Research on the No. 8 Coal Roof Aquifer Drain in No. 2 North District of Donghuantuo Coal Mine，Kailuan

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Abstract As the roof aquifer was the main and direct source of water filling in coal No.8 mining face in Donghuantuo coal mine, Kailua, it caused serious water filling in central district and No.1 north district, the largest yield of single mining face had getted 6.01 m^3/min. Now, this coal mine was getting extend to the No.2 north district, where was the syncline nose of the Chezhoushan syncline. Its hydrogeological conditions were more complex than those in syncline wings and the threat from roof aquifer was more serious. This research was done on roof aquifer discharge to safely mine coal No.8 as the first mining coal seam in the No.2 north district. First, the recharging from alluvial to the roof aquifer and the leakage amount were analyzed and estimated. Second, the large amount of statistic data about the roof aquifer was used to estimate its yield property and permeability space variation, which included its aquifer thickness, hydraulic conductivity, specific yield and ratio of brittle to plastic rock seam thickness. Then, the structural geology theory was applied to get the characteristics of fracture system in sedimentary rock under folding and faulting, and with the view of new structural controlling groundwater, hydrogeology secondary units and water rich regions had been zoned, which had different hydrodynamic conditions and its water disaster type had been proposed up during mining process. The designation and implementation of drilling project had achieved good results in roof aquifer drain.
Keywords coal seam roof, aquifer yield, water rich region, fracture system, aquifer draining

Introduction

Mine drainage was pre-drainage or drainage water under the controlled conditions in order to reduce or eliminate the water rich aquifer on the threat of mine water disaster. The drainage technology was widely used at home and abroad, and it formed the drilling drainage, roadway drainag, Shimen drainage and many other forms. The foreigners applied surface vertical borehole and submersible pump to drain aquifer (Guo 2013, Ma et al. 2013). In recent years, the mine drainage research in china was started around the safety of coal exploitation, the protection of ecological environment and the harmonious development of water resources. The scholars studied to utilize natural geological barrier to choose a reasonable drainage position and drainage intensity, which can ensure the safety of mining, and can not seriously affect the ecological environment in mining area (Liu et al. 2009, Zhong et al. 1996, Han et al. 2013, Zhang et al. 2013, Xu 2011, Yin 2013, Li 2010, Sun 2009). In this paper, the research of coal No.8 first mining face roof aquifer drainage in the No.2 north district of Donghuantuo Coal Mine, Kailuan was studied deeply based on this theory.

The prevention and controlling of water in coal No.8 roof aquifer drain in the No. 2 north district of Donghuantuo coal mine, Kailuan

The hydrogeological conditions of Donghuantuo coal mine

Donghuantuo coal mine in Kailuan was the famous water rich mine in North China, and Chezhoushan syncline was its main structure. It was a narrow asymmetric large coal bearing syncline, syncline axis was about N60°E; axial plane orientation of the NW, and the vertical angle was about 20°; hub to WS direction plunging 13°angle. Its northwest wing formation stroke by N70ºE, dip 65~80°; Its southeast wing formation stroke by N30°E, dip 12°~

25°,which was the main mining area in Donghuantuo coal mine. The syncline nose was located in the northeastern of the mine, and it extended in the plane as a "tongue".

The coal bearing strata and the Ordovician limestone formation in its bottom were all buried under the thick alluvium. It formed a multilayer inner and outer boundary communication aquifer stereo water filled in the mine geological structure. The major water-filled aquifer in the mining of coal No.8 included: the lower Quaternary alluvium aquifer Gravel (Ⅶ d), A ~ A0 aquifer group (VI) and A layer ~ coal No.5 strong aquifer group (V), the aquifer division was shown in table 1.

A layer ~ coal No.5 strong aquifer group (V) was the direct water-filled aquifer in coal No.8 seam roof, and the supremacy of the next can be divided into three layers as shown in Table 1. The No. 2 north district was located at the syncline nose, the bedrock topography was high, its distribution was different from the others: Because of the weathering and erosion, it was lack of A ~ A_0 aquifer group (VI); the upper section(Vd and Vc) of A layer ~ coal No.5 strong aquifer group (V) was basely lacked ,the roof direct water-filled aquifer was the more than coal No.5 100 m water section(Va + b), it was the lower part of A layer- coal No.5 strong aquifer group (V). During measuring moisture content over the mine water inflow, the specific yield was 0.016-1.507 L / (s·m), which was a strong water-rich segment.

***Table 1** The lists of coal 8# roof water-filling aquifer in Donghuantuo coal mine*

Aquifer layer		Thickness (m)	Name of aquifer layer	The significance
Ⅶ	Ⅶd	20～300	Quaternary Gravel aquifer	Indirect water-filled
Ⅵ	Ⅵb	50	A0 lower aquifer	Indirect water-filled
	Ⅵa	70	A upper aquifer	
Ⅴ	Vd	80	A moderate aquifer under A layer 80 m	Direct water-filled
	Vc	100	Under A 80 m ~coal No.5 upper 100 m strong aquifer	
	Ⅴa+b	100	0-100 m strong aquifer in coal No.5	

The drainage water in coal No.8 roof aquifer in the No. 2 north district of Donghuantuo Coal Mine, Kailuan

When mining coal No. 8 seam roof in the central and No. 1 north district of Donghuantuo coal mine, its roof flooding was very serious, and the water-filled intensity was high. The No.2 north district of Donghuantuo coal mine was the new mining area, it located at the syncline nose, and it was divided into independent hydrogeological unit with the No. 1 north district by F2 large water blocking fault, where still maintained the natural high head groundwater, and the head difference with the central - No.1 north district was 200 m or more, so the disaster problem was predicted to be serious when mining coal No.8 seam roof new region.

The water aquifer pumping test was carried by East View 27 hole and 42 hole on the coal No.8 roof water aquifer. The specific yield were measured to be 0.183 L/(s·m) and 0.117 L/(s·m), which was weak medium water. At the beginning of 2009, the drainage drilling was constructed in the lower of No.2 north district -500 cross-hole. They intended to drain coal No.5 or more water-filled aquifer. But when the drilling got to the target horizon, it failed to drain water. Because of the parameters of water aquifer were very small, and the phenomenon that the water could not be drained, so the wrong conclusion was got that coal No.8 roof water-filled aquifer was not a water-rich aquifer.

The coal roadway of No.2 north district was excavated In June 2010. At the end of 2010, the total water inflow of wind and transport channel was up to 4.2 m^3/min. The water inrush was very large. Since January 2009, the 17th water observation hole was added in the alluvium of No.2 north district. The level dynamic curve of the whole alluvial mining was counted and analyzed,as shown in fig. 1. It reacted that the whole mining alluvial water level tend to decline ,while it affected by the rainfall, so it also showed a seasonal cycle fluctuations. The curve comparison showed that from 2009 to 2010 by the exploration in coal No.8 mining area and the construction works in No. 2 north district, the water level on the 17th hole rapidly declined about 5 m, which was much faster than the others. This indicated that the mining work in No. 2 north district have a significant impact on alluvial. The Quaternary alluvium aquifer was extremely water-rich region, if the aquifer recharge on coal No.8 seam roof aquifer strongly, then it would be difficult to drain coal No.8 seam roof aquifer.

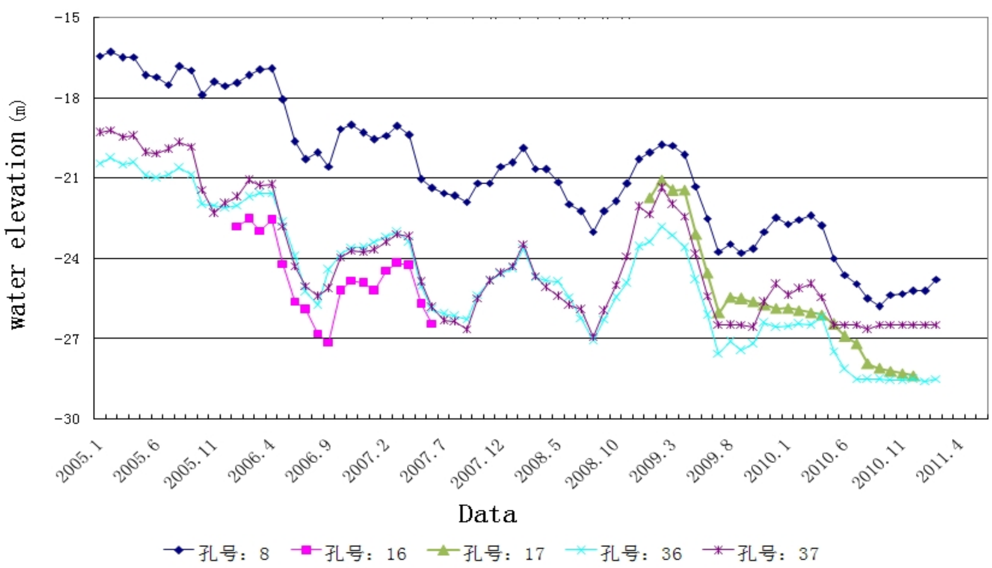

Fig. 1 *The alluvial level dynamic graph in Donghuantuo mine*

Thus, coal No.8 mining history of roof water gushing situation and the coal No.8 seam roadway gushing in No.2 north district mining area reflected the feature that the seam roof was filled with water, but the pumping test results and ineffective response of the roof hydrophobic pore reflected the feature that the aquifer water abundance was not strong. They are mutually contradictory. This protruded that the coal No.8 mining seam roof water-filled aquifer in No.2 north district was complex. The different distribution of buried conditions, cracks and uneven enrichment factors result in a strong aquifer heterogeneity, anisotropy, lead to its rich water. Therefore, it is difficult to drain in the mining area.

The research on drain of roof aquifer

Two extreme cases were not conducive to the aquifer drainage: (a) aquifer recharge abundant, thick, strong rich water, water was good, the large water drainage and antihypertensive effect was poor; (b) rich water aquifer and connectivity was poor, although you can get a better water drainage antihypertensive effect, but it was difficult to find a suitable place to drain water. Due to the poor connectivity aquifer, it was difficult to achieve the purpose of lowing the pressure in a large area. When it was under good connectivity aquifer recharge and limited conditions, the hydrophobic buck was most easily achieved (Wang et al. 2012). Therefore, a detailed study of the aquifer for coal No.8 seam roof was started. Its hydrophobicity was evaluated by analysis of the recharge condition and enrichment regularity of groundwater.

The analysis of alluvium bottom gravel recharge

The roof direct aquifer in coal No.8 mining of the No.2 north district mining area was mainly accepted the alluvium aquifer recharge down. The bedrock weathering zone existed between the alluvium aquifer and water filled coal No.8 roof direct aquifer. The alluvium thickness and permeability of recharge was in close relationship with the weathering zone.

The weathering intensity and depth of coal-bearing strata outcrop was related to the lithology and the degree of fracture development. Mudstone, tuff, coal, poor sorting or weak cementation in sandstone and feldspar content, were more easily weathered. According to the 1978 exploration report, the thickness of the strongly weathered zone in No.2 north district mining area was 4 - 14 m. The weathered rock was earthy or mashed.The mud leakage of the exploration drilling between 5 to gravel in No.2 north district mining area was analysised, the results indicated that the drilling mud loss volume value was close to 0 when it was near the gravel, which suggesting that its permeability was small. The weathered zone constituted a low permeability barrier. The Quaternary bottom gravel water through weathering weak permeability with downward leakage recharge. According to the 1993 infrastructure additional hydrogeological exploration report, the pumping test was uesd to inversed the aquifer parameters, the flow coefficient of the alluvium was $K/M=1.03\times10^{-5}$.

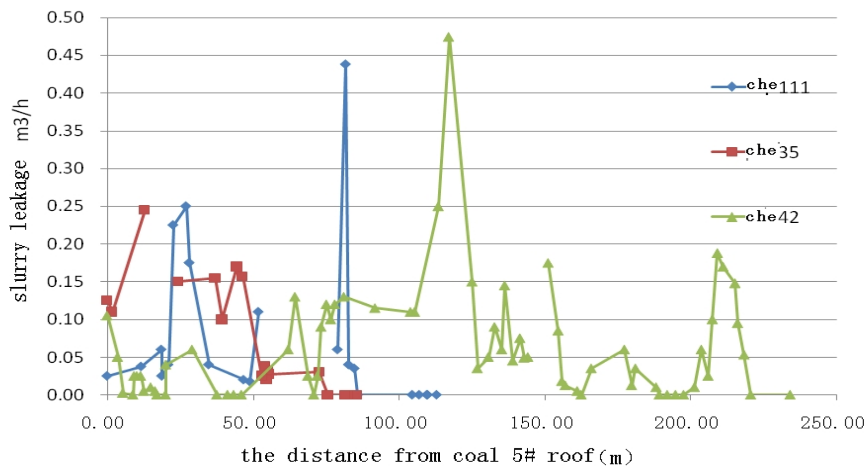

Fig. 2 *The drilling slurry leakage curves in No. 2 north district coal No.5 ~ bottom pebble*

The buried outcrop area of coal No.8 roof direct aquifer was estimated to be 1332717 m^2, the average pressure height of weathered zone was 120 m (January 2009), the flow coefficient was $K / M = 1.03\times10^{-5}$ m / d, the flux was estimated as $Q = AK/MH = 1.144$ m^3/min.

After approximate estimation, Quaternary alluvium on coal No.8 roof aquifer leakage recharge amount was not large, it is not enough to affect the drainage.

The variation of water level under the influence of mine drainage aquifer water was not only with the relevant, it also depended on the confined aquifer elastic storativity. The water balance equation was : $\Delta Q = \mu e \times \Delta H$, ΔQ was the amount of water changes, μe was aquifer discharge coefficient, ΔH was the aquifer water level changes. Assuming the aquifer water reduction was the same, the elastic storativity was smaller, the aquifer water level dropped more quickly. Quaternary confined aquifer pore water release elasticity coefficient positively correlated with the thickness of the aquifer. The Quaternary bottom gravel aquifer in Donghuantuo mine was added to the WS direction by syncline. The thickness was 20~320 m. As it was shown in fig.3. The thickness of bottom pebble in the No.2 north district mining area was only 20 - 40 m, the pore aquifer thickness was small, the water storage coefficient was small too, so the water level dropped fast. Therefore, the abnormal phenomenon that the gravel aquifer water level in the No.2 north district mining area decline fast did not mean that the connection between the Quaternary bottom pebbles and bedrock fissured aquifers was better than the whole mining area, this can not indicate that the regional bedrock fissured aquifer recharge condition was superior. So as the supply situation, coal No.8 seam roof direct aquifer can be discharged.

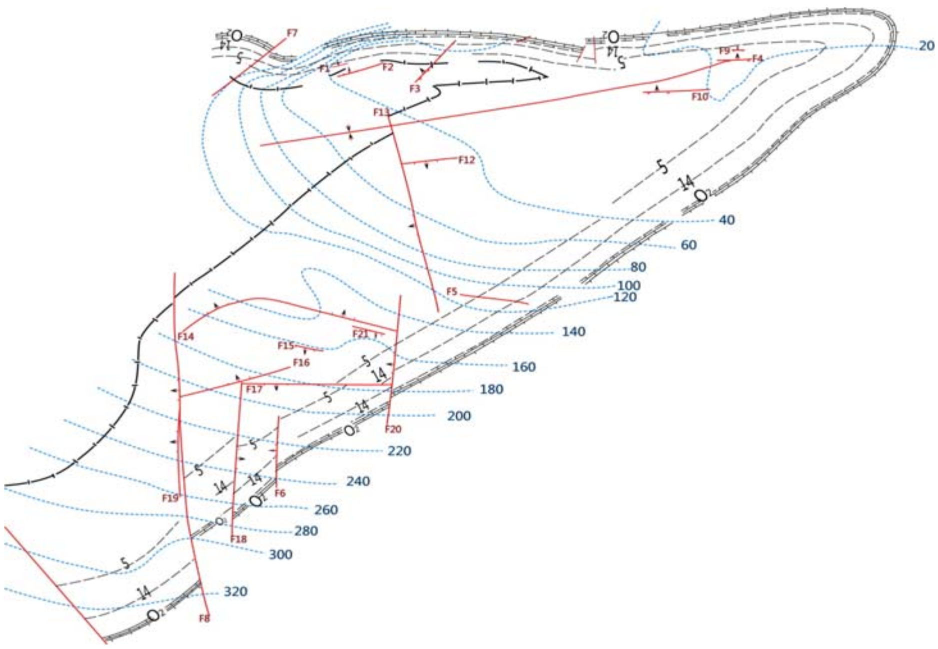

Fig. 3 *Thickness contour of the gravel aquifer*

Syncline turn ends geological analysis of water control law

The focus on the aquifer drainage was to judge the enrichment degree of aquifer and enrichment zone distribution, the development of reservoir water flowing fractured controlled the bedrock fracture groundwater aquifer (Ge et al. 2007, Jin et al. 2013). The bedrock fissured aquifer fracture of coal No.8 seam roof in the syncline nose of the No. 2 north district mining area included: layer fracture, which was developed in the original sedimentary bedding plane structure along the bedding plane based on the distribution of fracture, the cracks were generally small, and it often as the main water storage fissures. Tectonic fissures, which formed under the construction such as faults and folds and regional tectonic stress. They controlled the water flow in the fissured aquifers . Through the analysis of the No.2 north district mining area tectonic action to determine its structural joint group, the development of joint sets were different from each other in different structural parts, the water joints were different under the combined effect by late tectonic stress, lithology and groundwater flow direction and other factors. As they were shown in table 2. The weak water rich zone, strong water rich zone, extremely water rich zone were divided correspondingly, as shown in fig. 4. Overall, the No. 2 north district mining area was located in the syncline nose; tectonic action was strong; the fracture was relatively dense. The roof aquifer of coal No.8

seam in most regions was strong - extremely strong in richment; the water drainage work was difficult.

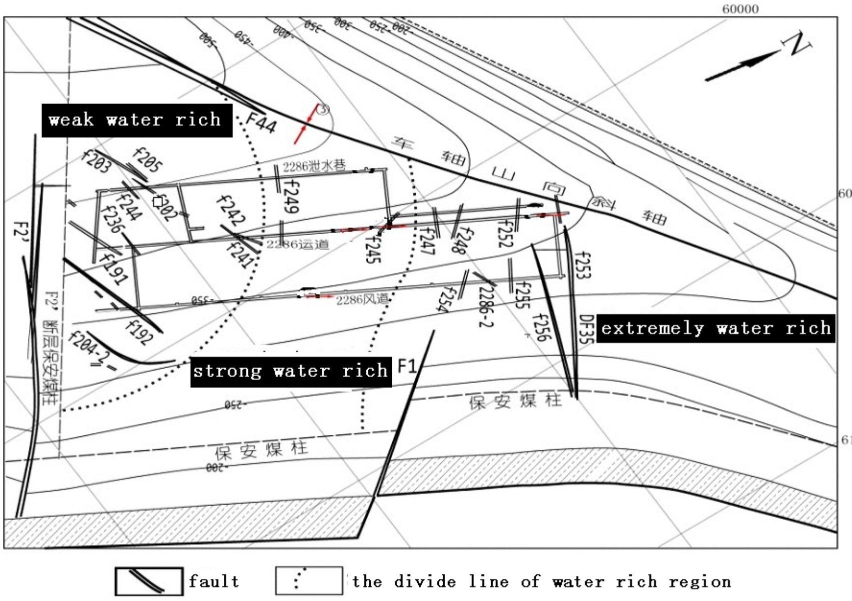

Fig. 4 *Joint development and zoning of water richment*

Depressurization

The principles of drilling layout

The roof water drainage adopts to take the principle of combining the overall advance drainage with partial parallel drainage in a straight line along the roadway pioneering style layout (Hu et al. 2009). After 2009 and the preparation period of first mining face. In 2011, by the use of one years on coal No.8 first mining face roof aquifer to advance drilling drainage; during the recovery period to drained further in local abnormal area.

Drilling layout

It was predicted that the water of the first mining face in No.2 north district of Donghuantuo coal mine poured amount. The special drainage lane was constructed for drainage under the mining face. The drainage borehole was layout by air roadway, transportation and discharge lane roadway. F2 fault was the impermeable boundary in the southeast area. The far boundary sparse dry descending strength should be added to ensure that the far boundary area had enough drawdown, and far from the border was also constructed with extremely strong water-rich fractured the water-rich region. Thus hydrophobic drilling outward from the mining face gradually arranged northwest opened cut. The DIP joint was developed in the mining region, aquifer hydraulic connection was good bedding, shallow drain hole was closure on deep drainage hole significantly. Therefore, the drainage hole was mainly distributed in the duct .

Due to the complexity of the hydrogeological conditions in the region, the method of combining ahead of sparse with parallel sparse simultaneous release was took. Five drilling holes were arranged from the inside to the outside in the airway, each drilling was radioactively arranged different quantity of drain hole, a total of 19 holes, all of them were advance drainage hole. Three drilling holes were arranged from the inside to the outside in the transportation way. A total of 12 holes were drilled. Ten advanced drainage hole were constructed in 2011 and two parallel hydrophobic holes were drilled in recovery phase in 2012; the first two hydrophobic holes were laid at the discharge of water in the mouth in March 2011. Four parallel drainage holes were added with surface mining process in the late 2012.

Conclusion

For the complex phenomenon of the coal No.8 roof water filling aquifer in the No.2 north district of Donghuantuo coal mine, Kailuan, by demonstrating the regularity of water flow in the Quaternary alluvial bottom pebble aquifers and structures controlling water in fractured bedrock aquifers, coal No.8 seam roof aquifer was identified that it can be drained, and the descending position was selected. A total of 31 advanced drainage holes and 6 parallel drainage holes were arranged. Drilling the hydrophobic volume statistics showed that Channel 19 drain holes water lasted 6-9 months period in water was reduced to very small. Until 2012 before the face stopping, only air inrushfollowed water . At the same time, recovery stage parallel hole on the additional hydrophobic contact poor local retention water further drainage, protected the minig safety of coal No.8 first mining face in the No. 2 north district of Donghuantuo coal mine.

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Table 2 The water assignmen of joint system in the No. 2 north district

Formation period	Jointed group	Hydrogeological characteristics	Developmental location		
			Weak	Strong	Extremely
Yanshan early-mid	①"X" high angle shear joints, NW toward joint; Vertical bedding joint system, the longitudinal layer between the rotation "X" type shear joint system	Yanshan early - mid joint by tectonic forces, closed, joint concentrated, poor water conductivity	√	√	√
	②Parallel fault pinnate tension joints, pinnate joint system	By late tectonic stress tends to closed, it was closed by cutting faults NEE, poor water conductivity	√		
	③ Parallel fault tension joints, shear joint system	Joints tend to closed affected by late tectonic, the vertical direction and groundwater runoff, water conductivity was medium	√		
	④ Parallel fault direction pinnate tension joints, pinnate joint	Fault affecting a wide range of large faults, tension-shear joints intensive development, consistent with the direction of groundwater flow, water conductivity was strong, in favor of water inflow			√
	⑤ Pinnate tension joints, parallel to fault strike pinnate joint	Fault spacing was small, densely jointed, consistent with the groundwater flow direction, in favor of the mine water inflow. If formed in the late Yanshan, water conductivity was strong			√
Late Yanshan	① NE and NNW direction, two groups of joints (transverse shear joints), NNE joint system	Brittle strata area affected by the new tectonic stress, tension-shear joint development, water conductivity was strong		√	
Joint density			Concentrated	Denser	Concentrated
Comprehensive evaluation of water conductivity			Medium	Strong	Very strong