Analysis of water conductivity and water gushing source of collapse column in Changcun mine

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Abstract. Based on the water conductivity of Lu’an coal mine collapse column and the analysis of the causes of water inrush of Lu’an coal mine collapse column, the water inrush source of collapse column in Changcun Mine was comprehensively analyzed by stable isotope tracing method. It was found that the groundwater runoff conditions and geological structure condition of collapse column seriously affected the water inrush of collapse column. It is determined that the water inrush source of N2-7 collapse column in Changcun coal mine is the same as the Upper Sandstone water source, that is, the infiltration supply of atmospheric precipitation, but has no direct connection with the aquifer of Ordovician limestone., which provides a relatively reliable method for the water inrush source identification of collapse column.

1. Introduction

When there is soluble rock in the coal seam floor, under the continuous dissolution of groundwater, the soluble rock gradually collapses, resulting in the collapse of the overlying strata and forming a columnar collapse body, which is called karst collapse column [1-2]. Collapse columns are widely distributed in China, among which the Taihang Mountains, Xishan of Taiyuan province to Fenxi, southern Yanshan, Ordos and the edge of Shandong block are the concentrated distribution areas of karst collapse columns [3-4]. Collapse pillars have a great impact on coal mining. Once the situation of collapse pillars occurs, it is easy to cause mine disasters. At the same time, mine water inrush phenomenon is often more common, in order to prevent the occurrence of water inrush events, it is necessary to analyze the source of water inrush. Stable isotope method is often used in the study of mine water [5-6]. In this paper, the water conductivity and its causes of karst collapse column in Luan mining area are analyzed, and the water inrush source of Changcun collapse column is explored by isotope method, which provides scientific basis and method for preventing safe mining of coal mine and distinguishing water inrush source of collapse column.

2. Water Conductivity of Collapse Column in Luan Mining Area

According to the current situation in North China mining area, most of the mining areas and collapse pillars in the mine field do not conduct water. For example, more than 400 collapse pillars forcibly
passed did not cause accidents in Dujiping Mine of Xishan Mining Area of Taiyuan province in recent years, and more than a dozen mines on the west side of Gushan Mine in Fengfeng Mining Area of Hebei Province revealed collapse pillars that did not divert water [7-8].

According to the situation of collapse pillars exposed in Luan mining area, most of the collapse pillars in mining areas or minefields do not conduct water. Water inrush occurs in individual collapse columns. Water inrush from collapse column occurred in Changcun Coal Mine on August 15, 2002. The maximum water inrush was 120 m³/h, and it declined to about 80 m³/h on August 31st.

3. Water Conductivity of Collapse Column in Luan Mining Area

3.1 Analysis of Water Conductivity of Collapse Column

The collapse column has the possibility of conducting water, and its ability of conducting water is directly related to its position. Under the action of tectonic movement, some of the positions of collapse pillars are uplifted to the surface and eroded, while the top recharge source is cut off, in some cases, the stratigraphic fracture reduces the connection with the surrounding water source. All of these may lead to the weakening or loss of the water conductivity of the collapse column [9-10]. According to the analysis of structural geological data, most of the collapse pillars in Luan mining area are located above the erosion base level, and these areas are often active areas where the karst groundwater runoff alternates. Because of the lack of water supply from the upper part of the mine, most of the collapse pillars in the mining area do not conduct water.

3.2 Analysis of water conduction condition of collapse column

The water conduction of collapse column must have certain conditions, that is, the surrounding aquifer is replenished, the structure is well developed and there is water conduction channel in the soluble rock stratum. After many periods of tectonic movement, the Luan area is a monoclinic structure with gentle westward dip. There are many tectonic faults and karst fissures are well developed in the area. The size of water inrush from collapse column mainly depends on the channel of the water conduction. The water conduction passage may be the collapse pillar itself, such as the water inrush in 103 working face of Anyang Copper and Metallurgical Mine and No.9 collapse column of the 2171 fully mechanized mining face in Kailuan [11-12], or the joint passage composed of water diversion fracture and collapse pillar. For example, the water inrush from the collapse column of No. 18 roadway in Tianguan District of Lifeng Mine in Jiaozuo Mining Area is through a normal fault, which cuts through the Ordovician lime, and introduces the high-pressure Ordovician lime water into the lower part of the collapse column to break through the fractured rock mass.

4. Analysis of water inrush source of collapse column

4.1 Analysis of water inflow

The total water inflow of the collapse column is about 2*10^5 m³. If the total water inflow comes from the stored water in the collapse column and the void fraction of the aquifer is taken into account at 0.1%, the drainage volume should be 2*10^8 m³. After detection, the diameter of the collapse column is about 50 m, the section of the collapse column is about 2000m², and the theoretical calculation of the height of the collapse column should be about 100000m, which is obviously impossible, so it can be concluded that water inrush has water supply. There are three possible sources of water in Luan collapse column: Thin limestone water from lower Taiyuan Group, deep Ordovician limestone water and sandstone water from upper coal measures. The change rule of water inrush from different sources is different. Sandstone water inflow generally presents a process from small to Large to small change, that is to say, there are signs in the early stage of water inrush, and water inflow will gradually decline in the late stage of water inrush. If the source of water inflow is from deep Ordovician limestone water, the water volume generally increases rapidly, which is sudden and bursting, and the water volume is large and stable. Water inflow usually starts at 100 m³/h. If the source of water inrush is from thin
limestone water of Taiyuan Group, its water quantity variation law should be similar to that of Ordovician limestone water inrush. Because the maximum water inflow of collapse pillars in Changcun mine reaches 120 m³/h, it is necessary to analyze the water inrush source of collapse pillars.

4.2 Analysis by Stable Isotope D, $^18$O
The D and $^18$O belong to the composition of water molecules. They participate in the circulation of groundwater as the water body itself. They are different from other substances entered by the dissolution of groundwater and can be used as the most ideal tracer in the natural circulation process. According to the modern infiltration rainwater line equation formed by atmospheric precipitation: \[ \delta D = 8 \delta^{^18}O + 10 \]
various water sources can be distinguished by accurate determination of the subtle changes of isotopes. The isotope analysis results of N2-7 collapse column in Changcun Mine are shown in Table 1 and Figure 1.

Table 1 Analysis results of various water isotopes in Changcun Mine

| Sample | Sampling horizons | $\delta^{^18}O$ (‰) | $\delta D$ (‰) |
|--------|-------------------|---------------------|---------------|
| 1      | Sandstone water on roof of No.3 coal seam | -7.08 | -47.9 |
| 2      | Limestone water | -10.10 | -66.8 |
| 3      | Ordovician limestone water | -10.15 | -69.0 |
| 4      | By detecting the collapse column of water | -6.99 | -46.7 |
| 5      | Collapse column water | -6.70 | -44.1 |

Fig 1 D relationship of water inrush in collapse column

From the relationship of $\delta^{^18}O$-$\delta D$, we can see that:

(1) The value of $\delta^{^18}O$-$\delta D$ of aquifer water samples distributes near the atmospheric precipitation line without obvious deviation and drift, which indicates that the groundwater in each aquifer is formed by the infiltration of atmospheric precipitation, and there is no groundwater formed by other
causes. That is to say, the water inrush from collapse column and sandstone water belong to one kind of water source, but have no direct connection with Ordovician limestone water and K2 limestone water.

(2) The value of $\delta_{1,45}$ is larger than $\delta_{2,3}$. At this time, because of the good runoff conditions and the close hydraulic connection, the stable isotopes in atmospheric precipitation are more accepted, which results in the higher content of the stable isotopes.

5. conclusions and suggestions
(1) Underground runoff conditions and geological structure conditions have great influence on the water conductivity and water inrush of collapse columns. Therefore, in the analysis of water inrush from collapse column, attention should be paid to its location and its relationship with geological and tectonic conditions.

(2) The value of $\delta^{18}O - \delta D$ of aquifer water samples distributes near the atmospheric precipitation line, that is to say, the outflow of collapse column and sandstone water in Changshan Mine belong to one kind of water source, but have no direct connection with Ordovician limestone water and K2 limestone water.

(3) Isotope analysis method can be well applied to water source identification of subsidence column, but all problems need to be analyzed concretely.

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