines, with waste rock dumps developed next to them due to the intense activity of enterprises. The Ternivska River flows through these localities and connects to the Samara River, with a swampy area developed around. The slope in river valleys reaches 12°, with the slope of dump being 32° [16–17]. Taking into account the above information and considering the data of the reference yearbook for 2020 on the activation of dangerous exogenous geological processes, the territory of Zakhidno-Donbaska Mine, which will be the target of research, is most prone to the development of engineering and geological processes. The production capacity of Zakhidno-Donbaska Mine is 6356 tons/day with a mine field area making up 39 km^2, which makes it more productive than others. As of 2022, the total area of territories of the mine with mining operations carried out is 22 million m^2, the width of the mining area exceeds 11 km in terms of rock extension and 3 km in terms of rockfall, with the total length of existing underground mine workings making up 94.8 km. The enclosing rocks are unstable in the hanging wall in the area of bailing operations, they are easy to dump, and in the bottom layer they range from unstable to medium-resistant, respectively, and the mining and geological operating conditions are difficult in the location.

The depth of the methane release zone reaches 200 m. All coal seams located in the methane zone. The natural gas content of the seams in the mine field varies from 5.6 m^3/t of dry ash-free mass up to 23.1 m^3/t of dry ash-free mass, growing from the depths, that is why Zakhidno-Donbaska Mine belongs to the supercategory mines in terms of methane gas content. Mining of reserves is accompanied by an influx of water into mine workings due to the drainage of aquifers. In 2022, the mine-wide water supply was set at 99–123 m^3/ hour.

We will analyse the factors influencing the displacement and deformation of rocks and the surface ground in the mining zone: the thickness of the extracted seam, the depth of mining operations, mechanical properties and structural features of rocks, and the slope angle in Zakhidno-Donbaska Mine [22].

Depth of mining operations significantly affects the deformation the upper layer of soil, the nature and degree of manifestation of rock pressure in the layer. As the depth of mining operations increases, all types of deformations of the upper layer of soil decrease. Mining pressure, on the contrary, increases with increasing depth of mining, with the concentration of tension in certain areas becoming more dangerous. Coal mining at Zakhidno-Donbaska Mine is carried out at depths from 360 to more than 730 m. Coal is most intensively mined in the bedrock of 500–700 m. The greatest depth at which coal seams are being mined in the conditions of western Donbas mines is 620 m registered at Zakhidno-Donbaska Mine.

Mechanical properties and structural features of rocks affect all processes that occur in the rock mass, both within certain limits of the geological environment of PRJSC DTEK ranging from 235 m to 730 m, and on the ground surface (fig. 4). The greatest dependence on this factor can be traced in the values of shear angles for various properties of rocks. A significant impact on the nature of deformation of the ground surface is exerted by the ratio of soft and solid rocks of the layer, as well as its tectonic disturbance.

Geostructurally, this coal field belongs to the eastern part of the Novomoskovsk-Petropavlivka monocline, which is located on the north-eastern slope of the Ukrainskyi Crystalline Core Area and extends along the south-western side of the Dnieper-Donets Rift. The thickness of quaternary deposits (Q) reaches 30 m along the entire section of Zakhidno-Donbaska Mine, where aeolian and deluvial deposits (e_1vdP_{III}) predominate as loess loam plateaus, which alternate with fossil soils and belong to type 2 in terms of subsidence properties. Man-made mineral formations (tH), which are common for the territories with anthropogenic load, are mainly mine dumps formed due to the activities of coal mining enterprises located nearby. In the floodplains of rivers, ravines and gullies they are represented by alluvial deposits (aH), in the lower part they are represented by sands admixed with pebbles, which are covered with silt loams, with an intense and widespread river and gully terrain erosion in sediments [25].

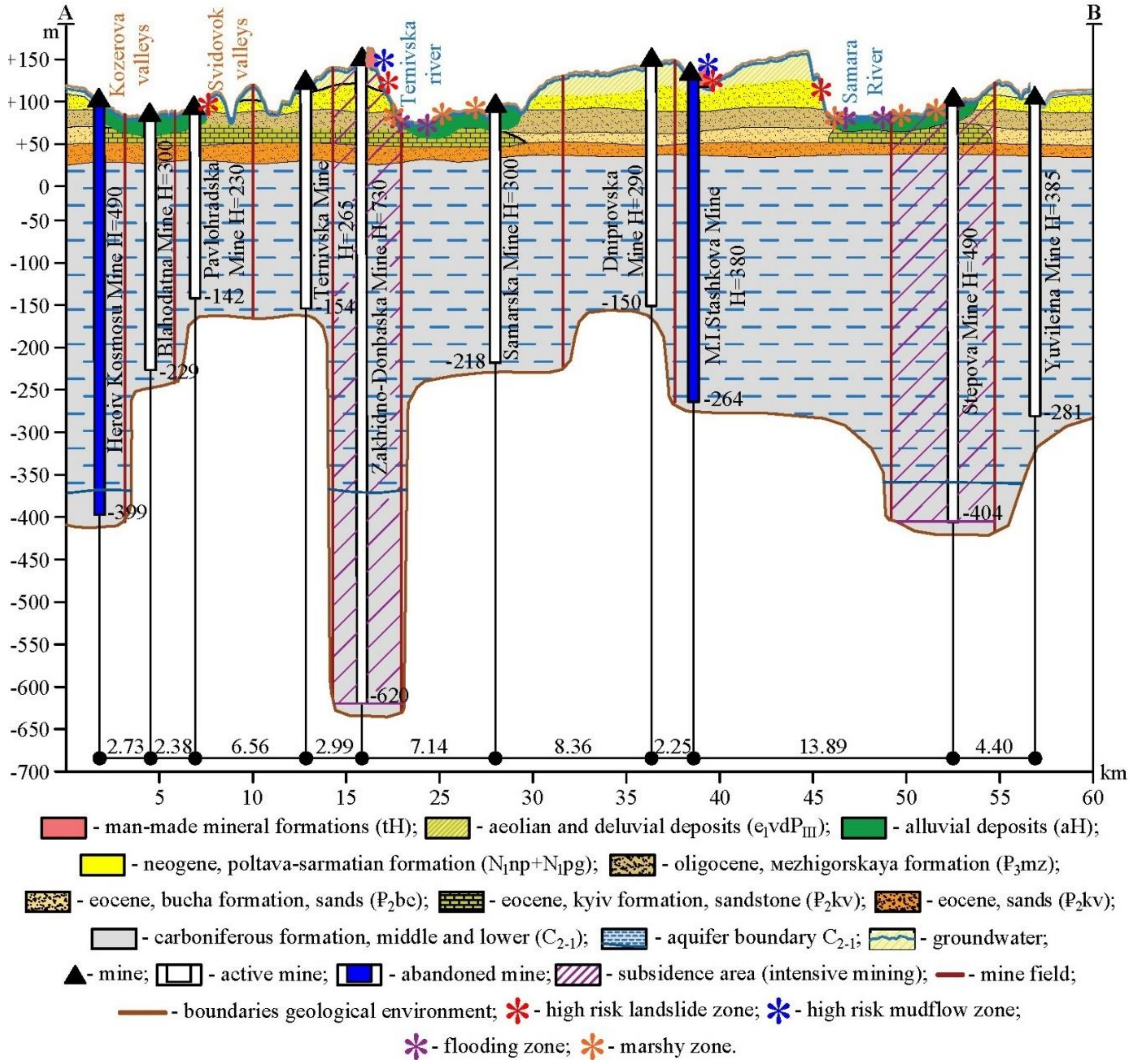

Fig. 4. Cut-line A–B. Geological environment boundaries

The carboniferous system (C) lies relatively deep, which is represented by the middle (C_2), middle and lower undivided (C_{1-2}) and lower (C_1) carboniferous divisions composed of mudstones, siltstones, limestones, sandstones and coal layers, which at small angles monoclinally dip to the northeast, which is complicated by tectonic disturbances of the faulting type. They are common for the technical boundaries of mines and beyond, and throughout their length they are accompanied by feathering of medium and small faults, intensive fracturing and crushing of rocks [26].

Thickness of the extracted layer is one of the main factors that determine the height of propagation of shear and deformation zones of rocks and the ground surface, since it regulates the subsidence of the hanging wall with their help.

The industrial coal-bearing capacity of Zakhidno-Donbaska Mine is associated with the deposits of the Samara Suite (C_{1-2}) and Lower Carboniferous, the coal-bearing thickness of which contains more than 50 coal seams and interlayers. The depth of coal seams ranges from 220 m (layer C_{10}^{B}) to 775 m (layer C_1). Seam C_8^{N} is 260–590 m deep, whereas seam C_5 is 340–690 m deep. Currently, Zakhidno-Donbaska Mine is mining seams C_{10}^{B}, C_9, C_8^{H}, C_7^{H}, C_6, C_5, C_1, with their thickness ranging from 0.6 m to 1.05 m.

The slope angle is one of the main factors that determine the degree parameters of the shear process and the distribution of deformations in the subsidence trough. The larger it is, the flatter the shear deformation angle and limiting angles. As the seam inclination increases, the ratio of horizontal faults to vertical one’s increases. This indicator significantly affects the development of the ground surface's subsidence, and with steep degree of dip of the seam it has a concentrated deformation nature, which is accompanied by abrupt elevation changes and breaks in the soil mass in small areas.

Factors influencing the development of deformations of the rock mass and the ground surface: seam thickness, depth of mining operations and the slope angle at the target of research, that is Mine №11 in the Nord-Pas de Calais Mining Basin, Lens, the northern part of France, and the western part of the Illinois Basin, Sangamon County, the Central Illinois, the United States, which have a similar geological structure and technical characteristics, are shown in table and are subject to further comparative analysis.

Table

Factors influencing the development of deformations

Factors	Coal mines		
	Zakhidno-Donbaska Mine	Mine №11, Lance	Mine №5, Sangamon
Mining depth, m	730	550–852	78
Seam thickness, m	0.6-1.05	1.0	1.8
Slope angle, °	2–5	1–6	6–6,6

During the comparative analysis of the above factors, we have found out that Zakhidno-Donbaska Mine and the mine located in the Nord-Pas de Calais Mining Basin are similar in all factors of impact on the process of fault and deformation of rocks and the ground surface. Besides, all three mines have a similar geological structure and tectonic disturbance.

Based on the past experience of the mines of Nord-Pas de Calais Mining Basin located in Lens, the northern part of France, and the western part of the Illinois Basin, Sangamon County, the Central Illinois, the United States, we should draw your attention to the experience passed from the period of coal field mining to the post-mining stage. During the period of the most intensive mining, the maximum depth of subsidence trough reached 0.9 m over Mine №11 and 1.87 m over Mine №5, which led to the destruction of buildings and infrastructure and caused considerable economic losses. Years after the mine abandonment, stable residual subsidence of up to 1.25 cm/year was observed, which manifested itself locally, mainly within urbanised territories. Besides, due to the location of urbanised areas and the presence of anthropogenic activities within the areas with mining operations carried out, uneven surface subsidence occurs, which, due to the sharp drop, can lead to deformation of buildings.

In Sangamon, mining operations were conducted at relatively shallow depths up to 78 m, and subsidence manifestations were more prominent than in Lens at a depth of mining being 475–800 m. Considering that the coal mining is carried out at a depth of 220 m to 730 m, respectively, the closer to the surface, the manifestations of disturbance of the ground surface will be more intense, which will decrease with increasing depth of coal mining, while simultaneously increasing the area of propagation of engineering and geological processes.

Based on the obtained data, the analysis of the following factors influencing the development of deformations of the rock mass and the ground surface in the area of coal mining operations has been carried out: the thickness of the extracted seam, the depth of mining operations, mechanical properties and structural features of rocks and the slope angle in Zakhidno-Donbaska Mine in comparison with mines №11 in the Nord-Pas de Calais Mining Basin, Lens, the northern part of France, and the western part of the Illinois Basin, Sangamon County, the Central Illinois, the United States, which have a similar geological structure and technical characteristics.

Conclusions. The article presents an analysis of the engineering-geological processes arising from the intensive development and closure of coal mining enterprises of DTEK PAVLOHRADCOAL PRJSC in the mine fields of the Pavlohrad-Petropavlivka geological and industrial area. Currently, in the villages of Ternivka and Bohdanivka, as well as beyond their boundaries, complex geological, hydrogeological, and mining-technical conditions are observed, leading to the following engineering-geological processes: soil subsidence, landslides, and changes in the hydrological regime caused by mining activities. To assess these processes, the average daily power and operational life of the mines were calculated, and geological profiles of the areas were constructed. Based on the analysis of the obtained data for the specified territory, the Zakhidno-Donbaska Mine was selected for further comparative analysis as the most vulnerable to engineering-geological processes.

A comparative analysis of the Zakhidno-Donbaska Mine with Mine №11 Nord/Pa-de-Calais in the city of Lens in the northern part of France and Mine №5 in the western part of the Illinois coal basin in Sangamon County, central Illinois, United States, based on a range of key factors with common features influencing the development of hazardous engineering-geological processes, confirmed the dependence between the intensity of coal deposit development and the occurrence of hazardous processes. As the depth of coal extraction increases, the intensity of hazardous engineering-geological processes decreases, but the affected area increases. For example, the manifestations of subsidence decrease from 1.87 to 0.9 meters, but the affected area expands significantly. Shallow seams create large subsidence zones with lower intensity, and residual subsidence continues to occur even in the post-mining stage, up to 1.25 cm per year, although these manifestations become more localized.

Перелік посилань

1. Bateson, L., Cigna, F., Boon, D., & Sowter, A. (2015). The application of the Intermittent SBAS (ISBAS) InSAR method to the South Wales Coalfield, UK. *International Journal of Applied Earth Observation and Geoinformation, 34*, 249–257. https://doi.org/10.1016/j.jag.2014.08.018
2. Yin, X., Chai, J., Deng, W., Yang, Z., Tian, G., & Gao, C. (2023). Pointwise Modelling and Prediction for Ground Surface Uplifts in Abandoned Coal Mines from InSAR Observations. *Remote Sensing, 15*(9), 2337. https://doi.org/10.3390/rs15092337
3. Blachowski, J., Kopeć, A., Milczarek, W., & Owczarz, K. (2019). Evolution of Secondary Deformations Captured by Satellite Radar Interferometry: Case Study of an Abandoned Coal Basin in SW Poland. *Sustainability, 11*(3), 884. https://doi.org/10.3390/su11030884

4. Gee, D., Bateson, L., Sowter, A., Grebby, S., Novellino, A., Cigna, F., Marsh, S., Banton, C., & Wyatt, L. (2017). Ground Motion in Areas of Abandoned Mining: Application of the Intermittent SBAS (ISBAS) to the Northumberland and Durham Coalfield, UK. *Geosciences*, *7*(3), 85. https://doi.org/10.3390/geosciences7030085
5. Samsonov, S., d'Oreye, N., & Smets, B. (2013). Ground deformation associated with post-mining activity at the French–German border revealed by novel InSAR time series method. *International Journal of Applied Earth Observation and Geoinformation*, *23*, 142–154. https://doi.org/10.1016/j.jag.2012.12.008
6. Harnischmacher, S., & Zepp, H. (2014). Mining and its impact on the earth surface in the Ruhr District (Germany). *Zeitschrift Für Geomorphologie, Supplementary Issues*, *58*(3), 3–22. https://doi.org/10.1127/0372-8854/2013/s-00131
7. Poulsen, B., & Shen, B. (2018). Surface subsidence from underground coal mining impacting residential housing: a case study of risk analysis, mitigation proposal and ongoing monitoring. *Risk Analysis XI*, *12*, 209–220. https://doi.org/10.2495/risk180181
8. Vervoort, A. (2020). The Time Duration of the Effects of Total Extraction Mining Methods on Surface Movement. *Energies*, *13*(16), 4107. https://doi.org/10.3390/en13164107
9. Pan, W., Li, X., & Zhan, Z. (2022). Strata Caving and Gob Evolution Characteristic in Longwall Mining. *Shock and Vibration*, *1*, 1–11. https://doi.org/10.1155/2022/3235063
10. Zhang, L., Bai, K. Z., Wang, M. J., & Karthikeyan, R. (2015). Basin-scale spatial soil erosion variability: Pingshuo opencast mine site in Shanxi Province, Loess Plateau of China. *Natural Hazards*, *80*(2), 1213–1230. https://doi.org/10.1007/s11069-015-2019-9
11. Zhuang, J., Peng, J., Zhu, Y., Leng, Y., Zhu, X., & Huang, W. (2020). The internal erosion process and effects of undisturbed loess due to water infiltration. *Landslides*, *18*(2), 629–638. https://doi.org/10.1007/s10346-020-01518-z
12. Гладкий, В. Н., & Матвієнко, Е. М. (1958). *Геологічна карта СРСР масштабу 1:200 000, аркуш M-37-XXXI (Петропавлівська). Центральноукраїнська серія. Пояснювальна записка*. Міністерство геології та охорони надр СРСР. Українське геологічне управління.
13. Гладкий, В. Н., & Матвієнко, Е. М. (1958). *Геологічна карта СРСР масштабу 1:200 000, аркуш M-37-XXXI (Петропавлівська). Центральноукраїнська серія*. Міністерство геології та охорони надр СРСР. Українське геологічне управління.
14. Шпильчак, В., Манюк, В., Сукач, В., & Некряч, А. (2007). *Державна геологічна карта України масштабу 1:200 000, аркуш M-36-XXXVI (Дніпропетровськ). Центральноукраїнська серія. Пояснювальна записка*. Міністерство охорони навколишнього природного середовища України, Державна геологічна служба. Казенне підприємство "Південукргеологія", УкрДГРІ.
15. Шпильчак, В., Манюк, В., Сукач, В., & Некряч, А. (2007). *Державна геологічна карта України масштабу 1:200 000, аркуш M-36-XXXVI (Дніпропетровськ). Центральноукраїнська серія*. Міністерство охорони навколишнього природного середовища України, Державна геологічна служба. Казенне підприємство "Південукргеологія", УкрДГРІ.
16. Лисак, С. П. (2023). *Екологічний паспорт Дніпропетровської області за 2022 рік. Затв. головою облдержадміністрації – начальником обласної військової адміністрації*.
17. Шаповалова, К. (2022). *Регіональна доповідь про стан навколишнього природного середовища в Дніпропетровській області за 2022 рік*.
18. Ghouzi, D. (1982). Mining subsidence and its impact on the environment: the example of the Nord/Pas-de-Calais coalfield. *Minerals and the Environment*, *4*(2–3), 93–98. https://doi.org/10.1007/bf02086781
19. Bauer, R. (2008). Planned coal mine subsidence in Illinois: a public information booklet. *Illinois State Geological Survey*, 18.
20. Grzovic, M., & Ghulam, A. (2015). Evaluation of land subsidence from underground coal mining using TimeSAR (SBAS and PSI) in Springfield, Illinois, USA. *Natural Hazards*, *79*(3), 1739–1751. https://doi.org/10.1007/s11069-015-1927-z

21. Guéguen, Y., Deffontaines, B., Fruneau, B., Al Heib, M., de Michele, M., Raucoules, D., Guise, Y., & Planchenault, J. (2009). Monitoring residual mining subsidence of Nord/Pas-de-Calais coal basin from differential and Persistent Scatterer Interferometry (Northern France). *Journal of Applied Geophysics*, *69*(1), 24–34. https://doi.org/10.1016/j.jappgeo.2009.02.008
22. Забєлін, Д. (2023). *Звіт з оцінки впливу на довкілля планової діяльності "Доробка запасів вугілля пластів c_{10}^{B} і c_8^{H} шахти "Західно-Донбаська" в блоці № 2, розташованої в Павлоградському районі Дніпропетровської області. Реконструкція"*.
23. Демчишин, М. Г., & Кріль, Т. В. (2016) Оцінка стійкості схилів з використанням методів 3D моделювання. *Будівельні конструкції, 83,* 433–441.
24. Примушко, С. І., Коваленко, Н. Б., & Пишна Н. Г. (2020). *Інформаційний щорічник щодо активізації небезпечних екзогенних геологічних процесів за даними моніторингу ЕГП – Київ*. Державна служба геології та надр України, Державне науково-виробниче підприємство «Державний інформаційний геологічний фонд України».
25. Волкова, Т. П., & Шилова, М. С. (2011). Інженерно-геологічне картування Донецької області. *Наукові праці УкрНДМІ НАН України, 9*, 203–215.
26. Горяйнов, С., & Удалов, І. (2023). Аномальна позиція палеозойських скидів Західного Донбасу. *Вісник Харківського національного університету імені В. Н. Каразіна, серія «Геологія. Географія. Екологія», 58*, 38–48. https://doi.org/10.26565/2410-7360-2023-58-03

АНОТАЦІЯ

Мета. Метою дослідження є визначення найбільш вразливої шахти ДТЕК «Павлоградвугілля» до розвитку небезпечних процесів на основі аналізу існуючих процесів, які викликані вуглевидобувною діяльністю в межах Павлоградсько-Петропавлівського геолого-промислового району, для порівняння її з шахтами з спільними технічними параметрами, які мали досвід аналізу існуючих небезпечних геологічних процесів.

Методика. Для прогнозування змін у геологічному середовищі шахтних полів застосовано комбінований підхід, що поєднує кілька методів аналізу, серед яких аналіз наукових досліджень і технічної документації та порівняльний аналіз за спільними рисами. Використання цих методів дозволяє виявляти закономірності, які повторюються у подібних геологічних і технічних умовах, на основі досвіду попередніх подій. Порівняльний аналіз є заключним етапом, що дозволяє створити типові сценарії розвитку інженерно-геологічних процесів, підвищити точність прогнозів можливих змін у геологічному середовищі.

Результати. Аналіз спільних рис досліджень шахтних полів дозволило сформувати типові сценарії розвитку геологічних процесів, підвищити точність прогнозів можливих змін у геологічному середовищі, на основі чого визначено залежність параметрів шахт до площі та інтенсивності розвитку небезпечних інженерно-геологічних процесів на земній поверхні.

Наукова новизна. Вперше запропоновано системний підхід, який дає змогу системно оцінювати закономірності, які повторюються у подібних умовах, спираючись на досвід минулих подій для прогнозу небезпечних змін у геологічному середовищі в межах вуглевидобувної діяльності. Визначено залежність параметрів шахт до площі та інтенсивності розвитку небезпечних інженерно-геологічних процесів на земній поверхні над шахтними полями.

Практична значимість. Отримані дані можуть бути використані для розробки стратегії управління ризиками на гірничих підприємствах, а також для екологічних і геотехнічних досліджень, що стосуються впливу гірничої діяльності на навколишнє середовище та розробки заходів з мінімізації їхнього впливу, а також для планування безпечних гірничих робіт з урахуванням потенційних ризиків, які несуть загрозу безпеці населення.

Ключові слова: *вугільна шахта, геологічне середовище, інженерно-геологічні процеси, негативний вплив, осідання.*