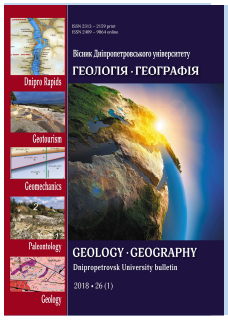

Geology • Geography
Dnipro university bulletin

Journal home page: geology-dnu-dp.ua

ISSN 2313-2159 (print)
ISSN 2409-9864(online)

Dniprop. Univer.bulletin. Geology, geography., 26(1), 158-164.

doi: 10.15421/111817

Обоснование критериев применимости селективной отработки угольных запасов в условиях Западного Донбасса

В.А. Соцков, Е.О. Подвигина, Н.И. Деревягина, Д.С. Малашкевич

Национальный технический университет «Днепровская политехника»,
e-mail: vadimsockov@gmail.com, natali.derev@gmail.com, malashkevychnmu@gmail.com

Received 03.02.2018
Received in revised form 16.02.2018
Accepted 01.03.2018

Аннотация. Для обеспечения энергетической системы Украины стабильными поставками угля в длительной перспективе необходимо оценить потенциал разрабатываемых месторождений. Месторождения Украины характеризуются сложными горно-геологическими условиями и залежами малой мощности, что существенно затрудняет добычу. В связи с этим необходимо разрабатывать и применять новые энергоэффективные технологии добычи угля. В работе обоснованы критерии пригодности маломощных угольных пластов Западного Донбасса, на территории которого залегает 25 млрд т угля, что составляет 21, 3% от общих ресурсов страны, к отработке селективной технологией. По геолого-структурному фактору выделены поля шахт гидродинамически «открытого» и «закрытого» типов, водопритоки в которых отличаются на порядок. На примере шахт Восточной группы обоснованы наиболее перспективные угольные запасы, целесообразные к отработке селективной технологией. Установлено, что в данных условиях технология селективной выемки угля не только позволит снизить зольность добываемого угля, но и продлит срок службы предприятий. За счет закладки выработанного пространства снизится техногенная нагрузка на подземную и поверхностную гидросферу, уменьшится величина просадки земной поверхности и объемы пустых пород.

Ключевые слова: угольное месторождение, Западный Донбасс, зольность, водопритоки, селективная технология

Substantiating the criteria for applying selective excavation of coal deposits in the Western Donbass

V. O. Sotskov, O. O. Podvyhina, N. I. Dereviahina, D. S. Malashkevych

"Dnipro Polytechnic" National Technical University,
e-mail: vadimsockov@gmail.com, natali.derev@gmail.com, malashkevychnmu@gmail.com

Abstract. The provision of the energy system of Ukraine with a stable supply of coal in the long term demands calculation of the capacity of the exploitable deposits. Ukrainian deposits are characterized by insignificant thickness and complicated mining-geological conditions, which significantly complicates the mining process. Therefore, it is necessary to develop and use new energy-efficient technologies of coal mining. The article evaluates the criteria of usefulness of thin layers of deposits in the Western Donbass, which contains 25 bn t of coal, i.e 21.3% of total resources of the country, for processing in selective technology. According to the geologic-structural factor, we distinguished the fields of mines of hydrodynamically "open" and "close" types, the water inflows of which differ by a factor of ten. Taking the example of the mines of the east group, we ascertained the potential of the most promising coal reserves, which are appropriate for mining using selective technology. It was established that in these conditions, selective technology of coal excavation would not only allow a decrease in the ash content of the coal output, but would also prolong the period of the industries` operation. Backfilling of mined-out areas decreases the technogenic load on the underground and surface hydrosphere, decreases the subsidence of the surface and the volume of waste rocks.

Key words: coal deposit, Western Donbass, ash content, water inflow, selective technology

Introduction. A special importance in the energy supply of Ukraine is attached to the Western Donbass, which contains 25 bn t of coal, i.e 21.3% of the total resources of the country. However, its specific mining-geological conditions cause certain difficul-

ties for mining. Over 80% of the coal reserve is concentrated in seams of less than 1 m thickness; at the same time, the productive reserve in relatively favourable conditions is already worked-out. On average, the useful excavated thickness of the workable seams is 0.82 m. Mining of the seams is carried out with cutting of the lateral rocks; this causes an increase in the ash content of the mined coal of up to 50-60% and leads to additional expenses, and is one of the causes of deterioration of the region`s ecological condition (Snihur, 2016; Fomichov, 2014; Sidorenko, 2016).

For solving this problem, a technology of selective excavation of coal and cut rocks has been suggested (Sidorenko, 2016; Byzilo, 2015; Bondarenko, 2016; Sotskov, 2017). The main advantage of this technology is separating the rock and the coal directly in the stope face and its excavation with ash content close to inherent ash. Its usage allows seams of 0.55-0.8 m thickness to be mined leaving the rock in position in the mined-out area of the face. Also it allows involvement of off-balance reserves, improvement of the quality of the extracted products, intensification of the working of the reserves and reduction of the technogenic load on the environment. The objective of this research was to substantiate the mining-geological criteria of usefulness of non-conditional thin coal seams of the Western Donbass for mining using selective technology.

The main part. For determining the usefulness and appropriateness of the coal seams for the selective mining, we conducted an integrated evaluation of the mining-geological and mining-technological base of coal-mining enterprises of the Western Donbass. During the evaluation, we considered the main quantitative and qualitative characteristics of the deposits, including: hydrogeological conditions, the geological thickness of the mined seam, its persistence along the field of the mine distribution; the ash content of the coal with consideration of dilution by intraformational rocks and technological cuttings; the amount of the reserves along the seam; physical-mechanical properties of the rocks of the roof and the foot of the seam; mining-technical conditions of mining of the deposit; other peculiarities of the geological structure (anomalies), which provide a potential risk during underground mining. Also, the criteria of applicability of the selective mining covers a set of factors (Table 1), which should be considered in justifying the choice of area, seam or field of the mine. Regarding the hydrogeological position, the Western Donbass is situated within two hydrogeological regions. The North and the North-East part belong to the Donetsk basin of strata-block artesian water, and the South and the South-East parts belong to the Ukrainian basin of artesian fracture-vein water (Ruban, 2005). The hydrogeological structure of the Western Donbass is a system of water-bearing horizons and complexes, which cover all the thickness of the sedimentary rocks and the upper part of the fractured area of the crystalline rocks. The total thickness of the watered rocks is 20 to 1660 m and greater, increasing in the direction of the deepening of the rocks towards the axis of the Dnieper-Donetsk depression.

Table 1. Criteria for proving the applicability of the selective working

I	*Technical*
- time of the mining operation; - technological coal cutting of the roof and the foot rocks; - operational ash content of the coal	
II	*Mining-geological*
- presence of the thin coal seams (<0.8 м); - difficulties of the hydrogeological conditions; - inherent ash content of the coal	
III	*Ecological*
- the opportunity of reducing the technogenic load on the underground and surface hydrosphere; - reducing the areas and the values of surface subsidence; - absence of tailings; - safety for important economic and natural objects on the surface	
IV	*Economic*
- involving the off-balance coal reserves in the working; - reducing the percentage of dilution and ash content of the rock; - reducing ecological fines for disturbing the ground surface, removing it from agricultural usage, pollution of the surface and ground water; - prolonging the term of operation	

In relation to the hydrogeological and engineering- geological conditions of the coal mining, the territory of the Western Donbass may be divided into 4 zones (Beseda, 2000; Sadovenko, 2010). The first zone covers a 5-7 km belt from the Mezheva station through Pavlohrad towards Novomoskovsk. The coal seams appear practically everywhere under the Buchakovsky water-bearing horizons of 20-25 m

thickness, possess quicksand properties (coal seams of a hydrodynamically "open" type). The formation of water inflows to the mine, apart from the thickness reserves, is caused by the resources applied due to the draining of the water-bearing horizons of the overburden sediments. Weathering of the coal sediments is seen to the depth of 80-100 m. The tectonic disorders occur in insignificant amplitude. In the conditions of this zone, the following mines of the east group are situated: "Yuvileina", "Stepna", "Dniprovska", N I Stashkov mine (Fig. 1).

The second zone includes the 3 km large belt, which is adjacent to the first zone along the line Blahodatne village – "Ternivska" mine. Regarding the hydrogeological conditions of the coal seam mining, this area is the most favourable, for the coal seams here occur in "closed" and "half-open" hydrodynamic types. The number of the tectonic disorders decreases, but there is a significant amplitude of shift. In the conditions of this zone, the following mines are situated: "Blahodatna", The Mine named after the Heroes of the Space, "Ternivska", "Zahidno-Donbaska", and "Samarska" (Fig.1).

The third zone covers the area North and the North-East area of the second zone. It covers the water-bearing horizons of Buchaksky horizon, Triassic and Jura deposits. Hydrogeological conditions of the mining are the easiest. The rocks of carbon sediments are not weathered, the capacity of the ground water is limited, and tectonic disorders are colmataged.

The fourth zone has all the complex elements of the aforementioned zones. The borders of the zone: to the East – a line linking Pavlohrad and Lozova; to the West – Karabynivsky fault; to the South – the outcrop of the coal (coal seam C_1); to the north – along the line of Verbky, Viazovok and Kocherezhki villages.

Water resources of the faces mostly depend on the peculiarities of the geological structure of the mine area, particularly the outcrops of the coal seams under the watered Buchaksky sands and tectonic disorders of the rocks, the area of the mined-out space and the sequence of the mining the coal seams. The key factor, which is a predicator of the presence of water occurrence on the stope faces of the mines in the Western Donbass, is soaking of the lateral rocks due to moisture and rapid loss of robust properties (Beseda, 2000; Sotskov, 2013; Sadovenko, 2016; Meng, 2017).

The main factors of the formation of the inflow to the mining faces are as follows:

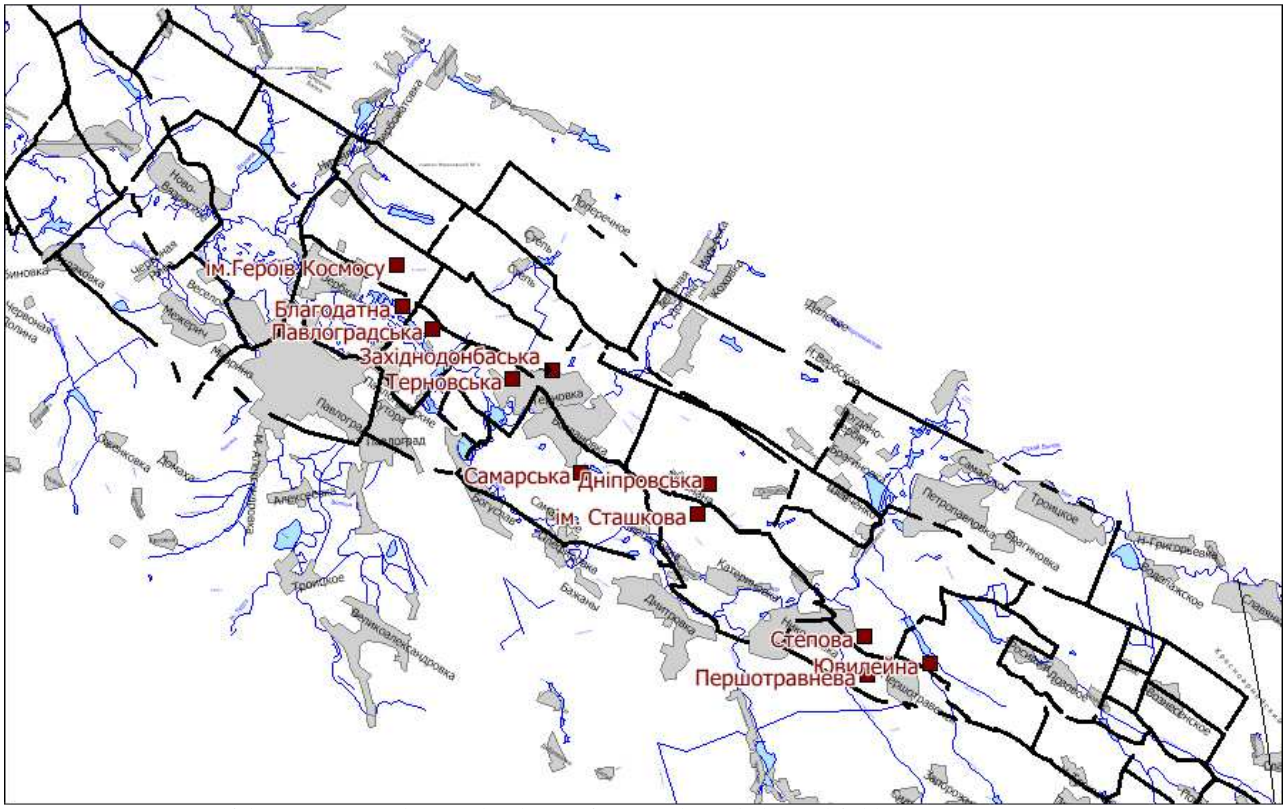

Fig. 1. *Map overview of the Western Donbass with scheme of cutting through the coal fields*

- Geological-structural factor, in accordance with which the water-bearing horizons of the coal seams drained by the mining workings appear under the watered overburden sediments. In this case, apart from the reserve capacity of carbon, a significant role is attached to the applied resources of water-bearing horizons of Mesosoic-Cainozoic deposits and the total water inflows of the mines, which reach

a speed of 1200 m^3/hour. In the places where this connection is absent or is obstructed, the water inflow to the mine does not exceed 100 m^3/h. Formation of the zone of water-conducting fractures of 25-30 m height at the collapse of the coal seam roofs and involvement of the thickness of the Paleo-channel sandstones, which are embedded both in the main and in the direct roof, in the zone of draining. In this case, the total water inflow of the mines increases from 1-5 to 20-90 m^3/h (Krukovskyi, 2017).

The order of the mining of the headblock and acclivitous parts of the minefield. Balance coal reserves of the Western Donbass equal 775 bn t, off-balance – 674 mil t. The seams of 0.5-0.54 m include 321 mil t of coal or 24.5% of the total reserve; 0.55 -0.59 m - 226 mil t or 17.2%; 0.6 – 0.7 m – 243 mil t or 18.5%; 0.71 – 0.8 m – 192 mil t or 14.7%; over 0.8 m – 330 mil t or 25.1% (Snihur, 2016; Byzilo, 2015; Saik, 2016). Therefore, 50.4% of the coal reserve is embedded within the geological thickness of 0.55 - 0.8 m, which can be mined using selective technology with ash content of 18 – 22% (Fig. 2). Among the coal mining enterprises of the Western Donbass, we distinguished the mines which are characterized by the highest specific weight of the coal seams of 0.55–0.80 m within the mining allotments. Regarding the capacity of such reserves, the mines were divided in decreasing order , as follows: "Stepna", "Zahidno-Donbaska", "Dniprovska", The Mine named after The Heroes of the Space, N I Stashkov mine, "Yuvileina", "Samarska", "PAvlohradska", "Blahodatna" and "Ternivska". Because the selective technology of mining with backfilling of mined-out areas decreases the technogenic load on the underground and surface hydrosphere, decreases the subsidence of the ground surface in the areas of worked flood plains, the most promising way to analyze its usage would be to consider it as suitable for the East groups of the Western Donbass mines, where the changes in the geological environments are the deepest (Beseda, 2000; Sadovenko, 2010).

The working of the seams in this zone is complicated by unstable enclosing rocks with f= 2 – 3 density coefficient, which are distributed on 60-70% of the area.

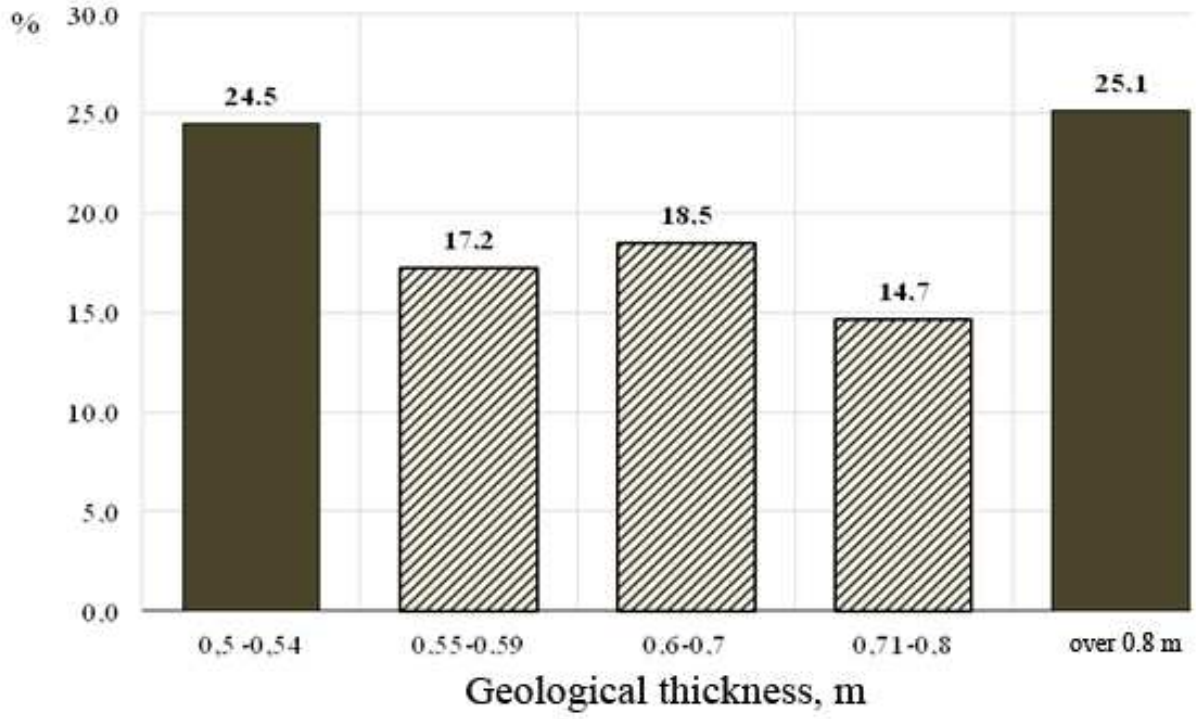

Fig. 2. Histogram of the distribution of coal reserves in the Western Donbass by thickness: - potential area of applying selective coal extraction

The "Stashkov" mine is characterized by complicated mining-geological conditions of exploitation due to its unstable, fragile roof, areas of washouts and fragmentations of seams, and also by intense water inflows due to the outcrop of the coal under the Buchaksky deposits in the valley of the Samara River. The total inflow of the mines reached 1756 m^3/hour. The mine works on the following seams: C_5+$C_5^н$, C_5+$C_5^в$,C_4^2+$C_4^{2в}$. Average ash content of the rock mass extracted from the face equals 59.8%, in which the seams of less than 0.80 m include 80.6 %: 0.5 – 0.54 m – 22.6%; 0.55 – 0.59 m – 30.7%; 0.6 – 0.7 m – 13.4%; 0.71 – 0.8 m – 13.7%, and the seams with working thickness of over 0.80

include 19.2%. The reserves of thickness less than 0.80 m can be mined using the technology of selective extraction of coal, which would allow the term of the mine operation to be prolonged 5-8 years.

The "Dniprovska" mine is working the C_{10}^{B} coal seam of 1.02 m thickness, which allows mining using practically no cutting. However, the ash content of the coal extracted from the face is within the range of 22.5 to 36.2% (at inherent ash content of 12.0%), and the total ash content of the mines – 44.2%. The main reason for increase in the ash content during the process of coal excavation is the fragile rocks of the roof, which collapse into the face after the sections are moved, causing dilution of the seam. The weakening occurs due also to the fluctuations of total inflow to the mines, which changed from 124 to 300 m^3/hour during the period of operation. Reducing the percentage of ash content and increasing the efficiency indicators could be achieved by exploiting the faces using the selective technology (with primary excavation of the roof rocks and sequential coal excavation) (Snihur, 2016; Byzilo, 2015; Beseda, 2000; Saik, 2016; Sadovenko, 2017).

Using selective technology would be promising in the mines "Samarska", "Stepna", and "Yuvileina". The balance reserves of the "Samarska" mine equal 57%, and the off-balance reserves equal 43% of the total reserves. Currently, the worked seams are C_5, C_4^2 and C_1, which contain 32% of the industrial reserves. The working thickness of the coal seams fluctuates within the range of 0.60 to 1.30 m. The industrial reserves of the coal in the seams less than 0.80 m thick are distributed as follows: 0,5 – 0.59 m – 31.8%; 0.60 – 0.80 m – 39.3%. The operational ash content of the worked seams (at average inherent ash content of 6.2 – 10.7%) fluctuates from 32.5 to 45.2%, which is explained by large scale cutting of the lateral rocks, which can achieve 0.35 m. Significant decrease in the ash content is possible by implementing the selective excavation of coal and lateral rocks. The technology allows decreasing the dilution of the coal by two times (Fig. 3). The complicating factor during the work is a thick layer of water-bearing sandstones. The total water inflow of the mines throughout its period of operation changed from 35 to 430 m^3/hour. In the zones of heightened level of fracturing and collapse of the main roof, cases of using powered supports on "rough bases" and increasing the water inflow to the face occur quite often. The North-West, East and the South-West parts of the coalfield are observed to experience significant tectonic disorders – Bohdanivsky, Bohuslavsky and South-Ternivsky faults. Therefore, a significant reserve for increasing the efficiency and the resource capacity of the "Samarska" mine is the possibility of selective excavation of coal from the C_1 seam, which allows extraction of over 6 mil t of coal with ash content not higher than 25% from the subsurface.

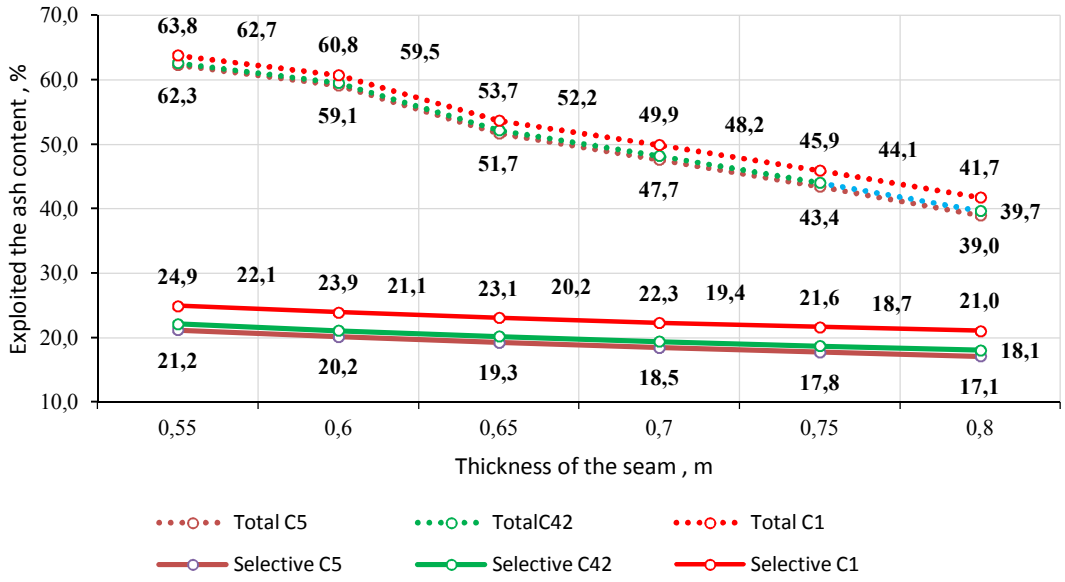

Fig. 3 Predicted ash content in the seams of the "Samarska" mine in relation to its useful thickness and the technology of mining

The "Stepna" and "Yuvileina" mines are working on the C_6 coal seam, which has quite limited balance reserves within the coalfields. The operating conditions of the deposits are complicated. The mining-geological conditions of working on the coal seams are directly affected by the watered fine-grained Buchaksky sands, which have properties of quicksand. The total inflow of the mines during the entire period of operation varied from 279 to 1400 m^3/hour. The peculiarity of the "Stepna" mine

is its composition from "open" and "closed" hydrogeological types. In the process of the excavation, due to cutting the lateral rocks, significant contamination of the coal occurs – the ash content increases from 6 – 10% to 17.8 – 36.4%. Despite the fact that the mines use modern equipment for intensifying the stoping, the problem of improving the quality of the extracted coal is not yet solved. The total mining extraction is distributed everywhere and is the main cause of the increase in the operational ash content of the extracted coal (Snihur, 2016; Byzilo, 2015; Ruban, 2005; Beseda, 2000; Sadovenko, 2010). The increasing of the operational term requires the working of the reserves of the C_6^1 and C_5 seams, within the limits of which, the selective technology of coal excavation would allow not only a decrease in the level of ash content in the extracted coal, but an extension in the term of the operation.

Also, backfilling of mined-out area significantly decreases the underground pressure, which reduces the number of installations of powered supports on "rough bases", improves the conditions of the extraction faces adjacent to the stope face, which in turn increases the safety level and the efficiency of working these reserves. Also backfilling decreases the technogenic load on the underground and surface hydrosphere, due to decreasing the area and the magnitude of ground subsidence.

Acknowledgement. The research was carried out within the framework of scientific topic GP-497 (№0117U006753) "Resource-saving geotechnical and hydrodynamic parametrization of the extraction of low-capacity mineral raw materials in a technogenically loaded environment", financed by the state budget of Ukraine.

Conclusions.

1. According to the results of an integrated evaluation of the mining-geological conditions in the Western Donbass, we found that 50.4% of the coal reserves are embedded in the seams with geological thickness of 0.55 – 0.8 m, which it would be advisable to mine using the selective technology with ash content of 18 – 22%.

2. Regarding the geological-structural factor, we distinguished mines of hydrodynamically "open" and "closed" types, where water inflow differs by a factor of ten.

3. On the example of the mines of the east group, we identified viable coal reserves, which could be effectively mined using selective technology. We established that in the current conditions, selective extraction would not only decrease the ash content of the extracted coal, but also would prolong the term of operation, thus improving the ecological condition of the region.

4. Backfilling of the mined-out area would significantly reduce the manifestations of underground pressure, improve the safety and the efficiency of the coal mining. Also, it would decrease the technogenic load on the ground and underground surfaces, decrease the level of the ground surface subsidence and the amount of waste rocks.

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