Study on Distribution Law of Formation Water in S209 Well Area

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Abstract: The Shaan 209 area of the 2nd section of Yulin gas field is a water-rich area. The water production of most wells is too large, which seriously affects the production of gas wells in the well area. Based on the research foundation work area formation water chemistry characteristics and distribution of the testing, laboratory analysis based on existing formation water, combined with geochemical classification, analysis of the formation water type, cause, distribution of well Shaan 209 in Yulin south area, the main control factors of the formation water in the working area are identified. Therefore, it is demonstrated that the Shan 2 section of water-rich area still has development potential, which provides a basis for the optimization of management strategies in the rich water area, and lays a foundation for the scientific and efficient development of the Yulin South area.

Keywords: Yulin gas field; Formation water; Gas and water distribution; Chemical characteristics.

1. Introduction
The upper Paleozoic of the Yulin gas field is dominated by the marine-continental transitional facies-inland lake basin deposits. From the bottom to the top, the Carboniferous Benxi Formation, Taiyuan Formation, Permian Shanxi Formation, Xiashihezi Formation, Shangshihe Formation and Shiqianfeng Formation were developed. The Shan 2 Member of the South Area of Yulin is a braided river delta sedimentary system consisting of two parts: the braided river delta plain and the braided river delta front subfacies[1,2]. Up to now, the proven gas area of Shan 2 in the self-supporting area of Yulin Gas Field is 773.59km², the proven reserves are 719.21×10⁸ m³, the proven gas area of Mawu 1+2 is 318.60km², and the proved reserves are 138.18×10⁸ m³. The total utilization of geological reserves in the southern area of Yulin Gas Field was 857.39×10⁸ m³, and the production capacity of 20×10⁸ m³ was completed. Since the completion of the 2 billion-yuan/year capacity scale in 2005, Yulin South District has achieved 7-year natural production without any new capacity[3-5].

In order to prevent the advancement of the water body in the mountainous water-rich area, no perforation and reservoir reconstruction were carried out on the reservoir of the Shan 2 Member of the Shaan 209 well area in the southern part of Yulin, resulting in insufficient use of geological reserves,
and with the reduction of the enrichment area, This kind of low-grade reservoir is the trend of gas field to make up for the decline of production. However, gas reservoirs in rich waters have problems such as large investment, low output, and difficult management[6-8]. It has always been a difficult point in the development of gas fields at home and abroad. Whether the reservoir development of the Shan 2 Member of the Shaan 209 Well Area in the southern part of Yulin has value, and whether the water-saving development idea of “separation mining, water control and gas production” is still applicable, and how to optimize the management of gas wells in the rich waters needs to be re-evaluated.

2. Chemical characteristics and distribution of formation water
The statistics of water samples in the Shaan 209 well area in the south of Yulin gas field indicate that the mineralization degree of the edge (bottom) water sample in the research area is between 390 and 252,740 mg/L. According to the classification of 1000, 10000, and 100000, draw the plane distribution map of the total salinity of the Shaan 209 well area, as shown in Fig. 1[9]. It can be seen from the figure that the distribution of the total salinity of the study area is characterized by a low north and a high south. Combined with the plane distribution map of chloride ion in the Shaan 209 well area in Fig. 2, it can be concluded that the produced water in the northeast part of the gas reservoir is condensed water, the middle part is mixed water, and the lower part is partially sealed formation water.

![Figure 1. Plane distribution map of total salinity in Shaan 209 well area](image1)
![Figure 2. Plane distribution map of Cl⁻ in Shaan 209 well area](image2)

It can be seen from the water pattern distribution map of the Shaan 209 well area (as shown in Fig. 3) that the formation water in the pores of the reservoir section of the Shaan 209 well area in the southern part of Yulin is mainly calcium chloride type water, indicating that the formation water is at Restore the environment and reflect the characteristics of deep stagnation[10].

From the pH plane distribution map (as shown in Fig. 4), the pH value of the formation water in the Shaan 209 well area in the south of the Yulin area is mostly between 5.3 and 7.2, indicating weak acidity-neutrality. Generally speaking, the high salinity metamorphic water in the closed pressure environment for a long time in deep basin does not have acidic water, and it is mainly alkaline water or weakly acidic water. Even the water whose surface is dissolved and balanced, its PH value Also shows alkaline water characteristics between 7.0-8.68[11]. 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. Formation water chemical characteristic parameters

For the reservoirs in the Shaan 209 well area, the formation sealing is better, and the Na\(^+/\)Cl\(^-\) values of the edge (bottom) water are concentrated between 0.1-0.35 (Fig. 5), which is consistent with the Boyarsky theory. The Na\(^+/\)Cl\(^-\) value of condensate water is unstable, mainly distributed between 0-1.5, indicating that it is greatly affected by other types of water. Residual fracturing fluid and gas layer residual formation water (including dense layer residual water) have a Na\(^+/\)Cl\(^-\) value distribution between 0 and 0.6. The residual layer water, condensate water and residual fracturing fluid in the gas layer have no special distinction between Na\(^+/\)Cl\(^-\) values, but overall, the Na\(^+/\)Cl\(^-\) values of the three types of water are higher than the edge (bottom) water.

Fig. 6 shows the plane distribution of the ratio of the bottom water (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) in the Shaan 209 well area. The edge (bottom) water of the Shaan 209 well area, the ratio of (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) is 31.14-98.67, and the ratio of (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) of condensate water is between -107.77-83.12. The ratio of (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) in the residual formation water of the gas layer is between 3.72 and 78.11, and the ratio of (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) of the residual fracturing fluid is between 5.50 and 80.22. In general, the ratio of edge (bottom) water (Cl\(^-\)-Na\(^+\))/Mg\(^{2+}\) is larger, and there is a tendency for the residual water from the edge (bottom) water to the gas layer to gradually decrease in the condensate.
combined with the plane distribution map of the water-sodium chloride coefficient and the metamorphic coefficient of the formation, the formation water in the entire Shaan 209 well area is mainly distributed in the southwest.

**Figure 7.** Characteristics of Stiff water type from south to north in Shaan 209 well area

**Figure 8.** Characteristics of Stiff water type from west to east in Shaan 209 well area

4. Distribution law of formation water

According to the existing formation water analysis and analysis, combined with geochemical classification, the formation water type, genesis and distribution law of Shaan 209 well area in Yulin South District were analyzed, and the main controlling factors of formation water in the construction area were clarified. Based on the results of logging interpretation, three main joint well profiles are plotted, reflecting the main distribution of gas-bearing water in the Shaan 209 well area, as shown in Fig. 9.

**Figure 9.** Yu153–Yu42-3A Joint well profile

It can be seen from the profile of gas-water distribution that the water produced in the Shaan 209 well area is mainly distributed near wells such as Yu50-3, Yu49-3B, Yu48-4 and Yu52-5. From the plane distribution map (Fig. 10), it can be reflected that the water production in the Shaan 209 well area is mainly distributed in the southwest.
Figure 10. Distribution plan of production wells in Shaan 209 well area

Water distribution characteristics of Shan 2-1 and Shan 2-2 small layers of main gas production. Fig. 11 shows the horizontal water level distribution of the small 2-1 mountain layer in the Shaan 209 well area. The water-rich area in the small layer of the Shan 2-1 covers an area of 78.2 km². The average effective thickness was 5.7 m, the average porosity was 5.5%, and the average water saturation was 51%. Take 20% of irreducible water saturation; The water size of Shan 2-1 small layer is 760×10⁴ m³; Considering the comprehensive compressibility is 0.001; The size of movable water is 19.0×10⁴ m³.

The area of the Shan 2-2 small layer water-rich area is 84.1 km²; the average effective thickness is 5.4 m, the average porosity is 5.7%, the average water saturation is 52.2%; the irreducible water saturation is 20%; the mountain 23-2 small layer water is 833.5×10⁴ m³; considering the comprehensive compression coefficient is 0.001; the movable water size is 20.8×10⁴ m³.

Figure 11. Water plane distribution map of Shan 2-1 small layer in Shaan 209 well area

Figure 12. Water plane distribution map of Shan 2-2 small layer in Shaan 209 well area

5. Conclusion
The distribution of total salinity in the Shaan 209 well area shows the characteristics of low north and high south. Combined with the analysis of the plane characteristics of chloride ion, the produced water in the northeast part of the gas reservoir is condensed water, the middle part is mixed water, and the lower part is partially sealed formation water. The cations in the formation water are mainly Na⁺ and Ca²⁺, and the Mg²⁺ is relatively small, the anion is mainly Cl⁻, the formation water is mainly calcium.
chloride type water, and the formation water is in a reducing environment, which reflects the characteristics of deep stagnation. The water produced in the Shaan 209 well area is mainly distributed near the well areas such as Yu50-3, Yu49-3B, Yu48-4 and Yu52-5, and the location is mainly distributed in the southwest. Combining the reservoir physical properties of each well area, the calculation of the movable water body of Shan 23-1 and Shan 23-2 is carried out. The size of the small water body of Shan 23-1 is $760 \times 10^4$ m$^3$, and the movable water size is $19.0 \times 10^4$ m$^3$. The size of the small water body of Shan 23-2 is $833.5 \times 10^4$ m$^3$, the movable water size is $20.8 \times 10^4$ m$^3$; The water body of the Shan 2 layer which is the main producing layer of the Shaan 209 well area is $1593.5 \times 10^4$ m$^3$, while the movable water body is only $39.8 \times 10^4$ m$^3$, and the movable water body is small.

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