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Exploration and Treatment Practice of A_9 Karst Collapse Column of Liuqiao Mine Field in the North of Anhui Province

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Abstract Liuqiao Mine Field in the north of Anhui Province has complicated hydrogeological conditions, and the collapse columns are well developed. In this paper, a comprehensive exploration of geophysical prospecting and drilling verification for A_9 collapse column was carried out to delineate the development range of collapse column and identify its water enrichment and transmissivity, grouting filling and preservation of protective coal pillar also have been implemented, so as to minimize the coal loss and ensure the safety of the coal extraction nearby the working face.
Keywords collapse column, development characteristics, exploration and treatment, safety evaluation

Introduction

The main body structure of Liuqiao Mine Field is an asymmetric synclinal structure that the east wing stratum of syncline is steeper and west wing stratum of syncline is slower. Due to the development of soluble carbonate rocks in the mine field, with the action of intensive runoff of groundwater, it causes the karst collapse column to be specially developed. 9 collapse columns have been found since the mine construction, among which although A_9 collapse column is safely passed through the fourth coal seam, it has a bigger threat to the mine extraction in the working face nearby the next group of the sixth coal seam. Therefore, a comprehensive exploration and treatment must be implemented to ensure the safety production of mine.

General

General situation of geology

Liuqiao Mine Field, located in the midwest of Huaibei Coal Basin and inside Liuqiao Town, Suixi County, Anhui Province, belongs to small Xuzhou-Suzhou area of western Shandong subarea of north China stratigraphic area in the aspect of stratigraphic regionalization. The cover stratum is deposited in the shape of stable platform. There is Qingbaikouan System, Sinian System, Cambrian System, Ordovician System, Carboniferous System, Jurassic System, Cretaceous System, Neogene System and Quaternary System from bottom to up, and the total thickness is about more than 3,000 m. The stratum disclosed by drilling in the mine field has Ordovician System (O1+2), Carboniferous System (C2+3), Permian System (P), Neogene System (N) and Quaternary System (Q), and the stratum thickness is more than 1,500 m. The mine field is generally a syncline structure form which is well developed. The coal measure stratum is of lower Shihezi Formation and Shanxi Formation of Permian System in the late Paleozoic Erathem of North China. The fourth and sixth coal seams are of the major minable coal seams, the interval of the above mining coal seams is about 90 m.

Hydrological geology

Hydrological geology of the mine field has complicated types and conditions. The main aquifers are quaternary system pervious aquifer, coal measures sandstone fissure water aquifer, Taiyuan Formation limestone karstic water aquifer and Ordovician limestone karst water aquifer from up to bottom respectively. The sandstone fracture water in the coal measure stratum is the direct water source of flooding to mine. Due to the well developed

fissure karst cave and good water abundance, the area of Taiyuan Formation limestone karstic water aquifer is the main aquifer and water source of flooding to mine. For example, in the process of mine extraction, the burst accident of Taiyuan Formation limestone karstic water occurs in both Ⅱ62 and Ⅱ626 working face of No. 1 Liuqiao Coal Mine, the maximum water yield is 367 m^3/h. Ordovician stratum is a major aquifer of mine field, which has the developed the karst fissure, strong formation communication and abundant water yield. However, Ordovician limestone aquifer is further from the working seam and it basically has no water power relation with Taiyuan Formation limestone aquifer.

Development rule of collapse column

In the past productions, 8 collapse columns have been found in No. 1 Liuqiao Coal Mine along the axial part near Chenji syncline, the disclosed collapse columns have the following development rule: (1) The collapse column is developed along the axial part of syncline, the long axis of collapse column tends to be in line with the direction of stratum and is closer to the axial deformation of synclinal axis; (2) The plane of collapse column is mostly elliptical, the column body is larger at the bottom and smaller at the top, the angle of draw is approximately 60°- 80°; (3) The minor fault is well developed near the collapse column; (4) The rocks in the collapse column are all in a mess, including various types of sandstone, mudstone and broken coals; (5) Most of the collapse columns are dry and waterless, the individual has a moist and humid phenomenon; (6) The plane of collapse column is of different sizes that the small one is only 710 m^2, but the large one is up to 296×104 m^2. The planar distribution is as shown in fig. 1.

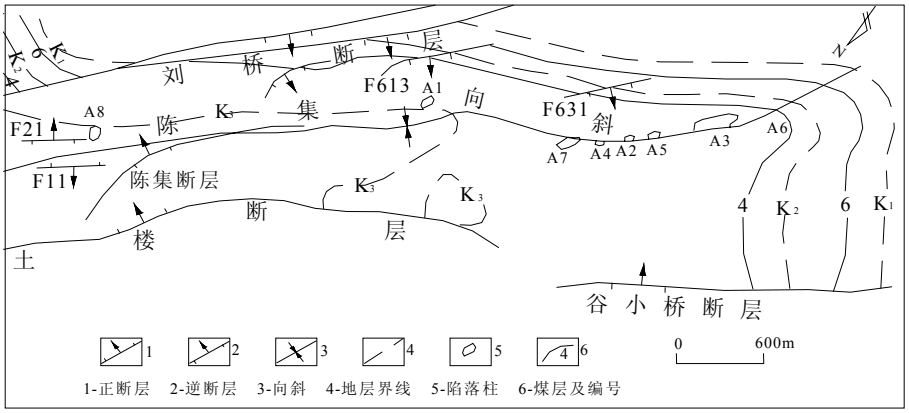

Fig. 1 *Distribution diagram of collapse columns in No. 1 Liuqiao Coal Mine*

Discovery of A_9 collapse column and analysis of A_9 collapse column on the safety of mine extraction in the sixth coal seam

Development situation of the fourth coal seam

A_9 collapse column is discovered in the working face Ⅱ465 of the fourth coal seam during the process of mine extraction. The methods of geophysical prospecting, tunneling prospecting, advanced drilling of hole combined with analysis by roof prospecting instrument etc. are taken to detect its range and water enrichment and transmissivity. Confirmed by the exploration and analysis, the rocks in the collapse column of the fourth coal seam are mainly fractured mudstone and sandy mudstone, with a small amount of fault ooze, mixed up with a large amount of sandstone rock or angular gravel, and with a small amount of coal briquettes inside(fig. 2); at the edge of the contact surface, one end is arc-shaped, and the other end is zigzagged, it is an irregular interface(fig. 3); the rocks inside the column have a better

compaction degree, part of rock surface inside the column is moister with no clear water seepage phenomenon; the collapse column appears approximate oblong, the length of long axis is 60 m, the length of minor axis is 40m, the angle of draw is 70°- 80°.

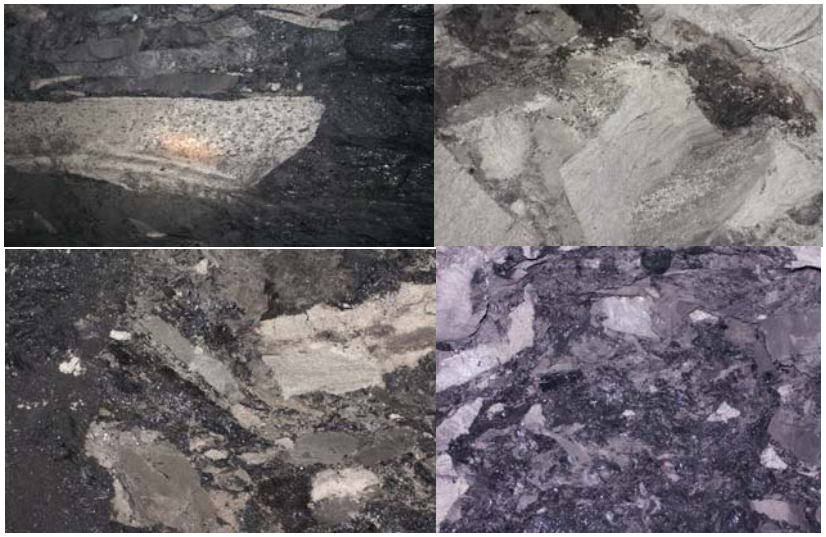

Fig. 2 *Real picture of A_9 collapse column disclosed in Ⅱ465 working face*

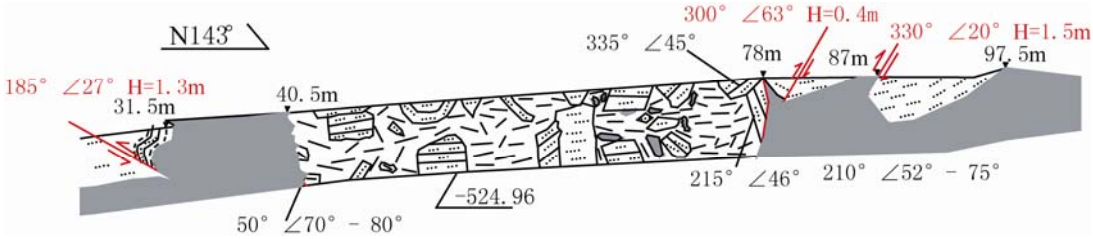

Fig. 3 *Diagrammatic real cross-section of A_9 collapse column disclosed in the working face Ⅱ465*

Analysis of A_9 collapse column on the safety of mine extraction in the sixth coal seam

Based on the data of A_9 collapse column actually disclosed by the fourth coal seam, the range of A_9 collapse column in the sixth coal seam was presumably delineated, and the safety protective coal pillar was preserved by extrapolating 50 m, however, it has the following problems:

(1) The exposure range of A_9 collapse column in the sixth coal seam is speculative, which has a great uncertainty;

(2) The water abundance of roof and floor in the working face Ⅱ661 of the sixth coal seam nearby the protective coal pillar line is unknown, and the upside of this face is a worked-out area of the working face Ⅱ465, there is wasted water;

(3) The floor of the working face Ⅱ661 has a high water pressure, Ordovician limestone water head is＋7.76 m, the water pressure is 6.27 MPa, the water bursting coefficient is 0.12 MPa/m; Taiyuan limestone water head is -320.0 m, the water pressure is 3.60 MPa, the water bursting coefficient is 0.071 MPa/m, both exceed the critical water bursting coefficient of 0.06 MPa/m (structural failing zone) of Water Control Stipulation in Coal Mine, thus it has a water bursting risk and poses a serious threat to the safety mining in the first mining face Ⅱ661 of mining area Ⅱ66.

Therefore, in order to further determine the distribution range of A_9 collapse column in the sixth coal seam, get clear on the water abundance of collapse column and its zone of influence, prevent the working face Ⅱ661 from water diversion due to the change, that is "activation" of the collapse column, in the inner structure of collapse column body caused by the effect of the mine pressure and mining in the process of extraction, or from water gushing (bursting) phenomenon due to the communication of coal seam roof and floor mining damage zone as well as collapse column and its zone of influence. Therefore, the exploration and treatment must be carried out for the collapse column before extracting the working face Ⅱ661, so as to ensure the safety of the mining of working face Ⅱ661, providing the reliable geological data for the reasonable layout of working face Ⅱ663 at the same time.

Exploration, treatment and characteristic analysis of A_9 collapse column

General idea

The general idea is: explore firstly, treat secondly, then inspect and evaluate.

Step 1: Design, construction and conclusion of exploration.

Step 2: Formulation and implementation of treatment scheme based on the exploration result.

Step 3: Validity check and safety evaluation.

Comprehensive exploration

(1) Excavation tunnel and advanced exploration: the mechanical roadway of the face Ⅱ661 is constructed along the protective coal pillar line of A_9 collapse column, the advanced exploration for A_9 collapse column has been done for twice in the process of excavation to get clear on the water enrichment of roof and floor in front of heading advance as well as check if the front of heading advance is influenced by A_9 collapse column and the water enrichment of roof and floor in front of heading advance, so as to ensure the safety of heading advance.

(2) Delineation of range: the methods like seismic wave perspective, etc. are used to explore the collapse column, the development range of collapse column is initially delineated.

(3) Exploration of water enrichment: a mine transient electromagnetic method is used to carry out the exploration for A_9 collapse column along the direction of bedding coal seam and roof and floor of coal seam on the mechanical roadway Ⅱ661, as a result, the abnormal area of water enrichment is found.

(4) Drilling exploration: in order to further determine the development range of collapse column and verify its water enrichment and transmissivity, 6 drill holes are constructed for A_9 collapse column in the two directions of angle of elevation and depression on the mechanical roadway Ⅱ661, the coring is done for all of them, the drill hole finished is 37 m above the top and 30 m under the bottom of the corresponding coal seam, among which 5 holes are disclosed with collapse column, but one hole is not. The water yield phenomenon occurs to the three holes with the angle of elevation, the water yield is 0.1 - 0.2 m^3/h, which is sandstone fissure water based on the water quality test; the drill hole finished of the three holes with the angle of elevation has no water. See Table 1 for the construction situation of each hole.

Analysis on the development feature of A_9 collapse column

(1) Combining with geophysical prospecting, drilling data and analysis on the exposure situation of the fourth coal seam, the collapse column appears approximate oblong, the length of long axis is 80 m, and the length of minor axis is 65 m. The exploration result is basically

the same as the original predicted delineated range. Compared with the prediction, in the long axis direction, the collapse column is deviated by 10 m to the part of inclined axle of Chenji syncline along the inclination of coal seam, the minor axis basically agrees well with the original one, the angle of draw is 70°±.

Table 1 *Practical situation of construction of drilling exploration*

Hole No.	Orientation	Angle of inclination	Hole depth	Depth of water yield	Depth when the collapse column is disclosed
A_9-1	5°	+5°	94m	0.2 m^3/h of water yield at the depth of 23 m	55.0 m when the collapse column is disclosed
A_9-2	27°	-27°	109m	No water yield	No fragmentation seen
A_9-3	343°	+2°	111m	0.1 m^3/h of water yield at the depth of 29 m	104.0 m when the collapse column is disclosed
A_9-4	343°	-29°	89m	No water yield	77.0 m when the collapse column is disclosed
A_9-5	5°	+5°	94.m	0. 2m^3/h of water yield at the depth of 23 m	62.5.0 m when the collapse column is disclosed
A_9-6	5°	-23°	91m	No water yield	76.3 m when the collapse column is disclosed

(2) The collapse column has no water abundance and transmissivity within the range of 35 m from the roof and floor of the corresponding coal seam.

(3) The inside of column is tightly filled, the lithological characteristic of the disclosed collapse column is mainly mudstone and silty mudstone, fine sandstone, among which mudstone is broken, a small amount of fine sand rock has a better roundness, and a small amount of coal briquette and carbonaceous mudstone is mixed up inside the collapse column.

(4) Form of contact surface: it is an irregular interface, along the coal seam, among which the upper side is zigzagged, and the lower side is close to the arc shape.

Treatment

(1) Grouting and filling: Upon the completion of drilling construction, the hole explored is used to carry out grouting and filling for the collapse column, a total grouting of 320 m^3 is conducted. The pressure of drill hole finished is controlled above 7.0 MPa. After the geophysical prospecting and chipping inspection, the grouting and filling effect is good.

(2) Reinforcement of floor around: the working face Ⅱ661 is the first mining face of mining area Ⅱ66. After the geophysical prospecting, it finds that water bearing fissure of the floor of this face is well developed, the maximum Taiyuan Formation limestone water pressure of the floor is 3.60 MPa, the water bursting coefficient is higher. To prevent working face from water diversion due to the "activation" of the collapse column caused by the effect of the mine pressure and mining in the process of extraction, a full-cover type floor grouting reinforcement measure is taken for the working face Ⅱ661, a total grouting of 5,695 m^3 is conducted.

(3) Preservation of protective coal pillar: Due to the wider development range of A_9 collapse column, the coal seam floor of the working face around bears a larger head pressure of Taiyuan Formation and Ordovician limestone, the distance from the floor of the sixth coal seam to the limestone is shorter (50 m±), for safety reasons, the safety protective coal pillar is preserved by extrapolating 50 m according to the range overall explored and delineated.

Safety evaluation

According to the analysis of the aforementioned exploration result, A_9 is a collapse column of weak aquosity and poor transmissivity. The minimum width of barrier pillar of the collapse column actually preserved is 50 m. In accordance with Water Control Stipulation in Coal Mine,the barrier pillar of the collapse column is preserved by comparing to the preservation method of fault coal pillar.

(1) The safety evaluation shall be carried out in accordance with non-transmissivity of collapse column.

The coal pillar preserved shall be no less than 20 m. The barrier pillar actually preserved shall be 50 m to meet the requirement.

(2) Accounting according to water diversion fault

In case of water diversion of collapse column, in consideration of water burst in the coal seam direction, the barrier pillar of collapse column shall be preserved in accordance with the preservation method of barrier pillar of aqueous or water diversion fault as stipulated in the Water Control Stipulation in Coal Mine, then the width of coal pillar can be calculated by the following formula:

$$L_1 = 0.5KM\sqrt{\frac{3P}{K_P}} \text{ ＜20 m} \quad (1)$$

Where*:* L_1 - width of coal pillar preserved (m); M - mining thickness (m); P - hydrostatic pressure (MPa); K_p - tensile strength of coal (MPa); K - safety factor, 2 - 5.

When it is calculated, the mining thickness M＝2.5 m, K_p＝0.2 MPa, Ordovician limestone water pressure value is 6.27 MPa, Taiyuan limestone water pressure value is 3.60 MPa. See table 2 for the calculation.

Table 2 *Calculation of coal pillar preserved with the empirical formula method*

Water pressure/MPa	L_1/m of coal pillar when K＝3	L_1/m of coal pillar when K＝3.5	L_1/m of coal pillar when K＝4	Actual coal pillar/m
6.27	36.4	42.4	48.5	50.0

From table 2, it can be seen that when the safety factor is taken as 3 - 4, the width of coal pillar preserved actually of A_9 collapse column can meet the requirement.

Conclusions

The karst collapse column is specially developed due to the special structure form of Liuqiao mine field and asymmetrical Chenji syncline, which threats and influences the safety production of mine. The exploration scheme for A_9 collapse column was formulated by carrying out the analytical investigation on the development characteristic, development rule, aquosity and transmissivity of the collapse column as well as the extraction safety in the sixth coal seam. An exploration of geophysical prospecting and drilling verification for A_9 collapse column was carried out to delineate the range of development of collapse column and identify its water enrichment and transmissivity, grouting filling and reasonable preservation of coal pillar were implemented, so as to minimize the coal loss, guide the rational distribution of mining working face and ensure the safety of the coal extraction nearby the working face.

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