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Accumulation pattern of groundwater containing Hydrogen Sulfide in the southern Junggar basin in China

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ABSTRACT

The surface water and groundwater flows from south to north to the interior basin in the midst of southern Junggar basin in China. The thick and loose gravel sand layer accumulates in the region, Tectonic depressions of echelon are arranged. Tectonic depression or basement uplift, under the control of hydrodynamic block gas, provides a large space for the occurrence and migration of groundwater (Hydrogen Sulfide). The water is rich in sulfate and chloride. Runoff, dissolution, and leaching may occur in the infiltration and runoff process, and under intense evaporation. The water with high salinity may form HCO_3-Ca-Na, HCO_3-SO_4-Na-Ca, Cl•SO_4-Na, and HCO_3-SO_4-Cl-Na-K. The water rich in SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+} and Na^+ through the hydrocarcon-rich zone (ΣCH, C), plays a role in geothermal warming. Under suitable geological conditions BSR or TSR may ocurr, and H_2S can be generated, resulting in a significantly lower concentration of calcium and higher concentration of hydrogen sulfide in the water.

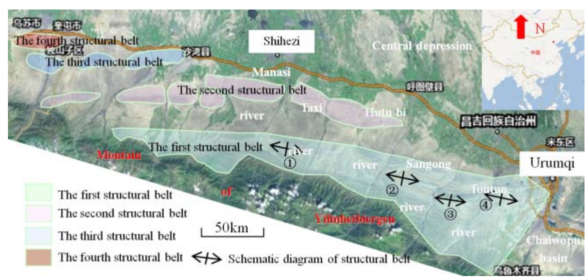
KEYWORDS：Southern margin of Junggar basin; Groundwater, Hydrogen Sulfide; Accumulation pattern

1. INTRODUCTION

The midst of southern Junggar basin lies in the combining site of southern Junggar and north Tianshan. The surface water and groundwater flows from south to north to the interior basin. Salinity and hardness is both in increase, while the concentration of Ca^{2+} reduces greatly. Hydrogen sulfide (H_2S) is rich in underground water. Although regional water containing hydrogen sulfide are widely distributed, the current understanding of the patterns of water containing hydrogen sulfide is still limited. Developing the accumulation pattern of hydrogen sulfide-bearing groundwater has theoretical significance and practical value.

2. REGIONAL STRUCTURE

Two or three belts of arching and syncline depression formed in the regional piedmont zone., These alternate with each other in the piedmont depression, and are divided into four secondary units, including, Shihezi sag, West of Urumqi piedmont fold belt, and Sikeshu sag (Jia et al., 2003; Fang et al., 2005; Wang et al., 2013). The lineament distribution and Tianshan fold belt direction structure consists of a series of syncline and anticline and thrust faults which lie east west-north east, as shown in Figure 1.



①-Structural belt of Qingshuihe, ②-Structural belt of Qigu, ③-Structural belt of Changji, ④-Structural belt of Kalazha

Figure 1: Regional structure in the midst of southern Junggar basin of China.

3. THE CHEMICAL CHARACTERISTICS OF WATER

The chemical composition, ion concentration, and salinity of groundwater have an important influence on the genesis and enrichment of H_2S. Sulfate ion is a sufficient condition in order for bacterial sulfate reduction (BSR) and thermochemical sulfate reduction (TSR) to occur. The chemical characteristics of groundwater in each coal mine of the study area from south to north are as shown in Table 1.

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Table 1: Coal mine groundwater chemical properties from south to north basin areas.

Coal mines	Hydrochemistry type	Salinity (g/L)	H_2S (mg/L)	pH
Daxigou	SO_4-Cl-HCO_3-Ca	1.1	7.89-25.32	8.3
Qianshuihe	SO_4-Cl-Na	2.6	9.26-51.29	8.5
Liuhuanggou	SO_4-Cl-K+Na	3.5	23.89-69.45	8.5
Xishan	Cl-SO_4-K+Na	6.2	41.89-259.63	9.0

(1) The depth of groundwater in Toutun river becomes gradually more shallow from south to north. There is a large amount of water surface overflow and flow into big and small Quangou in the first belt of the structure, leading to the development of hot river in the first row structure. The H_2S is rich in the water. Along the flow direction, the chemical types of groundwater by HCO_3-Ca-Na, HCO_3-SO_4-Na-Ca water evolve into HCO_3-SO_4-Cl-Na-K.

(2) The water salinity and hardness of surface water and shallow groundwater goes from low to high from the mountains of Yilinheibiergen to the research area. The salinity starts at less than 1.0 g/L, and increases to more than 6.0 g/L. The pH value also gradually becomes larger, from 7.1 to 9.6. The water is weak alkaline saline water.

(3) The ion constants (except HCO^{3-}) mass concentration components increase along the direction of deep confined water runoff. The cationic content of Na^+ and K^+ show a strong increasing trend, from 27.4% to 72.9%. The dominant evolution of Ca^{2+} dominant is given priority over Na^+. Ca^{2+} is reduced to 21.2%, from 57.8%. Anionic concentrations (mainly HCO^{3-}) are reduced, except for SO_4^{2-} and Cl^-.. HCO^{3-} is reduced from 73.5% to 48.1%. SO_4^{2-} increases from 19.3% to 30.2% and Cl^- increases from 6.7% to 13.3%. The evolution of the regional deep confined water chemical composition reflects the leached and the roles of cationic alternating adsorption effect on the evolution of deep confined water (Duan et al., 2007; Hou, 2001).

4. REGIONAL HOT SPRING (WELL) WATER FEATURES

New tectonic movement leads to the exposure of hot springs (well), most of which are fault springs. The water chemical characteristics of hot springs (well) in the study area are as shown in Table 2 (Wang, 1998; Gao et al., 2000; Xu 1994)..

Table 2: Water chemical characteristics of hot springs (well) in the study area.

Areas	Water chemical characteristics	H_2S (mg/L)	pH	Salinity (g/L)	T (℃)
Ergong	SO_4-HCO_3-Cl-Na	--	7.7	0.88	10.8
North gate	SO_4-HCO_3-Cl-Na+K	--	7.1	2.86	11.5
Maliaodi	SO_4-Cl-Na	--	7.2	2.86	10.4
Jianquangou	SO_4-HCO_3-Na+K	--	8.6	0.78	11.3
Shuimogou	Cl-HCO_3-SO_4-Na	135~204	9.6	1.66	19.5
Shuimogou	CO_3-HCO_3-Cl-Na	160~210	9.3	7.98	21.0
Hongyanchi	SO_4-HCO_3-Na	2.1~3.3	8.0	0.85	11.6
Hongyanchi	HCO_3-SO_4-Cl-Na	2.8~3.5	8.6	1.04	12.0
Gongyuan	SO_4-HCO_3-Cl-Ca+Na	--	7.6	0.86	10.4
Yongfengqu	Cl-Na+K	--		14.4	11.4
Daquangou	Cl-SO_4-HCO_3-Na	56.0~89.0	8.2	1.78	8.0
Baiyanghe	Cl-Na	6.4	7.3	0.44	35.8

As shown in Table 2, regional hot springs (well) are more exposed in the complex faults, anticline structure belt. Water is weakly alkaline and rich in H_2S, with the water chemical characteristics being HCO^{3-}, SO_4^{2-}, Cl^-, and Na^+.

5. ACCUMULATION MODEL OF WATER CONTAINING HYDROGEN SULFIDE

5.1 Hydrological control function in the region

The mountain of Yilinheibiergen is rich in ice and snow, which is the main source of groundwater. Surface water and groundwater flow from south to the north basin. Constituting a centripetal water system, the water system follows developed track extensional faults, where the end point is the northern edge of the desert, as shown in Figure 1.

The thickness of the regional quaternary sediments is about 400-1300 m. In the first and second structural belt between tectonic uplift, and the third and fourth structural belt format the echelon arrangement structure depressions there is a piled up thick and loose sand gravel layer. Sag tectonic or basement uplift provides a huge space for groundwater (H_2S) occurrence and migration. The groundwater circulation characteristics are as shown in Figure 2.

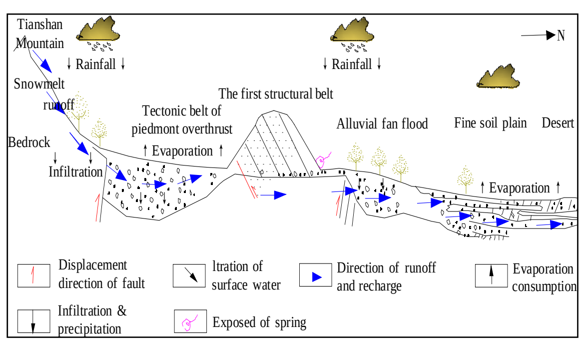

Figure 2: Characteristics of the water cycle in the region

Regional water types can be divided into loose rock pore water, clastic pore water, and fissure water. Local areas have the loess layer cross water, therefore local groundwater is under pressure, Hydrogen sulfide has significantly higher solubility under stress conditions, resulting in the abnormal enrichment of water containing H_2S. On 0 o'clock November 5, 2011 in Xishan coal mine, after drilling and shooting on the mountain track working face a large amount of water and harmful gas suddenly poured out from the B_{19} coal seam roof, due to the effect of the impact and vibration. Instantaneous H_2S concentration was as high as 400 parts per million, and the gas concentration was as high as 19.5%.

Regional hydrogeology controlling gas is the main factor in the effect of hydrodynamic seal controlling gas (Qiao et al., 2005), as shown in Figure 3.

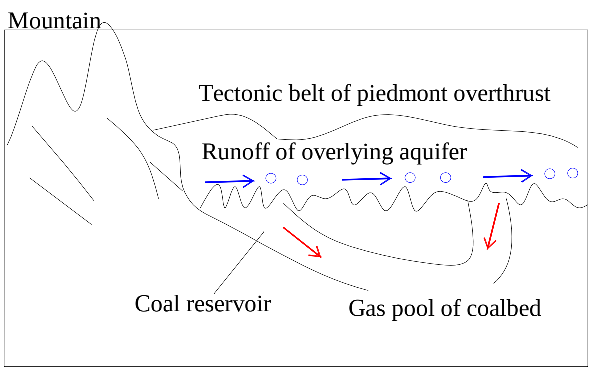

Figure 3: Regional hydrogeology controlling gas & archive mode of coalbed methane.

The groundwater accepts melting (surface water) supplies in sealing black bill root at the northern foot of the mountain strata outcrop, with bedding going from shallow to deep down the steep slope. Mudstone water-resisting layers develop at the top and bottom of the coal. The movement of the internal waters and gases are stopped due to the lithostatic pressure, which makes the coal seam permeability vary in the deep. In addition to the worsening continuity of sand body of surrounding rock, the coal bearing period of the groundwater movement was slow. Upward dissipation of H_2S in coal strata (gas) was blocked, and the groundwater carrying H_2S (gas) makes it move deeper, resulting in the abnormal concentration of H_2S in water and coal rock.

5.2 Regional lithologic control function

Most mountains towering in the southern region of the black bill mountain have snow and ice melt that is rich in SO_4^{2-} and Cl^-. Because the hydraulic gradient is large along the radial direction, the water exchange effect is strong. The make-up water with sulfuric acid salt rocks, silicate rock, carbonate rock, glauber's salt, and salt may be dissolved and leached in the process of rainfall infiltration and runoff. The potential chemical reactions are expressed by reactions 1 to 6:

$$CaCO_3 \cdot 2Al_2O_3 \cdot 4SiO_2(\text{Anorthite}) + 2CO_2 + 5H_2O \rightarrow 2HCO_3^- + Ca^{2+} + 2H_4Al_2Si_2O_9 \quad (1)$$

$$Na_2Al_2Si_6O_{16}(\text{Albite}) + 2CO_2 + 3H_2O \rightarrow 2HCO_3^- + 2Na^{2+} + 2H_4Al_2Si_2O_9 + 4SiO_2 \quad (2)$$

$$MgCO_3 + CO_2 + H_2O \rightarrow 2HCO_3^- + Mg^{2-} \quad (3)$$

$$CaMg(CO_3)_2 \rightarrow Ca^{2+} + Mg^{2+} + 2CO_3^{2-} \quad (4)$$

$$CaSO_4 \rightarrow Ca^{2+} + SO_4^{2-} \quad (5)$$

$$NaCl \rightarrow Na^{2+} + Cl^- \quad (6)$$

High salinity of *HCO_3-Ca-Na*, *HCO_3-SO_4-Na-Ca*, *Cl•SO_4-Na* and *HCO_3-SO_4-Cl-Na-K* type water can be formed under the action of the above dissolution, leached and strong drought evaporation.

Deep confined water in a closed environment is relatively good, under the effect of revivification and microorganisms and thermodynamic factors. When sufficient hydrocarbon organic matter is in coal strata ($\sum CH$, C), under appropriate conditions like a suitable temperature range, *BSR* or *TSR* can occur (Liu et al., 2011; Deng et al., 2013), The hydrocarbon organic matter can react with sulphate, producing H_2S and other compounds. The possible reactions are as follows:

$$\sum CH(or\,C) + SO_4^{2-} + H_2O \xrightarrow{BSR} H_2S\uparrow + CO_2\uparrow + CO_3^{2-}(BSR) \quad (7)$$

$$2C + CaSO_4 + H_2O \rightarrow CaCO_3\downarrow + HS_2\uparrow + CO_2\uparrow (TSR) \quad (8)$$

$$CH_4 + SO_4^{2-} + 2H^+ \rightarrow H_2S\uparrow + CO_2\uparrow + H_2O(TSR) \quad (9)$$

$$\sum CH + CaSO_4 \rightarrow CaCO_3\downarrow + H_2S\uparrow + CO_2\uparrow (TSR) \quad (10)$$

$$C_nH_{2n+2}(\text{Heavier hydrocarbons}) + nSO_4^{2-} \rightarrow C_{n-1}H_{2n}(\text{Lighter hydrocarbons}) + CO_2\uparrow + (n-1)H_2S\uparrow + S + H_2O + CO_3^{2-} \quad (n \geq 2)\ (TSR) \quad (11)$$

The result is lower Ca^{2+} concentration in groundwater, and the water becoming rich in H_2S and CO_2.

The groundwater of the mines (district) area is weakly alkaline, but H_2S is acidic, so there may be a balanced relationship as shown in reaction (12).

$$H_2S + OH^- \leftrightarrow HS^- + H_2O$$
$$HS^- + OH^- \leftrightarrow S^{2-} + H_2O \quad (12)$$

Groundwater is blocked near the fault, and water that is rich in H_2S (spring) is exposed on the surface. The accumulation mode of water containing H_2S in the region is as shown in Figure 4.

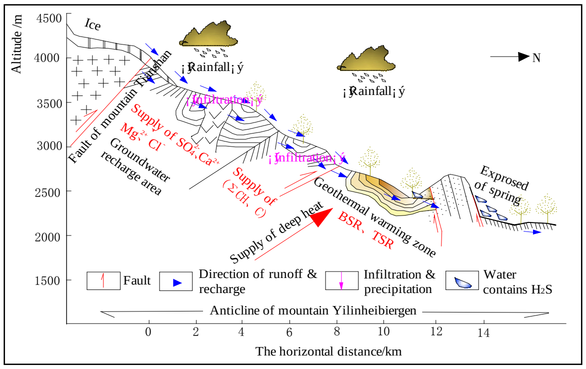

Figure 4: Accumulation mode of water containing hydrogen sulfide in regional

6. CONCLUSIONS

(1) The surface water and groundwater flows from south to north to the interior basin of southern Junggar basin. The thick and loose gravel sand layer accumulates in the region. Tectonic depressions of echelon are arranged. There is tectonic depression or basement uplift, under the control of hydrodynamic block gas, which provides a large space for the occurrence and migration of groundwater (Hydrogen sulfide).

(2) The water rich in SO_4^{2-} and Cl^- along the radial direction can form high salinity type water of HCO_3-Ca-Na, HCO_3-SO_4-Na-Ca, Cl•SO_4-Na, and HCO_3-SO_4-Cl-Na-K under the action of the dissolution, leached, and strong drought or evaporation reactions.

(3) When water rich in SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, and Na^+ flows through the area rich in hydrocarbons ($\sum CH$, C), BSR or TSR may occur. H_2S may then be produced in proper geological conditions, which lead to a large loss of Ca^{2+} in water, but a large increase of hydrogen sulphide in the water. Therefore, it is possible to draw the accumulation pattern of water containing H_2S.

7. ACKNOWLEDGEMENTS

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