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Quantitative characterization on the microscopic pore heterogeneity of tight oil sandstone reservoir by considering both the resolution and representativeness

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ABSTRACT

This study aimed to raise the new experiment method named "umbrella deconstruction" to reveal the microscopic pore heterogeneity of tight oil sandstone reservoir by considering both the resolution and representativeness. Based on the FE-SEM and image processing technology, parameters like porosity, the ratio of the maximum to the minimum of pore orientation frequency, the content of cement, the ratio of the maximum to the minimum of cement orientation frequency and the fractal dimension of reservoir space could be applied into the microscopic heterogeneity characterization. The final imaging observation scale could reach approximately 20 mm (which is 10 times CT observation scale), the precision can reach 10 nm (almost equal to the CT observation resolution). This method would help to the research work in the microscopic heterogeneity characterization of unconventional reservoir.

1. Introduction

Rock slicing is the most direct and effective way to study the development of minerals and pores in any type of reservoir. A series of major breakthroughs in reservoir geology, such as identification of pore and throat, and discovery of nano pores in unconventional hydrocarbon reservoir, all benefit from the observation and testing technology of rock slices (Zhao et al., 2018; Kareem et al., 2017; Mayo et al., 2015).

For the continental tight sandstone reservoirs in China, due to the frequent migration of the channels, strong diagenesis and transformation of the minerals, there is significant microscopic heterogeneity in minerals development and pore throat distribution in the reservoir. In recent years, the research ideas on microscopic heterogeneity of reservoir are mainly focused on micro and nano CT scanning and "focused ion beam-scanning electron microscopy(FIB-SEM)". Through the three-dimensional reconstruction of the CT data, the anisotropy and microscopic heterogeneity of the reservoir is studied (Tisato et al., 2016; Saxena et al., 2017; Rees et al., 2011). Therefore, research scholars mostly aimed to figure out how to improve the accuracy of observation but actually ignored the existing technical conditions which is the observation accuracy greater, the required sample size must be smaller, then the heterogeneity of the sample would be weaker (Baraka-Lokmane et al., 2009; Liu et al., 2017; Tiwari et al., 2013). It is deviated from the original research object which is the heterogeneity characterization. So the study of the microscopic heterogeneity of unconventional hydrocarbon reservoirs under the premise of both resolution and representativeness is worth exploring.

2. Principle

Based on the analysis of the former studies, the authors put forward the "umbrella deconstruction" method, tried to find a method that can take account of both the resolution and representativeness to extract the information from rock samples more directly so that we could study the heterogeneity of reservoir more flexible. We try to develop a new method for characterizing the pore & throat anisotropy of tight oil reservoirs in large sight effectively which could give consideration to both the resolution and scale (London et al., 2014; Baniak et al., 2013; Alyafei et al., 2016).

In Fig. 1 and Fig. 2, first, we drilled the standard core sample of the unconventional hydrocarbon reservoir. Second, we draw 8 remarkable lines every 22.5° in the overlook surface of the sample. Third, we cut the thin sections along the 8 lines. Fourth, we use the FE-SEM instrument to characterize the reservoir in 8 thin sections and get a large amount of images in small view. Fifth, we spliced all the images in small view into 8 images in large view. Finally, we could carry out the

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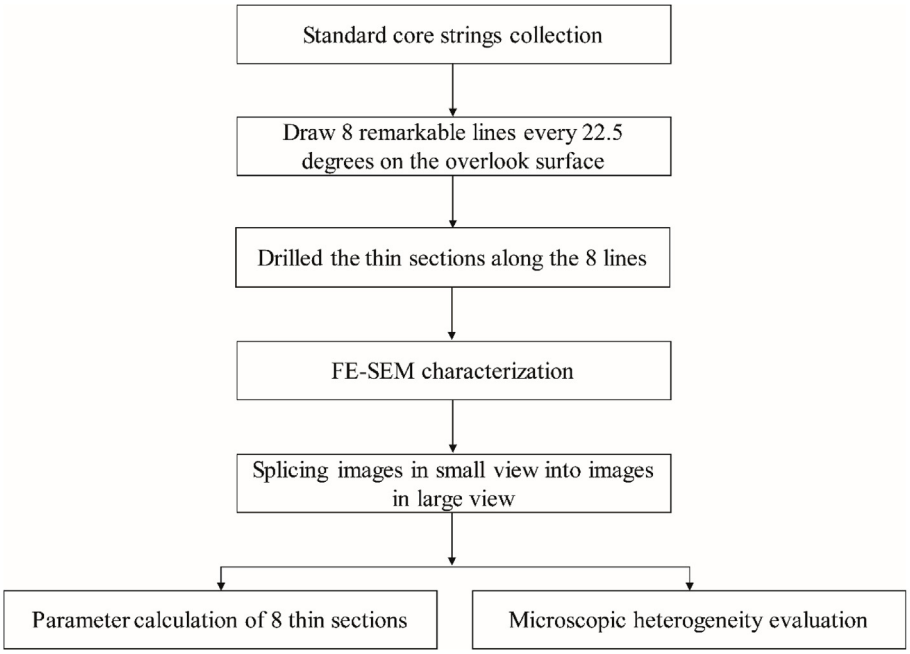

Fig. 1. Technical process of "umbrella deconstruction" method.

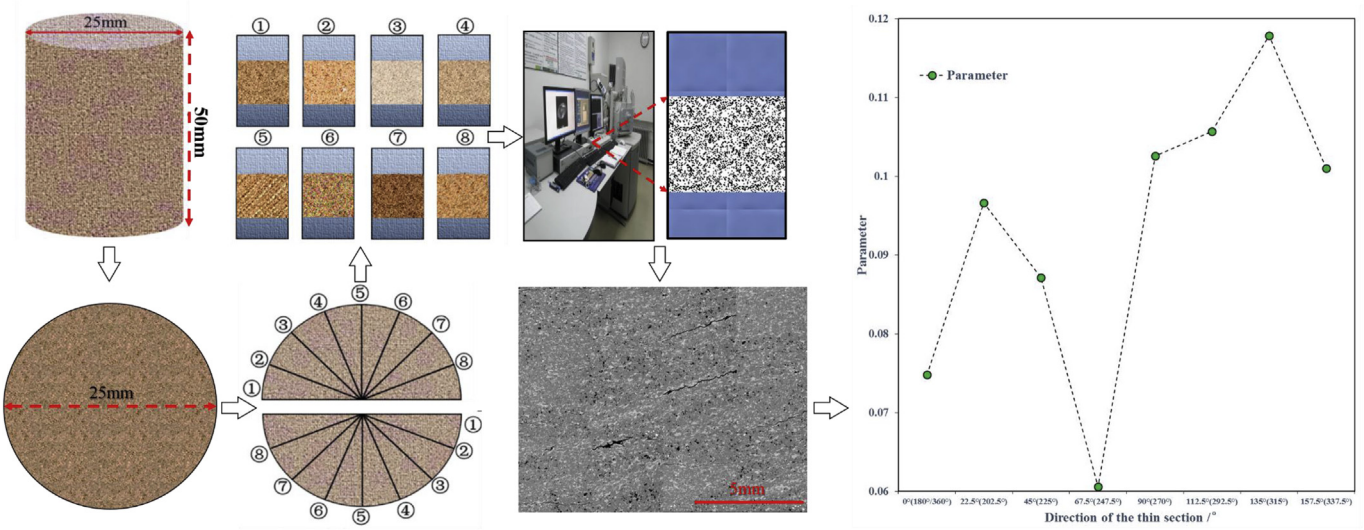

Fig. 2. Graphic description of "umbrella deconstruction" method.

parameter calculation of 8 thin sections such as the porosity, the fractal dimension, the pore direction and so on to evaluate the microscopic heterogeneity of the pore in unconventional hydrocarbon reservoir.

3. Discussion

3.1. Comparison between CT and "umbrella deconstruction" method

When we compared "umbrella deconstruction" method with other technologies like Micro-CT, Nano-CT and FIB-SEM, the new method has two important features illustrated in the following:

(1) Although Micro-CT and Nano-CT are nondestructive to samples, the required sample should be the plungers in millimeter (usually 2 mm) and micron scale respectively. When it comes to the process of 3D reconstruction, the sample scale of still needs to be reduced. Otherwise, it will greatly increase the computation and cause the operation difficulties. Although the precision of FIB-SEM can reach the micro and nanometer level, but the sample scale is smaller than the CT, the representative of the sample needs to be discussed (Ramandi et al., 2016; Josh et al., 2012; Busse et al., 2017). The research method of "umbrella deconstruction" could reach 25 mm in diameter when combining image mosaic technology, the final imaging observation scale could reach approximately 20 mm (which is 10 times CT observation scale), the precision can reach 10 nm.

(2) Someone may doubt that since we could observe the reservoir comprehensively by cutting the CT scanning data from any direction, what's the necessity of cutting the real sample from 8 directions to observe the reservoir? The truth is the CT data are limited to the sample scale, so the representative needs to be improved as the representative is one of the most important parameters to evaluate whether the conclusion is believable. Meanwhile, the mineral recognition principle is only based on the CT value (Honarpour et al., 1985; Heriawan and Koike, 2015; Ge et al., 2015). There is a shortage of the precise conversion criteria