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Distribution of saturation in thin oil polymer surfactant flooding after polymer flooding

Aiming at the problem of large precision error of oil saturation monitoring in the current physical simulation process, a self-made oil saturation monitoring system was used to measure oil saturation distribution in the displacement process of Huading I polymer surfactant and Haibo BI polymer surfactant flooding after polymer flooding. And the system is based on the theory of rock electricity and improved method of conventional saturated oil steady-state method. Under the injection of the same PV number, it is obvious that Haibo polymer surfactant is easier to use the unswept area of polymer flooding in various layers. The result shows that Haibo BI polymer surfactant can greatly expand the sweep efficiency of each layer, and Huading I polymer surfactant has a strong oil displacement efficiency.

Key words: *Physical simulation, polymer surfactant flooding, oil saturation distribution, sweep efficiency, oil displacement efficiency.*

1. Introduction

At present, the study on remaining oil distribution [1-4] law is the precondition to further improve oil recovery in-site. The accuracy of the remaining oil description has decided the effect of subsequent development and adjustment, and the accuracy of the reservoir original oil saturation directly affects the effect of remaining oil description.

Scholars at home and abroad have done a lot of research work about dynamic measurement of oil and water saturation in reservoir physical simulation [5-7]. And the methods [8,9] they used to be also varied, including super CT scan, results reconstruction, sonic method, resistance method, microwave method, nuclear magnetic resonance method. There are different types of pores in the sedimentary rock, and the pores contain a certain amount of oil and water. In the resistance method, when the porosity of the rock is constant, the higher the water saturation, the lower the resistivity of the rock; conversely, if the oil saturation of the rock is larger, the resistivity is significantly increased. However, the range of oil saturation is narrow with conventional resistivity method, the area of low oil saturation and high oil saturation has no accurate data on the resistivity and oil saturation.

Based on the experimental theory of rock and electric [10], according to the actual situation of main reservoir in Daqing oilfield, the self-made oil saturation monitoring system was used to test the oil saturation of the polymer surfactant flooding process after polymer flooding. This article is intended to provide strong guidance to the site.

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2. Experiment

2.1. Experimental conditions

Experimental temperature: 45ºC;

Experimental core:

High-permeability two-dimensional core: Permeability of the core is 1800×10^{-3} μm^2, the size of the core is 300*300*15 mm;

Middle-permeability two-dimensional core: Permeability of the core is 1000×10^{-3} μm^2, the size of the core is 300*300*15 mm;

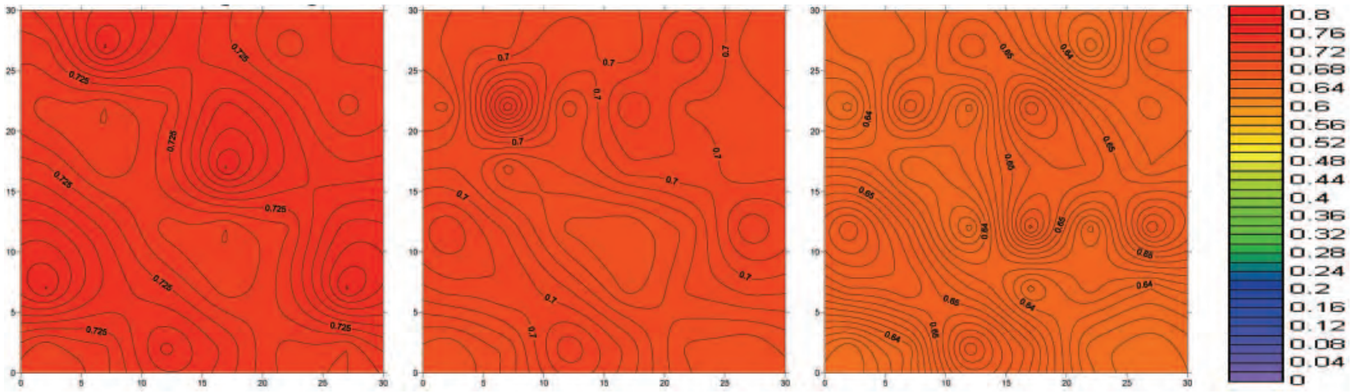
Low-permeability two-dimensional core: Permeability of the core is 200×10^{-3} μm^2, the size of the core is 300*300*15 mm;

Saturated water: The water which is used to saturated model is the simulation formation water of Daqing oilfield and the degree of mineralization is 6778 mg/L;

Flooding water: Recycled produced water;

Experimental oil: The oil used to experiment is simulation oil and the viscosity is 9.8 mPa·s in 45ºC;

Polymer for polymer flooding stage: Ordinary medium molecular weight polymer, and the concentration of the polymer is 1000 mg/L;



high permeability layer | middle permeability layer | low permeability layer

Fig.1 The distribution of original oil saturation each layer

Polymer surfactant flooding stage: Huading I polymer surfactant, Haibo BI polymer surfactant;

Injection speed: 3 mL/min.

2.2. Experimental equipment

Oil saturation monitoring system, constant temperature box, plunger pump, piston containers, agitator, beaker, test tube.

2.3. Experimental procedure

(1) The core is evacuated and then saturated with water and oil; (2) Electrode connection; (3) According to the experimental scheme for displacement monitoring experiments.

2.4. Experiment scheme

Scheme one: water flooding is conducted until the water content is above 98%, and then medium molecular weight polymer whose injection is 0.6 multiples of pore volume(PV) and injection concentration is 1000 mg/L is injected, and then water flooding is conducted until the water content is above 98% again, after that Haibo BI polymer surfactant whose injection is 0.15PV and injection concentration is 1500 mg/L is injected, and Haibo BI polymer surfactant whose injection is 0.9PV and injection concentration is 1000 mg/L is injected afterwards, and after that the water flooding is conducted until the water content is above 98% again.

Scheme two: water flooding is conducted until the water content is above 98%, and then medium molecular weight polymer whose injection is 0.6 multiples of pore volume(PV) and injection concentration is 1000 mg/L is injected, and then water flooding is conducted until the water content is above 98% again, after that Huading I polymer surfactant whose injection is 0.15PV and injection concentration is 1500 mg/L is injected, and Huading I polymer surfactant whose injection is 0.9PV and injection concentration is 1000 mg/L is injected afterwards, and after that the water flooding is conducted until the water content is above 98% again.

The viscosity of the displacer was measured before the experiment. The obtained viscosity data are shown in Table 1:

Table 1: The viscosity of the displacer

System	Medium molecular weight polymer (1000 mg/L)	Huading I polymer surfactant main slug (1000 mg/L)	Haibo BI polymer surfactant main slug (1000 mg/L)
Viscosity (mPa·s)	20	58	53

3. Experimental results and discussion

Distribution of oil saturation in each permeation layer of the core under different displacement schemes:

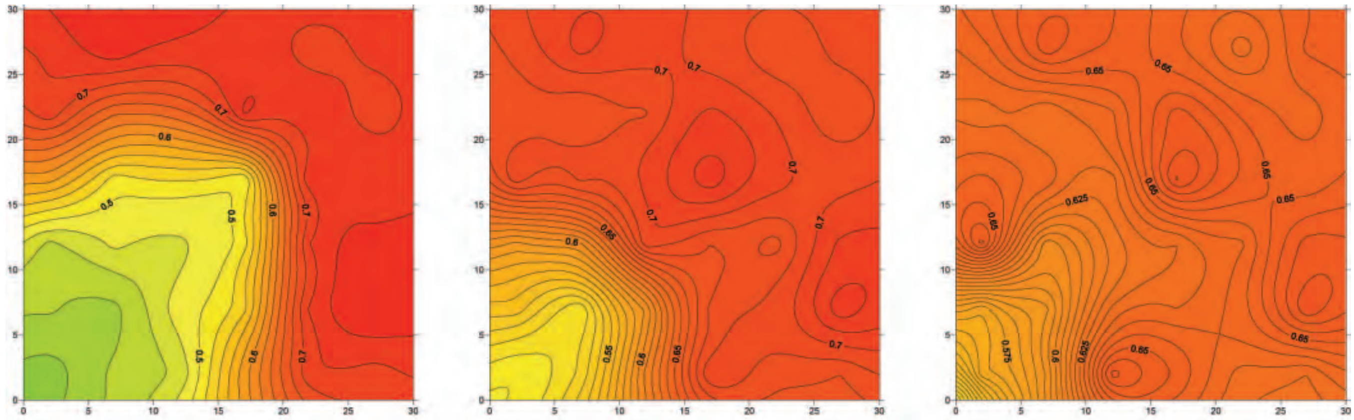
Based on the corresponding standard curve measured by the completed study, the self-developed oil saturation real-time monitoring system was used to monitor the flooding process. And then the distribution of oil saturation in different displacement stages is obtained.

1. The original oil saturation in the core

Fig. 1 shows the original oil saturation in the high, middle and low permeability layers of the core. It can be seen from the figure that distribution of oil saturation from the high permeability layer to the low permeability layer gradually becomes lighter, that is, the saturated oil content in the core decreases gradually. Because the greater the permeability, the higher the porosity of the core, the more saturated the amount of crude oil, so the higher the oil saturation. This part gives the original oil saturation at different positions of each layer, and it is convenient to compare to the subsequent displacement figures. All of rulers of the following oil saturation distribution figures are the same.

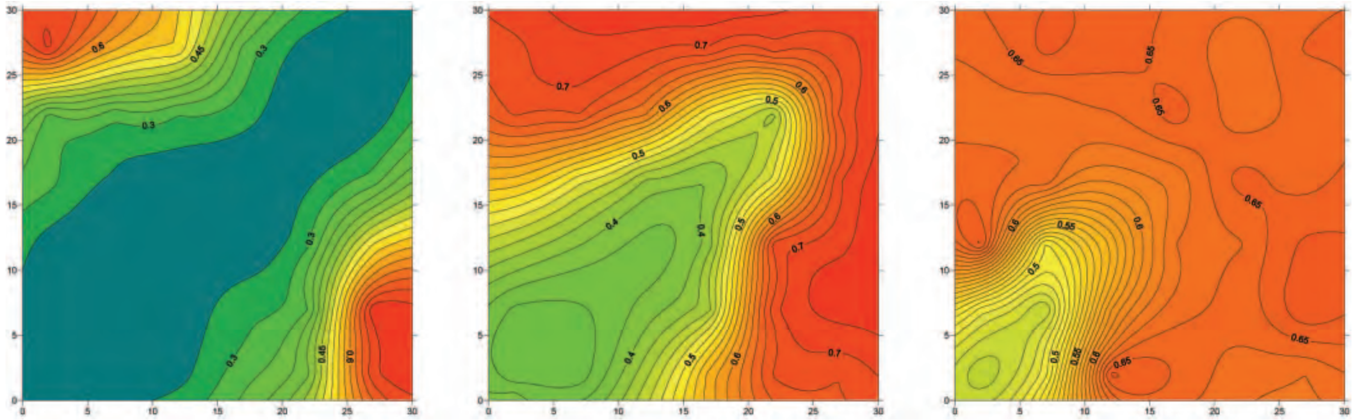
2. Water flooding stage

From Fig. 1 to Fig. 3, it can be seen that in the water flooding stage, the three layers are initially used, and most of the displacer enters the high permeability layer, and with the increase of the amount of the injected water, obvious fingering phenomenon appeared in each layer. When the water oil frontal of the high permeability makes a breakthrough, after the production wells can see the water, in



high permeability layer middle permeability layer low permeability layer

Fig.2 Distribution of oil saturation of each layer at initial water injection phase



high permeability layer middle permeability layer low permeability layer

Fig.3 Distribution of oil saturation of each layer at the end of water injection

the middle and low permeability layer, the amount of liquid output is gradually reduced, almost stopped the liquid, while the oil saturation in the mainstream channel of high permeability layer is relatively low under the action of repeated flushing.

3. Polymer flooding stage

It can be seen from continuous monitoring displacement pictures that the beginning of the injection of polymer, the polymer advanced to the high permeability layer. Because of the high polymer viscosity, it can effectively improve the mobility ratio, increase the flow resistance and the injection pressure, and more fluid flow into middle and low permeability layer to increase the sweep efficiency of the model and further improve the model's recovery efficiency.

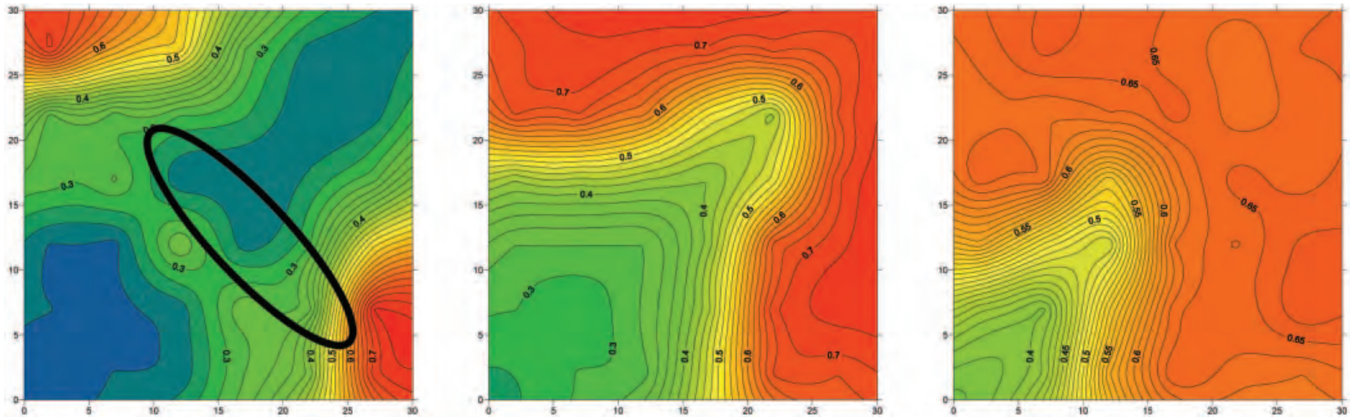
4. Haibo BI polymer surfactant flooding stage

Haibo polymer surfactant is used for the displacement after polymer flooding. With the increase of the injection amount, liquid flow is roughly the same as Huading I polymer surfactant flooding trend. Because the oil on both sides of the mainstream line is swept and replaced, and the oil on both sides flows to the mainstream channels, the oil bank is formed in the high and middle permeability layers.

5. Huading I polymer surfactant flooding stage

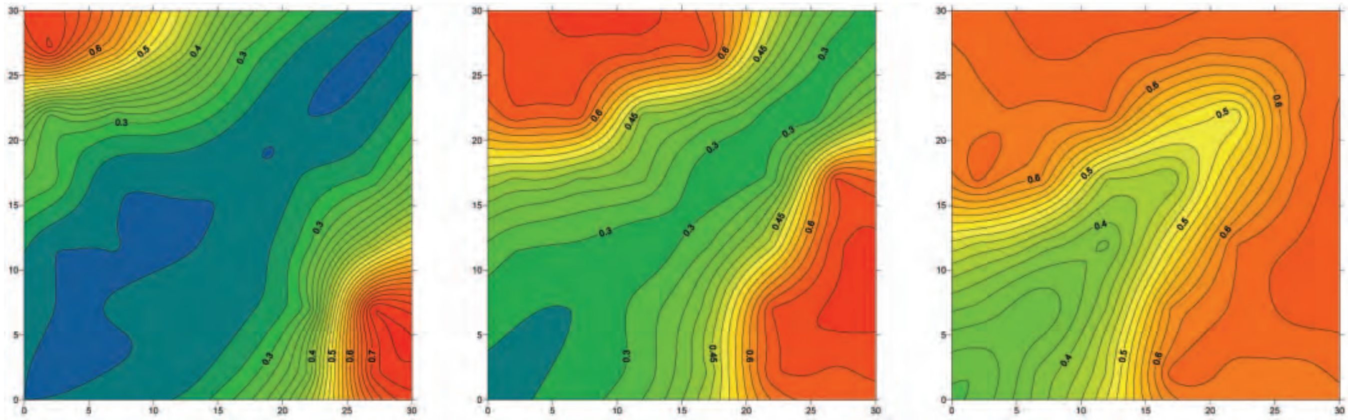
Huading I polymer surfactant is used for the displacement after polymer flooding. At the beginning, the polymer surfactant flows into the high permeability layer with lower resistance, because the deformation ability on the basis of the pore of Huading I polymer surfactant is strong, it is easy to access to pores that polymer flooding did not sweep, and promote the oil on both sides of the main line in core moves forward. With the movement of oil flow, the pressure on the mainstream line is relatively small, the oil on the wings of the mainstream line gradually moved closer to the mainstream line, the core will form an oil wall under the action of this displacement, as shown in Fig.10. The formation of the oil bank causes the oil column to block in the pore throat so as to increase the injection pressure, and polymer surfactant starts to enter the low permeable layer to increase the producing degree under the high injection pressure.

With the continuous injection of the Huading I polymer surfactant, the oil saturation of the mainstream line and the two sides of the middle and high permeability layer is



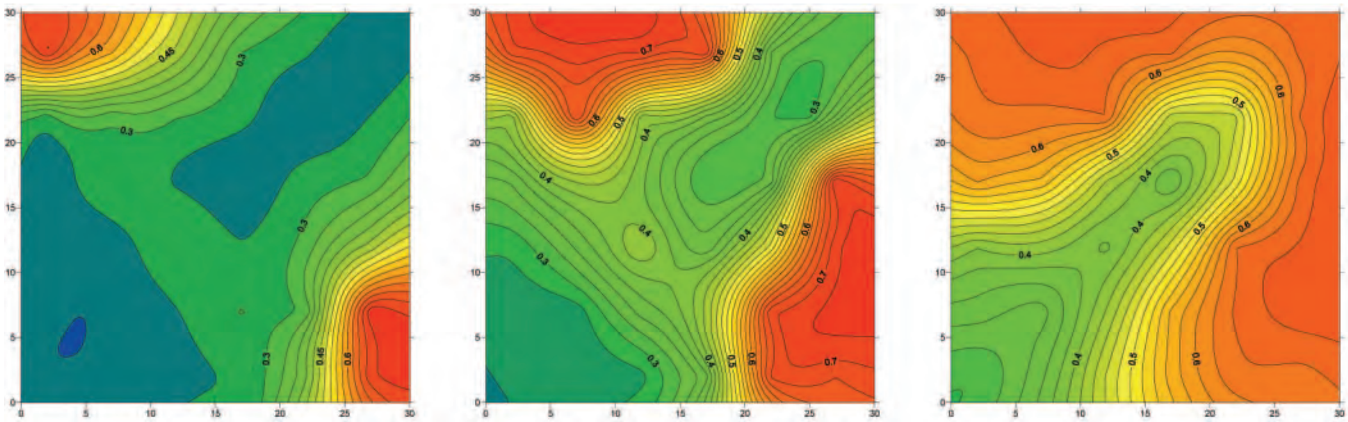
high permeability layer middle permeability layer low permeability layer

Fig.4 Distribution of oil saturation of each layer at initial polymer injection phase



high permeability layer middle permeability layer low permeability layer

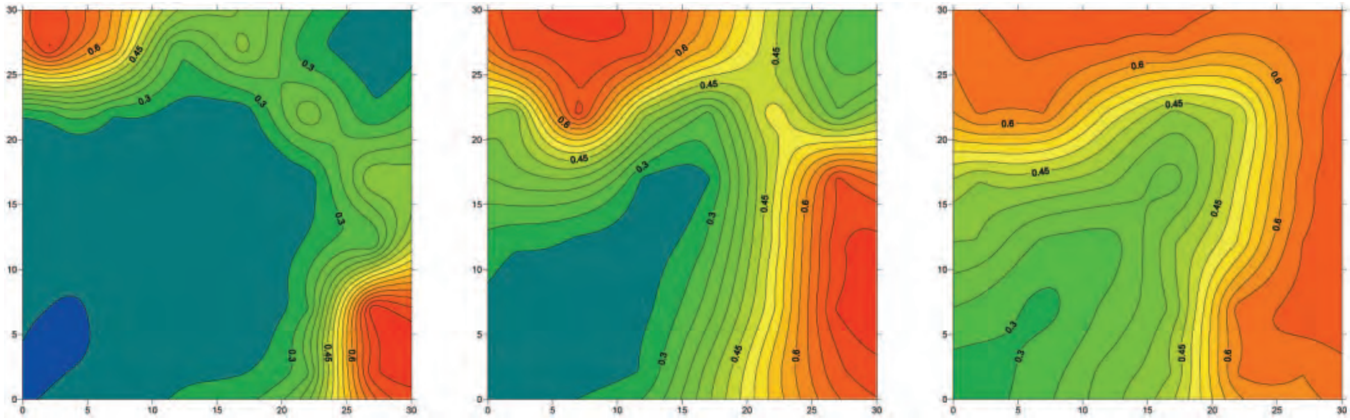
Fig.5 Distribution of oil saturation of each layer at the end of polymer injection



high permeability layer middle permeability layer low permeability layer

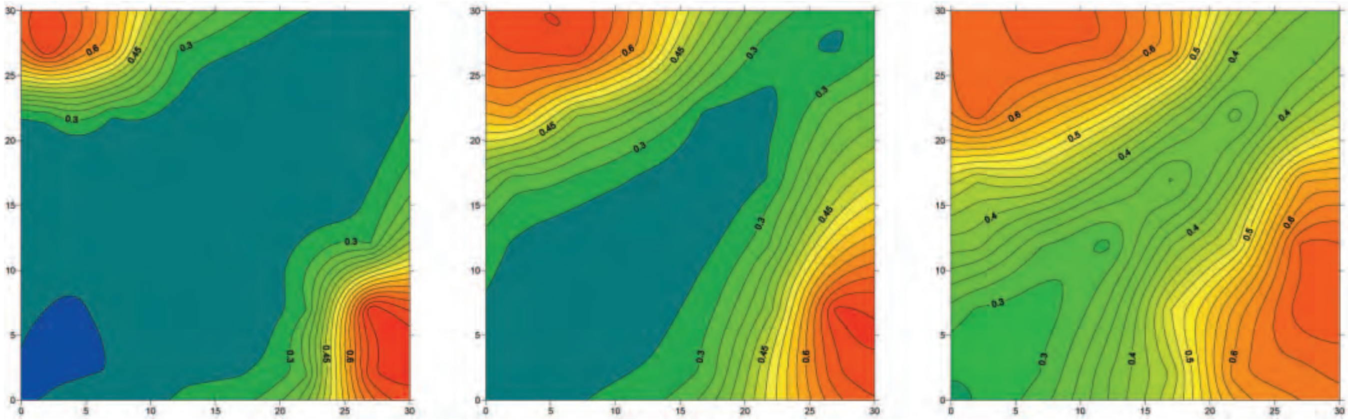
Fig.6 Distribution of oil saturation of each layer at the early stage of Haibo displacement

obviously reduced, and the oil bank is gradually pushed forward. At higher injection pressure, the flow rate of the low permeability layer increases gradually, and the mainstream line shows a continuous forward like finger-shaped, and at the same time, the swept area near two wings of the mainstream line of the injection well is gradually enlarged. Because of the high viscosity of the polymer surfactant, it can improve the mobility ratio in the rock sample, so that it can enter the small throat under the action of relatively low force, and then drag the oil film.



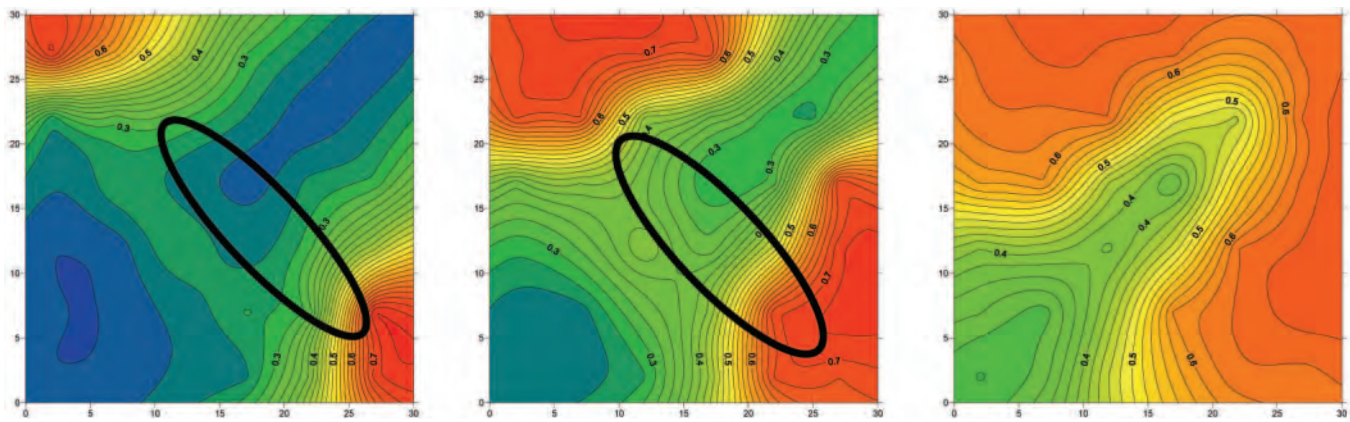
high permeability layer middle permeability layer low permeability layer

Fig.7 Distribution of oil saturation of each layer at the middle stage of Haibo displacement



high permeability layer middle permeability layer low permeability layer

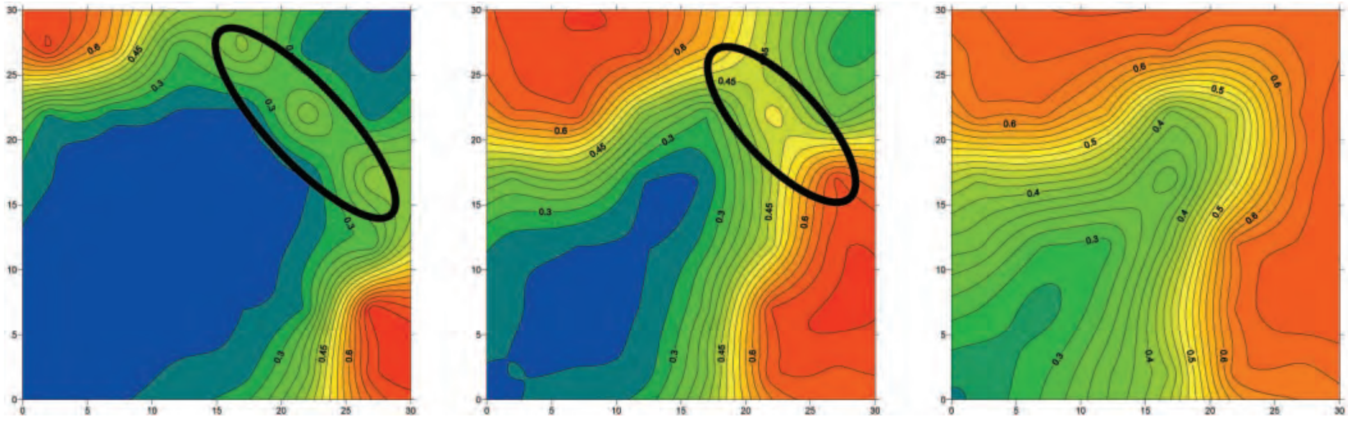
Fig.8 Distribution of oil saturation of each layer at the end of Haibo displacement



high permeability layer middle permeability layer low permeability layer

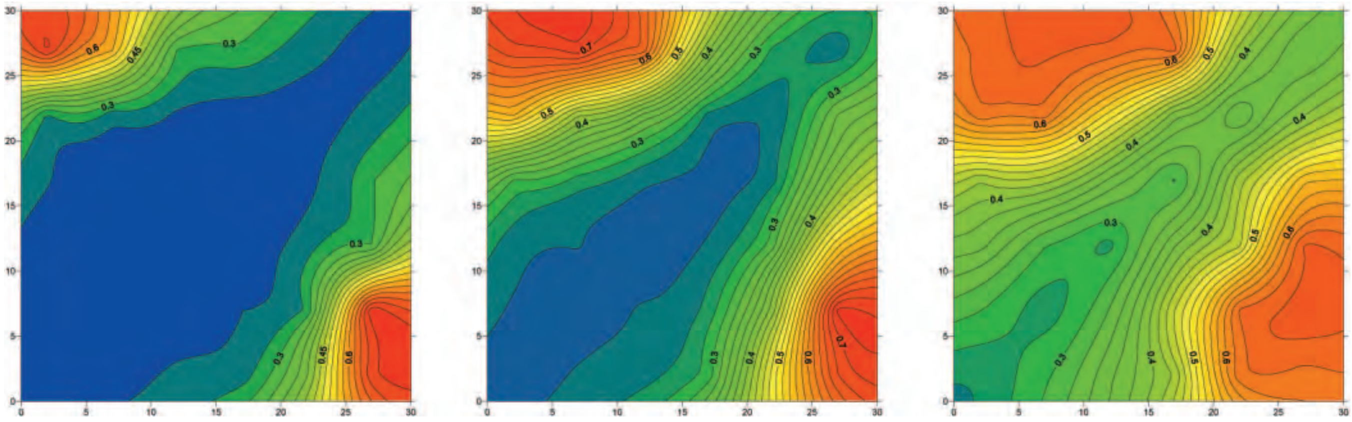
Fig.9 Distribution of oil saturation of each layer at the early stage of Huading I displacement

After the completion of the injection of Huading I polymer surfactant, the mainstream line of the low permeability layer is completely open, the oil bank of the high permeability layer has been broken, the sweep efficiency of the high permeability layer is increased to 0.912, and the oil saturation of the large area on mainstream line and both sides is reduced to less than 0.24, indicating that the displacement efficiency of Huading I polymer surfactant is very high, the use of its high viscoelastic can drag out oil which is not easy to use by polymer flooding. The low oil saturation range of the



high permeability layer middle permeability layer low permeability layer

Fig.10 Distribution of oil saturation of each layer at the middle stage of Huading I displacement



high permeability layer middle permeability layer low permeability layer

Fig.11 Distribution of oil saturation of each layer at the end of Huading I displacement

mainstream line in the middle permeability layer becomes wider. The swept area of the low permeability layer increases greatly and the mainstream line reaches a breakthrough.

4. Conclusions

Under the injection of the same PV number, it is obvious that Haibo polymer surfactant is easier to use the unswept area of polymer flooding in various layers; however, the remaining oil saturation in the core is slightly higher than the remaining oil saturation after the displacement of the Huading I in the same displacement time. Overall: Haibo polymer surfactant can more expand the sweep efficiency of each layer, and after Huading I polymer surfactant flooding, a very wide low oil saturation band is formed on the core mainstream channel, it shows that Huading I polymer surfactant has a strong oil displacement efficiency.

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