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Mechanism of Separation Water Inrush Due to Coal Mining under Hard Rock

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Abstract 5.21 water inrush accident in Haizi Coal Mine of Huaibei Mining Group are studied in this paper. The hydrological and engineering geological conditions of the water inrush are investigated and tested. Due to the existence of intact and hard rock, separation zones develop in overburden rock caused by coal mining. The separation zones are in-situ investigated by borehole televiewer and flow rate logging test. The three basic conditions of water accumulated in separation zones are put forward. The overburden hard rock fails and releases massive of energy abruptly when the separation zones develop to some extent. They impact on the beneath separation water and rock and then result in rock-failure and water-inrush instantly.
Keywords coal mining, water inrush, separation water, hard rock, bed separation zones

Introduction

Water inrush threats the production of coal mines heavily in China. A new type of the roof water hazard, i.e. the separation water inrush, occurred and received more concerns in recent yearsfulness (Zhao and Li 2008; Li and Chen 2009; Zhu and Wang 2009; Qiao and Li 2011). This paper takes 5.21 water inrush accident as a case study, which occurred in Haizi Mine of Huaibei mining area with a maximum water inrush of 3887 m^3/h and resulted in 5 deaths.

The characteristics of 5.21 water inrush are as follows: (a) Large amounts of water inrushes instantly, having no water inrush symptom and resulting in peoples having no time to escape. The phenomenon is different from the previous roof water inrush in Haizi Mine basically. In the past, the roof water inrush changes from small amounts to large amounts and workers have time to escape. (b) The amount of the water is very large in the beginning of the water inrush and decreases heavily with time. 3.5 hours later, the decrement of water reaches up 97%. The phenomenon shows that the water inrush haves the characteristics of enclosed water body. (c) Massive of crushed rock and mud, approximately 300 m^3, pour into working face with water (Li and Chen 2009; Qiao and Li 2011). This paper studies the formation mechanism of 5.21 water inrush by theory analysis, field tests, and experiments in the lab.

Geological conditions and mining characteristics

The overlying rock on coal 7 in working face 745 is quaternary sediments, igneous rock, siltstone, sandstone and mudstone from top to bottom. The igneous rock which is mainly diorite porphyrite in lithology and 96~169 m in thickness overlies on coal 7. The igneous rock is intact and hard, with RQD of 100%, compressive strength of 102.30~161.91 MPa and tensile strength of 6.78~16.94 MPa. The existence of the intact, hard and thick igneous rock results in the development of bedding separation during coal mining and the great quantity of energy released by the abruptly-failure of it (Xu and Qian 2004).

The average thickness of the main mining seam in Haizi Mine, i.e. coal 7, 8 and 10, are 1.99, 1.77 and 2.67 m, respectively. And the average dip angle of main mining seam is 18º, seen in Fig. 2. Working face 745, where 5.21 water inrush accident happened, is 400 m long in strike, 70~120 m in dip, with the average thickness of 2.2 m. Working face 745 is blasting mining face, with entire roof subsidence. The mining sequence of the working faces can be seen in fig. 1. It should be noted that the mining of working face 1047 and 1049 beneath face 745

have been done 3~5 years before the mining of face 745. It is beneficial to the water accumulated in separation.

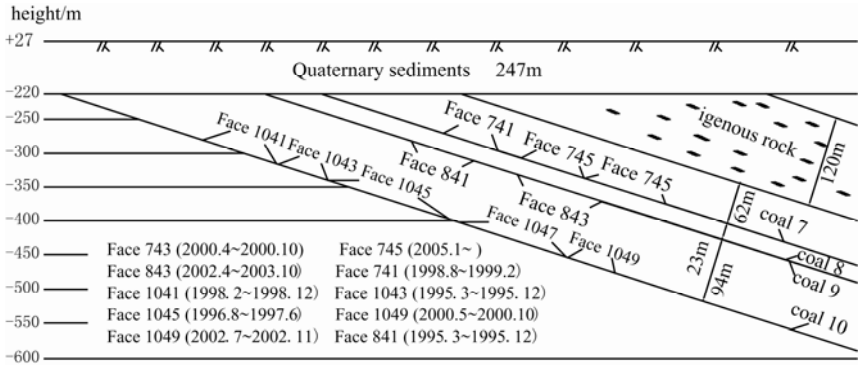

Fig. 1 *Inclination profile of working face 745*

Insitu investigation on separation

The existence of separation is the precondition for separation water inrush. It is well known that, separation will develop in overlying rock on goaf due to coal mining if intact and hard rock overlies (Gao 1996; Zhang and Liao 2001; Xu and Qian 2004; Zhao and Chen 2005). Obviously, the existence of the intact, hard and thick igneous rock in working face 745 will result in the development of separation in overlying rock.

The separation is investigated by borehole televiewer in borehole R455, R456 and R459. But the TV pictures in borehole R455 and R456 aren't clear due to the existence of water in borehole. The TV pictures of separation in borehole R459 can be seen in fig. 2. It verifies that the existence of hard igneous rock results in the development of separation in overlying rock on working face.

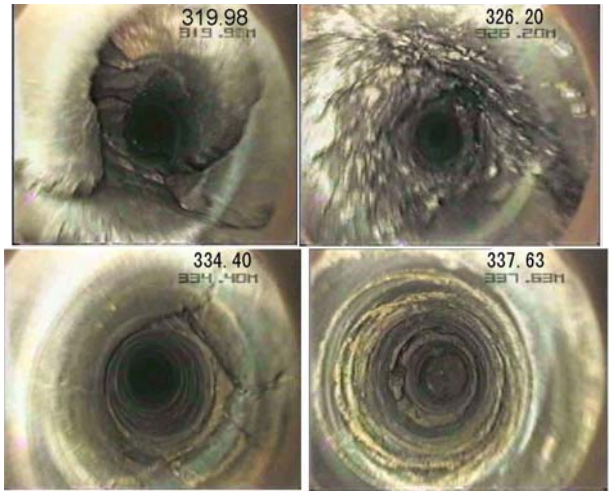

Fig. 2 *The borehole TV picture of separation zones in siltstone and medium sandstone*

And the flow rate logging test has been done in borehole R455, R456 and R459 for separation investigation (Zhao and Li 2008). The test results show that some separation zones develop in overlying rock in all of borehole R455, R456 and R459. Among them, borehole R455 locates nearby the water inrush position. The flow rate logging results of it (fig. 3) show that 3 separation zones are caused by coal mining and named as separation zone T1, T2 and T3 from the bottom to top. It is the same as the result of borehole televiewer. The distance of separation zone T1, T2 and T3 to coal 7 is 34.8, 51.3 and 59.8 m, respectively.

And the unit water absorption of separation zone T1, T2 and T3 are 0.32, 0.056 and 0.16 L/s·m, respectively.

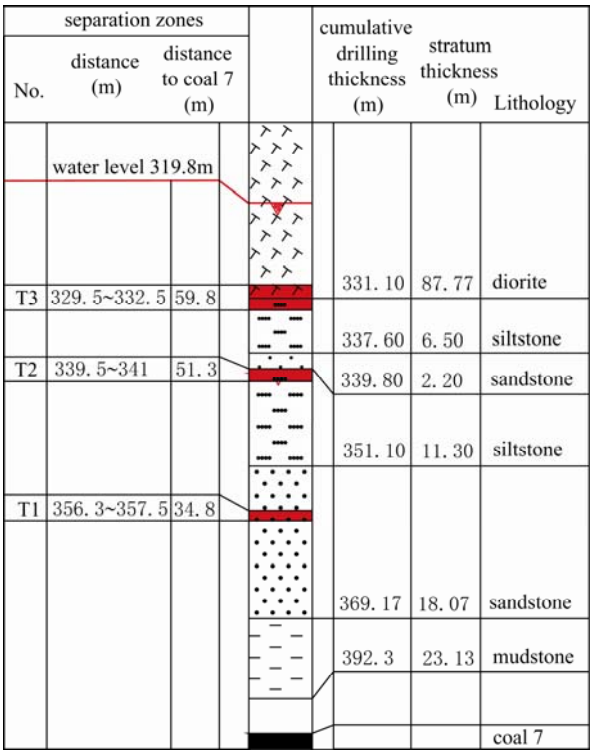

Fig. 3 *The position of separation zones by flow rate logging results in borehole R455*

In addition, the height of the water flowing fractured zone in working face 745 is 30.8 m decided by borehole televiewer, flow rate logging test and empirical calculation comprehensively. Thus, the distance between separation zone T1 in R455 and the water flowing fractured zone is approximately 4 m. That is to say, if the separation water inrush into the working face, it should break through the 4 m- thickness rock.

Water accumulated in separation zones

Obviously, the existence of separation is the precondition for water accumulated in separation. But the existence of separation dose not stands for the existence of separation water. The accumulation of separation water should satisfy 3 basic conditions:

(a) The separation should be relatively closed. That is to say, the position of separation should be higher than the water flowing fractured zone caused by coal mining. If not, the water will flow into working face through the water flowing fractured zone. The borehole R455 explore water in separation zone T1, T2 and T3 lasting for 44 days. It is noted that the water in separation zone T1, T2 and T3 is from the injected water in injection test and is dewatered by underground borehole later. It indicates that water can be accumulated in the separation zones.

(b) One or more recharge water sources exist around the separation. The sandstone where separation exists is aquifer. And the separation can be recharged from it.

(c) The separation can last for enough time to be accumulated enough water. The land subsidence observation results in Haizi Mine show that the land subsidence before working face 745 mining is 0.1m. It should be noted that, the mining of working face 1047 and 1049

beneath face 745 have been done 3~5 years and the mining thickness of coal 10 is 2.67 m. It indicates indirectly that the separation beneath the igneous rock last for long time.

The formation mechanics of inrush channel of separation water

Experimental study on outburst-proneness of the medium sandstone and igneous rock are conducted with MTS815.02 system. And the impact energy index K_E, elastic energy index W_{ET} and dynamic failure time t_D of the medium sandstone and igneous rock are tested (Qiao and Li 2011). It is concluded that both the medium sandstone and igneous rock have strong outburst-proneness in Haizi Coal Mine. Therefore, massive of energy can be released when the igneous rock derumpent abruptly. And then it impact on the beneath separation water and rock and a certain range of rock will be failed inevitably (Gao and Zhang 2012).

The water inrush channel of 5.21 Accident consists of two parts. One is the water flowing fractured zone caused by coal mining; the other is dynamic impact failure zone (Abbrev. DIFZ) which is caused by the dynamic impact of the igneous rock derumpent abruptly. We can describe the formation procedure of DIFZ as follows. (a) The igneous rock ruptures abruptly; releases strain energy and shock waves (Teng and Yan 1999; Du and Luo 2003). The shock waves propagate and attenuate in separation waters. (b) The shock waves attenuate as stress waves in the separation water-rock interface and impact initial shock pressure on the rock. (c) The rock stress changes with the propagation and attenuation of the stress waves. (d) The failure zone in rock caused by the stress waves can be calculated by rock strength criteria (Lin 1993; Chen and Lin 1996). It is noted that the dynamic formation procedure of DIFZ is similar to the procedure of water-decoupled blasting. We can choose a unit width overburden rock in the direction of face advancing for analysis. The unit width rock can be simplified as composite beam. The separation zone can be equivalent to the expansion of a unit height cylinder.

The results show that the size of DIFZ is 14.66 m by calculations. The previous flow rate logging test result in borehole R455 shows that the distance between the separation water and the water flowing fractured zone is 4 m. Obviously, the DIFZ can arrive at the water flowing fractured zone downward. Therefore, the water inrush channel of 5.21 Accident is formed by co-action of the water flowing fractured zone and DIFZ. And then the separation water pour into working face 745 instantly.

Conclusions

(1) The overburden igneous rock is intact, hard and thick. And the existence of it results in the development of separation zones during coal mining and massive of energy released by the abruptly- failure of it. (2) The existence of separation zones in siltstone and sandstone are insitu investigated by borehole televiewer and flow rate logging test. (3) The accumulation of separation water should satisfy 3 basic conditions: (a) The separation should be relatively closed. (b) One or more recharge water sources exist around the separation. (c) The separation can last for enough time to be accumulated enough water. (4) The water inrush channel of 5.21 Accident consists of two parts. One is the water flowing fractured zone caused by coal mining; the other is dynamic impact failure zone (DIFZ). (5) The accumulation of the water in bed separation is the critical reason of the separation water inrush disaster, and then the control technology of the water inrush is to prevent or advance dewater the water in bed separation.

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