An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)
©2014 China University of Mining and Technology Press, Xuzhou, ISBN 978-7-5646-2437-8

An In-situ Exploration for Hidden Collapse Columns Using Comprehensive Geophysics

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Abstract This paper takes the forward looking results of hidden collapse Column in Renlou Coal Mine as an example to expound the application effect of integrated geophysical prospecting technique in the detecting of hidden collapse columns. The survey and exploration results show that in the special area which forecasts the hidden collapse column of coal mine in advance, makes full use of integrated geophysical prospecting technique of coal mine, which can quickly identify the abnormal properties, determine the spatial distribution of abnormal location, provide a good target area for drilling verification, and the later subsided column treatment with security technology base.
Keywords transient electromagnetic method, DC law, forward looking prospecting, hidden collapse column.

Introduction

Water bursting in mine is one of problems plaguing the coal mine safety production, especially for Renlou Coal Mine of Anhui Hengyuan Coal Industry and Electricity Power Co., Ltd.. In 1996, due to exposure of the hidden water diversion collapse column, the first exploration working face $7_2$22 had an especially big water bursting disaster, with the maximum water bursting amount of 34,570 t/h, resulting in flooded pit, suspend production of mine and huge losses; in 1999, the working face $7_2$18 machine lane had hydrogeological abnormality during the tunneling process. The water diversion collapse column existing in the front was predicted by complex geophysical prospecting in advance, and timely treatment was conducted after exploration and verification. Therefore, how to effectively prevent and treat damage by water and guarantee against flood and mine flooding is one of the primary tasks in coal mine safety production. While identifying the hydrogeological conditions of mine working face (tunneling) roadway is the premise of effectively preventing water damage and ensuring safety production. At present, many universities and colleges, research and development institutions and mine areas threatened by water damage explore the channels of effectively preventing water damage, and have conducted highly effective studies in many aspects such as hydrogeololgy, geophysical prospecting and grouting. Since 1995, our company has successively carried out the experimental study and exploration work using geophysical prospecting methods such as direct current electric method, Rayleigh wave method, seismic method, radio wave penetration method, transient electromagnetic method and sound frequency electricity penetration method. Especially since the water bursting accident of Renlou Coal Mine in 1995, we have strengthened the geophysical prospecting strength, conducted a lot of complex geophysical prospecting work and obtained relatively sound effect. Practice has proved that complex geophysical prospecting technology is a simple, fast, economic and effective method in exploring coal face and geological structure in front of tunneling working site, exploring the water abundance of aquifer and the structure of hidden water diversion (bearing) etc..

Basic working principle of mine geophysical prospecting

The basic principle and method of mine geophysical prospecting is to judge the reasons causing these abnormalities, make qualitative and quantitative explanations for the form, attitude and spatial distribution etc. of geologic body and achieve the objective of solving geological problem by utilizing the differences in physical properties such as density, magnetic susceptibility, electrical resistivity, elasticity and radioactivity of various rocks and ore beds in the nature, adopting special instruments to detect the change of their natural or artificial geophysical field (such as gravitational field, magnetic field, electric field, elastic wave field and radioactive field), based on the physical parameters and graphic analysis and combining with materials in stratum and structure of working area and physical and mechanical property of rocks. The current widely applied mine geophysical prospecting methods in coal system are mainly radio wave penetration method, transient electromagnetic method, sound frequency electricity penetration method, direct current electric method, seismic method and Rayleigh wave method, etc. Several geophysical prospecting technologies, which are comparatively mature and widely applied by our company, will be introduced in the following.

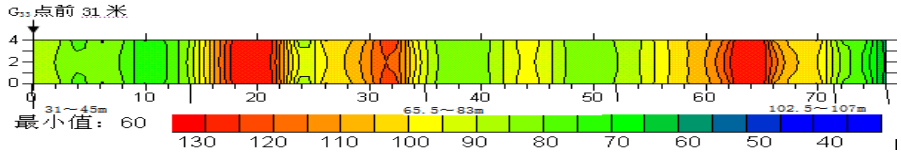
Analysis of application examples

Ⅱ51 track roadway of Renlou Coal Mine

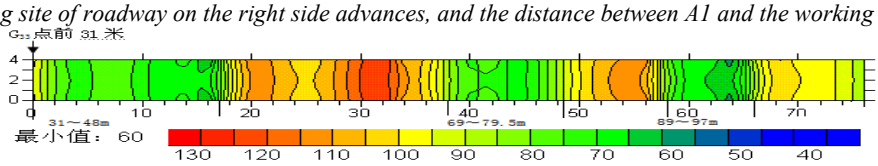
Ⅱ51 track roadway is the new tunneling area in Renlou Coal Mine construction. When constructed to 28.5 m before G33 point in roadway, local anchor bolt eyelets yield water on the rise side, and the initial water yield is 2 – 8 m^3/h. After several days' continuous water quality tests, the water hardness gradually increases, possessing the possibility of limestone water supply. In order to find out the developmental condition of water-bearing structure in front of roadway working site, further explore whether there exists hidden geologic structure in front of this roadway working site and provide data for arranging verification borehole and water prevention and control work, we successively adopt the direct current electric method, transient electromagnetic method and three-dimensional seismic method to explore the front and side wall of working site.

Exploration results of high resolution direct current electric prospecting

Comprehensive analysis of the advanced superposition results of two survey lines: There are four relative low resistivity abnormalities (No. 1, No. 2, No. 3 and No. 4 low resistivity abnormal section for short) within the range of 31-48 m, 65.5-83 m, 89-97 m and 101-107 m before G33 point in front of roadway. The resistivity value of abnormal section is between 45-85 Ω·m, among which the resistivity value of 93-97 m and 106-107 m section is below 50Ω.m(The local resistivity values of No. 3 and No. 4 low resistivity section are relatively lower). No. 1 abnormal section (31-48m before G33 point) may be caused by ponding in front of working site and fracture surface crush after analysis. The range of No. 2 abnormal section is very larger (64.5-83 m before G33 point) which may be affected by low resistivity crushed zone after analysis. The resistivity values of No. 3 and No. 4 abnormal section (89-97 m, 101-107 m before G33 point) are much lower, which may be affected by local roof and floor fissure development containing water after analysis.



The working site of roadway on the right side advances, and the distance between A1 and the working site is 14 m



The working site of roadway on the left side advances, and the distance between A1 and the working site is 14 m

***Fig.1** Contour map of high resolution tripolar electrical method*

Exploration results of high density direct current electric method

(1) There are 3 apparent resistivity abnormal areas existing in the exploration zone, which are successively named as No. 1, No. 2 and No. 3 abnormal area.

(2) No.1 abnormal area is located between No.10-14 survey points of geophysical prospecting survey points, which is within the range of 10-90m from G34 traverse point to the direction of working site; both the abnormal amplitude and range are relatively large, extending from around lateral side to the depth of 75 m; this abnormal area corresponds to the strong water enrichment detected by transient electromagnetic; and there is a DF9 fault passed by this abnormal area, it is suspected that the abnormality is affected by the relative development and relative water enrichment of fault crevice. No. 2 abnormal area is located between No. 4-5 survey points of geophysical prospecting survey points, which is within the range of 20m northeastward the G35 traverse point; the abnormality mainly concentrates in the deep, and both the amplitude and range are relatively small. No.3 abnormal area is located between No. 0-2 survey points of geophysical prospecting survey points, extending from around lateral side to the depth of 75 m, and the water yield of borehole near this abnormal place is 0-2 m^3/h. Moreover, the abnormal area with relatively small amplitude and range is found between No. 6-8 and No. 15-16 survey point , which may be affected by the nearby fault development.

(3) In the lateral side exploration process, since the lateral side is stone drift which can hardly supply power, the current electrode is generally arranged near the junction of lateral side and floor. Therefore, in the exploration results, the abnormal condition is the combined action of lateral side and floor to a certain degree.

(4) The above-mentioned results are analyzed from the real reflection of geophysical prospecting data combining with relevant hydrogeological data. Due to the limitation of height (or depth) of downhole geophysical prospecting and exploration, in practice, the hydrogeological information reflected by the result data is limited to the hydrologic data of stratum within a certain depth range. However, the change of water gushing is not only influenced by the hydrogeological condition of stratum in the region involved by geophysical prospecting, but also related to many factors such as the development of water-bearing structure under the exploration depth limit, connection condition, supply source, head pressure and thickness of coal seam, coal mining method and extraction speed. Therefore, it is suggested that relevant technical department shall strengthen the inspection work of hydrogeological data in abnormal area and timely feed back to relevant technology competent department so as to take effective technical measures.

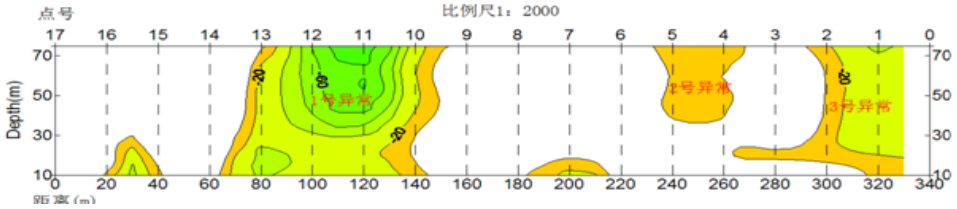


Fig.2 *Apparent resistivity abnormal areas in the wall of belt entry Ⅱ51*

Exploration results of transient electromagnetic method

According to the forward-looking exploration results of this mine transient electromagnetic method and previous exploration experience, combining with the analysis on the geological and hydrogeological data of mine, the following conclusions are drawn:

(1) Compared with the three-direction exploration results analysis of Ⅱ51 belt entry G33-30 m working site, there is water enrichment fissure development within the range far from about 40m in front of working site, between 30-65 m above roof and below 20 m under floor, which has obvious hydraulic connection with deep stratum.

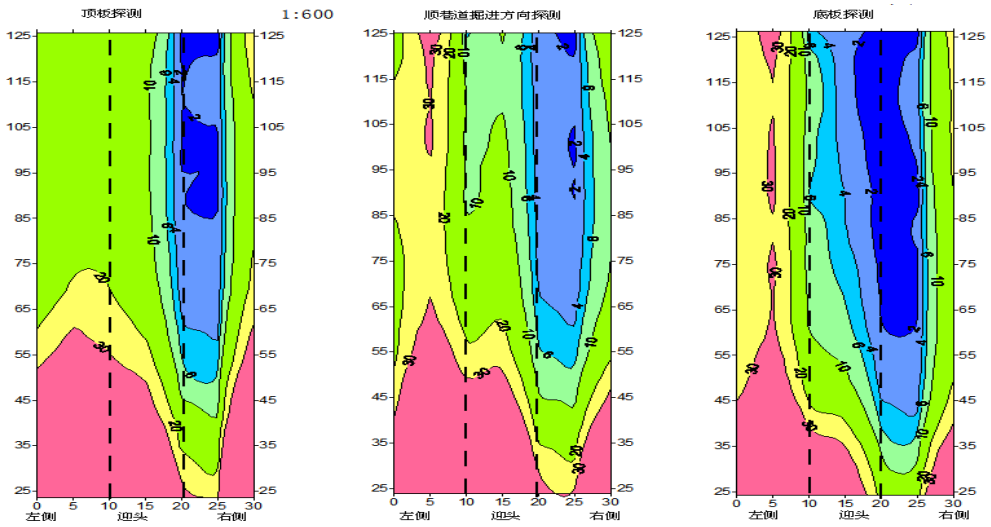


Fig.3 *Apparent resistivity abnormal areas in the working face of roadway 720*

Drill hole exploration analysis

(1) At 28.7m in front of G33 point, at the same height of water yielding anchor bolt on the rise side, 4 holes are constructed on the shoulder of rise side of working site at the same height, and the total water is 25m^3/h±. The grouting & sealing are conducted for the working site and rise side of water yielding section of roadway soon afterwards. Four grouting holes are constructed in total. After grouting & sealing, the water yield always maintains at 9m^3/h±.

(2) Through the analysis of the conditions of 5 coal measures through drill hole, DF8 fault throw is 5m±, and the fault basically does not diverse or contain water.

(3) Through drilling construction condition, the drilling control range does not disclose collapse column.

(4) Through drilling construction condition and what actually sees in working site, there is a set of diversion fissure in the trend of 160°.

Through comprehensive direct current electric method (high resolution direct current electric method, Xi'an high density direct current electric method), transient electromagnetic method and geological data of mine, and data from drilling exploration, the following conclusions can be drawn:

(1) Through the downhole drilling exploration, it is analyzed that there is a set of diversion fissure in front of roadway working site which communicates with deep limestone water, and the occurrence is 250°∠75°.

(2) Through the comprehensive exploration of downhole drilling and geophysical prospecting, it is analyzed that there is suspected collapse column at 65-115 m behind working site from the rise side of roadway and 38-65 m to the rise side of roadway in horizontal direction, which can be regarded as the target area of ground exploration.

(3) Through analyzing the drilling data, it is believed that the development height of collapse column is 5 coal floor.

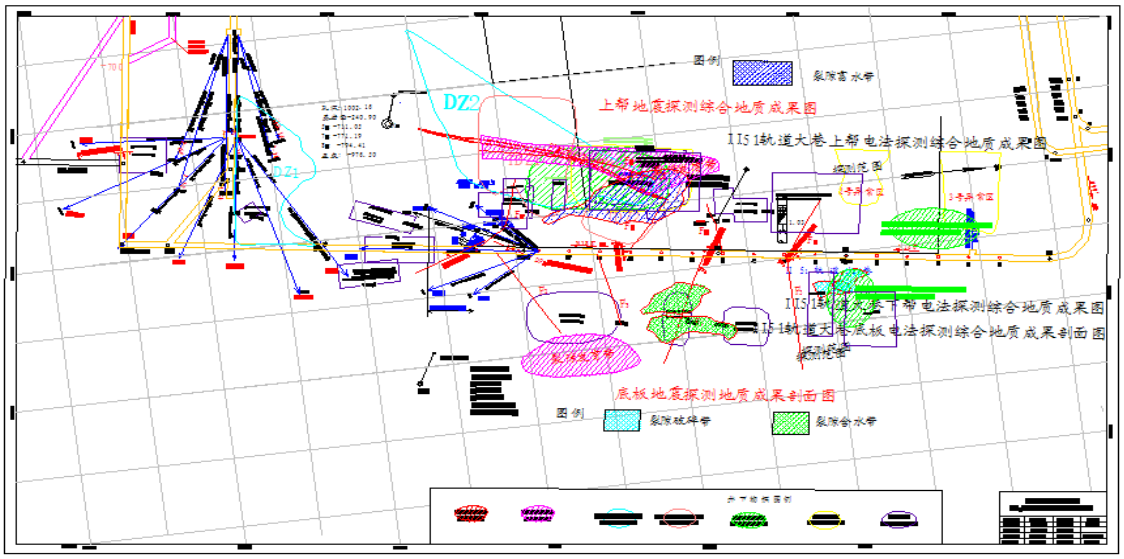


Fig. 4 *Comparison diagram of the abnormality of complex geophysical prospecting technology*

Moreover, it's worth noting that only a few metals (metal anchor net, steel tube and anchor bolt, etc.) in tunneling head and lateral side cause a certain interference to complex geophysical prospecting, thereby influencing the accuracy of exploration. This complex geophysical prospecting exploration obtains the desired effect. However, any geophysical prospecting technology has a certain degree of multiplicity and limitation. The electromagnetic method exploration shall combine with geological analysis and geological drilling and conduct comprehensive analysis according to specific hydrogeological condition to reduce the multiplicity of geophysical prospecting data to the greatest extent. Finally, it is suggested that, in geophysical abnormal area, especially the geophysical prospecting water containing area, the advanced exploration borehole shall be designed and constructed strictly according to the "Water Control Stipulation in Coal Mine", so as to verify the accuracy of geophysical prospecting result and take corresponding safety measures. In the area where no geophysical anomaly is found, appropriate advanced borehole shall be drilled according to the "Water Control Stipulation in Coal Mine", so as to ensure the safety. In case abrupt change of water inflow occurs in construction, the personnel shall be evacuated timely, and the condition shall be reported to the leader.

Blocking condition

The exploration results of Ⅱ51 belt entry basically correspond to the drilling disclose condition. After verified by drilling, the floor fissure in the right front of the working site is much more developed, and the water enrichment is much more abundant, which has a certain hydraulic connection with the deep, which is identical with the exploration results; however, the abnormality of the left front is not obvious. As for the exploration results of two lateral side floors, the conformity of the right lateral side is better; the left lateral side floor has no obvious abnormality. Ⅱ51 belt entry was started to block on November 8, 2011; the inside 159 m is filled by waste rock, and 7 pipelines are embedded according to design requirements. Two retaining walls are constructed at 30 m in front of and back of the outside section. The external retaining wall is constructed at 159 m standing back from the working site, which is built by tile and stone with anchor bolt and W steel strip as framework in the middle 1 m and poured by concrete. The external retaining wall is constructed at 189 m standing back from the working site, with the wall thickness of 0.5 m, which is built by tile and stone.

To ensure the absolute safety of blocking section, before pouring the concrete, the roadway within the range of 5 m before and after the two retaining walls shall be strengthened in the whole fracture surface by grouting anchor bolt. Moreover, 4 rows of a total of 26 grouting boreholes are constructed by the drilling machine, and strengthening is conducted for the range between retaining walls and 10 m around the roadway.

After the grouting of inside Ⅱ51 belt entry, block the water output of the roof outside the wall and the right wall floor, and the water yield is 5 m^3/h. After the research, it decided to reinforce the surrounding rock of 30 m roadway outside the blocking wall, construct 14 groups of grouting rock bolts 30 m standing back from the outside retaining wall, and conduct grouting reinforcement for 57 holes. Adopt the method of afterteeming of cement grout mixing the saw dust,achieve the sound effect and reduce the tricking water of track roadway obviously.

Since November 8, 2011 when Ⅱ51 belt entry was blocked off, it has lasted more than 3 months. Now under the circumstance of No. 5 and No. 6 injected hole closing, the pressure is 2.5 MPa±, the tricking water of track roadway is 3 m^3/h±; under the sew condition of No. 6 hole, part of the track roadway has little tricking water, achieving the effect of blockage.

Conclusion and suggestion

Through the living examples of exploration, complex geophysical prospecting exploration has improved the reliability of data interpretation, determines the nature of abnormity more accurately, and reduces the unnecessary, even blind drilling. Take the exploration of hidden collapse column in Renlou mine Ⅱ51 belt entry as an example: using transient electromagnetic method, direct current electric method and complex geophysical prospecting of three-dimensional seismic, we can explain abnormal superposition and enhance abnormal reliability, and give qualitative interpretation for it. Take effective drilling measures to determine the nature of abnormity, forecast and predict in advance, eliminate the aquifer structure threat of high insidiousness collapse column existed in the heading end. The advanced exploration of the anomalous body location can provide smaller target area for the drilling exploration, dramatically reduce the workload of drilling, win time for the elimination of hidden danger and the restoration of production.

To complete the exploration of water abundance in the front area of effosion activity, on the

basis of the principle of geological prospecting first, drilling verification, timely drainage, so as to prevent momentary water gushing of water abundance area in roof and floor sandrock. By supplemental geological prospecting, the key point is to find out the groundwater regime, water abundance and the development degree of karst fissure of Taiyuan Formation limestone, Ordovician limestone aquifer, pay attention to the reconnaissance of buried structure. The underground water from the collapse column and fault channeled into the downhole weak channel, which may bring hidden danger to the safety production of coal mine. For fault and collapse column, as the requirement of "Water Control Stipulation in Coal Mine", preserve waterproof coal pillar, it shall pay attention to observe the augury before collapse column and fault appear during the mine production, adopt the means of geophysical prospecting, drilling and tunneling prospecting to reinforce exploration work, strengthen the research of fault activated water diversion, prevent the occurrence of water disaster, before mining working face getting through the fault and collapse column, its water abundance should be ascertained, then take the control method of grouting reinforcement.

Using the geophysical prospecting means, such as the method of transient electromagnetic, direct current electric method, etc. to conduct complex geophysical prospecting work, find out the quaternary system aquifer, Taiyuan Formation limestone, Ordovician limestone aquifer development situation of area, find out the water diversion section and transmissivity of fault, determine the degree of flood threat of No. 7 and No. 8 coal mining in the area. Strengthen the use of a variety of means, such as geophysical prospecting, drilling, geochemical exploration and dewatering test to comprehensively explore the hidden vertical water diversion structure. Based on the scale of water diversion structure, the degree of water diversion and degree of supply, take appropriate countermeasures for water control, and prevent occurrence of disastrous Ordovician limestone water inrush.

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