Analysis of chemical characteristics of water in the formation of the Sudong area

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Abstract. In Sudong area, the relationship between gas and water is complex and the hydrochemical characteristics of formation water is unclear, therefore, site managers are eager to figure out the formation water properties and its distribution characteristics in Sudong gas reservoir. In this paper, based on the analytical data of formation water, we studied the type of formation water, the chemical characteristics of produced water, and the hydrochemical characteristics coefficient. The results showed that the water produced in the south and north is formation water and the middle is condensate water; the fracturing fluid is discharged at the early stage of the gas well production, and the formation water is gradually produced in the later stage; the salinity is high in the southwest and lower in the northeast; the water storage condition in the southern formation is higher than that in the north; the time of the water and rock action in the southern area is stronger than that in the north, and from the perspective of oil and gas preservation, the south is better than the north. The research would have a great significance for improving the understanding of formation water in the Sudong block and guiding the rapid and efficient development of the gas field.

Keywords: Sudong area; formation water; hydrochemical characteristics.

1. Introduction
In oil and gas reservoirs, formation water coexists with oil and gas in different forms of underground rock pores, which is an important driving force and carrier for oil and gas migration and accumulation. Its formation and movement laws and hydrocarbon generation, migration and accumulation, and reservoir formation, Conservation and destruction are closely related. The Ordos Sugeri gas field is characterized by low porosity, low permeability, low abundanc, and low yield. The formation water distribution is mainly controlled by hydrocarbon generation intensity and reservoir heterogeneity[1]. In the Su 20 block, as an important development block, the gas-water relationship and distribution law are often affected by the conditions of gas intensity, structure, temperature, and pressure in the reservoir[2-3]. For the study of the relationship between stratigraphic water and natural gas in the Shige Formation of the Sugeri gas field, the distribution characteristics and control factors of the gas and water in this group can be obtained by combining the actual stratigraphic characteristics and the analysis of the
salinity of the formation water[4-6]. It is not difficult to find that for the same gas field, the distribution characteristics of gas and water in different blocks are very different. Therefore, it is very necessary to understand the relevant characteristics of formation water in the development process of oil and gas fields. The study of water chemistry characteristics is an important basis for understanding the laws of oil and gas migration and formulating reasonable mining plans. The gas-water relationship in the Sudong area is complex, the chemical characteristics of the gas produced by the gas well are different, and the reservoir heterogeneity is serious. Therefore, it is necessary to understand the chemical characteristics of the gas reservoir and its differential causes, and guide the economic and efficient development of the gas reservoir.

2. Stratigraphic water types in the Sudong area

The water production types of production wells in the Sudong area are divided into three categories:

(1) Formation water: The analysis of mercury intrusion in the Sulige gas field shows (as shown in Figure 1): the water saturation is located in the gas-water two-phase seepage zone in the region of 41% to 78%. Due to the production pressure difference, the formation liquid water The water that flows from the reservoir into the wellbore eventually produces ground.

![Graphic and scale](Sudong 13-75)

**Fig 1.** Water-based characteristics of part of the stratum water in the Sudong gas field

(2) Condensate water: According to the theory of saturated water content of natural gas, if there is only bound water and natural gas in the reservoir section, the temperature and pressure will continue to decrease during the process of natural gas flowing from the reservoir into the wellbore to the wellhead out of the wellhead, due to the ability of the gas to contain water. When it falls, the water vapor continuously condenses into water droplets, and finally, the liquid water is condensed. The condensate water is in the form of water vapor in the ground.

(3) Residual liquid entering the well: It is a part of the fracturing fluid remaining in the formation after the production wells are subjected to fracturing construction before being put into production, and the liquid which is rapidly produced in the early stage of production due to poor ground lamination (as shown in Fig. 2).

![Graphic and scale](Sudong 20-68)

**Fig 2.** Water-soluble characteristic diagram of partial fracturing residual liquid in Sudong gas field

In actual production, the effluent may be less, and the single water type may be less. It is more likely to be mixed by two or more types of water. For example, considering the factors of reservoir fracturing and returning, the initial stage of production, formation water and fracturing residue The mixed liquid
is common, and the fracturing can be completely discharged after a long period of production; in the production process, the condensed water is mixed with a small amount of formation water to form a desalinated formation water. It can be seen from the water pattern (Fig. 3) that the water produced in the south and north is formation water and the middle part is condensate water. For the same gas well, the fracturing fluid is discharged initially, and the formation water is gradually produced later.

3. Analysis of chemical characteristics of produced water

(1) Salinity

Due to the serious mixing of condensate water, the average value of chloride in single well in the work area is low, which is 27,937.04 mg/L, the average mineralization degree is 47,723.88 mg/L, which is lower than the average value of formation water 52,924.9 mg/L. Most of the water type CaCl$_2$ (as shown in Table 1). In 2013, the degree of chloride and mineralization was the highest, and the overall change in recent years was small.

![Fig 3. Comparison of water patterns of Stiff graphs in different directions and at different times](image)

| Date | Sample Well | Cl$^-$ (mg/L) | Salinity (mg/L) |
|------|-------------|---------------|----------------|
|      |             | Range         | Average        | Range           | Average        | Type     |
| 2011 | 54          | 527.14 ~ 11,7516.75 | 28380.04 | 1448.64 ~ 259,097.02 | 54,382.31 | CaCl$_2$ |
| 2012 | 55          | 5040.28 ~ 17,9654.93 | 29351.23 | 9334.62 ~ 297,648.87 | 49,433.1 | CaCl$_2$ |
| 2013 | 66          | 3627.6 ~ 13,1806.65 | 42859.63 | 7833.04 ~ 214,486.5 | 72,188.61 | CaCl$_2$ |
| 2014 | 73          | 264.1 ~ 11,0952.83 | 22286.33 | 742.27 ~ 180,477.56 | 36,775.07 | CaCl$_2$ |
| 2015 | 143         | 2002.22 ~ 148,286.29 | 26635.1 | 3338.76 ~ 232,385.76 | 43,702.57 | CaCl$_2$ |
| 2016 | 15          | 806.84 ~ 65,446.73 | 18109.94 | 1613.81 ~ 104,702.69 | 29,861.64 | CaCl$_2$ |
| Average | | 27937.04 | | 47723.88 | |

(2) pH value

The pH value of the produced water in the Sudong gas field is mostly between 5.3 and 7.2, indicating weak acidity-neutrality. Considering the desalination of condensate water, the pH value of the actual formation water should be stronger. Under normal circumstances, the high-mineralized metamorphic water in the deep-medium basin in the closed-pressure environment is generally free of acidic water, and it is mainly alkaline water or weakly acidic water. Even the water whose surface is dissolved and balanced, its pH value Alkaline water characteristics are also shown between 7.0 and 8.68. The reason for this phenomenon may be that the dissolution of the formation water has not reached equilibrium, the residual organic acid content is high, the pH value is low, and it may also be related to the low PH value of coal seam water.
(3) Analysis of constant elements

The actual water analysis data (Fig. 4) showed an average calcium ion content of 8.25 g/L, which accounted for 48.89% of the total amount of cations. The average total content of Na\(^+\), K\(^+\), and Ca\(^{2+}\) ions accounts for 99.83% of the cation. The content of Mg\(^{2+}\) ions in the produced water is 0.028 g/L, which accounts for 0.17% of the total amount of the cations. The average content of chloride ions in the produced water of Sudong gas field reached 28.71 g/L, accounting for 94.39% of the total anion. The average HCO\(_3^-\) content in the produced water was 0.41 g/L, accounting for 1.35% of the total anion. The content of SO\(_4^{2-}\) produced water is less than 10000 mg/l, which reflects that there is little difference between the water and rock environment of the formation. In summary, the cations in the Sudong gas field are mainly Na\(^+\) and Ca\(^{2+}\) ions, and the Mg\(^{2+}\) ions are relatively small; the anions are mainly Cl\(^-\). It can be seen from the plane distribution map that the salinity, Na\(^+\), and Cl\(^-\) are higher in the southwest and lower in the northeast, and have better consistency with each other.

![Fig. 4 Distribution of ion planes in the produced water of the Sudong gas field](image-url)
4. Analysis of water chemical characteristic coefficient

Considering that the formation water desalination is serious and it is difficult to judge the mixing ratio, it is of little significance to analyze each ion concentration separately. However, the mixing of condensate does not affect the ratio of the equivalent concentration between the formation water ions, so it can be analyzed from the characteristic coefficients. According to Boyarsky's research, when the sodium chloride coefficient ($\frac{\text{Na}^+}{\text{Cl}^-}$) is greater than 0.75, the formation water is mixed with fresh water, and the sodium chloride coefficient of the oilfield water under storage conditions should be less than 0.75. The $\frac{\text{Na}^+}{\text{Cl}^-}$ values of groundwater in the work area are concentrated between 0.2 and 0.5, indicating that the formation sealing is better and the formation water is in a sealed state. By plotting the sodium chloride coefficient and the salinity (Figure 5), it can be found that the sodium chloride coefficient is negatively correlated with the salinity. Therefore, the water storage conditions in the southern part of the Sudong block are higher than in the north.

Under normal circumstances, the slower the runoff of the formation water, or the longer the action time of the water rock, the more thorough the ion exchange will be, the less Na$^+$, Mg$^{2+}$ ions may be, and the more the Ca$^{2+}$ ions are, the deeper the water metamorphism will be, the more favorable it is for oil and gas preservation. The groundwater associated with oil and gas ($\frac{\text{Cl}^-\text{-Na}^+}{\text{Mg}^{2+}}$) is generally greater than 1, $\frac{\text{Cl}^-}{\text{Ca}^{2+}}$ is less than 26.8, $\frac{\text{Cl}^-}{\text{Mg}^{2+}}$ is greater than 5.13; the ratio of $\frac{\text{Cl}^-\text{-Na}^+}{\text{Mg}^{2+}}$ in the eastern region is mainly 1.3-58.7. As the degree of mineralization increases ($\frac{\text{Cl}^-\text{-Na}^+}{\text{Mg}^{2+}}$ and $\frac{\text{Cl}^-}{\text{Mg}^{2+}}$ coefficients decrease (as shown in Figure 6). It indicates that the water-rock action time in the southern region is stronger than that in the north. From the perspective of oil and gas preservation, the south is better than the north.
5. Conclusion
1) The water produced in the south and the north is the formation water, and the middle part is the condensate water; for the same gas well, the fracturing fluid is discharged initially, and the formation water is gradually produced in the later stage;
2) The degree of mineralization is higher in the southwest and lower in the northeast, indicating that the water storage conditions in the southern stratum are higher than in the north, and the southern part of the water and rock is stronger than in the north. From the perspective of oil and gas preservation, the south is better than the north.

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