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特　　集

Analysis on Causes of Large-scale Ordovician Karst Water Inrush at 27080 Working Face of Eastern Caoyao Mine

Song-ying LI*, Bo FAN** and Ping-ping LUO*

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The large-scale Ordovician Karst water inrush occurred at 27080 working face in Caoyao Eastern Mine on December 23th, 2006, the maximum water inflow arrived at 1693 cubic meters per hour. The source of this water inrush was the Ordovician karst water; the dynamic condition was high hydraulic pressure; the water conducted channels were formed by hydraulic pressure and rock pressure in the weak area of floor; and the space of that was offered by excavation. The proposals for preventing and controlling water were put forward.

Keywords: Mining face, Karst water, Water inrush, Grouting

1 INTRODUCTION

Eastern Caoyao mine, located in the middle of Shanmian coal field, is one of the relatively small mines belonging to Yima Coal Industry (Group) Co. Ltd. Its designed mine capacity is 300 thousand tons per year and the Permian Shanxi group coal has been mined, the coal type of which is coking coal. The thickness of coal seam changes from 0 to 13 meters, averagely, 3.5 meters. And that the roof of coal seam is the interbedded strata between sandstone and marl. As for the source of water inrush, the sandstone water in roof and marl water of the Taiyuan group in floor are made. The average thickness of the artesian aquifer of karst fracture, where the water-rich property is highly uneven and which is closely associated with the Cambrian aquifer, is 50 meters from roof to coal seam. According to the recent pumping test of the Ordovician and Cambrian marl, the permeability coefficient is from 0.213 to 570.146 meters per day and the unit water inflow is 0.001~71.092 L/(s・m), thereby the mine would be threatened with the Karst water inrush. Additionally, the annually average normal water inflow is 211 cubic meters per hour, and the mining hydrogeological condition is attributed to the mid-complex type that the hydrogeological condition of the low level is of simpleness but complexity towards that of the deep level.

The 27080 working face is situated in the western flank of the 27 district dip of eastern Caoyao mine. The lengths of the strike and dip are 125 meters and 88 meters, respectively, and the thickness of coal seam, being inner thick but outer thin, is from 1.8 to 5.9 meters, the average thickness 3.7 meters and the reserves 56.9 thousand tons. The top and bottom of it are respectively the 27060 and 27100 working face, neither of which is mined (Fig. 1). The elevation of working face is from 275 to 310 meters, respectively corresponding to the ground elevation from 680 to 702 meters, and the mining depth is from 380 to 405 meters. The original water level of the Ordovician aquifer is 538 meters, while the geological condition of this working face is relatively simple and the geological structure such as fault has not been examined. The dip angle of coal seam is from 8 to 18 degrees, averagely 13 degrees. The 27080 working

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face commenced coal winning on November 13th, 2006, the length of which was 45 meters and the workable reserves 25 thousand tons. In the process of coal winning, the open-off cut needed to be made due to the water inrush and caving of roof for two times. While the length of the first district sublevel was 15 meters and that of the second and third one were not more than 7 meters and 10 meters, respectively. Furthermore, these two coal pillars did not both arrive at 5 meters.

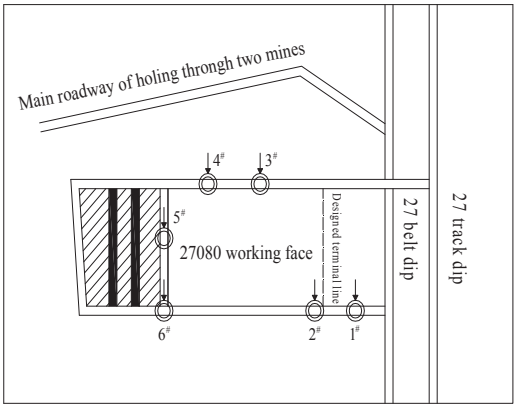

Fig.1 27080 working face plane position sketch map

2 BRIEF ON PROCESS OF WATER INRUSH

The large-scale Ordovician karst water inrush arose in goaf of the 27080 working face on December 23th, 2006. At 12 o'clock, the water inflow arrived at 121 cubic meters per hour, and after that inflow increased to 270 cubic meters per hour. Henceforth, the inflow rose constantly to the peak value of 1693 cubic meters per hour at 2 o'clock on 26th, following that it remained steady at about 1400 cubic meters per hour. Owing to water inrush, the water level of the observation well for the Ordovician karst water, being 430 meters apart from the water inrush spot, had dropped stably from the foregoing level of 538 meters to the minimum level of 494 meters, so that the water level fell over 44 meters and the water drained away for 2.1 million cubic meters totally.

3 ANALYSIS ON CAUSES OF WATER INRUSH

3.1 Source of water inrush

The source of water inrush was the Ordovician karst water on the bases as follows:

Firstly, the type of water quality was judged as the saleratus water on the ground of the sampling analysis, which exactly reflected the primary characteristic of the Ordovician karst water[(1)].

Secondly, the water level of the observation well under ground for the Ordovician karst water, being 430 meters apart from the water inrush spot, had decreased continually by 44 meters totally, and that the water level of the original well, being 15 kilometers away from the water inrush spot, had also fallen over 15 meters, which all indicated that the depression-cone had formed around the center of the water inrush spot.

Thirdly, the maximum water inflow arrived at 1693 cubic meters per hour and the steady inflow 1400 cubic meters per hour at the water inrush spot. Yet the other aquifers did not hold such strong capacity of water inrush.

Fourthly, the water level of the observation well rose steadily over 20 meters for 1 month and amounted to 37 meters for 4 months during the evening of grouting for water-blocking.

3.2 Water conducted channel

The fault structure was not founded at the working face when the mining activity was developed. The water inrush, belonging to the retardation type, occurred in goaf. Before exploration, the Ordovician karst water experienced such high rock pressure that it produced an initial ascending height in the impermeable layer of floor as about 10 meters, and yet the ascending height in the breaking district sublevel was much greater. However, the small water conducted zone or rock-pressure breaking zone was formed by way of the longwall mining on the strike in the floor of working face, which developed to the depth of 10~15 meters[(2)]. Since the caving technology was employed at this working face leading to the cutting height of 6 meters and the coal winning length of 45 meters that had already been made was divided into three district sublevels, which of them was 7~15 meters, all of them brought about the difficulty of caving the roof and the state of suspending the roof in some zones. The breakage of floor would also extend to the deep zones under the circumstances. Thereby, the water conducted channels were formed on condition that the weak district sublevel of floor was ripped by the combined effect of hydraulic and rock pressure and the initial fractures brought by the long-term hydraulic pressure in the impermeable layer of floor connected with the above mining fractures and expanded subsequently.

According to the boring check on grouting for water-blocking, it implied that the working face was at a distance of 43.5~67.33 meters from the Ordovician roof and the water conducted channels were in the vicinity of the 5th borehole, being in the middle of the working face, where the fractures of floor fairly developed and broke.

3.3 Dynamic condition

The karst water pressure exerted on the floor of the 27080 working face was 2.5 MPa on the average, so that it provided the dynamic condition for water inrush.

3.4 Space of water inrush

Beyond doubt, the mining activity was a key factor inducing the water inrush and offered the space

of that.

3.5 Analysis on the coefficient of water inrush

The chance and strength of water inrush are both controlled and determined by the factors including the thickness and integrality of the impermeable layer of floor, hydraulic pressure and the runoff condition of groundwater. Here, analysis on the risk of water inrush at the 27080 working face is to be made by applying the computing formula for the coefficient of water inrush as follows:

$$T_S=P/(M-C_P-H_d) \quad (1)$$

where, T_S denotes the coefficient of water inrush, MPa/m; P represents the hydraulic pressure, namely the karst hydraulic pressure imposing on the floor, MPa; M indicates the total thickness of the impermeable layer of floor, m, since the chance of water inrush is controlled by the thinnest area, the minimum value of thickness may be substituted; C_P is the thickness of water conducted zone formed after the floor losing the impermeable capability due to the mining disturbance, m; H_d is the initial ascending height of the impermeable layer of floor, m.

To consult other experiential data of mines, C_P and H_d are, respectively, adopted as 15 meters and 12 meters. The average hydraulic pressure of floor at the 27080 working face is 2.5 MPa and the distance from coal layer to the Ordovician top is merely 43.5 meters, and follows that substituting these data into Eq.(1), it yields T_S=0.1515 MPa per meters. Referring to the nationwide practical information and Mine Hydrogeological Regulations, it suggests that the coefficient of water inrush at the breaking floor is generally not more than 0.06 MPa per meters and that of normal zone not more than 0.15 MPa per meters as well[3]. In contrast with above data, it is, however, not difficult to find that TS of 0.1515 is more than 0.15 and far more than 0.06. By this token, even though the floor is integrated at the 27080 working face, there exists a risk of water inrush (Fig. 2). Furthermore, the

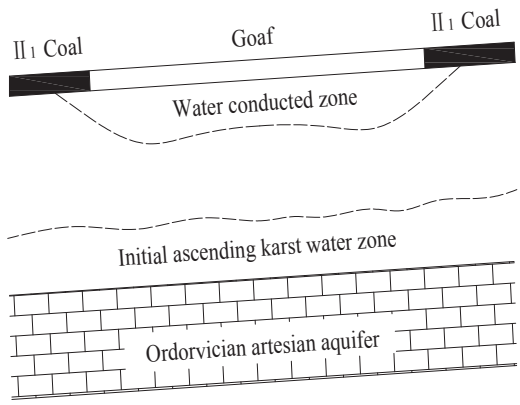

Fig. 2 Analysis map of Ordovician karst water inrush after mining

breakage of floor and the suspending roof or the less-caving destructively extending to the floor are all to raise the risk of water inrush.

Consequently, this water inrush was a result associated with hydraulic and rock pressure which jointly performed on the weak district sublevel of floor, and the destructive depth of floor was also increased by mining by areas. In conclusion, the source of water inrush was provided by the artesian aquifer of the Ordovician karst water, the dynamic condition was the high hydraulic pressure and the space of that was offered by the mining activity, moreover, the water conducted channels were formed by the combined effect of hydraulic and rock pressure on the weak district sublevel of floor. By means of the calculational analysis on the coefficient of water inrush, the risk of water inrush at the 27080 working face was validated as well.

4 CONCLUSIONS

4.1 Translate of mining hydrogeological condition towards complexity

With the productive region extending to the deep area, the karst water pressure imposed on the floor rises continually so that the risk of water inrush increases as well. Accordingly, there is a tendency of translating the mining hydrogeological condition towards complexity. Furthermore, a great mass of the karst water pressure has already come to above 2.0 MPa in the current region, which is on the brink of water inrush. If the mining site is in the rich water area or runoff area, there would get the risk of water inrush; and if there exists a fault structure, the increase of the risk of water inrush would be made. Therefore, the emphasis should be placed on the prevention of water inrush for the future anti-water work.

4.2 Well-done exploration of hydrogeological condition

In this mine field, the Ordovician aquifer is in possession of the highly uneven water-rich properties that there are some better water-rich areas and runoff areas but worse water-rich areas in the major field. Hence, only mining in the better water-rich area and runoff area does the water inrush take place. Consequently, the exploration of hydrogeological condition must be well employed in the mine field and working face. For the five years later, the Ground Transient Electromagnetic Method will be firstly utilized in the productive region and the extended mine area for the sake of confirming the water-rich area. Meanwhile, the underground geophysical prospecting and boring will be implemented, which, in detail, include the Direct Current Electrical Method (or the Transient Electromagnetic Method) exploring the water-rich situation of floor in the mined channel and the Underground Electromagnetic Wave Perradiator prospecting for the geological structure in the inner working face. With regard to the abnormal

hydrogeological area, it is extremely essential to take further exploration and make comprehensive analysis on the information of the geophysical prospecting and boring for any possibility of water inrush in the future.

4.3 Grouting reinforcement in floor

By virtue of the comprehensive analysis on the information of the geophysical prospecting and boring, the grouting reinforcement should be performed in the district sublevel accessible to the water inrush and the fault structure may be sewn up[(4)]. Moreover, the weak district sublevel could be reconstructed for the improvement upon resisting hydraulic pressure of the impermeable layer. After above process, it follows that the necessary countercheck of the geophysical prospecting and boring could be also made in order for the validation of the grouting effect, as well as eliminating the threaten of the karst water inrush.

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採掘地域における活性断層

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概要

本論文では，関連するいくつかの事例を紹介することにより，人間による採掘活動が採掘地域において断層を再活性化させることを概説する．

最活性化断層は地面の亀裂，王冠陥没，石炭ガス爆発などに繋がりえる．いくつかの地質的な災害は，炭坑の閉鎖後も何十年にわたって持続的に発生した．石炭の抽出，地下水の排水や再注水はそれぞれ，採炭地域における各開発段階で，地表の動きを促進する重要な役割を果たした．いくつかの再活性断層の研究手法を紹介し，再活性断層の予測と予防が，採炭中および閉鎖された採掘地域における再開発計画で考慮すべきであることを主張する．

Keywords: Mining face, Karst water, Water inrush, Grouting

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