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Digital Core Technique in the Application of Microscopic Reservoir Characteristics Description: Taking Gaotaizi Oil Layer of Qijia Area in Songliao Basin as an Example

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***Abstract:* -** Tight sandstone samples from Gaotaizi oil layer in Qijia area of Songliao basin were mainly studied in this paper. In order to further study on the mechanism of seepage, 3D digital core model with real pore throat structure was constructed by Avizo 8.0, which had advantages such as non-destructive to samples, visualized results and abundant data. The research showed the storage space was mainly composed of intergranular dissolution pores, intragranular dissolution pores and micro-fractures, pore& throat in 3D space is more tubular and ribbon, micro-pore distribution has the heterogeneity, narrow throat radius is the main cause of low permeability of the sample.

***Keywords:* -** Qijia Area; X-CT scanned image technique ; Tight sandstone; Microscopic pore structure; Digital core

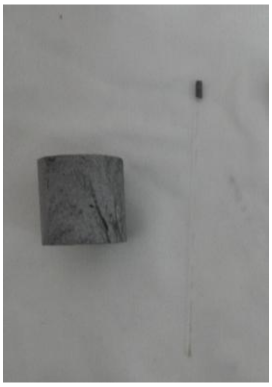
I. INTRODUCTION

Microscopic pore structure refers to pore and throat of geometric shape of the reservoir rock, size, distribution and interconnected relations, the microscopic pore characteristics of the reservoir rock directly affects the reservoir capability and seepage capability[1]. In recent years, tomography in the application of ‘microscopic pore & throat characterization is becoming more and more widely[2-5], relative to the mercury injection experiment and scanning electron microscopy (sem) analysis method, compared with the conventional X-ray CT imaging technology core testing method, the result of X-ray CT imaging technology is intuitive, simple and feasible. Taking the samples of Gaotaizi oil layer of Qijia area in Songliao Basin as the research object, combining with a variety of advanced mathematical algorithm of Avizo8.0 software, realizes the pore network model visualization and quantitative characterization of the pore parameters, laid the foundation of multi-scale microscopic pore structure characterization and seepage mechanism research.

II. CT SCAN

Phoenix Nanotom S multifunctional 3D computed tomography system is used in this experiment (Figure 1), its maximum voltage/power is 180 kV/ 15 W, its resolution is up to 1um, and its voxel size is up to 0.5 um. According to the statistics of core physical characteristics, in G3 and G4 sections of Gaotaizi oil layer in Qijia area, Songliao basin, the porosity is generally 4%-12%, with an average of 8.5%; the samples whose porosity is less than 12% account for 80%; with the horizontal permeability being 0.01-0.5×10^{-3}μm^2, the samples whose horizontal permeability is less than 1×10^{-3}μm^2 account for 93%. Argillaceous siltstone samples of G3 and G4 sections in the two key exploratory well, Jin 18 and Jin 16 are selected for this experiment, and they conform to the poroperm characteristics of compact oil in Qijia area as a whole and have certain representativeness. This study selected 2 mm high 2 mm diameter cylinder sample (figure 2), the resolution is up to 1 um, obtaining 2D gray images of 1200 (figure 3), CT image grey value reflects the relative density of material inside the rock, the bright part is considered high density material, and the dark part is considered the pore structure.

Fig.1 Phoenix Nanotom S Micro-CT



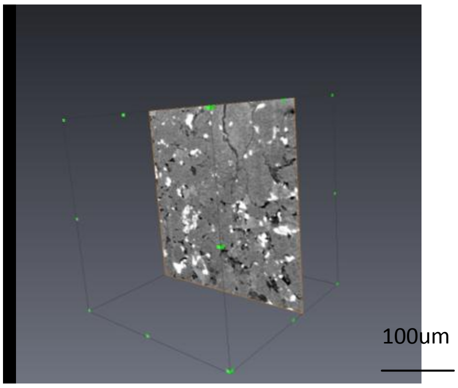
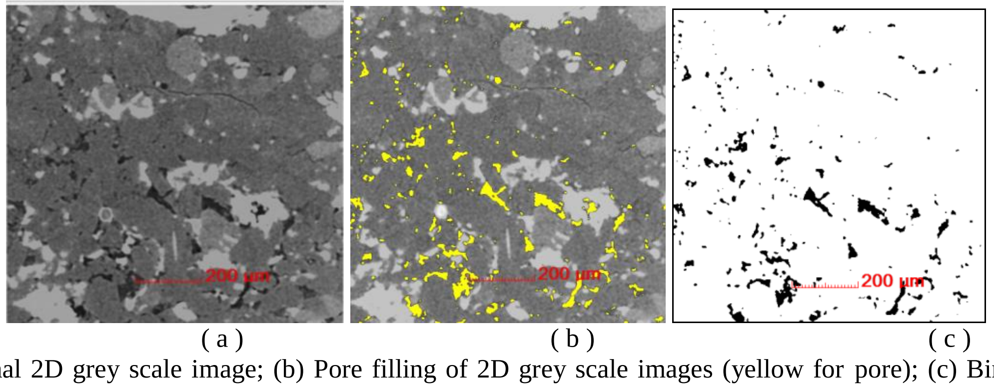


Fig.2 Rock sample Fig.3 2D images of CT scanning(resolution 1 um)

III. IMAGE PROCESSING

The system noise existing in the gray level image obtained through CT scanning can lower image quality and go against follow-up image segmentation and quantitative analysis, the reconstructed micron-sized gray level image is carried out two-value segmentation to mark off pore and grain matrix, and the pore area is rendered with yellow (Figure 4b) to further obtain segmented image which can be used for pore network modeling and percolation simulation (Figure 4c), with the black area in it representing pore within sample and the gray and white areas representing matrix of rock (white representing matter with higher density).



(a) Original 2D grey scale image; (b) Pore filling of 2D grey scale images (yellow for pore); (c) Binarization results (black on behalf of the pore, white on behalf of rock matrix

Fig. 4 Image binarization segmentation flowchart

IV. ESTABLISHMENT OF 3D PORE & THROAT MODEL

Pore network modeling means extracting structured pore and throat model from two-value three-dimensional core image through a special algorithm. Such pore structure model keeps the pore distribution characteristics and connectivity characteristics of the original 3D core image; the advanced mathematical algorithm built within Skeletonization module in Avizo 8.0 software is used to build three-dimensional pore network modeling (Figure 5c and 5d) which is carried out pore connectivity rendering (Figure 5a and 5b) (neighboring colors being the same represents micropore connectivity, and neighboring colors being different or the same color taking apart represents micropore non-connectivity). The main characteristics of three-dimensional pore & throat model are as follows:

① Pore & throat size and morphological analysis

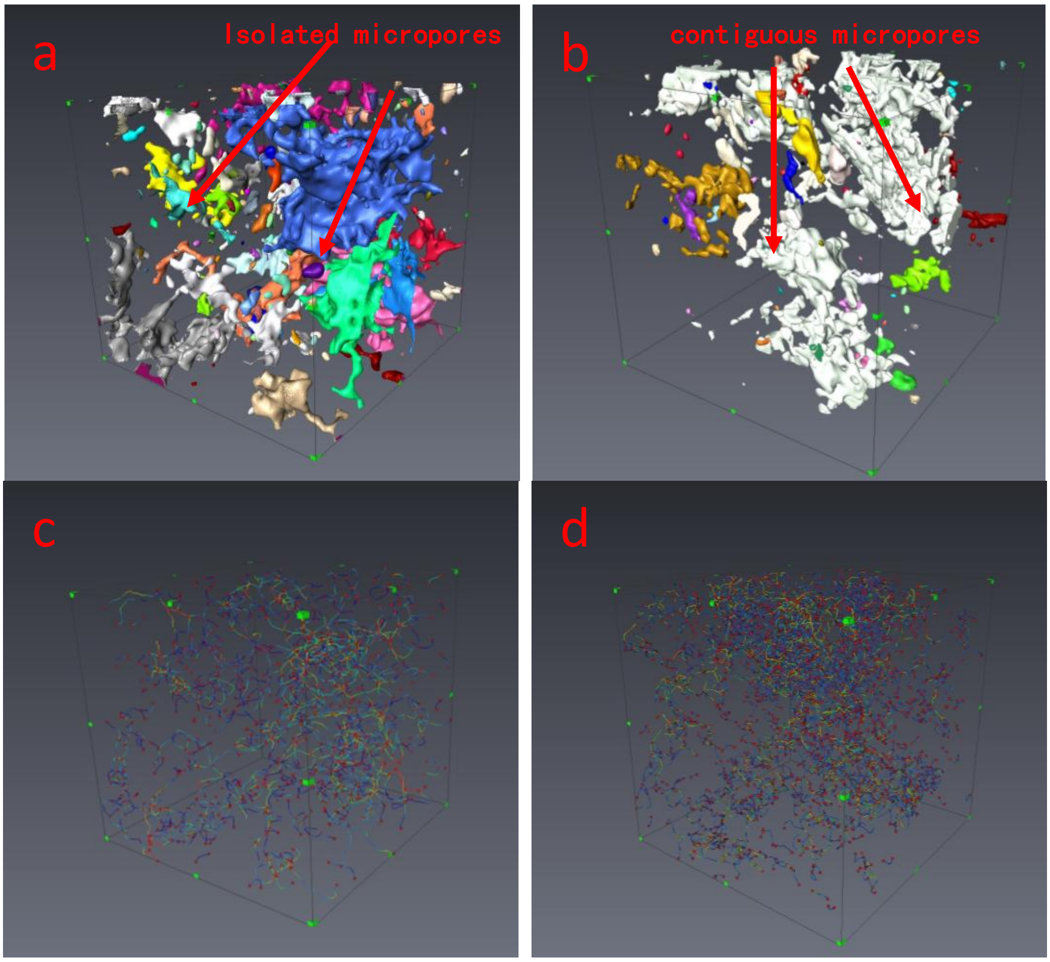
Pore & throat often take on tubular morphology and globular morphology in three-dimensional space (Figure 5). According to the calculation of sample 10, its porosity is 7.9 %, its average pore radius is 8.91 um, minimum pore radius 1.91 um, average throat length 12.9 um, and average throat radius 1.66 um; according to the calculation of sample 19, its porosity is 8.1 %, its average pore radius is 9.1um, minimum pore radius1.88 um, average throat length 11.9 um, and average throat radius 1.66 um. Due to the fact that the sample is relatively compact and the limitation of the resolution of CT scanning, the nanoscale pores in the core which are smaller can't be identified, this results in errors in porosity calculation. Throat radius being narrower is the main reason for the actually-measured permeability being lower.

② Pore & throat spatial distribution characteristics

The distribution of micropores has heterogeneity; local micropores show better development; micropores between corrosion grains are concentrated relatively and often take on band shape in space, micropores within corrosion grains are disperse relatively and often take on ball shape in space (Figure 5).

③Pore & throat connectivity analysis

It can be seen from connectivity rendering (Figure 5a and 5b) that pore morphology mainly includes contiguous micropores and isolated micropores and that compared with isolated micropores which are generally "dead" pores, disperse micropores have better connectivity.



(a) Connectivity analysis, Jin18 well, 2307.58m, grey argillaceous siltstone; (b) Connectivity analysis, Jin 16 well，2311.64m, grey argillaceous siltstone; (c) 3D pore network model of the pore structure (ball for the pore, tube for the throat), Jin18 well, 2307.58m, grey argillaceous siltstone; (d) 3D pore network model of the pore structure (ball for the pore, tube for the throat), Jin16 well，2311.64m, grey argillaceous siltstone

Fig.5 Tight sandstone digital core model in Qijia area

V. CONCLUSION

1. The research showed that the storage space was mainly composed of intergranular dissolution pores, intragranular dissolution pores and micro-fractures, pore&throat in 3D space is more tubular and ribbon, micro-pore distribution has the heterogeneity, narrow throat radius is the main cause of low permeability of the sample.
2. Compared with the conventional X-ray CT imaging technology core testing method, the result of X-ray CT imaging technology is intuitive, simple and feasible, the technique of microscopic pore throat based on CT scanning realizes the pore network model visualization and quantitative characterization of the pore parameters, laid the foundation of multi-scale microscopic pore structure characterization and seepage mechanism research.

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