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Micro pore structure and oil displacement mechanism analysis for deep zone and low permeability reservoir in Mobei oilfield

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A B S T R A C T

The Mobei reservoir is a low-permeability-sandstone reservoir, due to differences in pore geometry, it can be divided into two independent reservoirs: A1 reservoir and A2 reservoir. For better understanding the water flooding development effects of Mobei reservoir, the mercury intrusion porosimetry, water flooding CT scanning and micro-CT scanning experiments are used in this study. The result shows that the reservoir has the strong heterogeneity which is weaken gradually from A1 reservoir to A2 reservoir. Reservoir pore radius is mainly distributed in the 100–200 microns, the throat radius is mainly distributed in the 1–3 micron. The water flooding core experiment in each reservoir shows a short water-free oil production period and rapid water cut after breakthrough. The A2 reservoir core flooding process is similar to piston displacement, the A1 reservoir core flooding process refers to the phenomenon (The fingering phenomenon in the process of core flooding in the A1 reservoir is obvious). The calculated water drive efficiency of the A2 reservoir is 61.2%, which is higher than 49.1% of the A1 reservoir. According to the CT scanning process, the Mobei oilfield has low micro displacement efficiency and the A1 reservoir has a smaller spread (sweep area) and higher residual oil saturation.

1. Introduction

The microscopic oil displacement mechanism of water-flooding in low permeability sandstone is different from that in medium to high permeability reservoirs. It has the characteristics of small pore throat radius, low permeability, and large seepage resistance, mainly including piston displacement and crawling mechanisms (Lenormand and Zarcone, 1984; Lv et al., 2013). At present, there are many methods for studying microscopic pore structures at home and abroad. For example, the scanning electron microscopy can analyze information of pores, throats, and types of clay minerals; the cast thin sections can analyze rock components, thin section face ratio; the conventional mercury injection can analyze pore throat structure, hole throat size, hole throat sorting and connectivity; the constant velocity mercury injection can quantitatively analyze the pores and throats to obtain capillary pressure curves of pores and throats; the NMR can reflect distribution characteristics of movable fluids in the cores; the X-CT scanning can reconstruct the three-dimensional pore structure of rock without destroying samples (Liu et al., 2006; Lang et al., 2015; Xiao et al., 2016; Fang et al., 2017; Ning et al., 2017). Due to complexity and particularity of the microscopic pore structure of the deep low-permeability reservoir, it is necessary to comprehensively use a variety of methods to understand the oil displacement mechanism and microscopic pore structure characteristics. The characteristics of water flooding in deep low-permeability sandstone reservoirs are different from those in conventional reservoirs, such as wettability, heterogeneity of microscopic pore structure, Jamin effect, and the capillary resistance has a great influence on the oil displacement efficiency (Ren et al., 2006; Zhang et al., 2011; Liu et al., 2018).

Sangonghe Formation, located in the Mobei bulges of central Junggar Basin, has a buried depth of 4000 m with the oil-bearing

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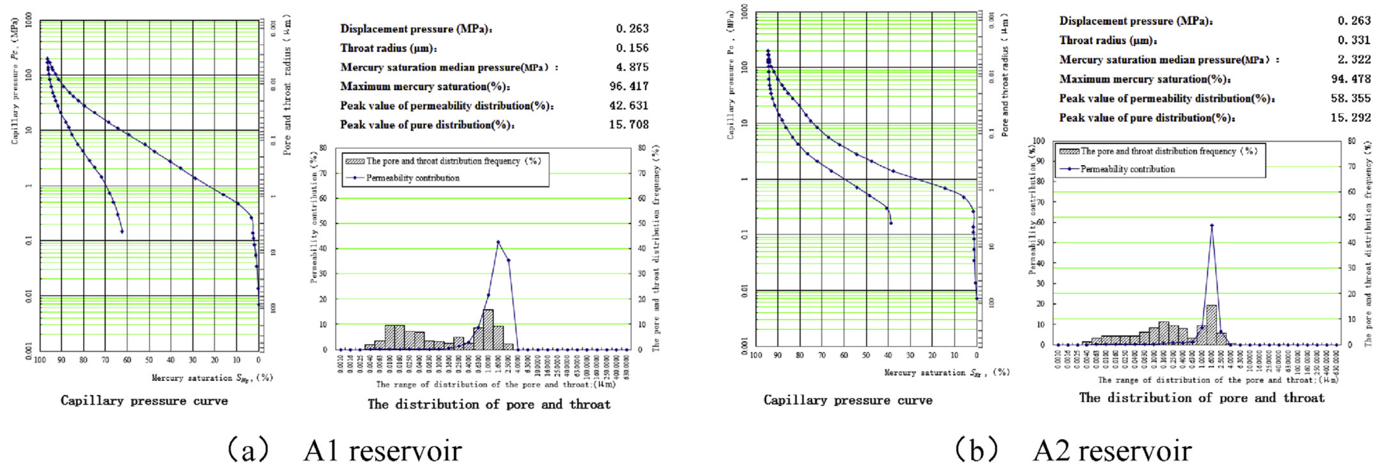

Fig. 1. The conventional mercury injection test for Sangonghe Formation.

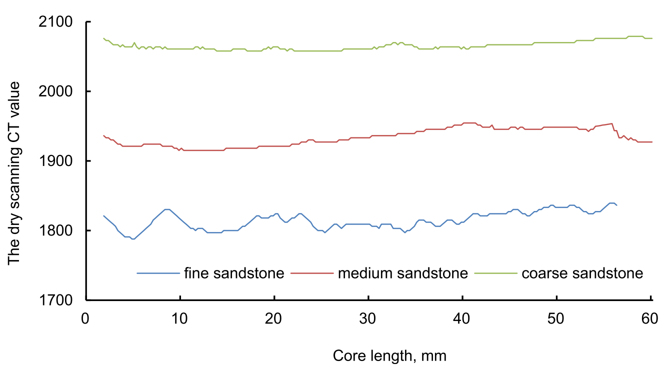

Fig. 2. Different lithology behavior on CT values.

formation of the Jurassic. The lithology is mainly composed of medium sandstone, fine sandstone and contains a little coarse-grained sandstone. The reservoir is generally divided into two parts: the A1 reservoir with an average porosity of 12.8%, average permeability of $23.2 \times 10^{-3} \mu m^2$, and the A2 reservoir with an average porosity of 13.7%, average permeability of $56.9 \times 10^{-3} \mu m^2$, suggesting it belongs to the low-porosity and low-permeability reservoir with strong heterogeneity. According to the literature, the oil displacement efficiency is varied with the reservoir pore structure, which further influences the whole reservoir development effect (Hu, 2013; Zhang et al., 2015a,b; Du et al., 2016; Zheng and Zhang, 2016). In this paper, a series of laboratory experiments are applied, including the mercury injection experiments, micro-CT scanning and core displacement experiment with CT observation (Chen et al., 2005; Su et al., 2011; Oliveria et al., 2012; Bai et al., 2013; Simjoo et al., 2011; Withjack et al., 2013; Deng et al., 2014; Gao et al., 2015; Leng et al., 2015; Zhang et al., 2015a,b; Zhao and Xu, 2016). The reservoir characteristics such as the flow behavior, the heterogeneity and the residual oil distribution, are well studied in both micro and macro scales (Lin and Shi, 2000; Wang et al., 2009; Liang et al., 2011; Zhang et al., 2013).

2. Evaluation of reservoir micro heterogeneity

2.1. Conventional mercury injection test

High-pressure mercury injection experiments can measure nano-scale pores. Pore throat radius distributions can be obtained

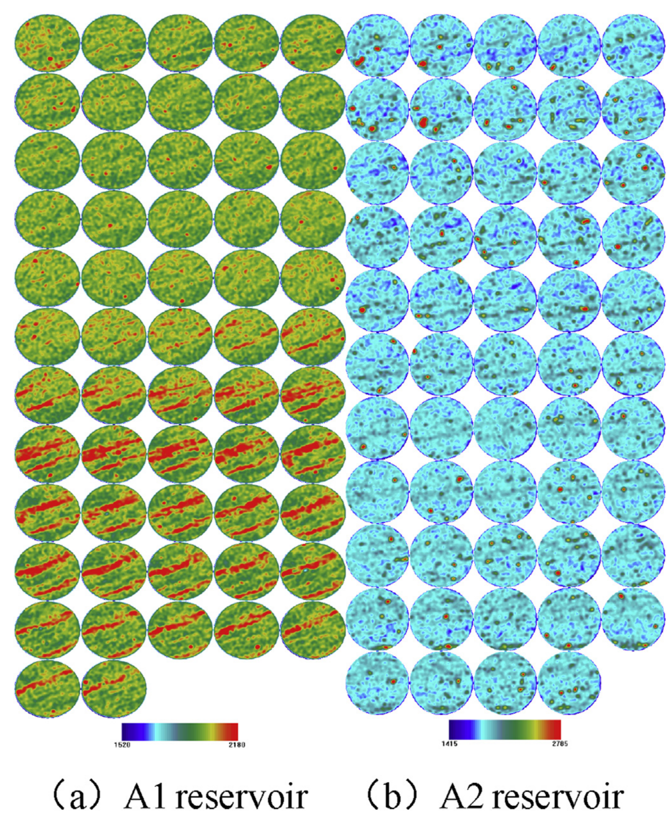

Fig. 3. The dry scanning image of cores in Sangonghe Formation.

under different injection pressures. The capillary pressure curve reflects the relationship between capillary pressure and mercury saturation. From the capillary pressure curve, the variation characteristics of pore throat structure and contribution of different throat radius to permeability can be analyzed. According to Fig. 1, both reservoirs show the bimodal pore-throat distribution, which indicates a strong micro-heterogeneity. At the same time, both capillary pressure curves are characterized by fine pore throat, fine skewness and poor sorting. While, the fine-sandstone A1 reservoir has a relative high micro heterogeneity than A2 reservoir which is mainly composed with pebbly and medium sandstone. The distribution of pore throat radius of the A1 reservoir is relatively large,