



Safe Exploitation Solution and Reduction of Resources Loss for the L7 Seam at the West Wing Area of the 790 Open Pit Site of the Mong Duong Coal Mine

Pham DUC HUNG^{1,*}, Le TIEN DUNG¹, Nguyen VAN QUANG¹

¹) Department of Underground Mining, Hanoi University of Mining and Geology, Hanoi, Vietnam, email: phamduchung@humg.edu.vn, t.d.le@humg.edu.vn, nguyenvanquang@humg.edu.vn

<http://doi.org/10.29227/IM-2020-02-28>

Submission date: 06-03-2020 | Review date: 22-09-2020

Abstract

In the next time, deepening exploitation and increasing capacity in underground mines are extremely necessary to meet the demand of using coal for developing economies. This problem is not only done in underground mines but also in areas that cannot be exploited by open-pit methods such as the open-pit edge. When exploiting deep underground mines, there are many difficulties for tasks such as: controlling ground pressure; ventilation; drainage, transportation etc. When cutting coal in longwall, it will create a goaf, causing a natural imbalance of stress in the ground, leading to the phenomenon of displacement of rock deformation and destruction of roadways, which creates a risk of unsafety labour. The L7 seam at the west wing area of the Mong Duong coal mine has an average thickness of 7m, an average slope angle of 15°, located near the edge of the 790 open pit site. According to the production plan, this mine will exploit this reservoir with blasting-drilling technology, longwall support by the semi-mechanized shield (self-moving hydraulic frame GK/1600/16/24/HTD). The preliminary assessment of hydrogeological conditions of the mine shows that this is a potential area with a high risk of water burst into the longwall. Until now this mine has not yet given a specific solution to this problem. Finding a reasonable mining solution to ensure production safety and reduce resources loss is extremely important problem not only for the Mong Duong coal mine but also for mines that have similar mining conditions of Vietnam National Coal – Mineral Industries Holding Limited (Vinacomin), Vietnam.

Keywords: exploitation technology, mining solutions, water burst

1. Introduction

According to the development plan of Vietnam's coal industry to 2020, with prospects to 2030 approved by the Prime Minister in Decision No. 403 / QD-TTg dated March 14, 2016, one of the important strategic goals is safe exploitation, reducing resources loss in mining in general and underground mining in particular. Specifically, "Striving to reduce the rate of mining losses by the underground mining method to about 20% and below 20% after 2020" (The Prime Minister, 2016). In fact, coal mines exploited by open-pit mining tend to decrease, this will lead to an increase in demand for underground mining. The process of underground mining causes deformation of the rock wall, the deformation that can be displacement form of rock and soil without being destroyed, may also be in the form of cracks and fractures (e.g., (E. Bakhtavar, 2013, FuYuHua, 2010)) the movement of rock to the ground when the size of the goaf is too large. Initially, the layers of rock lying on the coal seam were destroyed, then the fracture occurred. The strata can be divided into three zones from goaf to the top, characterized by the degree of destruction of different rock: collapsed zone, fractured zone, deformed zone. In the collapse zone, the movement of discrete rocks and blocks take place in cycles, along with the progress of the longwall faces. With large exposed area, the height of this area reaches 2-4 times of the thickness of the seam (e.g., (Penghongge, 2012, Pham et al., 2018)).

It is much more difficult to exploit open-pit edge areas by underground mining method than exploit deep mine because of the complexity of working conditions in the longwall.

The waste dump is not only merely a waste rock caused by open-pit mining but also an area that contains a lot of water. The dumping process is not strictly controlled, leading information on hydrogeological conditions difficult to identify. The underground mining activities at the edge of the open pit landfill will have problems such as controlling the ground pressure, the risk of water splinting into the longwall. Therefore, the movement of rock stratigraphy at the longwall under open pit area will have the potential for unsafe pit mining activities. In each of the different mining conditions in the longwall, such as the seam thickness, the height of cutting, the speed of cutting, the physical conditions of the rock wall will have different results of the wall rock state in the longwall (Final report of the topic, 2017). It is the difference in the dynamic movement of the rock, shown in the height of collapse, the height of fractures, the secondary fracture system formed after the coal extraction process in the longwall. It also shows that the influence of water contained in open-pit dump areas to the longwall area will be different. Therefore, it is necessary to identify specific geological conditions in order to study and propose reasonable technical solutions and exploitation technologies for this resource object.

The L7 seam at the west wing area of the Mong Duong coal mine has an average thickness of 7 m, an average slope angle of 15°, next to the edge of the 790 open pit site (Report of the Mong Duong coal mine). According to the production plan, this mine will exploit this reservoir with blasting-drilling technology, longwall support by the semi-mechanized shield (self-moving hydraulic frame GK/1600/16/24/HTD).

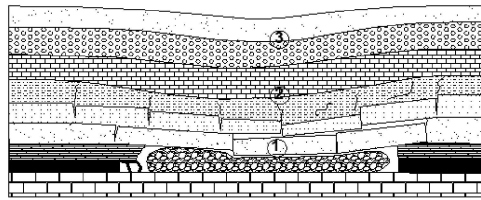


Fig. 1. Caving and deformed zones above longwall face. 1 – Caving zone, 2 – Fracture zone, 3 – Sagging zone
Rys. 1. Strefy zawalowe i deformacyjne powyżej przodka 1 – Pustka eksploatacyjna, 2 - Strefa pęknięcia, - 3 - Strefa ugięcia

Tab. 1. Mechanical properties of roof rock
Tab. 1. Właściwości fizyczno-mechaniczne skał stropowych

Type of rock	Rock unit	Value	Compressive strength σ_c (kG/cm ²)	Tensile strength σ_k (kG/cm ²)	Density d (t/m ³)	Average hardness f
Immediate rock	Siltstone	Max	549.00	58.29	3.00	
		Min	435.60	47.22	2.78	
		Medium	495.37	49.75	2.84	4.95
Main roof rock	Siltstone	Max	958.60	95.86	2.85	9.58
		Min	297.60	35.80	2.71	2.97
	Sandstone	Medium	528.90	51.09	2.76	5.28
			1267.30	101.57	2.72	12.67



Fig. 2. Cross-section II of the L7 seam near the 790 open pit site of the Mong Duong coal mine
pokladu

The preliminary assessment of hydrogeological conditions of the mine shows that this is a potential area with a high risk of water burst burst into the longwall. Until now, this mine has not yet given a specific solution to this problem. Therefore, the study on solutions for ensuring production safety and reducing resource loss for the L7 seam at the west wing belonging to the 790 open pit site of the Mong Duong coal mine, is scientific and practical problem. Ensuring safety in production process, increasing mining and economic effects, protecting environment are main objectives of this research. The obtained results will give a deeper understanding of the dynamic rock wall when exploitation in complex geological conditions. This is a scientific basis for researchers and mining engineers to give better technical solutions in order to treat the water burst, ensure the safety of workers and equipment in the longwall, and contribute to the coal industry's development of Vietnam in coming time.

2. Geological conditions of the L7 seam at the west wing area next to the 790 open pit site of the Mong Duong coal mine

The 7 seam at the west wing area has an average thickness of 7 m and an average dip angle of 15°.

+ Characteristics of the roof rocks:

Immediate rock is siltstone with 1.0–15.7 m thickness, average of 7.3 m. It is easy to cave.

Main roof rock has a thickness of 16.45–37.24 m, average of 30.8 m, consists of sandstone and siltstone. Siltstone ranges from

fine to grain, occupies 45.47%, laminates in a thickness of 0.1–0.3 m. Sandstone ranges from fine to grain, occupies 54.53%.

+ Characteristics of the floor rocks:

The immediate floor has a thickness of 4.48–13.30 m, average of 7.43 m. It consists of brown-grey to light grey siltstone in the lamination of 0.1 to 0.3 m, the hardness of $f = 3.71$ –5.44 (Protodiaconov's classification), average of $f_b = 4.57$.

+ Characteristics of hydrogeological conditions:

Above the L7 seam, the mining areas are at the K8 and H10 seams, which have been exploited from the level of -100 to the coal seams with a distance of 32.1–42.4 m including layers of siltstone, sandstone. Sandstone accounts for 54.53% of the layers that are capable of containing water. On the surface of terrain, the outer dump of the 790 open pit site is located. Due to the impact of the dynamic factors when exploiting at the longwall, water from the above areas can flow through the rock layers, affect the exploitation longwall. Water stored in the wall rocks and surface water replenishes underground water through dynamic cracks of the reservoirs K8 and H10, can penetrate into the longwall, affect the coal production and cause the dangers to workers and equipment in the longwall, especially in the rainy season.

Conditions of rock stratigraphy in the exploitation area of the L7 seam at the west wing area next to the exposed pit are shown in Figure 2..

3. Solution to safe exploitation and reduction of coal losses for the L7 seam

Tab. 2. Mechanical properties of rock in the L7 seam at the west wing edge of the 790 open pit site
 Tab. 2. Właściwości fizyczno-mechaniczne skały w krawędzi zachodniego skrzydła odkrywki 790 na pokładzie L7

Sample location	Rock unit	Value	Compressive strength σ_n (kG/cm ²)	Tensile strength σ_k (kG/cm ²)	Internal friction angle	Cohesion C	Density ρ (g/cm ³)
	sandstone	max	800.13	90.58	34.30'	265	2.75
		min	738.21	64.38	32.05'	219	2.64
		medium	775.94	76.57	33.13'	240.67	2.69
	siltstone	max	593.77	61.73	34.00'	179	2.73
		min	315.94	38.16	32.12'	93	2.64
		medium	442.04	46.12	33.13'	134	2.685
Seam 7 floor	shale	max	1877	187.1	34.05'	575	2.71
		min	968.57	90.26	33.50'	294	2.63
		medium	1422.79	138.68	33.55'	434.5	2.67
	siltstone	max	465.39	47.97	34.15	265	2.79
		min	273.73	33	32.13	81	2.61
		medium	366.27	40.48	33.2	162.3	2.697

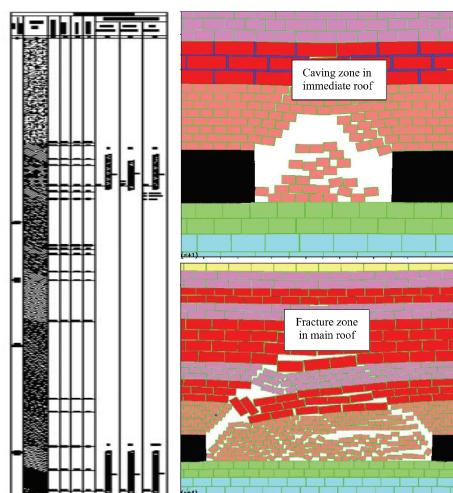


Fig. 3. Lithological column MD269 and simulation of roof rock by UDEC 2D

Rys. 3. Kolumna litologiczna MD269 i symulacja skał stropowych oprogramowaniem UDEC 2D

The water in the 790 open pit site near the west wing reservoir area includes the amount of water available in undergone rehabilitation of open pit site and the amount of rain-water supplied in years. According to the calculation results of the Mong Duong coal mine, the total amount of water in the open pit site is about 422,817 m³/year, with the area of the open pit site is about 189,412 m². According to the exploitation plan of the mine, the levels of -50 ÷ -100 will be exploited in the L7 seam area near the edge of the 790 open pit site by the drilling-blasting technology, the longwall support by self-moving hydraulic frame GK/1600/16/24/HTD. The L7 longwall has a cut-height of 2.2 m, the rest is recovered by coal roof, and the mining area has a length of 200 m. When cutting coal in longwall, it will create a goaf, causing a natural imbalance of stress in the ground, leading to the phenomenon of displacement of rock deformation and destruction of the buildings and environment. The process cut coal will create a large space in the longwall due to the coal being removed, leading to the rock that tends to collapse to fill that space. This process involves the movement of stratigraphy around the mining area. This causes the secondary cracks in the stratigraphic stratification, which is the source of water into the longwall area. Analytical methods of fluid movement caused by underground mining are divided into three groups:

+ Group 1 includes methods based on traditional mechanical theory, such as the thickness-span ratio method and K. B. Lu Peinie theory,

+ Group 2 includes similar simulation test methods, by building models similar to the real ones (equivalent models), stresses, deformation and destruction of rock,

+ Group 3 includes numerical simulation methods that have been developing recently.

To determine the height of the collapse and cracks caused by pit mining (the main source of water into the longwall area) and the parameters of the water flow (contained in rocky soil) using special methods. These methods were developed based on hydrological methods, numerical simulation methods based on physical/rock parameters in the mining area. Thus, the number of numerical modelling methods has been widely applied in mining practice in the world, which is not common in Vietnam. A new numerical model capable of simulating dynamic rock movement, the process of forming secondary cracks caused by longwall operation in the rock wall, assessing the impact of hydrogeological conditions of the open pit area will overcome the limitations in previous studies. At the same time, this is a good tool for assessing and forecasting the water burst when exploiting longwall with complicated geological conditions. This is also the way to solve the problem of exploiting the L7 seam next to the open pit edge of the Mong Duong coal mine.

3.1. Solution basic

UDEC-2D software is the main means, suitable for solving problems in discontinuous environments of rock and soil, in two-dimensional space under the action of static or dynamic

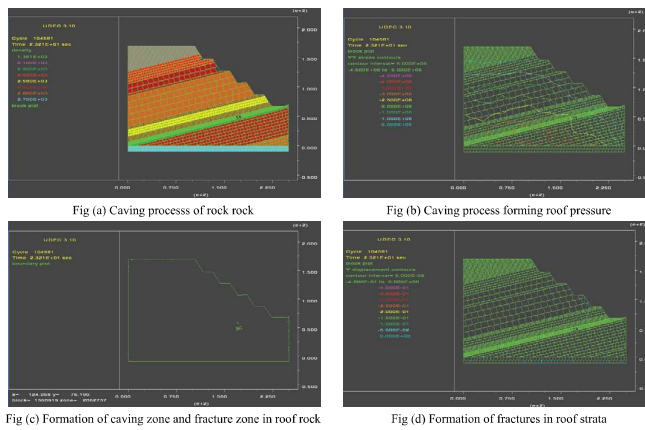


Fig. 4. The state of the roof when the longwall cut of 8 m in the strike in option 1 with 50% coal recovery rate
 Rys. 4. Stan stropu przy cięciu ściany 8 m wzdłuż rozciągłości w wariancie 1 z 50% odzysku węgla

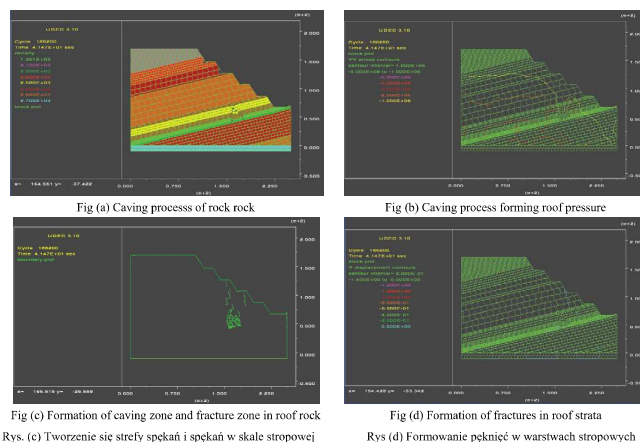


Fig. 5. The state of roof when the longwall cut 20 m in the strike in option 1 with 50% coal recovery rate
 Rys. 5. Stan stropu przy cięciu ściany 20 m wzdłuż rozciągłości w wariancie 1 z 50% odzysku węgla

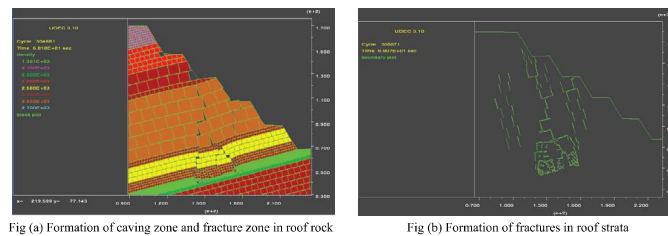


Fig. 6. The state of roof when the longwall cut 34 m in the strike in option 1 with 50% coal recovery rate
 Rys. 6. Stan stropu przy cięciu ściany 34 m wzdłuż rozciągłości w wariancie 1 przy 50% odzysku węgla

loads, through small blocks. The discontinuous faces are present in spaces between small blocks, allowing them to sink and move sharply. In the underground of mining, especially when exploiting in-depth, UDEC-2D is an effective means of forecasting the process of collapsing longwall rock during mining (Pham et al., 2016). Within the scope of the author's article based on the geological structure characteristics of a West Wing L7 reservoir having stratigraphic distribution as shown in Figure 2. with the mechanical parameters of the rocks as in Table 2 combined with using UDEC - 2D software to model, simulate the change state of the wall rock when coal is cut in the longwall. Based on the analysis results on the models to determine the total collapse height, the height of fractures

and the density of the cracking system in the rock wall area caused by the exploitation in the longwall. At the same time, combined with the results of the hydrogeological exploration boreholes assessed the influence of water in the 790 open pit site to the L7 reservoir area.

3.2. Reasonable exploitation solution for the longwall of L7 seam

As analyzed above, finding the mining solution for the longwall of L7 seam near the edge of the 790 open pit site to ensure both safety and maximum saving resources is an extremely urgent problem. The use of numerical models is combined with experimental methods to determine the dis-

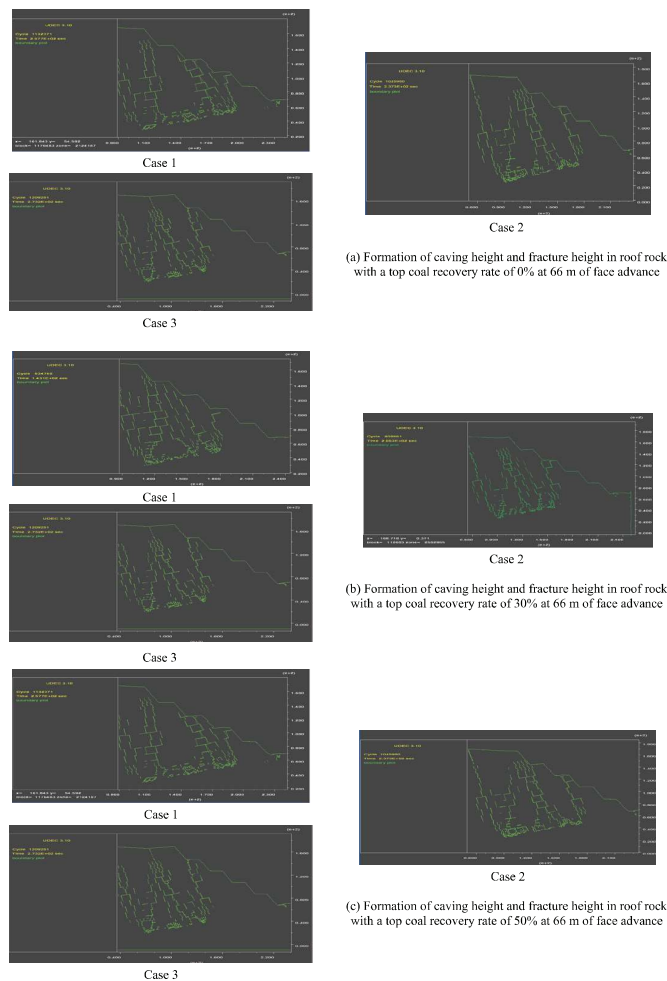


Fig. 7. Formation of fractures in roof strata of L7 seams at the west wing area of the 790 open pit site
 Rys.7. Powstawanie pęknięć w warstwach stropu pokładów L7 na krawędzi skrzydła zachodniego odkrywki 790

placement of rock to assess the influence of water in the exploitation area of the 790 open-pit site. Based on the geological condition of the mining area at the west wing of the L7 seam next to the 790 open pit site, using UDEC – 2D software to model numerically with the physical and rock parameters provided by the mine. The model was prepared with the size of coal pillar (Ltr) turns of 50 m, 70 m, 90 m (Option 1, Option 2, Option 3) with 0% different coal recovery rates, 30%, 50%. The model has dimensions of 250 x 180 m, corresponding to the rock in the borehole column of MD 269, as shown in Figure 3.

3.3. Analyze results of running numerical models

Using UDEC 2D software, write a numerical program code that simulates the rock wall state according to the process cut coal in the longwall. The velocity of cut coal in longwall corresponding to the running of the program is 2 m/day-night. Running UDEC 2D program to determine the impact of the 790 open pit site containing water to the longwall at the levels of -50 ÷ -100 of the L7 seam with three options of coal pillar size and roof coal recovery rate is 0%, 30% and 50%. When cutting coal in the longwall until the completion of the first weighting of the main roof, the state of the wall has similarities with the different mining options. Therefore, the

results from the production of illustrations of the models conducted only in Option 1 with 50% coal recovery rate until the crack system develops strongly in the exploitation area next to the edge of the open pits. From there, the detailed evaluation of the proposed mining plans is the basis for the selection of reasonable exploitation plan to ensure safety and reduce resource loss for the L7 seam reservoir at the west wing area of the Mong Duong coal mine. In the most difficult conditions in the proposed mining options (coal pillar size of 50 m, top coal recovery rate of 50%) when cutting the coal longwall is 8 m in the direct line, the wall state of the long wall is as shown in Figure 4. Figure 4 shows that the longwall is cut to the position of 8 m in the direction of the exploitation plan, the direct roof, the main roof has not collapsed. The process of forming cracks has not happened. The rock area is affected by open pit mining far from the edge of the pit, so there is no influence of water from the pit to the longwall area. The pressure around the longwall area is around 2-4 MPa.

When longwall is cut a length of about 20 m in the strata, the immediate roof will happen cracks, delamination and collapse. The main top of the longwall starts occurring cracks at the edge of the pits, then appearing secondary cracks with different measures. In Figure 5b, the pressure in the mining area ranges from 2 to 4 MPa.

Tab. 3. Total heights of caving and fracture zones. Top coal recovery rate 0%, 30%, 50%

Tab 3. Total heights of caving and fracture zones

No	Borehole	Mv	M	H ₁	H ₂	H
1	MD171	6.34	2.2	9.0	36.90	46.60
2	MD267	6.06	2.2	9.0	36.90	46.60
3	MD269	7	2.2	9.0	36.90	46.60
4	MD371	8.45	2.2	9.0	36.90	46.60
5	MD374	9.7	2.2	9.0	36.90	46.60
6	MD397	7.98	2.2	9.0	36.90	46.60

No	Borehole	Mv	M	H ₁	H ₂	H
1	MD171	6.34	3.44	11.98	43.79	55.78
2	MD267	6.06	3.36	11.85	43.42	55.28
3	MD269	7	3.64	12.28	44.62	56.91
4	MD371	8.45	4.07	12.88	46.27	59.15
5	MD374	9.7	4.45	13.35	47.51	60.86
6	MD397	7.98	3.93	12.69	45.76	58.45

No	Borehole	Mv	M	H ₁	H ₂	H
1	MD171	6.34	4.27	13.13	46.93	60.06
2	MD267	6.06	4.13	12.95	46.46	59.41
3	MD269	7	4.6	13.52	47.97	61.50
4	MD371	8.45	5.325	14.29	49.94	64.23
5	MD374	9.7	5.95	14.87	51.35	66.22
6	MD397	7.98	5.09	14.06	49.34	63.40

Tab. 4. Borehole for aquifers exploration of the L7 seam

Tab. 4. Odwiert do badań pokładu wodonośnego L7

No	Borehole	Distance from tailgate to the bottom pit, (m)	level of bottom open pits, (m)	Observed water flow Q (m ³ /h)
1	KD 661, KD661BS	115	-5y	10
2	KD 667	74	-47	22
3	KD 668	60	-47	18
4	KD 669	104	-30	No water
5	KD 662(1)	46	-45	17
6	KD 663 (1), 663(3)	120	-35	2
7	KD 662 BS	60	-41	100
8	KD 664-1	46	-44	30
9	KD 665-1	84	-50	2
10	KD 432	70	-55	No water

The longwall continues to be deducted in the direction of 20 m, the wall rock status in the mining plans is shown in Figure 5.

If there is no local geological hazard at the longwall, the pressure is relatively stable. In the mining plan, the coal pillar size is 50 m and the coal recovery rate is 50% of the crack density that forms the rock area next to the edge of the 790 open pit site is the largest due to the coal losses. When the longwall is cut a length of 34 m in the direction of strata, the rock wall state is shown in Figure 6.

While the proposed mining plans mainroof are broken. The case of top coal recovery with the rate of 50% of the forming process of cracks at the edge of the pit has appeared with the highest density.

When the coal roof was not reclaimed because the remaining coal combined with the collapsed direct rock wall completely goaf.

Therefore, crack system of mainroof in the area around the edge of the pit is less dense and the size of the cracks is much smaller than in other cases where coal roof is recovered. The longwall continues to be cut discounted to 66 m and in the direction, the wall state of the longwall is shown in Figure 7.

With a cut of speed of about 2 m/day and night, the longwall is cut to 66 m in the direction after more than two months of exploitation of the weighting of main rock area gradually being compacted. At that time, the roof pressure in the pro-

posed mining plans was little changed without the catastrophic geology. It can be seen that when the longwall is cut from the 66th m in the direction, the roof rock behind the longwall has gradually been tightened, so there is a similarity in status. However, the density of secondary cracks appearing next to the edge of the pit has differences in the project. In Figure 7, it is clear that the crack density here thrives in the size of a 50 m coal pillar with a 50% coal recovery rate. The results from the established numerical model determine the total collapsed height and fractured height in the options of the size of coal pillars of 50 m, 70 m, 90 m corresponding to the coal recovery roof rate of 0%, 30%, 50% is 46 m, 61 m, 67 m. However, due to the distance of the coal pillar varies in size. Therefore, the distance from the cliff area is affected by the longwall to the edge of the open pit, so the influence of water penetrating into the mining area is also less. Thus, the risk of water burst enters the mining area will be reduced because of dependence on the amount of water.

3.4. Determining the impact height due to mining the L7 seam next to the waste dump of the 790 open pit site of the Mong Duong coal mine by experimental method

For safe reasons, the underground mining is not done under the waste dump of open pits, the separated rock layers of the waste dump. When mining pit walls controlled by caving

Tab. 5. Analysis result on impact of water in the open pit site to the L7 seam at the west wing area of the Mong Duong coal mine

Tab. 5. Wyniki analizy wpływu wody w odkrywce na ścianę pokładu L7 zachodniego skrzydła kopalni Mong Duong

No	Cross-section	Top coal recovery rate, %	Distance from tailgate to open-pit bottom, m	Level under the impact of water in open pit
1	KD 661, KD661BS	0%	115	Insignificant impact due to large distance (115 m)
2	KD 662 BS	0%	70	+37
		30%		+30
		50%		+27
3	KD 432	0%	60	+31
		30%		+27
		50%		+20

method, the wall rock will move – deform – crack – collapse. According to research by the Russian and Chinese Federation scientists, the stone blocks on the longwall after caving can be divided into three regions from the bottom up. According to the degree of influence of the work deformation, within the displacement tank, it will distinguish the areas: non-hazardous influence, dangerous influence and dangerous area with cracks spreading to the ground. Thus, the exploitation below area will cause surface subsidence, causing water from the surface to flow down through cracks, collapse areas, caving, water will flow into the old mining area. Many authors believe that zone 1 – chaotic collapsed area and zone 2 – moving fractures have a very good capacity of containing underground water, bringing these two zones together and called the water-conducting fractured zone.

Chinese mining scientists provide the following empirical equation for calculating caving zone (Qian Ming Gao, 2011) as follows:

+ Zone 1: Caving zone near face roof

In this zone, rock fails and cave as soon as the face pass by, leading to complete failure:

$$H_1 = \frac{100EM}{2.1EM+16} \pm 2.5 \quad (1)$$

+ Zone 2: Fracture and displacement zone:

$$H_2 = \frac{100EM}{1.2EM+2.0} \pm 8.9 \quad (2)$$

In this zone, rock fails and develops in the cycle. It is formed after the formation of zone 1.

+ Zone 3: Deformation zone

In this zone, the displacement and sagging are not continuous, limited to the surface. :

$$H = H_1 + H_2$$

where: H_1 – caving zone height, m, H_2 – fracture zone height, m, M – Seam thickness at holes, m, H – aquifer zone height, M – Mining thickness, m.

The calculation result of total caving height and fracturing height caused by underground mining is given in Table 2

Based on the calculation results in Table 2, it is clear that recovery coal roof rate of 50% in the coal pillar project will cause the largest stratigraphic displacement in the rock roof, with the height of collapse and cracking. The largest cracks reach 66 m. Calculation results also show that the coal protection pillar is length 50 m, 70 m, 90 m corresponds to the cause of coal loss is 105,103 tons, 147,103 tons, 189,103 tons of coal. Based on the results of the exploration drilling to re-evaluate the structure of L7 seam water exploration in the west of Mong Duong coal mine. Based on the completed cross-section structure, the drilling holes are completed in

this area. The result of determining the distance from the level of ventilation to the bottom of the pit and the amount of water observed through the exploration boreholes, the results are shown in the following Table 3:

In addition, in 03 protective coal pillar project, the horizontal difference of 20 m means that the influence of the water from the waste dump of the open pit to the mining area is enhanced according to the size of the protection pillar. Therefore, analyzing results of UDEC 3.1 software for the three boreholes with Option 1 is the basis for the selection of a plan to ensure safety for the L7 seam longwall next to the waste dump edge of the 790 open-pit site. Based on the results of the coordinates transfer from the cross-sections to the results from the monitoring model in order to determine the impact of the water at the waste dump of the 790 open pit site to the L7 seam longwall mining area at the west wing area of the Mong Duong coal mine. With the length of protection pillar is 50 m and the roof coal recovery rate is 0%, 30%, 50%, the influence of water in the open pits at the extraction area is shown in Table 4.

Thus with the calculation results on the model UDEC 3.1. In the projects, the size of coal pillar is 50 m in the completed borehole sections KD662 BS, KD662 BS1, the water level in the waste dump of the 790 open pit site affects the L7 seam mining area at the west wing area with the roof coal recovery rate of 0%, 30%, 50%, respectively levels of +37, +30, +28. Combined with the water pressure monitoring results of these two boreholes that Mong Duong coal mine has conducted, the water level in the waste dump of the 790 open pit site is levels of -6.8 and -4.5. This means that the projects have a protection pillar size of 50 m and a coal recovery rate of 50% to meet all safety requirements and allow to reduce resource losses for the mine.

4. Conclusion

Based on geological conditions, excavation plans, water exploration cross-sections in the area of the L7 seam next to the edge at the waste dump of the 790 open-pit site of the Mong Duong coal mine, UDEC 3.1 models using parameters of borehole stratigraphic column MD269 and rock mechanical parameters of this exploitation area were developed.

Model results show that with three plans of protection pillars and cases of top coal recovery at the rate of 0%, 30%, 50% the collapse step of the immediate roof and the breaking step of the main roof were from the 20th m and 34th m in the direction of the longwall and the primary roof completely filled the mined-out area.

The protection pillar plans with the cutting rates have the same characteristics when the longwall advances in the strike direction from the 66 m onwards.

Roof rock of the L7 seam longwall has little change due to the consolidation of the rock behind the longwall area.

Options 2, 3 are less affected by water from the waste dump of the open pits compared to Option 1 because the horizontal intermediate beds of soil and rock layers are 20m and 40m, thicker than that in Option 1. However, the coal loss is 42,000 tons and 84,000 tons higher than that in Option 1.

Based on the cross-sections of the mine's water exploration boreholes, the results show that most of these sections have a distance from the ventilation roadway (the roadway is planned to be used in the L7 seam longwall next to the edge of the 790 open-pit) is at least 46 m. (in the two boreholes of KD 662 (1), the remaining KD 664-1 mainly from 60m up to 115m. At the borehole KD 662 BS and borehole KD 432 with a cut height of 2.2m and the top coal recovery at 0%, 30%, 50%

of the water level in the 790 open pit site, affects the exploitation areas at the levels of +37, +30, +27 and +31, +27, +20.

The water levels need to be removed the same in all three coal pillar protection plans. The result of water pressure test in the drainage boreholes of KD-662 BS, KD-664 BS1 at the borehole No. 1 and No. 2 at the level -50 of the L7 seam reservoir at the west wing area shows that the water levels at the waste dump of the 790 open pit site is -6, 8 and -4.5, respectively. This confirms that the combination of protection pillar size of 50 m and the top coal recovery of 50% fully meets the exploitation safe requirements and can reduce the resources loss for the Mong Duong coal mine.

Literature – References

1. E. Bakhtavar. "Transition from open-pit to underground in the case of Chah-Gaz iron ore combined mining," Journal of Mining Science, vol. 49, no. 6, pp. 955–966, 2013.
2. Final report of the topic "Study on the option to ensure safety for longwall mining operation 11-1.16 of Ha Lam coal joint stock company, 2017.
3. FuYuHua. "Study on stability of rock mass and rule of strata movement for transition from open – pit underground mining. China University of Mining and Technology, Doctor of thesis 2010.
4. <https://www.mining.com/these-10-mines-will-set-the-copper-price-for-the-next-decade/>
5. <https://www.mining-technology.com/features/feature-the-worlds-top-10-biggest-diamond-mines/>
6. <https://www.austral-ianmining.com.au/features/the-next-age-of-mining/>
7. Penghongge. Determination and optimization of boundary parameters of open-pit and underground combined mining. China University of Mining and Technology Doctor of thesis 2012.
8. Pham Duc Hung & NNC. Technical solution to ensure safety when exploiting reservoir 11 under open pit - Ha Lam Vinacomin Coal Joint Stock Company, ERSD 2018.
9. Pham Duc Hung, Nguyen Van Quang. Application of UDEC - 2D software for simulation of the behaviour of the rock strata above a longwall coal mining. ESASGD 2016.
10. Qian MingGao. Strata Control and sustainable coal mining. China University of Mining and Technology Press, 2011.
11. Report on investment project on construction of underground mining projects below -97.5 Mong Duong Coal Joint Stock Company, 2018.
12. The Prime Minister. Decision No. 403 / QD-TTg on Approving Adjustment of Vietnam Coal Industry Development Planning to 2020, with prospects to 2030, 2016.

Bezpieczne rozwiązanie technologii i ograniczenie strat zasobów dla pokładu L7 na krawędzi zachodniego skrzydła odkrywki kopalni Mong Duong

W ostatnich latach, w Wietnamie intensywnie prowadzono nie tylko rozbudowę i modernizację istniejących kopalń lecz także zagospodarowano nowe złoża na szeroką skalę. W górnictwie podziemnym istnieje wiele ważnych problemów technicznych, które należy rozwiązać, mianowicie: ciśnienie, wentylacja, transport podziemny, odwadnianie itp. Wykonanie wyrobiska powoduje zaburzenie początkowego stanu równowagi w górotworze nienaruszonym, skutkiem czego w otoczeniu wyrobiska zmieniają się naprężenia których wartość jest większa od naprężeń początkowych. Odprężenie górotworu w otoczeniu wyrobiska górniczego powoduje przemieszczanie się skał w kierunku pustej przestrzeni. Pokład L7 w zachodnim skrzydle kopalni Mong Duong ma średnią miąższość 7 m, średni kąt nachylenia 15 ° znajduje się w pobliżu krawędzi odkrywki 790. Zgodnie z planem wydobywania kopalni, zakład górniczy Mong Duong będzie kontynuować eksploatację tego pokładu z technologią wiercenia strzałowego, podparcie ściany za pomocą pół-zmechanizowanej osłony (samojezdna rama hydrauliczna GK / 1600/16/24 / HTD). Wyniki badań warunków hydrogeologicznych kopalni wskazują, że obszar badany jest potencjalny o dużym ryzyku wtargnięcia wody do ściany. W artykule, przedstawiono odpowiednie rozwiązania technologiczne wydobywczej, które zabezpieczają kopanie przed zagrożeniem wodnym i ograniczy straty zasobów. Opracowana metoda jest zastosowana nie tylko dla kopalni Mong Duong, ale także i dla kopalń należących do Vinacomin, które mają podobne warunki górniczo-geologiczne.

Słowa kluczowe: *technologia eksploatacji, straty zasobów, zagrożenie wodne, kopalnia Mong Duong*