Graphic Methods for Judging Sources of Roof Water Inrush – A Case Study, China

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Abstract

Water inrush usually is an exposure of hydrogeologic conditions of a coal mine and the characteristics of water-inrush itself could be used as indispensable evidences to quick judge the sources of water inrush. The graphic method is actually a specific application of hydrogeologic analysis. Using the limited data on an unexpected roof water inrush at Yuanbo coal mine (Shansi, China), this article developed a set of vertical and lateral graphic methods to judge the source aquifers, infer the water level of the source aquifers and analyze the reasons of roof inrush accident. It concluded that the sources of roof water inrush were the overlying fractured conglomerate aquifers and the medium-to-coarse sandstone aquifers, which got no direct recharge from the underlying Ordovician karst aquifers. It is advised that more hydrogeologic analysis expertise should be collected and published for wide dissemination, instead of learning the lessons and acquiring the expertise from accidents or hazards again and again.

Key words: roof water inrush; sources of water inrush; graphic methods

Introduction

Inevitably almost all active mines, especially those underground coal mines, always have to be facing a variety extent of threat from water inrush. Most of reported methods used for identifying the sources of water inrush belong to water quality judgement, which depend on how narrowly the quality of inrush water is similar to that of a known aquifer source. Various kinds of mathematical methods were developed over the past decades to measure the "distance" of water quality of the inrush water to the known aquifer water, for example Grey Correlation Analysis (Li 1995), Mahalanobis Discriminant Analysis (Wang 2011), Bayes Discriminant Analysis (Chen 2009), Clustering (Sun 2014), Projection Pursuit Method (Qian 2012), Particle Swarm Optimized Neural Network (Wang 2013), Support Vector Machine models (SVM) (Yan 2007), etc.

However, the inrush water itself often doesn't show such obviously distinct chemical features at all and the difference between inrush water and the known source water are so entangled that we ourselves are not sure whether the "distance" judgement is really reliable or not. Especially for those hydrogeologically complicated coal mines in East China, the engineers and practitioners thereof always encounter various types of water inrush accidents and they can rarely count on solely using water quality judgement to figure out where the water comes out from. For these experienced engineers, traditional hydrogeologic analysis are their first priority and they always use the chemical features of inrush water to prove their judgement or search implicit clues for their first inference. Traditional hydrogeologic analysis methods play a more preliminary and essential role in engineering practice. Although there had published several collections of mine water inrush cases (Zhao 2006) in China, an issue arising from the situation is that the practical expertise and skills of these practitioners' are seldom formally developed into systematic methodologies. To more effectively prevent mine water inrush accidents, it is important for us to share and disseminate these valuable expertise, instead of learning the lessons and acquiring the expertise from accidents or hazards again and again.

The aim of this paper is to present a very complicated roof water inrush accident and show how a hydrogeologic analytical method was developed to identify the sources of roof water inrush.

Background

The Yuanbao coal mine is located in the north of Shanxi, China and belongs to the typical semi-arid continental climate region with an annual average precipitation of 384mm and an annual average evapotranspiration of 1847.8mm. Yuanbo mine is also hydrogeologically within the west carbonate outcrop boundary of Shentou Ordovician Karst System.

Owing to being at the west edge of Datong Carboniferous-Jurassic Syncline Coalfield, the Jurassic coal seams is lapped out here. The geologic sequence of Yuanbao coal mine mainly consists of the middle Ordovician Majiagou Formation, the upper Carboniferous Benxi and Taiyuan Formations, the lower Permian Shanxi Formation, the middle Permian Shihezhi Formation, the lower Cretaceous Zuoyun Formation, and the Pleistocene non-consolidated deposits. Majiagou Formation is the base of the late Paleozoic coal bearing sequences, and the mainly minable coal seam called No. 9, with 4m in thickness and 160-300m in depth, bears in Taiyuan Formation. With a simple structure, the overall geologic formations of the coal mine strikes NE-SW and dips at 5～10° to NW. As reported by the authorized exploration company, the hydrogeologic conditions of the coal mine would be fairly simple and the estimated maximum mine drainage would be 80 m^3/h.

The Yuanbao coal mine was designed at an aim annual output of 5×10^6 t/year via longwall & top coal drawing and put into production in 2009. In the beginning year, the successful extraction of the first working face, called Face No.1901, which drained almost no water during mining, seemed to prove that the hydrogeologic conditions of Yuanbao were simple in deed.

However, since Feb., 2012 as the belt gate of Face No. 1916 was western & downwardly driven up to 480m, mine water through roof fissures infiltrated into the tunnel stronger and stronger. The parallel tail gate of the face also suffered heavy room water inrush as it drove near the open-off. By the time the belt and tail gates headed through, the maximum rate of roof water had gone up to 160 m^3/h. Two months later, the inrush stabilized around 120 m^3/h and then last for almost one and a half year until the face was mined out. Such kind of long time and large scale inrush had never happened in this semiarid region and it was against its exploration result. Don't know where the water come from and feared that a near fault, called Fault F1, had conveyed the Ordovician karst water into the roof aquifers, the Face No. 1916 was put aside for almost a whole year.

The limitations and difficulties to judge the sources of roof inrush are (1) the water quality of inrush water was so similar with that of bottom water and underlying karst water; (2) no doubtable fault encountered in two gates when driving; (3) there was no groundwater monitoring borehole and reliable water level data was unavailable; and (4) the nearby Fault F1 was also hydrogeologically unclear. The only available data was a simple inrush description.

Methods

Except for the questionable roof water inrush itself, we collected all kinds of water inrush accidents previously happened within the coal mine together, laid all of them out on the mine's excavation plane map, and drew them respectively on their own sectional maps. Thus, the bulk lateral and vertical water-bearing body were deduced. By post-interviewing the drilling workers and re-constructing a composite drilling geologic column, we further determined the water-bearing aquifers. Addtionaly, we took use of the minute water quality difference, supplementary bottom probe-drilling, etc. to examine other uncertain factor. The scheme of methodologies is as shown in Fig. 1.

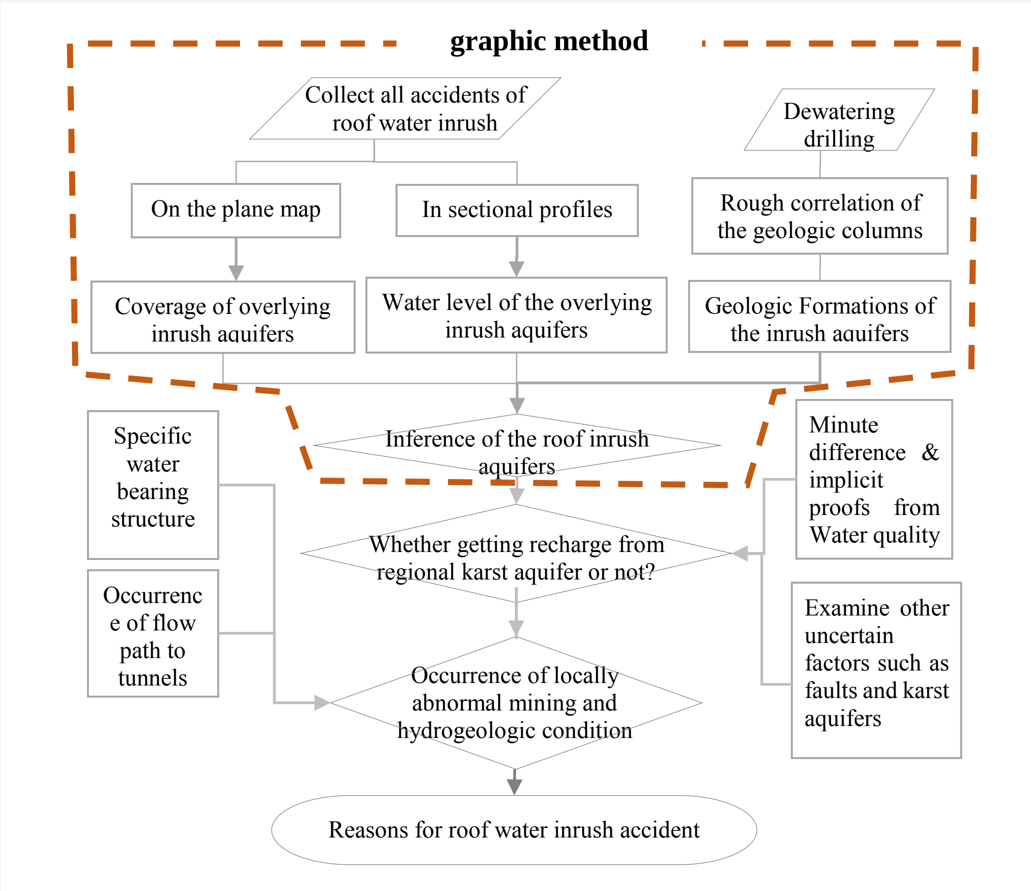

Fig1. Scheme of the graphic methodologies

Results

Totally 76 water inrush accidents were collected and laid out both on the mine's excavation plane map and on the mine's geologic map. It can be drawn that (1) 90% of accidents belong to roof water inrush, (2) the flow rate of most water inrush is less than 5 m^3/h, (3) roof water inrush accidents preferably happened near a fault or syncline, (4) the magnitude of water inrush obviously increased with the depth of the engineering and went up by 4 times up to 20 m^3/h at the bottom of the panel sub-mains, (4) the abnormal roof inrush happen at the lowest site of the coal mine (+1105m) where the Face No. 1916 just went into, and (5) the overall roof water inrush washows an obvious dewatering feature. So it can further deduce that the abnormal roof water inrush at Face No. 1916 is subject to the whole dewatering procedure of the coal mine.

From the plane map of the 76 inrush points, it can be drawn that (1) the highest boundary of water-laden area of the roof aquifers was roughly corresponding to the floor contour line of coal seam No.9 at +1170m, (2) the intensely water-laden area of the roof aquifer was limited at the NW corner of the coal mine and corresponding to the +1140 contour line of the floor, and (3) the roof water-laden aquifers had been dewatered from +1170 to +1140m.

To further infer the water level of the inrush aquifers, we overlapped the section profiles of the belt and tail gates of Face No. 1916 and that of the belt and ventilation of the panel sub-mains. The overlapped section profiles showed that (1) in the panel sub-mains, the roof water inrush initially happened at the level of +1170m and then was getting much heavier up to 8-20 m^3/h at the level of +1140m, (2) in the two gates of Face No. 1916, the roof inrush also coincidently reach its biggest value below the level of +1140m, and (3) to some degree, the Face No. 1916 actually was like a lowest discharging point for dewatering the whole mine.

At the beginning of the roof inrush accident, the mining company had tried to dewater the overlying aquifer via 53 upwardly drilled probing holes and no regular drilling notes were left. By investigating the drilling workers, we re-tracked the information on drilling fluid, water rate, etc. and re-constructed a composite drilling geologic column. By comparison with that of a nearby Borehole 1501, it can be concluded that the water-laden formations are the early Permian Shanxi Formation and medium-to-coarse sandstone aquifers of the medium Permian Shihezi Formation.

The qualities of roof water, floor water and underlying karst water are all neutral, low TDS, low Hardness and could be entitled as HCO_3-Ca、HCO_3-Ca·Mg or HCO_3-Ca·Na water. Judging from the minute difference of these water, we know that (1) the values of TDS, Na^+, Cl- and HCO_3^- of floor water are 1.5, 2, 5~10, 1.5~2 times that of roof water respectively and the values of TDS, Na^+, Ca^+ and HCO_3^- of underling karst water are 2, 2, 1.5, 1.5~2 times that of roof water respectively; (2) the water quality of roof water remained steady and had not been affected by the bottom water and the Ordovician karst water, and (3) it can exclude the possibility that the roof water had got recharge from the underlying Ordovician karst aquifer.

Conclusions

In all, it can be concluded that the roof aquifers had not got direct recharge from the underlying Ordovician karst aquifers, the roof water inrush at Face No. 1916 was subject to the whole dewatering process, and only if the drainage system and security measures be guaranteed could the Face No. 1916 be safely mine out.

From March, 2013 to Dec., 2013, the Face No. 1916 was successfully excavated. In Aug. 2014, when another Face No. 1911, which was located in the same panel as the Face No. 1916 and 200-3000m away to the Face No. 1916, drove to area below +1140m, it got roof inrush as the Face No. 1916 previously did. Both of the practice actually exposed the mine and further proved the reasonability of our method and result.

It is advised that more hydrogeologic analysis expertise be collected and published for wide dissemination, instead of learning the lessons and acquiring the expertise from accidents or hazards again and again

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