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Cause Analysis of Dominant Channel in Water Flooding Sandstone Reservoir

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Abstract: - The old oil field will enter the stage of high water cut, high recovery degree after a long-term water flooding development, the seepage resistance in strongly water washing part will become more and more small, and it can produce the consequences of ineffective circulation of the injected water along the edge passage, which will seriously affect the oil recovery and the development benefit. The formation of dominant channel is the inevitable trend and result of the water flooding oil field. By studying its formation, it can be divided into two aspects: the development characteristics of the reservoir itself and the influence of the production process. Its development features include: reservoir rock facies, physical characteristics, sedimentary rhythm, heterogeneity, thickness and the characteristics of the pore structure. The effects of production process include: hydrodynamic flushing action, fluid friction and the impact of the drilling process.

Keywords: - *Dominant channel; Big hole; Water injection development; Cause analysis*

I. INTRODUCTION

As the old oilfield has entered into the super high water cut stage, because of the difference of permeability anisotropy of reservoir, difference of oil/water viscosity and imbalance of water dynamic field in the development process, which causes the injected water along the edge of channel water channeling for a long time and makes the original aperture to further expand, and the injection water becomes serious " noneffective ", which lead to an early water breakthrough of the production well, and the moisture content becomes higher and higher, recovery degree becomes lower and lower, thus we put forward the concept of "channel" and the "big hole". By strengthening the analysis of the causes of dominant channel, we can further understand the reservoir heterogeneity after a long-term water flooding, at the same time, we can also make use of it to guide the sand control, which will promote the development of sealing technology and improve the recovery factor.

II. THE CONCEPT OF DOMINANT CHANNEL

Permeability of sandstone reservoir is high in most of the reservoirs, the more is given priority to argillaceous cementing way, and is often loose, the reservoir heterogeneity is serious, the oil-water viscosity ratio is big. So after a long period of high speed water injection advance, under the effect of soak scouring of the injection water, reservoir temperature and pressure changes, and the reservoir parameters change too. Because of the difference of permeability and the gravity differentiation of the oil-water, reservoir pore structure will have great changes, part of the reservoir permeability and pore throat radius will increase, thus resulting in the formation of high permeability zone and high permeability zone, so that a large number of injected water under the action of displacement pressure gradient will flow along the relatively high permeability channel, this path is the dominant channel [1].

III. THE CAUSE OF DOMINANT CHANNEL

The dominant channel is mainly manifested in two aspects: the development characteristics of the reservoir itself and the influence of the production process. The former is regarded as the internal cause, mainly

embodied in the reservoir heterogeneity, including lithology, permeability, pore structure, thickness, etc. There are mainly continental oil reservoirs in China, and its heterogeneity is serious, pore structure changes great, especially, the high permeability of sandstone reservoir in argillaceous cementing way is easier to form the dominant channel of the injected water under the condition of long time high pressure water injection[2]. The latter is taken as the external cause, mainly embodied in strong production process and strong mining or long time of water injection development. The strong mining advance mode is easy to cause the formation of macroscopic throats.

3.1 Geological conditions of the formation of dominant channels

Dominant channel is the relatively high permeability channel or crack. Its appearance is the consequence of the combined action of various factors. It is explained as the following: reservoir lithofacies characteristics, differential permeability and permeability, thickness and the characteristics of the pore structure.

(1) Petrographic characteristics of the dominant channel

The formation of large channel is mainly restricted by the particle size and the amount of the cement, the greater the particle size is, the easier it is to form a sizable hole. The higher the degree of consolidation, the higher start-up pressure and displacement velocity the rock particles require. Whereas for the stratum of weak cementation strength, the sandstone particles are easily to fall off from the ground surface with the scour of the injected water, which leads to the clay dissolve rapidly, and accelerate the shedding of sand particles, thus the scouring velocity that the sand particle migration needs decreases, and easy to form a big hole (Fig 1).

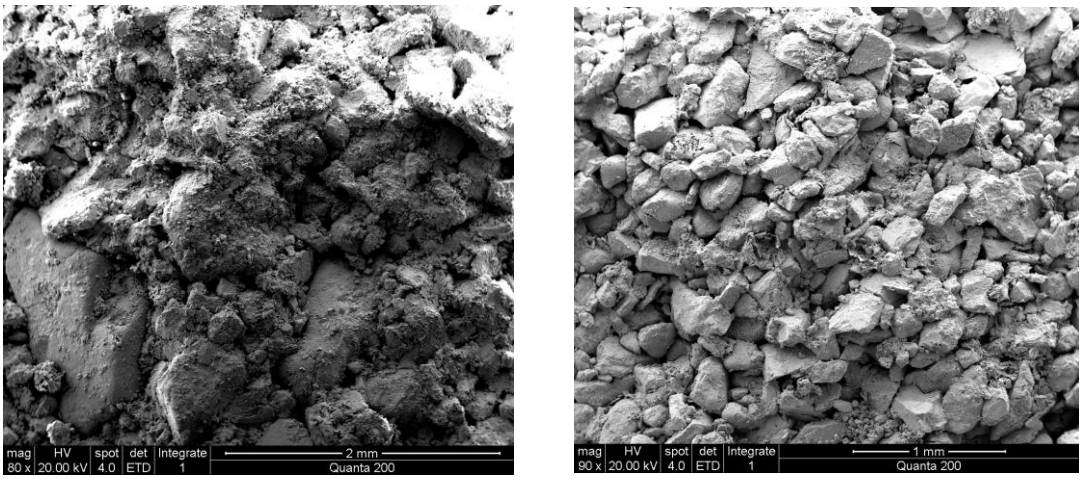

Fig 1 Contrast of scanning electron microscopy under different washing strength (left weak washing, right strong washing)

(2)The influence of sedimentary rhythm for macroscopic throats forming

In different sedimentary rhythm models, injection water mainly flows into high permeable formation, and because of the same pressure difference on both ends of the high and low permeable formation, the velocity of high permeable formation is greater than the low permeable zone, flushing action to the high permeable zone is strong as well, thus resulting in a single layer and one-way dash of the injected water, forming the big hole [3].

(3)The influence of physical properties of reservoir

Based on coring data statistics, in the present well pattern and injection-production pressure system, the

formation of the benefit channel is closely related to the physical properties of the reservoir, especially the permeability. Generally speaking, the better the reservoir physical property, the more development of the reservoir pore throat size, the smaller the filtration resistance, the higher the flow rate of the injected water, the greater the effect on reservoir space transformation(Fig 2).

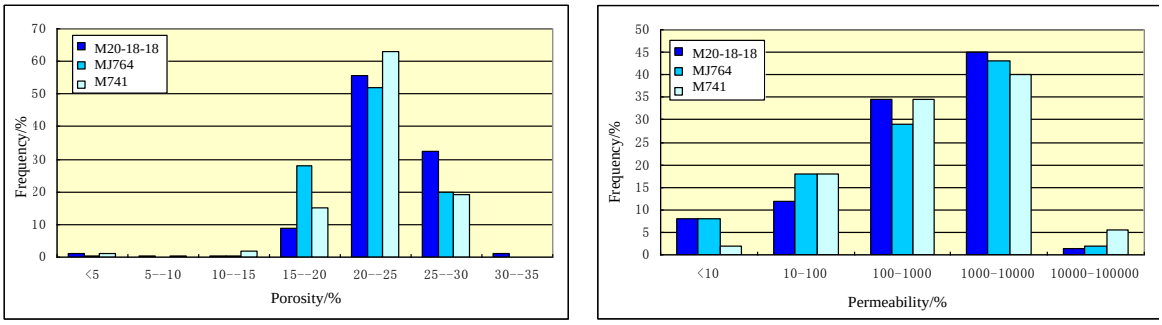

Fig 2 pore permeability distribution of three coring Wells of Ma 20 block in different periods

(4)Heterogeneity characteristics

Benefit channel is the extreme manifestation of inner contradictions, thus controlled by the intraformational heterogeneity. Due to the reservoir heterogeneity, injection water priority flows along the high permeability layer in the process of the water injection development, with the increase of injection volume ratio, the water saturation of high permeable increase faster than the low permeability layer. When water saturation increases, the average viscosity of mixture decreases, water permeability greatly increases at the same time, making the flow resistance of high permeable zone decline far more quickly than the low permeable formation, causing bigger resistance differences between the high permeable zone and low permeability layer, bringing about further increase of water quantity in high permeability layer and further decrease of water quantity in low permeable formation(Fig3,Fig4). When the injection volume ratio reaches a certain value, the high permeability layer will form a kind of "set" flow, then the injected water will flow along the high permeability layer and thus form the dominant channel [4].

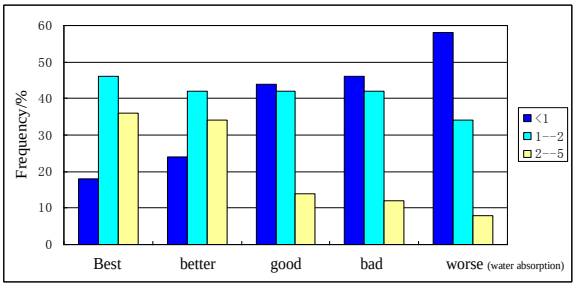

Fig 3 The distribution of breakthrough coefficient of sand body of different water condition

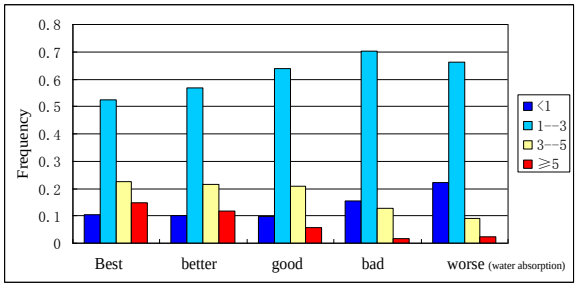

Fig 4 The distribution of thickness of sand body of different water condition

(5) Control function of thickness on the formation of dominant channel

After the statistics of thickness distribution of the sand layer of different degree of water absorption, we found that the higher the degree of water absorption, the higher the proportion of thick sand layer(Fig 5). It is mainly due to the thickness of sand layer, the greater the thickness ,the greater the injected water is influenced by gravity, the better the water absorption, especially for the channel sand of positive rhythm, water flows along

the bottom of positive rhythm reservoir for a long time, on the one hand, the erosion intensity to the bottom of reservoir is big, the degree of sand production is high, so it is easy to form dominant seepage channel; At the same time, the dominant seepage channel contributes to the formation of vertical heterogeneity of reservoir, making the water quantity of relative good layers further increase. Generally, thickness and permeability have good correlation, that is to say, the greater the thickness, the higher the permeability, this is the reason that the thick sand layer is easy to form strong seepage channel.

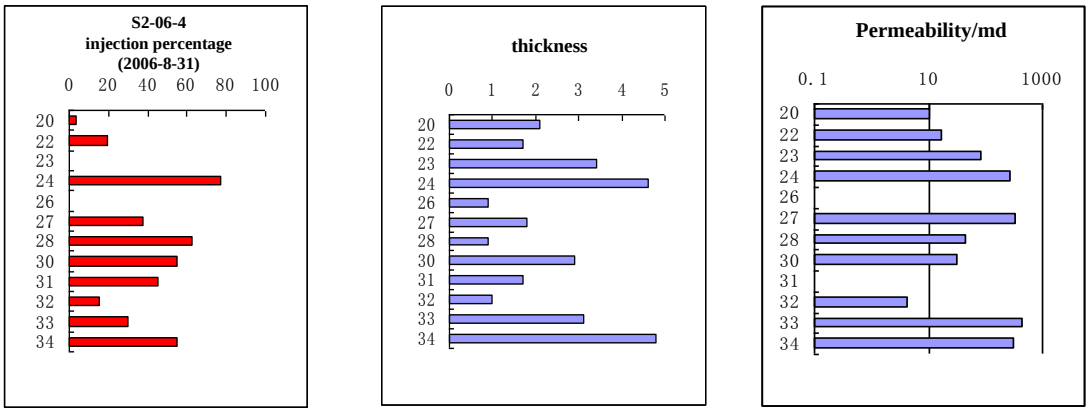

Fig 5 diagram of thickness and injection percentage

(6)Pore structure characteristics

In the long-term water flooding sandstone reservoir, the skeleton structure of reservoir changes constantly, mainly reflected in the change of contact relations of rock particles and the migration of cement. Identification of core slice showed that reservoir flushing action is limited in the early water flooding stage, the contact relations of skeleton particles changed little. In high water cut stage, the support way of skeleton particles and the original point and line contact relationship between particles changed, the cement in the original pore and grain contact has been washed away or transported to other parts. Large porosity increased, part of the particle will be in a fluid foil or free state, fine particles and miscellaneous fill in the connected pore.

The long-term washout of injection water not only makes rock skeleton destroyed, but also cause the change of pore throat structure of the reservoir. It can make pore throat radius become bigger, forming the dominant channel. The main reason of increase of pore throat radius in high water cut stage is: one is that some cement in the pore throat is washed by water, the produced oil is pumped at the same time, there is no other substances in addition to the fluid in pores; The second is that the skeleton is affected by water flushing, and it will burst through from vulnerable support part of the point line contact of the original particles, making its throat become bigger and connectivity turn better.

(7) The influence of crude oil viscosity on the forming of macroscopic throats

High viscosity of crude oil is an important factor to form the macroscopic throats. The migration of clay minerals and debris particles in the channel is mainly rely on the friction and carry of the high viscosity of crude oil. High viscosity of crude oil at the same time also prevents the settlement of sand particles in the process of migration, to ensure that the sand particles evenly distributed in the crude oil. When the fluid viscosity becomes higher, the ability of carrying and suspending sand will be enhanced, and drag force will be increased, the impact of the erosion of sand body is more serious, and eventually led to the increasing of sand production [5]. In a word, the greater the viscosity of crude oil, the easier it is to cause the migration of sandstone particles, the result is that it becomes more conducive to forming a large hole(Fig 6).

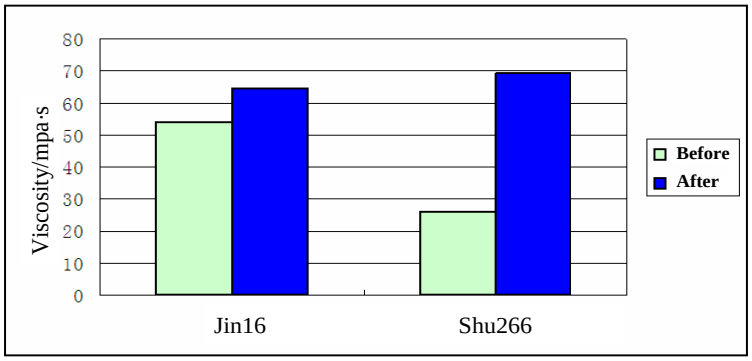

Fig 6 the histogram of viscosity variation before and after washing of Jin 16 and Shu 266 block

3.2 Development conditions of forming dominant channel

In oilfield development, the loose of a stratum is the most fundamental reason to produce the phenomenon of sand. Strata that buried shallow, with low degree of consolidation and high shale content adsorbs amounts of clay particles in the pore surface, under the effect of hydrodynamic flushing, fluid friction and carrying, they are easily to be taken away, so making the clay close to the rock particles be exposed under the fluid scouring, reducing the degree of consolidation, then it is easy to form a big hole. In addition, drilling, drilling process could also be the cause of forming dominant channel [6].

(1)Hydrodynamic flushing action

A large number of indoor research shows that when the water velocity is low, it is not easy for reservoir to produce sand, as the flow velocity increases gradually, the reservoir started to produce sand and the sand production rate increased rapidly, which caused the reservoir permeability increase rapidly. That means only when the fluid seepage velocity reaches a certain standard can the reservoir have the phenomenon of producing sand. The sanding process is summarized as follows: when the reservoir began to produce sand, there will be part of the sandstone particles break out from production wells, with the increase of flow velocity, the sand phenomenon is getting serious, sandstone particles will slowly migrate forward, among them the velocity in the middle part of the flow channel is the fastest, thus it will form a high-speed flow of stripe.

(2)Fluid friction effect

Delete the formation stays away from oil wells. The effect of water flow speed is not obvious. Fluid friction is dominant. Through the research for many times, we found that sand production phenomenon will still occur when the flow rate is not high, this is because the resistance is bigger when the reservoir oil is thick oil, the fluid friction is bigger, it can make the rock particles be towed from the formation in the process of flow, thus produce sand production phenomenon; And that, sandstone particles will flow together with heavy oil, it is easy to flow out of formation along with the crude oil.

(3)The influence of extraction process to sand production

The development mode of forced injection and forced production is easy to cause the formation of macroscopic throats. The higher the production speed, the greater the injection-production strength, the greater the effect of sand particles on the rock pressure gradient, the more easy for sand particles to fall off, the bigger the quantity of sand, the more easy to form the high permeability zone, the greater the pressure drops. And the drop degree of pressure has much effect on the sand, the more sudden the pressure drops, the easier it is to produce sand.

(4) The influence of drilling process to sand production

The drilling process can cause stress that near the borehole reduce. Despite the borehole keep stable, yield phenomenon still exists in uncemented formation. The existence of yield area shows the loss of cohesion of rocks and the expansion of rock volume. So the reduction of rock cohesion is the potential influence factor of sand production.

IV. CONCLUSION

This paper analyzes the geological conditions of the formation of dominant channels, and carries on the cause analysis of dominant channel in water flooding sandstone reservoir in two aspects. One is the development characteristics of the reservoir itself, including reservoir rock facies, physical characteristics, sedimentary rhythm, heterogeneity, thickness and the characteristics of pore structure, the other is the effect of production process, including hydrodynamic flushing action, fluid friction and the impact of drilling process. By strengthening the analysis of the causes of dominant channel, we can further understand the reservoir heterogeneity after a long-term water flooding, and we can also make use of it to guide the sand control, which will promote the development of sealing technology and improve the recovery factor.

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