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STUDY ON FACTORS OF CO_2 GAS CHANNELING

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Abstract: CO_2 flooding has certain development prospects in improving recovery efficiency of low permeability reservoir, but there are some problems such as gas channeling, poor gas injection development effect, and low understanding of influencing factors of gas channeling. As an injection well in the study area W20, gas discovery occurs in nearby Wells, resulting in increased pressure and decreased oil production. The factors of CO_2 gas channeling are analyzed from the aspects of sand body distribution, microfacies type, reservoir heterogeneity and fracture development scale. The law is verified according to the actual work area. The research shows that the distribution of sand body is the main gas channeling channel, and different microfacies types have different gas channeling capabilities. The vertical heterogeneity of the reservoir controls the gas channeling capability inside the sand body, and the development of fractures controls the gas distribution. The research results provide a theoretical basis for the selection of gas injection Wells and the improvement of gas injection development results.
Keywords: CO_2 displacement; Numerical simulation; Tight reservoir; Volumetric fracturing

1 INTRODUCTION

CO_2 gas has the characteristics of low viscosity and easy compression, and its injection capacity is higher than that of water injection, so it is easy to establish an effective displacement system. When the reservoir pressure is higher than the miscible pressure, CO_2 gas can form miscible with crude oil and improve the recovery rate [1-2]. Therefore, CO_2 flooding technology is an important means to develop ultra-low permeability reservoirs [3-4]. Due to the influence of reservoir heterogeneity, fluid characteristics, injection and production development parameters and other factors, gas channeling is easy to occur in the process of CO_2 flooding, which seriously affects the gas injection development effect [5]. At present, the existing research results of gas channeling are few, mainly based on the actual production data of the mine, although the judgment results are more accurate, but correct
The low degree of understanding of the influencing factors of gas channeling can not achieve the purpose of real-time early warning and prevention, which reduces the effect of oil displacement and increases the cost. The numerical simulation of different gas channeling factors was carried out in this study. Through the numerical simulation results, the main factors affecting CO_2 gas migration and gas channeling were further identified.

2 INFLUENCING FACTORS OF CO_2 GAS CHANNELING

2.1 Sand Body Distribution

Sand body, as the main oil supply channel, is closely related to the distribution of oil and gas. At the same time, sand body serves as the main migration channel of gas drive in the process of CO_2 gas injection due to the larger porosity and permeability characteristics compared with mudstone. In view of the distribution of sand body, selecting the location of CO_2 drive injection well can effectively improve oil recovery on the one hand. On the other hand, it can also effectively avoid gas channeling and affect injection and production.
A mechanism model for sand body distribution is established (**Figure 1)**, and it is found that mudstone, as an effective sand body shield, also has a strong shielding effect on the diffusion range of carbon dioxide gas during the process of carbon dioxide injection. Due to the connectivity of sand bodies, carbon dioxide gas exists in the top sand body, but its distribution pattern is affected by mudstone shield, and the middle right sand body is affected by mudstone shield. No gas display exists. Therefore, the connectivity of sand bodies provides the main migration channel for gas diffusion (**Figure 2)**.

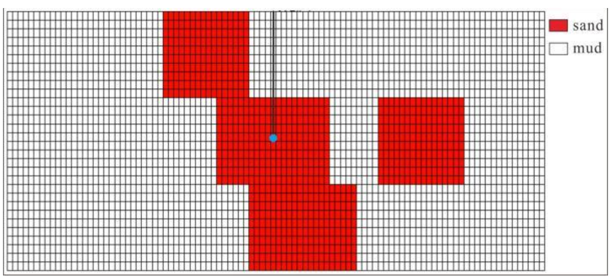

Figure 1 Profile of Sand Body Distribution

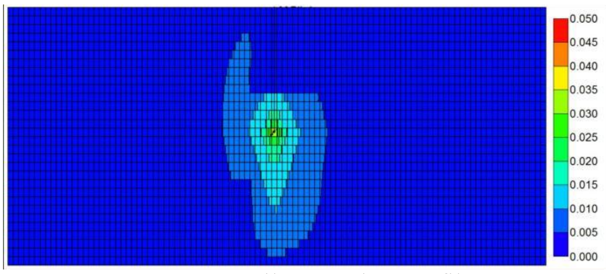

Figure 2 Oil Saturation Profile

2.2 Types of Sedimentary Microfacies

Sedimentary microfacies control the geometry and distribution of the reservoir sand body on the macro level, and determine the precursor of the reservoir physical properties on the micro level. Different sedimentary microfacies types also have different levels of physical properties and pore structures. When carbon dioxide flooding is carried out, the diffusion capacity of carbon dioxide in the reservoir is also different due to the difference of pore structure types of different microfacies.

The mechanism model of CO_2 diffusion area under different microfacies types was established. In the study area, the porosity distribution of channel sand body was 0.062~0.241%, with a median value of 0.077%; the permeability distribution was 0.09~2.45mD, with a median value of 0.11mD; and the porosity distribution of overflowed bank sand body was 0.044%~0.071%, with a median value of 0.053%. The permeability distribution ranged from 0.051 to 0.1047mD with a median of 0.073mD.

According to the pore permeability characteristics of different microphase types, it is found that the diffusion range of carbon dioxide in the channel sand body is larger than that in the overflow bank sand body at the same injection amount. According to different sedimentary microfacies types, the better the reservoir physical properties, the faster the gas diffusion rate and the shorter the breakthrough time (**Figure 3)**.

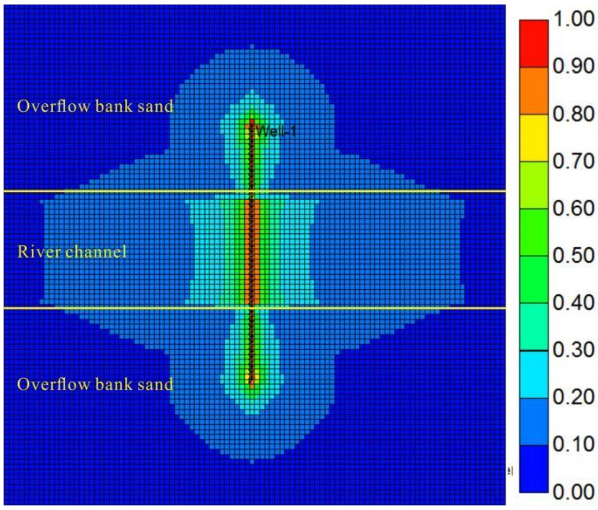

Figure 3 Oil Saturation Distribution of Different Microphase Types

2.3 Heterogeneity

In heterogeneous reservoirs, the injected CO_2 preferentially enters the high permeability zone. As a result, when the oil in the low permeability zone is not completely swept, the CO_2 has burst from the high permeability zone into the production well, resulting in viscous pointing, which reduces the oil displacement efficiency. Therefore, the less heterogeneous the reservoir rock, the better,

In the study area, the sand body has vertical heterogeneity, the channel sand body is mostly in a positive rhythmic form, and the physical property of the bottom sand body is better than that of the top sand body. During carbon dioxide injection, the gas affected by the structure is the first to preferentially replace the upper part. However, the permeability of the bottom sand body is higher, and carbon dioxide gas has been widely diffused from the bottom high permeability part before the top low permeability reservoir is completely displaced.

The mechanism models were established by injecting the upper middle part of the sand body in different ways, and the analysis showed that: When the horizontal well is drilled into the upper part of the sand body, the gas drive location of the carbon dioxide sand body is relatively average; when the sand body is drilled into the middle part of the sand body, the distribution is trapezoidal, and the production degree of the top sand body is weaker than that of the bottom sand body; when the horizontal well is drilled into the bottom sand body, the production degree of the top low permeability reservoir is very low. Therefore, when the sand body is drilled into the top sand body during gas drive, it has a good displacement effect(**Figure 4)**.

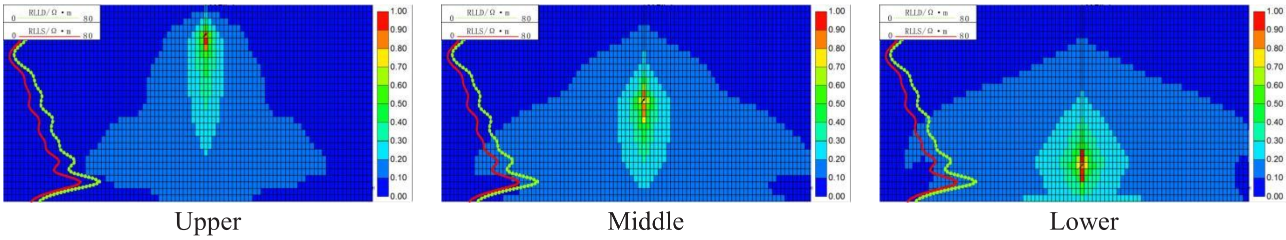

Figure 4 Profile of Gas Saturation Distribution at Different Locations of Horizontal Well Drilling

2.4 Scale of Artificial Fracture Development

Whether it is artificial fracture or natural fracture, its large pores and strong seepage capacity, for medium and low permeability oil fields, most of the water injection development, the water injected into the reservoir through the fracture to both sides of the drive, the fracture of the water injection interval can improve the water flooding effect, but also bring some difficulties to the stable exploitation of the oil field, resulting in early flooding water channeling, affecting the oil field recovery. For gas injection production in tight reservoirs, gas has a stronger diffusion ability than water, and gas has a stronger gas channeling ability along fractures. The mechanism model of horizontal well fracturing and non-fracturing is established to study the gas distribution law after gas injection.

Through comparison, it is found that cracks have a strong seepage capacity, and gas enters into cracks quickly after injection and spreads along the direction of cracks. The overall distribution is zigzag along the direction of cracks, and vertically affected by cracks, the distribution is uniform. The gas is mainly distributed along the cracks (Figure 5, 6).

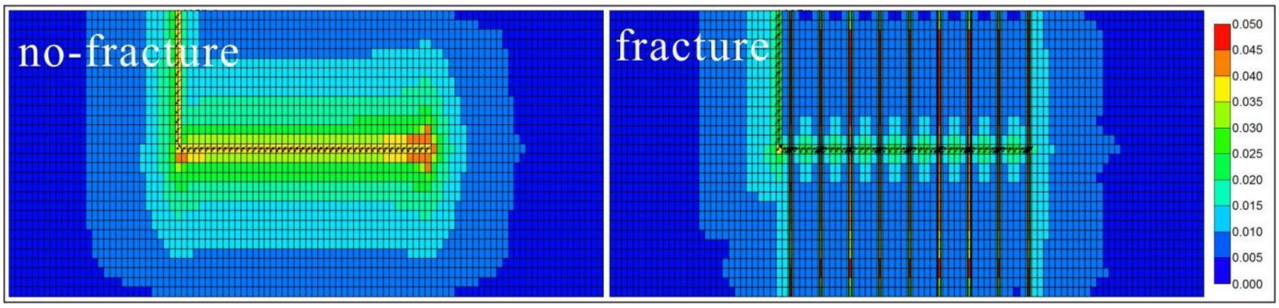

Figure 5 Horizontal Well Fracturing Oil Saturation Distribution Plan

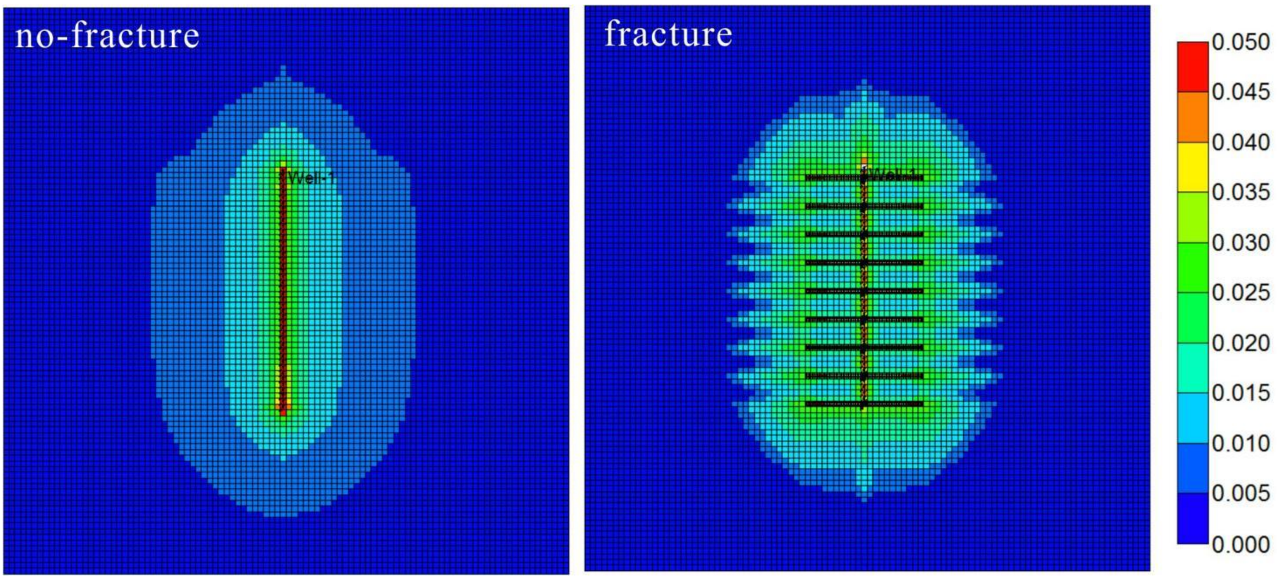

Figure 6 Horizontal Well Fracturing Oil Saturation Distribution Profile

3 INFLUENCING FACTORS OF CO_2 GAS CHANNELING

The study area is located in the Fuyu oil reservoir in the southern Songliao Basin, which is dominated by low-ultra-low permeability delta plain-delta front sandstone. The Fuyu oil reservoir in the southern Songliao Basin is a tight reservoir with a burial depth greater than 1750m, porosity less than 12% and permeability less than 1.0×10-3 μm2.

At present, carbon dioxide flooding is being carried out in the horizontal well area to improve production. In the carbon dioxide injection in well w20, it is found that w1-5, w14 and wpf2 all have gas discovery phenomena. A numerical simulation model is established to analyze the gas channeling phenomenon in the study area. Grid step size 40m*40m, carbon dioxide gas injection amount based on the actual, the average daily injection amount is 180m3.

As shown in Figure 7, combined with the sedimentary microfacies distribution diagram and gas saturation distribution diagram of the study area, well w20, as a carbon dioxide injection well, was drilled into four small layers. After gas injection, the gas diffusion range was mainly affected by the location of sand body, and the distribution of mudstone effectively controlled the gas diffusion direction.

As shown in Figure 8, the time variation curves of gas saturation in different Wells are analyzed. After artificial fracturing, the fractures of WFP2 vertical well are connected with the second cluster of fractures of w20 well, and gas development preferentially occurs after CO_2 injection. Affected by the occlusion between the shunt of the three small layers, the gas diffusion site decreases, and the gas of W1-5 Wells comes from the four small layers, and that of W14 Wells comes from the two small layers. Therefore, well W1-5 is preferred to well W14 for gas development.

As shown in Figure 9, combined with the time curve of gas saturation of each small layer, the analysis shows that due to the influence of the shunt between the three small layers of well w20, the gas diffusion ability is weakened, and the gas saturation of the three small layers is lower than that of the five small layers. When carbon dioxide flooding is carried out, it is necessary to take into account the vertical sand body overlaying relationship, and effective mudstone blocking horizon can effectively control the carbon dioxide displacement range and improve the oil displacement efficiency of the target horizon.

Horizontal Wells in the study area have been substantially fractured, and fractures not only improve the mining efficiency, but also act as the main gas dispersion channel in gas drive. Compared with the diffusion velocity between fractures and non-fractures in the study area, the gas migration velocity in the fracture range is four times that in the non -fracture range. Therefore, in the process of gas displacement, in order to reduce the impact of gas channeling, the gas migration velocity is four times that in the non-fracture range. In addition to the fractures formed by artificial fracturing, the natural fracture development zone should be moderately avoided.

Layer 1. Channel sand body and overflow bank sand body are developed in small beds. Due to the different physical properties of the sedimentary microfacies of the two, gas preferentially diffused along the channel sand body and then in the overflow bank sand body during gas injection, and the channel gas diffusion ability is better than that of overflow bank sand.

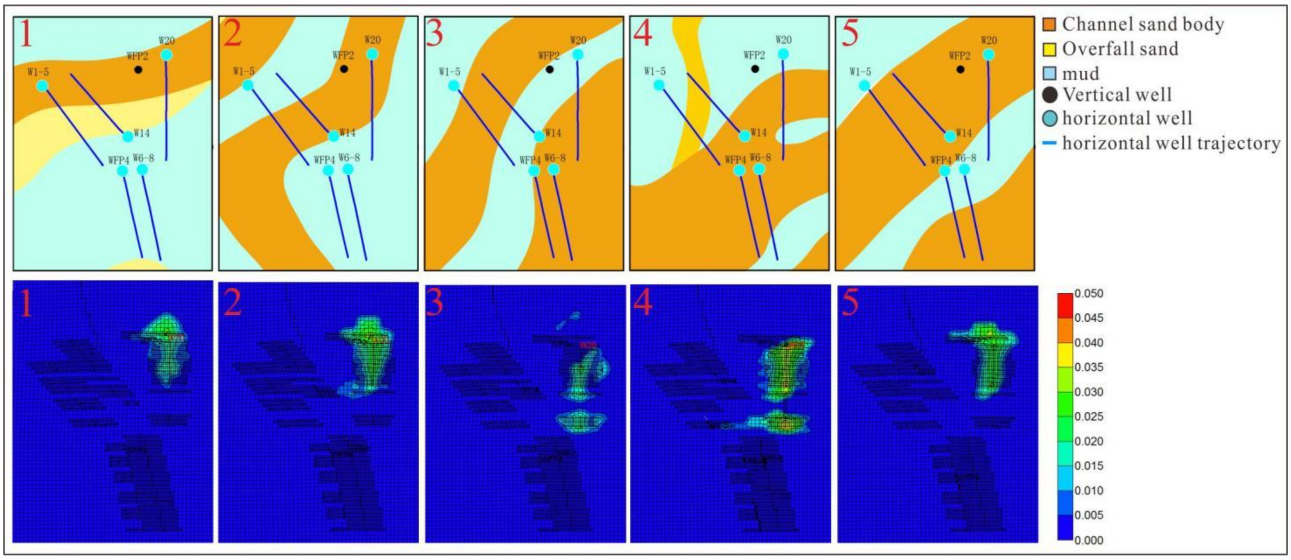

Figure 7 Horizontal Well Fracturing Oil Saturation Distribution Profile

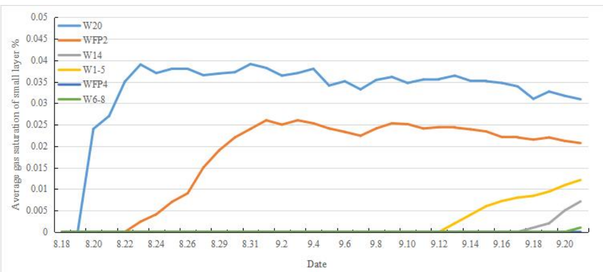

Figure 8 Oil Saturation Curves of Different Wells

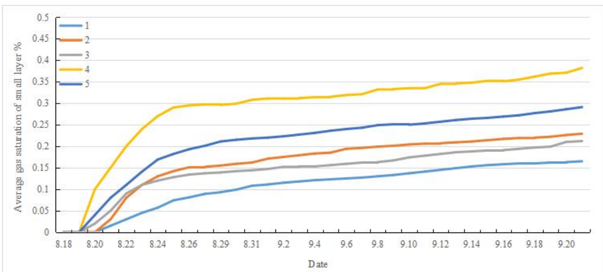

Figure 9 Oil Saturation Curves of Different Layers

4 CONCLUSION

1. Sand body distribution is the main migration channel after carbon dioxide injection. Determining the sand body distribution near the injection well can effectively control the diffusion range of carbon dioxide gas and avoid the abnormal increase of pressure in nearby Wells caused by gas diffusion, so as to effectively improve oil recovery.
2. Different microfacies types will lead to changes in the diffusion capacity of gases. When the differential distribution of sedimentary microfacies is effectively utilized, the diffusion range of gases can be further controlled to achieve the purpose of local effective displacement.

3. In the positive rhythm channel, when horizontal Wells meet the part or middle of the channel, the effect of carbon dioxide gas is better than that of drilling the bottom sand body due to vertical heterogeneity, which can effectively reduce the problem of remaining oil enrichment at the top of the sand body.
4. As a fast channel for gas migration, gas injection Wells should minimize communication with neighboring fractures during fracturing, resulting in reduced gas injection effect.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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