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Identification of Water Filling Source by Hydrochemical Characteristics at Liuqiao No. 1 Coal Mine

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Abstract This paper describes in detail the hydrogeological characteristics of all aquifers of the coalfield, clarifies that the sandstone fracture aquifer and floor limestone aquifer of coal measure strata are the main water filling sources. Ion content histogram and Piper trilinear chart are used to preliminarily identify the type of water of each aquifer, providing effective methods and basis for mine technicians to quickly and accurately determine water filling source.
Keywords hydrochemical characteristics, Piper trilinear chart, identification of water source

Foreword

Liuqiao No. 1 Coal Mine has complicated hydrogeological conditions. The sandstone fracture water, floor limestone water, gob water, drilling water and water from subsided column threaten the production safety of the mine. Water disaster control is the first to be undertaken. The accurate judgment of water filling water source is an important precondition for water disaster control. The study of hydrogeological characteristics is the basis for determining water-bursting source. Recognizing the hydrogeological characteristics of aquifers, a complete understanding of the groundwater storage rules can contribute to rapid identification of water-bursting source, improvement of emergency response speed, saving manpower and resources as well as providing guidance for the further prevention and resolution of water disasters.

Main water-filling sources of the mine

Sandstone fracture aquifer of coal measure strata

The sandstone fracture aquifer of coal measure strata of Liuqiao No. 1 Coal Mine mainly includes four coal roof with seven-aquifer sandstone fracture water and six coal floor with eight-aquifer sandstone fracture water. It is the main water-filling source of the mine. It is a confined fracture aquifer and featured in medium water-bursting property. Wherein, seven-aquifer sandstone fracture water of four coal seams is strong in aquosity. During recovering No. II 464 working surface, seven-aquifer sandstone fracture water-bursting accident occurred, causing the working surface flooded, wherein the maximum water-bursting amount was 140 m^3/h.

Limestone karst aquifer

This stratum is 137.25 m thick and composed of 13 layers of limestone, 58.56 m thick. Limestone karst fracture is uneven in development and differs a lot in water yield property. The first and second layer of limestone of Taiyuan Formation is not thick but pure, with developed karst. The third and fourth layer of limestone is thick, with developed karst fractures and featured in good water yield property, water transmissibility and abundant water. The four layers of limestone are featured in high permeability coefficient and sufficient hydraulic connection. All layers are just a few meters away from each other. Thus, they are treated as an aquifer. The specific yield of this group: q=0.992~0.815 L/s·m, K=2.857~0.045 m/d, so, as medium water-rich aquifer, it is the focus of water control of the mine.

Liuqiao No. 1 Coal Mine used to suffer small faults so that limestone water flow out from No.

63 mining area winch room along coastal mudstone and the maximum amount of water was 169 m^3/h, resulting that the south return airway was flooded. North Ⅱ 623 and Ⅱ 626 working surfaces also suffered water bursting of floor limestone water during mining process, the working surface was flooded, wherein the maximum water amount was 375 m^3/h.

Hydrochemical characteristics of major water aquifers

Sandstone fracture water of coal measure strata

Sandstone fracture water of coal measure strata mainly refers to Permian System sandstone aquifer, which is the roof water-filling source of Shanxi coal seam. In this paper, six groups of coal measure strata sandstone water samples are selected for analyzing the hydrochemical characteristics of the aquifer. The water mainly contains SO_4^{2-}- K^++Na^+, and the average content of six major ions are as follows: 991.8 mg/L of K^++Na^+, 26.2 mg/L of Ca^{2+}, 5.6 mg/L of Mg^{2+}, 213.5 mg/L of Cl^-, 1377.3 mg/L of SO_4^{2-}, 393.3 mg/L of HCO_3^-, Germany degree of 3.95 ~ 6.02 mg/L with the average of 4.95 mg/L, and average salinity of 2813.3 mg/L, as shown in table 1.

Table 1 *Content of major ions of coal measure strata sandstone fracture water (mg/L)*

No.	Type of water source	K^++Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	Germany degree	Salinity
1	Sandstone water of coal measure strata	1153.05	28.54	5.29	229.17	1146.92	436.09	5.21	2705.50
2		860.27	29.73	6.25	230.06	1111.79	299.17	5.60	2452.25
3		922.78	23.78	5.56	175.96	1479.31	365.09	4.61	2972.49
4		1211.32	15.88	4.57	234.96	1912.34	425.71	3.28	3816.51
5		874.20	29.08	5.60	227.15	1511.69	493.60	5.36	2541.32
6		929.29	29.92	6.30	183.72	1102.04	340.39	5.64	2391.66

Taiyuan Formation limestone aquifer

Exploitation of coal mine No. 6 is divided into No. 66 and No. Ⅱ 66 mining areas. In order to accurately determine water-bursting source, underground water drainage drilling and six groups of floor grouting transformation drilling water sample test data is used to analyze hydrochemical characteristics of limestone aquifer.

No. 66 mining area: According to analysis, the water mainly contains SO_4^{2-}·HCO_3^--Ca^{2+}·(K^++Na^+), and the average content of six major ions are as follows: 373.2 mg/L of K^++Na^+, 195.3 mg/L of Ca^{2+}, 66.1 mg/L of Mg^{2+}, 112.1 mg/L of Cl^-, 824.3 mg/L of SO_4^{2-}, 369.1 mg/L of HCO_3^-, Germany degree of 19.8-56.79 mg/L with the average of 33.7 mg/L, and average salinity of 2026.5 mg/L.

Table 2 *Content of major ions of Taiyuan Formation limestone aquifer in No. 66 mining area (mg/L)*

No.	Type of water source	K^++Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	Germany degree	Salinity
1	Taiyuan Formation limestone aquifer in No. 66 mining area	202.53	312.66	56.52	97.02	611.17	338.19	44.89	2811.88
2		193.45	181.11	26.60	94.95	785.92	289.24	19.8	1066.39
3		254.94	152.86	81.48	92.98	854.94	307.56	24.04	1111.75
4		397.04	153.18	90.13	146.22	819.95	454.44	33.00	2032.28
5		518.18	262.27	57.09	147.76	805.40	461.25	56.79	2881.96
6		673.31	109.55	84.93	93.58	1068.69	363.38	23.73	2254.74

No. II66 mining area: According to analysis, the water mainly contains SO_4^{2-}·HCO_3^--Ca^{2+}·(K^++Na^+), as shown in table 3. The average content of six major ions are as follows: 410.8 mg/L of K^++Na^+, 282.6 mg/L of Ca^{2+}, 118.4 mg/L of Mg^{2+}, 143.7 mg/L of Cl^-, 1470.9

mg/L of SO_4^{2-}, 204.6 mg/L of HCO_3^-, Germany degree of 49.79～67.94 mg/L with the average of 60.8 mg/L, and average salinity of 2640 mg/L.

Table 3 *Content of major ions of Taiyuan Formation limestone aquifer in No. II 66 mining area (mg/L)*

No.	Type of water source	K^++Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	Germany degree	Salinity
1	Taiyuan Formation limestone aquifer in No. II 66 mining area	271.16	278.26	278.26	145.24	1153.61	205.53	57.94	2185.21
2		382.41	312.55	104.93	186.11	1477.18	176.30	67.94	2748.80
3		330.52	222.81	80.68	123.94	1222.24	213.81	49.79	2158.01
4		341.91	335.79	75.74	105.57	1353.74	189.12	64.46	2547.86
5		764.91	280.21	75.19	169.14	1375.41	251.51	65.56	3668.37
6		373.64	266.26	95.80	132.42	1442.95	191.51	59.36	2531.87

Comparison of content of major ions of the various aquifers

Table 4 *Comparison of content of major ions of the various aquifers (mean) (mg/L)*

Aquifer name	K^++Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	Germany degree	Salinity
Sandstone facture water	991.8	26.2	5.6	213.5	1377.3	393.3	4.95	2813.3
Limestone water in No. 66 mining area	373.2	195.3	66.1	112.1	824.3	369.1	33.7	2026.5
Limestone water in No. II 66 mining area	410.8	282.6	118.4	143.7	1470.9	204.6	60.8	2640

According to the above table, content of K^++Na^+ ion in the sandstone fracture aquifer is much higher than that in the limestone aquifer, and the content of Ca^{2+} and Mg^{2+} ion in the sandstone fracture aquifer is far less than that in the limestone aquifer. The water hardness of sandstone aquifer is much lower than that of the two limestone aquifers. The Mg^{2+} and SO_4^{2-} ion content and Germany degree of the limestone aquifers in different mining areas differ a lot and can be deemed as the basis for judging limestone water in different mining areas.

Recognition of water source

Identification of water-filling source by hydrochemical histogram:

(1) Identification of coal measure strata sandstone water and limestone water

According to table 4 and fig. 1, the content of K^++Na^+ in coal measure strata sandstone fracture aquifer is significantly higher than that in limestone water, which can be used as a basis for discrimination of water source. Secondly, the content of Ca^{2+} and Mg^{2+} in sandstone aquifer is very low, and only the content of HCO_3^- is high. Therefore, Ca^{2+} and Mg^{2+} ions can be used as the basis for judgment of sandstone water. Furthermore, average Germany degree of sandstone water is only 4.95, far less than that of limestone water, namely 33.7 and 60.8, which can also be used as basis for judgment.

(2) Identification of limestone water in different mining areas

According to table 4 and figure 1, the content of SO_4^{2-} in limestone water in No. 66 mining area is 824.3 mg/L, which is significantly lower than that in limestone water in No. II 66 mining area, namely 1244.59 mg/L, which can be used as the basis for discrimination of limestone water in two different mining areas. Secondly, the content of HCO_3^- in limestone water in No. II 66 mining area is 204.6 mg/L, which is significantly lower than that in limestone water in No. 66 mining area, namely 369.1 mg/L, which can be used as the basis

for discrimination of limestone water in two different mining areas. Furthermore, the hardness of limestone water in No. 66 mining area is 33.7 mg/L, which is significantly lower than that of limestone water in No. II 66 mining area, namely 60.8 mg/L, which can also be used as the basis for discrimination of limestone water in two different mining areas.

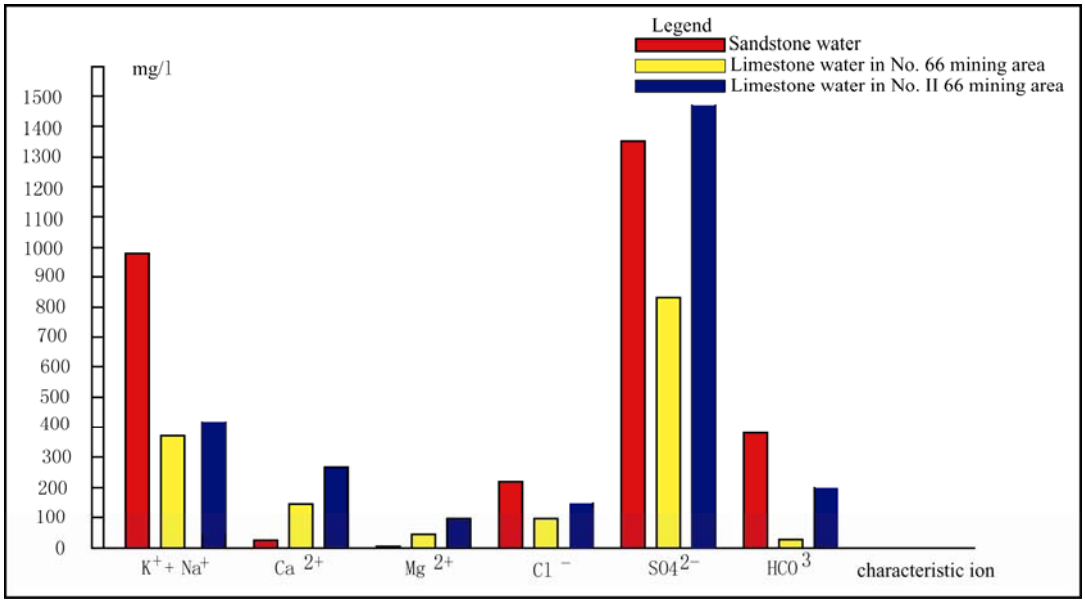

Fig. 1 *Major ion content histogram of each aquifer*

Identification hydrochemical characteristics of water-filling source by Piper trilinear chart

Milliequivalent percentage is used as the unit of Piper trilinear chart. The milliequivalent percentage of the anion and cation is used to determine the water source. The parallel lines intersect at parallelogram position of the position of two triangles so as to draw a lot of water quality data on the graph.

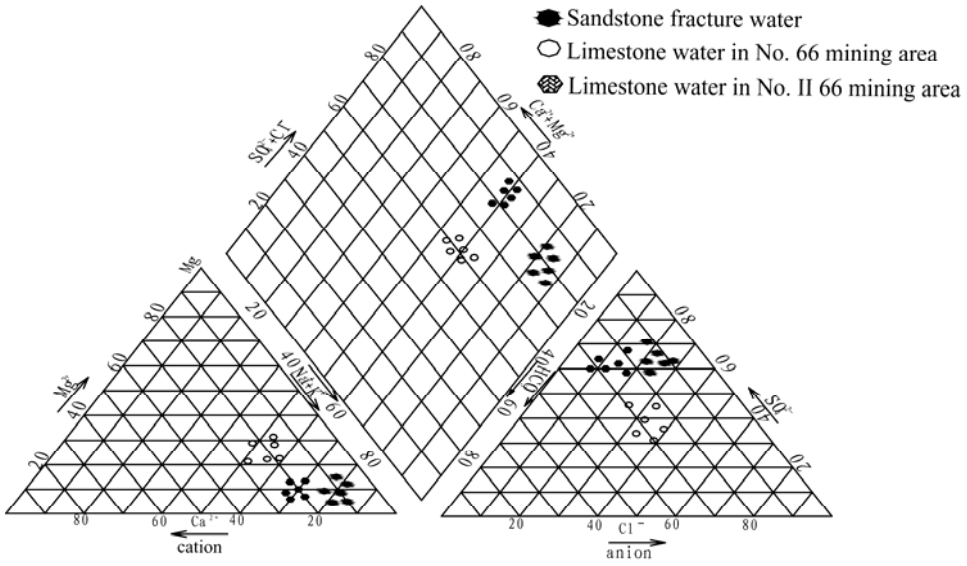

Fig. 2 *Distribution of water quality data on the trilinear chart*

18 water quality testing data of the mine is utilized in this study to be mapped on the Piper trilinear chart (as shown in fjg. 2). According to the distribution of water quality on the chart,

the water source is divided into two categories. One is in the quadrangle and is distributed along K^++Na^+ 80% mEq line, belonging to sandstone fracture water. The other is distributed along Ca^{2+}+Mg^{2+} 40% mEq line, belonging to limestone water. Second, limestone water in different mining areas is distributed in the quadrilateral along SO_4^{2-}+ Cl^- 60% mEq line, belonging to No. 66 mining area limestone water, and that along SO_4^{2-}+ Cl^- 80% mEq line belongs to No. Ⅱ 66 mining area limestone water. Results are consistent with that of the first method.

Conclusions

Based on the analysis of the chemical characteristics of main water-filling source of main mining layers of Liuqiao Coal Mine, the ionic characteristics of each aquifer is determined in this paper. Ion content histogram and Piper trilinear chart are used to analyze hydrochemical characteristics of coal measure strata sandstone fracture water and limestone water aquifer and distinguish the water quality type of each aquifer in this area (including careful analysis of limestone water in two mining areas suffering threat of limestone aquifer) so as to provide effective method and basis for mine technical personnel to quickly and accurately determine the type of water bursting sources.

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