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Improving the process of mining the steep coal seam. Case study of the seam 6(7) in Nam Khe Tam mine, Quang Ninh, Vietnam

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Abstract: Safe and efficient exploitation of steep coal seams is a significant challenge for Vietnamese mining engineers. Traditional extraction techniques—including shortwall methods with wood support, single hydraulic supports, and flexible shield models (such as XDY)—have proven to offer low efficiency and result in high casualty rates. Some mines have attempted longwall technology; however, mechanized coal separation is often unsuccessful due to poor adaptation of equipment to strong impacts from complex geological conditions. Recent experimental trials have successfully demonstrated the diagonal longwall technique using the ZRY support model, providing a foundation for wider application across Vietnamese mines. Nonetheless, this technique revealed drawbacks during the mining preparation phase.

Previously, installation of ZRY flexible supports was performed in an upward sequence from below, causing imbalance at the roadway floor and uneven loading at the roof, which led to support failure and collapse at the longwall face. This paper analyzes mining systems and leverages the technical features of the ZRY support to reorganize the initial installation direction—from the ventilating roadway down to the haulage roadway, progressing stepwise toward the transport entry.

Research results and actual applications have demonstrated that the improved method eliminates the cost of additional installation roadways, shortens the time required for

longwall faces to reach design capacity by 10–15 days (from 85–90 days down to 75 days), achieves a coal recovery rate of 90–95% (25–30% higher than traditional shortwall methods at 70–75%), and attains labor productivity of 6.0–6.5 tons per shift—2–3 times higher than conventional sublevel mining methods.

Keywords: Support model ZRY, ventilating roadway, transportation roadway, installation raise, load, coal seam 6(7).

INTRODUCTION

A coal seam is considered to be dip when the buried angle is more than 45° , mining for these steeply inclined hard coal deposits is very difficult [122633]. Compared to the gently inclined coal seams, mining for the LDACSs (large dip angle coal seams) causes a reduction in the normal component and an increase in the tangential component of supporting gravity [4648]. The reduction in the normal component leads to a reduced weight that the support can bear, therefore, smaller working of the support will be resisted. The high tangential element increases the sliding power, which impacts the support along the inclination direction of the coalface. As a result, support is likely to tilt and slide [102024]. Moreover, the stability of longwalls with steep seams is affected not only by the dip angle but also by the strike angle of the coal seams (i.e. underhand or overhand mining) or passing through faults and other tectonic zones [1719]. In particular, the support in the coalface is subjected to the large horizontal stress imposed by the roof, which will significantly reduce stability of the support [24043]. Thus,

mining for the large dip coal seams has potential risks because of instability caused by the weak nature of the surrounding rocks and their movement after excavation 253944.

The shortwall techniques such as sublevel, room and pillar, blasting gallery... or the longwall can be used to exploit the steep seams. The sublevel caving system originated from the ore mining, sublevel caving (SLC) is a mass mining method that based on using the gravity flow of the blasted ore and waste rock in cave. This method has been applied for mining the dipping steep coal seams for over sixty years despite only being fully mechanized at the beginning of the 21st century 194851. In recent years, with the saturation of conventional coal mine resources, increasingly, steeply dipping coal seams (SDCS) with a dip angle of 35–55 and complex enrichment conditions are being mined 2952. Many scholars have carried out systematic research on the mining technology of SDCS, for example, top-coal caving mining and staggered roadway layout mining were successfully applied for SDCS 4851.

To extract high-quality coal resources, a completely mechanized variant of the sublevel caving system was designed on the basis of standard machines and equipment applied in coal mining. Exploitation was conducted from top to down at the levels of the particular mining sub-level drilling wells with the roof caving 23. The faces in the extracted coal release areas were protected by a pair of system of specially designed mechanized mining. One of the basic issues that is revealed during the extraction process of subsequent mining panels is the changeability of the rate of resource mining. The mining losses changed in the available resources from 10% to 50% 5051.

The room and pillar method, known as the bord and pillar method, is a shortwall method. This method is developed by pushing the water to drift from the main roadways to the block of coal seam forming the rooms. Pillars are formed by letting the coal be non-adhesive between the rooms. Depending on the characteristics of the coal and the rock above the seam, a part of coal in the pillars will be extracted, the remaining coal pillars will be

used to support the roof and control the movement of the strata. The diagram of the room and pillar method is presented in Figure 2b. This method is widely applied in areas whose surfaces need to be improved, for example, coal seams located under the residential areas, rivers, or roadways. The room and pillar method is also applied in areas where longwall methods face up with difficulties due to poor corrosion of coal at the top and/or in the beneath strata 42527.

Another method, named the blasting gallery (BG) method which is considered a modern room and pillar method, has been used in French and Indian coal mines. Operation of the BG method is roadway development along the door of the coal seam in the room and pillar pattern, following as the final extraction of the seam in the transmission line, creating drill holes from the developed galleries in ring patterns. The coal will be broken by the blasting method then. Blasted coal is removed by load haul dump machines (LHD) 42527. The difference between the two methods is that coal extraction from the pillar in the BG method is undertaken by the drill and blasting method, while in the room and pillar method, roadway development and coal extraction are carried out by the continuous miners. As a result, the BG method can exploit very thick seams by one transmission line, which is usually divided into slices when the continuous miners extract. A diagram of the BG method is presented in Figure 2c and 2d. The shortwall methods achieve high productivity but a low rate of coal recovery, resulting in a lot of labor accidents.

In the 1970s, the Soviet Union developed fully mechanized mining technologies for mining thick, medium-thick, and steeply dipping coal seams 56. In the 1980s and 1990s, the United States, Germany, France, the United Kingdom, India, Spain, and other countries also applied mechanized mining methods and ground control techniques to access steeply dipping coal seams; these methods were also used to handle limited experiments 131424. After nearly two decades of

research and development, China has made significant progress in developing the mining theory, application of essential technology and equipment to exploit steeply dipping coal seams, has succeeded in transforming from non-mechanized mining to fully mechanized longwall mining (fully mechanized caving) in certain conditions, and has solved the basic safety problem in mining steeply dipping seams 2122145. The main technical difficulties in applying fully mechanized mining technology are controlling the surrounding rock and mining equipment stability, skidding prevention, and flying gangue prevention. Based on the analyzed trend, prosperous development directions for steeply inclined coal seam mining are proposed 93347. Hongsheng said that: 1. Controlling the equipment stability of steeply inclined working face needs to be advanced. Gliding and toppling over of equipment are the main problems in steeply inclined working faces during mining. The adaptive capacity of supports to the change in coal seam thickness must be improved; 2. More working faces need to be automated. The difficulty for workers in walking in the steeply inclined working faces restricts the cutting speed since the machines are operated by those workers. Thus, automatic mining machines and self-advancing supports are investigated and developed. 3. Rib spalling control techniques need to be improved. Anytime, the roof fractures and the face guard are not stretched out, the massive rib spalling can happen. This would lead roof falling which block the lower end of the working face. Therefore, the structure and capacity of face guard should be enhanced to change the mechanical characteristics of coal walls and the wall stability.

Thus, almost all mines still use non-mechanized mining methods such as oblique short-wall and longwall, except for some mines that have medium-thick or extra-thick coal seams, which are mined by the fully mechanized methods. Mines in which fully mechanized methods are not applied meet restrictions of production and operation, such as low production efficiency, poor safety

operating environments, and frequent casualty accidents. Fully mechanized mining is very clearly difficult for a steep coal seam with a large inclination angle and a hard roof 262849.

DIFFICULTIES IN MINING THE STEEP SEAMS IN VIETNAM

In Viet Nam, coal is distributed mainly in Quang Ninh, Thai Nguyen, Hoa Binh, Hai Duong.... but the coal basin in Quang Ninh possesses most of the national coal reserves. All mines in Quang Ninh have steep seams such as seam 5, seam 6, seam 7 in Ha Lam coal mine, seam 10, 9V, 9T, 9BT in the South of the projects of shield pillar underground mining in Mao Khe, Uong Bi, Ha Long Moreover, these steep seams have small coal reserves, are divided by faults, strongly changes in thickness, slope angle so it is very difficult to return on investment if fully mechanized mining methods are used there. Total coal reserves at these steep seams are 40% of the reserves in the whole region. The steep seams have been exploited with the support of wood instruments, I-shaped steel bars tied by cables, the single hydraulic support, the flexible shield for a long time. In the longwall, most of the working faces are supported by the wood instruments, therefore the height of the longwall is usually from 2,0 - 2,2 meters, thus workers of average height can access the roof and attach the beams, as well as control the risks that may occur when the roof falls. However, the main problem of mining the thick seams is that coal is left on the roof or at the door of the mining table 13738. With an effort for increasing the coal production and improving the rate of recovery coal, the longwall method with many slices is used to exploit seams whose thickness is more than 4,5 meters. This method was applied at the end of 1980s in some Quang Ninh underground mines such as Vang Danh, Ha Lam, with a view of improving the ability of coal recovery in mining the thick seams. A thick seam of coal is mined by two or more slices taken parallel to the mine in descending order. Slices are sequentially taken in independent sides from top to end, simultaneously or not simultaneously; the

height of each slice is 2.0-2.2m. To separate the underlying slices, an artistic roof is created by leaving a layer of coal seam with a thickness of 0.4 to 1.0m among the slices 353738.

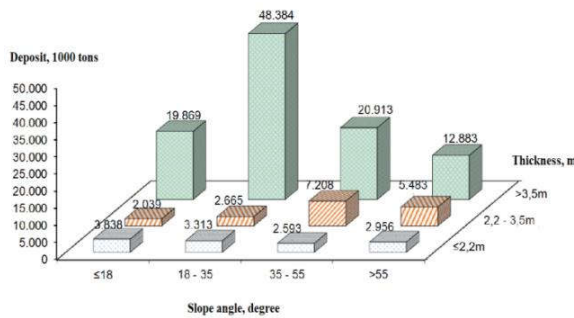


Figure 1. Statistics of reserves with thickness and slope angle of the coal seams in Quang Ninh

Although the multi-slice longwall method improves the rate of coal recovery more than the single-segment longwall, the mining productivity is low due to some peaks. The main issue of extracting the beneath slices is that controls the stability of the roof. The remaining art charcoal layer among the slices is easy to be fractured due to the weight of the rock blocks broken from the goaf of the upper slices. Therefore, if the art coal layer is too thin, it is necessary to do more work to control the potential hazards of the fallen roof on the longwall, especially in which the face of the beneath slices operate under the goaf area of the upper slices. In addition, the instability of the roof can make it unsafe. Leaving a thick layer of art coal among the slices can prevent the potential danger from the broken rock block that falls down, but in this case, loss of coal is greater 63738.

With steep seams, the most common methods used in Vietnam in the past were the blasting gallery method BG as Figure 2c, the Blasting sub-level stopping system in Figure 2a. The supporting material is wood or steel, coal is separated by the dynamite. These two systems have the low investment capital, fast payback time, and easy operation. The other challenge of the application of the room and pillar method in Quang Ninh mines is the road development technology being used there. In the room and pillar method, many gateroads

need to be driven, and coal that was extracted from roadway development accounts for a large proportion of the total coal product. The gateroads should be operated by mechanized mining equipment in order to get a high output from the room and pillar method. However, the disadvantage was seen that almost all gateroads in the underground coal mines in Quangninh have been driven by the drilling and blasting method, coal is loaded on the chain conveyor or locomotive cars by manual means, and the face is supported by steel arches or timber beams 43437. The main reason for the low advance rate is the attrition of time and labor in transporting and erecting support materials, because all the gateroads are supported by arch steels or steel/wooden bars. when the coal seams are so steep that the workers must exploit continuously, driving through the gateroads and transporting support materials by manual method will certainly increase the costs and time of roadway development. Therefore, the low advance rate of the process of roadway development will limit the efficiency and prevent the increase of coal production if the room and pillar method is applied in the Quangninh coal field 43538.

In reality, the production BG method has high productivity per man-shift. However, the ability of coal recovery is low and the proportion of accidents is high, which are disadvantages of the method. Statistics from many coal mines applying the BG method show that coal recovery is less than 60%. The reason is due to the weak or moderately strong roof of seams, so in mining process a large amount of coal is blocked by collapsing rock from the roof, or by drifting props for supporting before blasting, as illustrated in Figure 2d. In some situations, a large volume of coal was still hanging in the goaf area. Workers were easy to break safety management regulations, they entered into the goaf area to drill one or more small blast holes in order to get some of the stuck coal.. In reality, a lot of death has been reported in the Quangninh coal eld because of cases like that 41637.

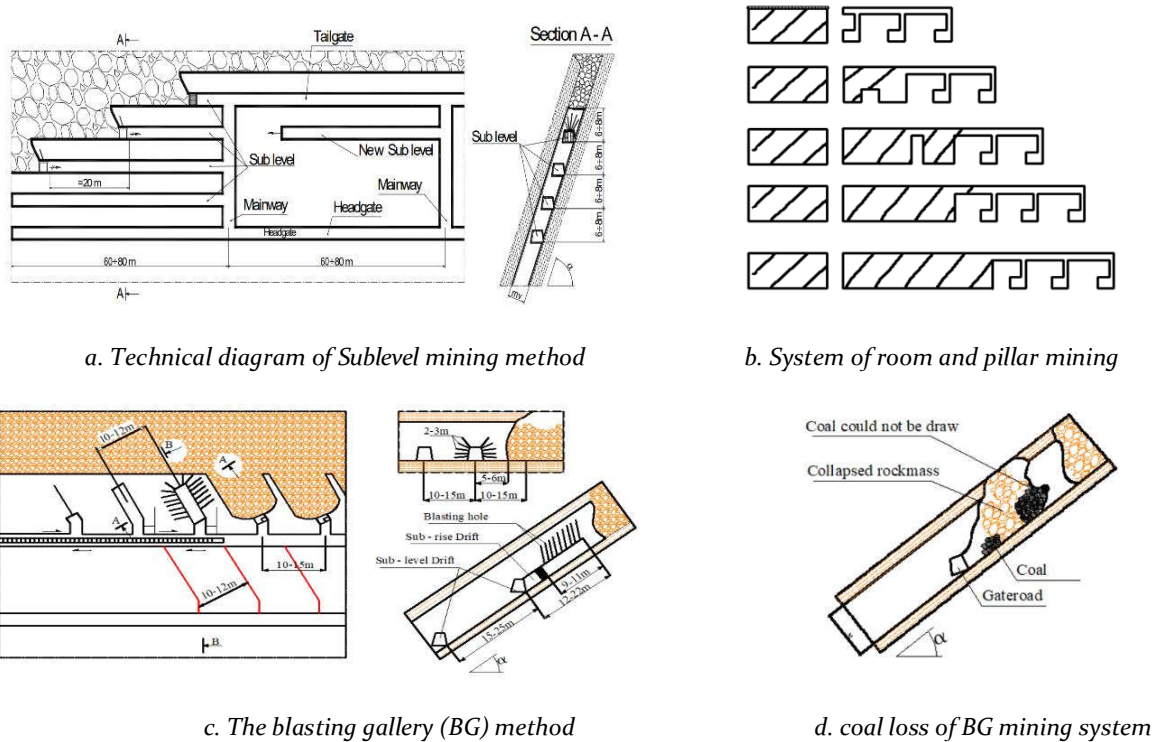


Figure 2. Mining system of room and pillar method, BG and Sublevel method

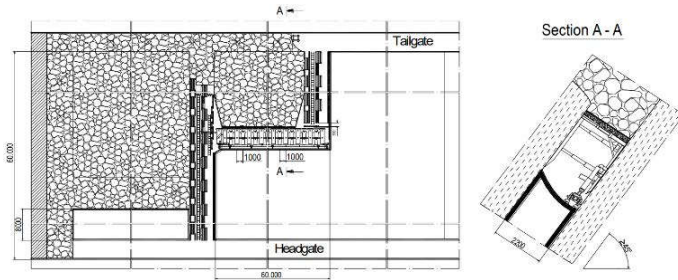
In Viet Nam, exploiting by sublevel method with using the single hydraulic supports, supported by semi-mechanized shields model XDY-1T2 / LY or mining by dynamite are being limited (Shown in fig 2a and 3). This method has the same disadvantages as BG method such as low coal recovery, high proportion of happening accidents, large ratio of roadway development per produced tons of coal, many driven gateroads in steeply flooded conditions 353638. The mechanization technology retreats along with the seam dip, extracting the high steep thin coal seams by coal plough has been applied since 2008 in Mao Khe and Hong Thai coal mine, supported by shield support 2ANSHA. In the period of 2007-2013 (Figure 3a), with mining of steep thick seams, Vang Danh and Ha Long coal mines had trial application of shortwall technology, face was supported by power shield model KDT-1, KDT-2, and top coal caving through blasting drilling in the long hole (Figure 3b) 7811. However, both of the projects fail to achieve the proposed target. Objective reasons are complicated geological conditions, water making coal slurry, too big

mine pressure ... Subjective reasons are that distance between the rigs is large, the manual dynamite charging technology is inefficient and time-consuming due to non mechanized explosion stage, in the bordering area between the longwall and the ventilation roadway, and transportation continuously has to resist cropping ... (for the longwall using the KDT rig); Much work must be done manually, the jacking in the adjacent area between the longwall and the ventilation roadway, transportation takes many stages due to large-scale face sliding, and slipping, toppling of the equipments, so application of fully mechanized mining technology be difficult and limited, the large investment capital is not suitable to the seam with small reserves, the slope angle of the seam makes the support fall ...

Fully mechanized mining is very difficult for a steep coal seam with a large inclination angle and a hard roof [12]. As a simple and easy mining method, a flexible shield method for supporting minerals mining has been widely used in the steep coal seam mining. However, mining under a hard roof by the caving

method, a large area of the roof can be hung, which will lead to a collapse of integrity and

will have a strong impact on the working face 32629.



a. Diagram of mechanized mining in Mao Khe



b. Using the support model KDT

Figure 3. The fully mechanized technique was used in Mao Khe and Ha Long mines

MINING METHOD FOR OVERCOMING THE INFLUENCE OF THE LARGE SLOPE ANGLE

Rationale

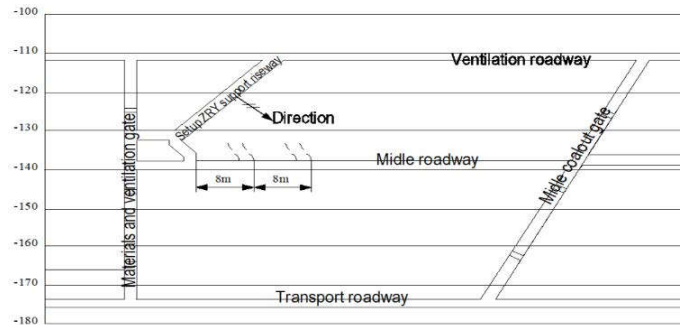
For a long time, underground mining in Vietnam has faced many challenges in exploiting the steep seams; it is essential to increase productivity and safety in these areas. The above analysis shows, shortwall face has high productivity per shift but the amount of preparation roadway is large (sublevel), coal loss is big (room and pillar, BG), or equipment is inappropriate with regional geological conditions (KDT rig or 2ANSH technology) so it is necessary to improve technique to match the specific characteristics of Vietnamese mines 8151832. Besides, the longwall operates more stably than the shortwall. Therefore, the mining direction for the steep seams is the longwall method. In term of geometry, the inclined angle created by the diagonal of the rectangle is always smaller than the right angle. This is an important basis for forming the diagonal longwall system. The diagonal longwall is established by building a raise that is dug diagonally at a steep angle to the direction and slope angle of the seam, then form a diagonal face with a slope angle of 20 to 30 degrees (Figure 4a). The key technical issues for achieving the safe, efficient coal mining and high coal recovery ratio are the surrounding rock control in strong strata behaviors that operate face -to- face, efficient mining technology, and development of equipment in

the complicated mining seam. Thus, the paper studies “hydraulic support and surrounding rock coupling control theory and technology” based on long-term technological research and innovation practice 202941.

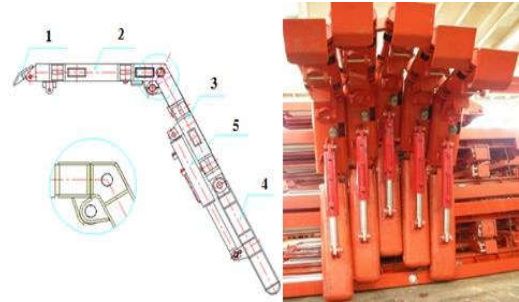
The invent of the support model ZRY (Figure 4b) is the result of specialized research for the slope seams, especially suitable for small-scale seams because the price of the model ZRY is cheaper than the mechanized support [18, 33, 34]. The support ZRY is flexible with all variation conditions in thickness and slope angle of the seam. Each soft support ZRY consists of details: (1) oriented bar: connects to the roof bar by turning pegs, slide on the seamwall when the support moves, (2) roof bar (main bar): connects to the oriented bar (turning pegs) and the rear bar (hard pegs), (3) rear bar: connects to the roof bar (hard pegs) and the tail bar (turning pegs), (4) Tail bar: connects to the rear bar by the turning pegs to control the tail bar straight or folded, (5) Piston for controlling the tail bar: One side is connected to the rear bar, the other is connected to the tail bar, operated by control hand and hydraulic system. – The hydraulic system controls piston of the tail bar: the cyclic hydraulic system, has 3 control hands to operate the tail bars of three supports. With such a structure like that, all the pressure generated by the collapsed rock wall is transferred to enhance the friction force at the top and foot of the support, so, the protection

ability for the longwall space is increased. Because of not having the beneath plate, the hydraulic piston is both a force transfer

element and a flexibility creating part when the thickness and slope angle change.



a. Diagram of digging the mining previous preparation roadway method.



b. The support model ZRY

Figure 4. Diagram of constructing the diagonal longwall using the support model ZRY

Experiment for assessing the production reality

Base on the above analyzed theory, the Vietnam Coal and Minerals Corporation conducted experiments from 2015 to 2018 in 3 different steep seams in some mines such as Hong Thai (2015-2017), Uong Bi (2016-2019), Mong Duong (2017-2020).

Preparation: The mining area is prepared by stratifying according to the ventilation roadway and the transportation roadway. The vertical height of the longwall floor (stratified) is usually chosen $30 \div 50\text{m}$, corresponding to the length of the diagonal longwall of $60 \div 110\text{m}$ (the slope angle of the longwall is $25 \div 28^\circ$). At the ventilation level and the transportation level of the floor (or strata), the roadway is dug along the ventilation seam and the transportation seam to the field border. From the longwall along the transportation seam at the border, a coal removing crosscut and the initial travel crosscut are dug, the distance between two crosscuts is $6 \div 8\text{m}$. The length of the crosscut depends on the width of the coal pillar for protecting the transportation roadway, the minimum length of crosscut is 5.0m . At the point where stop digging the crosscut, a roadway that connects two crosscuts is opened, then the diagonal raise is opened up to the ventilation roadway based on the connecting roadway. From the initial raise,

the soft support will be installed to exploit the longwall. During the mining process, digging the coal removing crosscut and ahead ventilating the longwall face is conducted simultaneously, the distance between the crosscut is $6.0 \div 8.0\text{m}$ so that, in front of the longwall face, $2 \div 3$ crosscuts are maintained ahead.

The longwall mining: Mining is conducted by drilling and blasting, the sequence of mining is from bottom to top in segment with the length shown according to the mining passport, the mining progress of the face is 0.8m per one cycle. The longwall uses the mechanical soft support, on the top of the support, a steel mesh is covered to prevent and limit rock from entering the longwall and to help the support to be recovered conveniently. At the foot of the longwall, the horizontal longwall is maintained with a length of $15 \div 20\text{m}$, at the head of the longwall, the horizontal longwall is maintained with a length of $10 \div 15\text{m}$. After each mining cycle, the supports themselves move in the direction of the mining face with a distance that is equal to the mining progress through rock pressure broken above the support and the weight of the support. According to the progress of the movement, the horizontal longwall part at the foot is longer and the horizontal longwall part on the ventilation roadway is shorter. Therefore, after a certain number of mining cycles, the supports

at the foot of the longwall need to be recovered and moved to along the ventilation seam to install additionally.

Coal transportation: Coal mined from the longwall face slides down to the coal removal crosscut, then flows to the roadway raking trench along the transportation seam. From the roadway along the transportation seam, coal is transferred outside through the mine's general transportation route

Ventilation: Ventilation for the longwall is conducted through the general pressure reducing line of the entire mine. Clean wind outside enters the open roadway, go up the transportation seam and the coal removing crosscut to ventilate the longwall. The waste wind of the longwall goes through the ventilation seam and is pushed out according to the wind escaping roadway.

Drainage: Water released from the mining area of the longwall flows itself through the drainage ditch system on the roadway designed with an outward slope of 5‰ and drains outside by the drainage system of the mine.

Diagram of preparation and exploitation steps applied for underground mines in Quang Ninh is shown in Figure 3a, 4, 5.

Step 1: Dig the preparation roadway system that includes the transportation raise connecting the ventilation roadway and the main transport roadway, then from the raise excavate the stratified roadway, dig the diagonal raise to install the support model ZRY. Dig other roadways as (Figure 4°, 5a).

Step 2. Install equipment system and the support model ZRY in the diagonal roadway. Drilling and blasting to load for the support (Figure 5b).

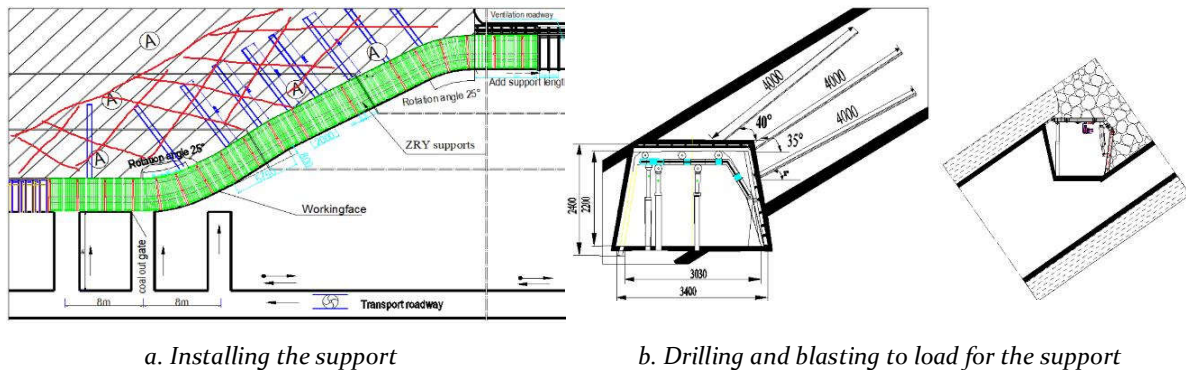
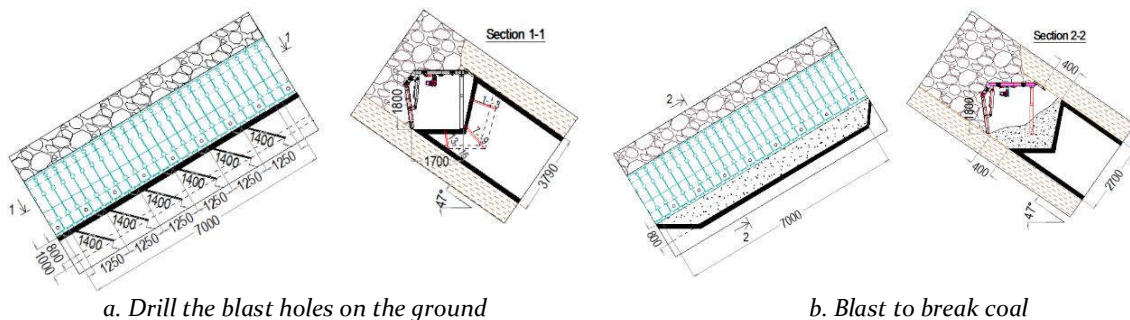


Figure 5. Install and load for the support

Step 3. Conduct periodic mining (reach design capacity) as Figure 6.



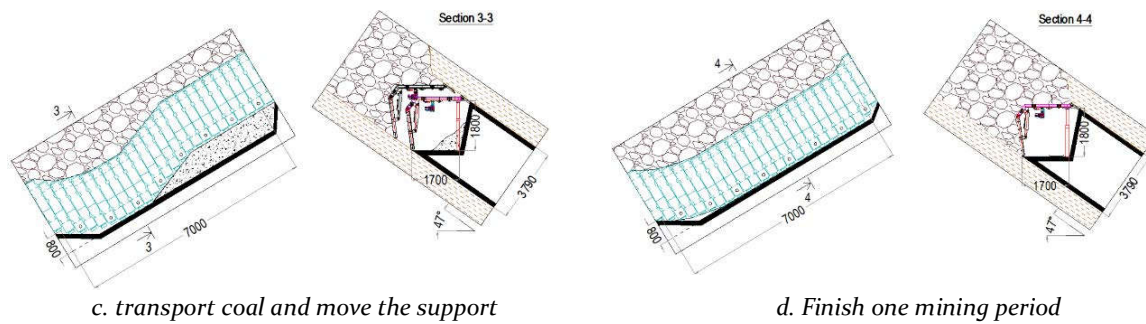


Figure 6. Diagram of the periodic mining

The experiment result in period of 2015-2020

The real experiment was conducted in Hong Thai coal company (2015-2017) at the seam 9B# level + 30 / + 95. The used technology achieved remarkable efficiency: average coal production was 400 tons/a day, the labor productivity reached 5.5-6.0 tons/a day (2-3 times as high as the sublevel method), and the coal loss was only from 12.6-16.3% [1, 18]. This technology has improved safety and has been suitable to working conditions in the steep seams. Moreover, application of the diagonal longwall system with the support ZRY reduced the development speed of roadway per ton of coal production, only 16.7 m/1000 tons (average degree of 30-40 m/1000 tons in sublevel and BG method). The time is 90 days from preparation period of the mining area to mining period with designed capacity achievement, the proportion of residual coal in the goaf area is about 30-35%.

The next tests in Uong Bi (2016-2019) and Mong Duong (2017-2020) had the similar results. Summary of application results of the new method until the end of 2020 shown that this mining technology has many outstanding advantages of technique and safety that are better than the other mining technologies at the same conditions. In terms of economic - technical indicators, the method gains the high labor productivity, coal loss and cost for roadway preparation are low, expense for wood is low. In terms of safety, process of mining is simple and easy to access, the longwall is ventilated by the wind network of mine so the working conditions for workers are improved.

The equipment in the longwall is little, the structure is simple, so the incidents in production are quickly overcome, which helps exploitation stably and continuously. The flexibility of the support model ZRY in geological conditions that strongly changes in thickness, slope angle, ensures a good support for the mining space in the longwall. Average labor productivity of 6.0-6.5 tons/ton (per man-shift) is 2-3 times as high as sublevel mining method. On the other hand, the construction cost for roadway meters/1000 tons of coal of the sublevel mining method is 35-45 m/1000 tons of coal, this of the diagonal longwall method using the support ZRY is 16.7-25 m/1000 tons of coal. This technology has the same productivity and safety level as some longwall faces that operate with lower slope angles and it is very suitable with steep seams, small reserve scale.

IMPROVEMENT OF TECHNIQUE IN THE MINING PREPARATION PHASE. CASE STUDY OF THE LONG WALL AT SEAM 6 (7) LEVEL - 175/-110 IN NAM KHE TAM MINE

Figure 4a shows that the process of load for the support is incapable of recovering fully coal behind the longwall (the red circle lines), the amount of recovery coal is 65-75% of total coal in the letter A area. It takes 85-90 days to complete the preparation steps for the periodic mining phase (gaining the design capacity). However, the rate of recover coal can increase more and the expense of digging the installation roadway is able to be economized on the base of the moving feature of the support ZYR in the diagonal longwall. Therefore, the proposed solution is that

accesses the ventilation roadway and dig down the transportation roadway. To demonstrate the above theory in practice, an experiment is conducted in Nam Khe Tam mine at seam 6(7) level -175/-110.

Natural characteristic of the area

The experimental area is at seam 6, Nam Khe Tam, Cam Pha city, Quang Ninh province, Vietnam. Seam 6(7) has some characteristics as: Average thickness (m_{tb}) is 3.79 m; Average slope angle (α_{tb}) is 48° ; Volumetric weight of coal (γ) is $1.44T/m^3$; Side length (L_p) is 260m; Length in slope direction of stratification (L_d) 40; rock in the side of seam: a siltstone layer located directly on the coal seam has the thickness of $8.6 \div 32.2m$, average of 15.8m, there are layers of claystone, lenticular coal clay. The siltstone layer has compressive strength $\sigma_n = 41.61 \div 3910.00kG/cm^2$, average of $425.79kG/cm^2$, average volumetric weight $\gamma = 2.68g/cm^3$. The wall rock layer is a siltstone of moderate stability and collapse. Above the siltstone layer there is a set of sandstone with a thickness of $12.7 \div 34.8m$, with an average of 22.3m. Compressive strength of sandstone layer $\sigma_n = 117.74 \div 3433.51kG/cm^2$, volumetric weight $\gamma = 2.70g/cm^3$. The wall rock layer is sandstone which is stable and difficult to collapse. Pillar

rock: a layer of siltstone whose thickness varies from 2.1 to 3.2m lies under the coal seam.

Designing and experimental construction in the longwall at seam 6(7) level -175/-110 nam khe tam mine

The support was chosen to be ZRY 36/45L model, the distance between central points of the pillars which were used to support the end roof and the roof of the working face is 1.15 m. The guide girder, the top girder, the guard girder and the tail girder were shown as (Figure 3b). Among them, the guide beam (1.000 mm) is connected to the top beam (1.940 mm). The globe-shaped pillar head is used as an auxiliary support. The guard girder (950 mm) is connected to the tail girder (1,200 mm) and a hydraulic jack was installed in the middle of the connection segment to adjust the angle of the tail girder for coal separation and also adjust the chord length of the support with a view to adapting to different changes in thickness of coal. Working range of the model ZRY 36 / 45L is suitable for the thickness of 2.5-6m, the slope angle of the seam from 45° - 81° . Coal was separated by using dynamite. Roadway are dug in coal, level roadway -110 serves ventilation, the one level -175 is used to transport coal. The diagram for establishing the mining system is shown as (Figure 7b).

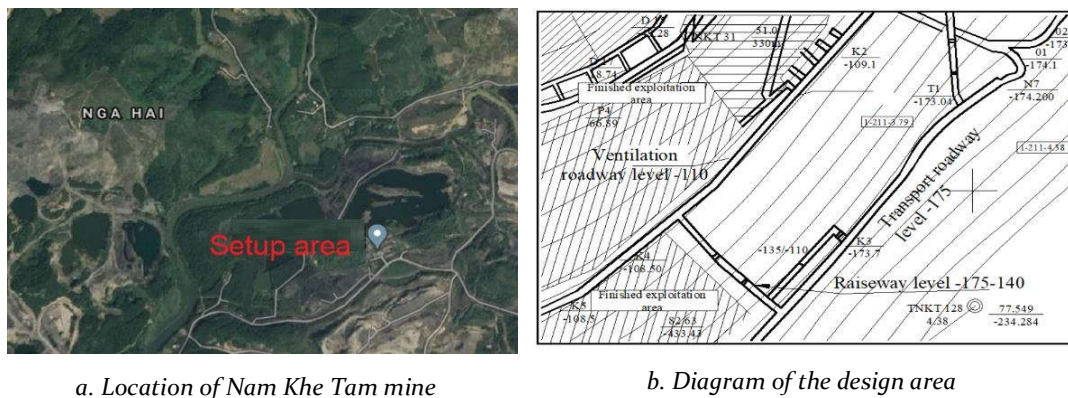
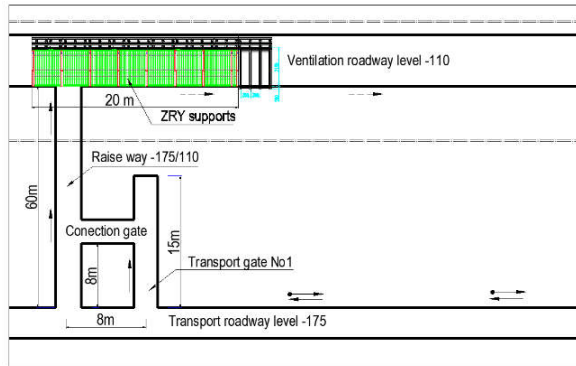


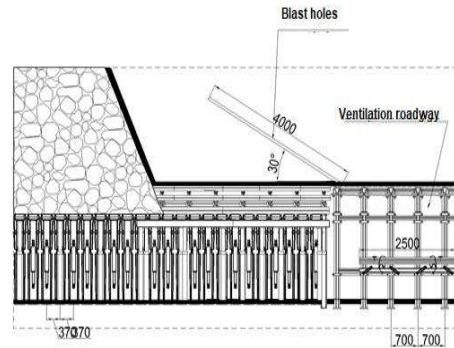
Figure 7. Location of the studying area

Step 1. dig the raise level -175/-110, dig other roadways and install the support model ZRY in the ventilation roadway with the length of 20 m as Figure 7b and 8a .

Step 2. Drill blasting and loading on the support in the ventilation roadway (Figure 8b).



a. Step 1 dig the preparation roadway and install the support ZRY in the ventilation roadway



b. Step 2. Drill blasting and load for the support in the ventilation roadway

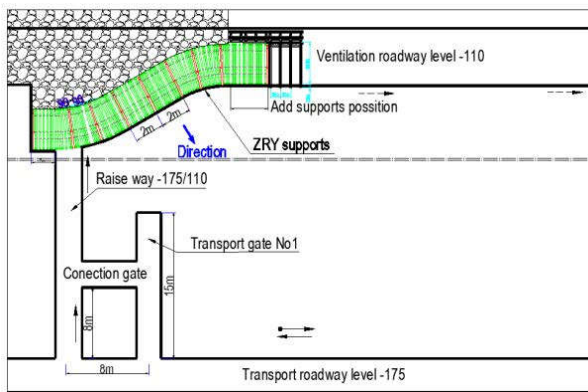
Figure 8. Diagram of construction in step 1 and 2

Step 3. To conduct coal separation, explosives are sequentially loaded into the boreholes to break up the intact coal mass. The procedure progresses in order from the haulage roadway up toward the ventilation roadway.

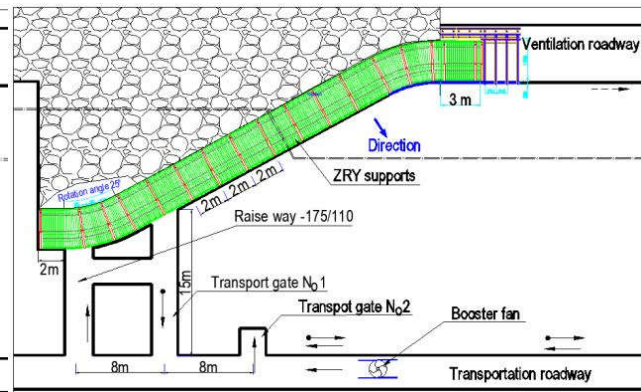
The extension of the longwall resulting from this coal extraction process is supplemented with additional ZRY supports at the ventilation roadway. The footwall points are gradually lowered, step by step bringing the longwall to the designed inclination of 25 to 28 degrees. During the cutting process, the

flexible support at the crown of the longwall becomes shorter; therefore, it is necessary to install auxiliary supports in the ventilation roadway (Figure 9a).

Step 4. Continue to drill and blasting to separate coal - transport - move the support as shown in 9a until the longwall approaches to flute throat 1. At any time, flute throat 1 is the coal loading line, the raise level -170/-110 will be the material transportation roadway (Figure 9b).



a. Step 3. Lower the coal floor



b. Step 4. Lower the coal floor until approaching to the crosscut roadway No1 (transport gate No1)

Figure 9. Diagram of implementing in step 3 and 4

Step 5. Continue to align the foot of the furnace to have enough length of 10-15m. At that time, the process of building the diagonal

longwall finishes, the working face transfers to the periodic mining state as shown in Figure 10a.

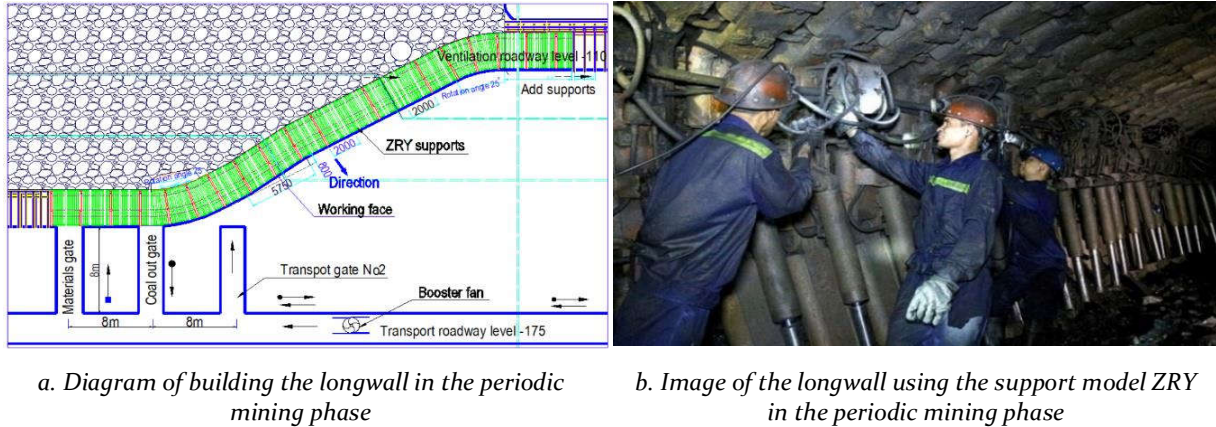


Figure 10. Results of building the longwall ZRY in the periodic mining phase

RESULTS AND DISCUSSION

Table 1. Compare obtained results from the old method and the new one

Criteria	The old method (shortwall technique)	The new method (longwall technology)
Construction time for achieving the design capacity	85-90 days	75 days
Rate of coal recovery	70-75%	95%
Expense for production	Must dig the roadway to install equipment	No need to dig the roadway for installing equipment

The new way of mining preparation shortens time of achieving the design capacity with 10 -15 days, hardly spends money and labor digging the installation roadway, the recovered coal production is 9.356 tons (about 95% of total reserves in the area where loads for the support A. The whole *periodic* mining process has gone very smoothly without any significant errors. Thus, the improvement of technique in the initial set-up for the ZRY longwall gives chance to widely apply this technique for many other areas with similar exploitation conditions.

CONCLUSIONS

The diagonal longwall mining technique, utilizing the ZRY support model and dynamite for coal fragmentation, represents an optimal solution for steep, medium-thick, and small-scale coal seams in Quang Ninh. By leveraging the movement characteristics of the ZRY support, installing support within the ventilation roadway, and progressively lowering the floor level according to the

designed slope angle toward the transportation route, the mining preparation phase can be completed efficiently. Preparation for initial installation as the proposal in the article solves shortcomings of the old plan and achieves some advantages such as: (1) - Longwall was exploited earlier; (2) - Reduce the metres coefficient of the preparation roadway: The upper face at the beginning which was dug perpendicular to the seam is shorter than that in semi-inclined excavation, it was unnecessary to dig the roadway system along the stratified seam, so the cost of support wood was saved; (3)- The initial blast and break almost took place on the support in the DVTG roadway, so the work was very convenient.; (4)- The recovery of resources was maximum, there was no loss of the coal pillar behind the working face of the diagonal longwall.; (5) - Safety in construction and installation was good , the longwall was ventilated by the general antihypertensive of the mine, so microclimate factors were guarante.

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