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Characterization of Pore Structure Based on Nondestructive Testing Technology

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***Abstract:* -**Tight sandstone samples from Fuyu oil layer in Daan oilfield of Songliao Basin were mainly studied in this paper. A 3D digital core model with real pore throat structure was constructed by combining Tomography with advanced "Maxima-Ball". The research showed that the tight siltstone samples had bad pore connectivity. The storage space was mainly composed of intragranular dissolution pores. Image computed porosity was 0.5 %, with an average pore radius of 1.89 um and an average throat radius of 1.01 um. Tomography relative to conventional core testing method had advantages such as results intuitive, rich data and non-destructive to sample. With the further development of computer technology, nondestructive testing technology will become an important technology involved in the oil field exploration and development.

Keywords:* - *Tight sandstone ; Nondestructive testing technology; Maxima-Ball; Pore structure

I. INTRODUCTION

Industrial nondestructive testing technology in our country has played a very important role in industry [1].According to industry detection and scientific research, and the application of measurement in recent years, such as structure of nondestructive testing ,defect analysis and quality assurance and control, nondestructive testing technology in the increasingly become a powerful X-ray tomography imaging detection tools, and its application in characterization of reservoir pore structure is becoming more and more widely [2-3], X-ray CT imaging technology has the advantage of rapidly, all-round, and a wide range of rock sample scanning imaging [4-5], the digital core can be more intuitive to study the porosity of the reservoir rock characteristics [6-8], its application in the direction of the evaluation of pore structure will be more broad.

This paper takes Daan oilfield in southern Songliao Basin dense sandstone samples as the research object, using X-ray CT imaging technology has realized the pore network model extraction and quantitative characterization of the pore parameters, the visualization of microscopic pore structure laid a good foundation for the multi-scale pore structure study.

II. MICRO CT SCAN

This experiment using MicroXCT-200 scanner produced by Xradia company (fig. 1), the sample size is 1-70mm, resolution is 0.5-35 um, the measure voltage is 40kV-50kV, instrument and X-ray CT system layout is shown (fig.2), X-ray source and detector were placed on both sides of the turntable, cone-shaped X-ray penetrate the sample on the turntable, then X-ray wear by detector, sample can be vertical translation, horizontal translation and vertical lifting movement to change the scanning resolution . When the core sample is lifting vertically, The closer distance from X-ray source, the greater the magnification, core samples internal details can be amplified, 3D images are more clear, but at the same time the detectable area will be reduced accordingly; Sample, on the other hand, the closer distance from detector, the smaller the magnification, the lower the image resolution, but detectable area increased. Samples of horizontal and vertical lifting is used to change the scanning area, but not change the image resolution. the core sample turntable itself can be rotating, the CT scanning, the turntable drives samples, each roll after a small angle, sample projection drawing is obtained by X ray irradiation. After rotating 360 degrees, we obtain a series of projection reconstruction three-dimensional image of the core samples. Compared with .This experiment of dense sandstone samples from Daan oilfield in southern Songliao basin (fig. 3), sampling depth is 2343.4 m, the scanning resolution is 1.0664 um, we received 2D gray images of 1984 (fig.4).

Fig.1 MicroXCT-200

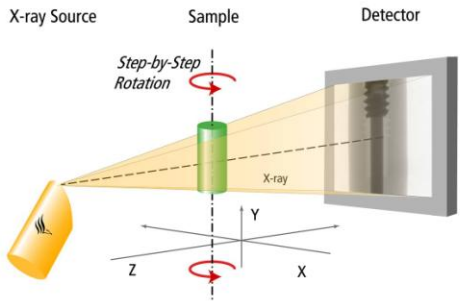


Fig.2 X-ray layout system schematic diagram

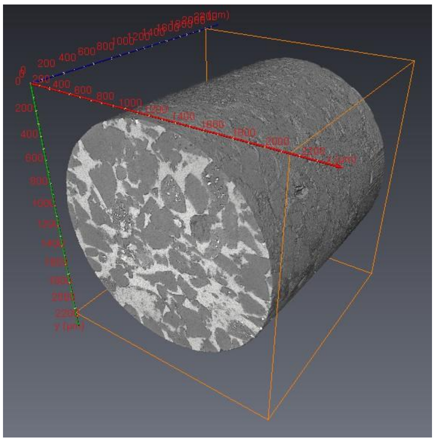


Fig.3 Rock sample

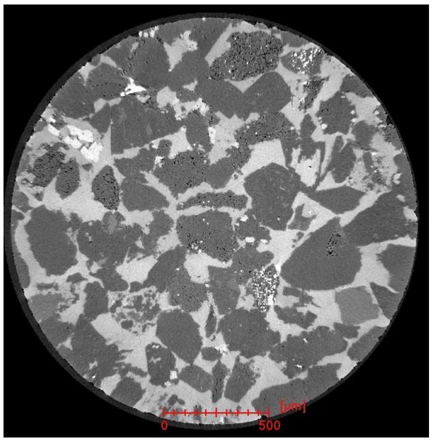
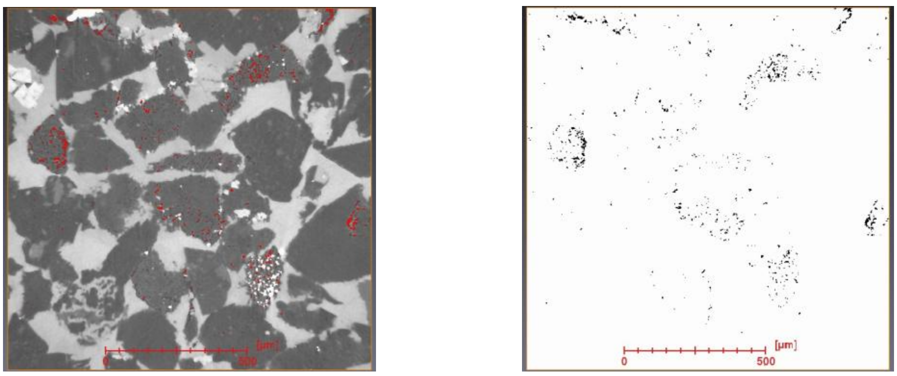


Fig.4 2D images of CT scanning(resolution 1.0664um)

III. 2D IMAGE ANAIYSIS AND PROCESSING

Using Avizo 8.0 software image segmentation techniques, we get reconstruced 2D gray image of binarization segmentation, the bright part of CT images is high density material, the dark part is considered as pore structure, the pore area is red rendering (fig. 5a), divided into pore and granular matrix, the seepage simulation can be used in pore network modeling and segmentation image (fig. 5b).



(a) (b)

(a) Pore filling of 2D grey scale images (red for pore)

(b) Binarization results (black on behalf of the pore, white on behalf of rock matrix)

Fig. 5 Image binarization segmentation flowchart

IV. 3D VISUALIZATION PROCESSING

3D visualization aims at represent the 3D digital core image of pore structure and particle distribution in the most intuitive way to present. Through Avizo8.0 3D visualization tool for data visualization, we can express and simulate simply and easily, intuitively. Using Avizo8.0 provide powerful data processing function, we can show not only express the core of 3D pore structure (fig.6), we can also be intuitive representation of the pore connectivity (fig.7).

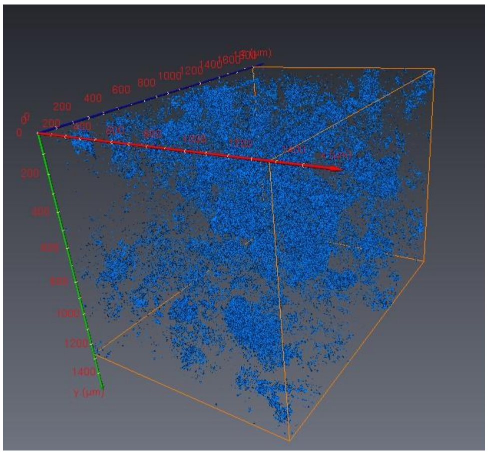


Fig. 6 3D stereogram of core

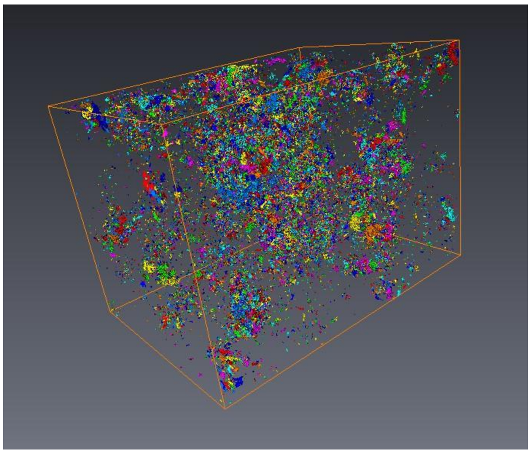


Fig. 7 Pore connectivity rendering

V. ESTABLISHMENT OF 3D PORE NETWORK

Using the method of " Maxima-Ball" to get pore network structure of extraction and modeling, we can not only improve the speed of network extraction, and also ensures the accuracy of the pore distribution and connectivity features. " Maxima-Ball " method is a series of different size of the spheres filling into the pore space of 3D core image, there is a connection relationship according to the radius between filling various sizes of the ball . The core internal pore structure will be sent to you by overlapped and contained ball string to represent (fig.8. Pore network structure of pore and throat is established through the ball string to find local smallest ball l between the two big ball, thus forming the “pore-throat-pore” matching relationship (fig.9 and fig.10), and eventually the whole ball string structure can be simplified to pore network structure model (fig.11).

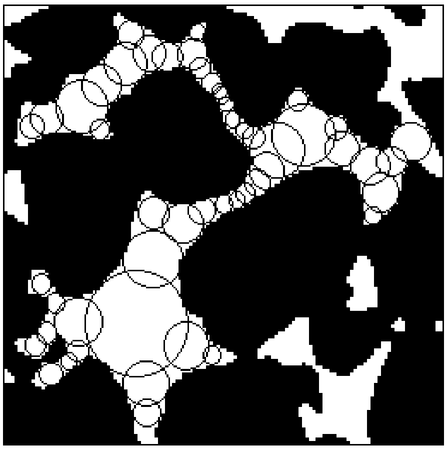


Fig. 8

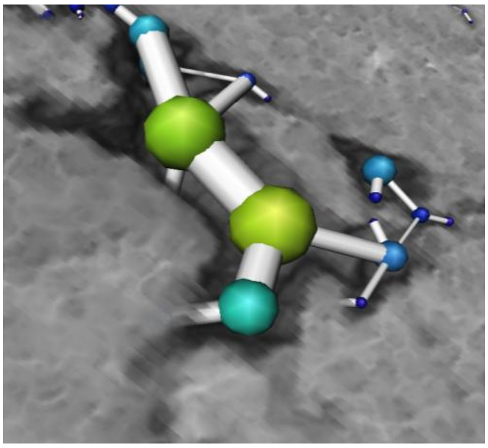


Fig. 9

Fig. 8" Maxima-Ball " method to extract the pore network structure of 3D pore
Fig. 9 Filling schematic diagram of 3D pore

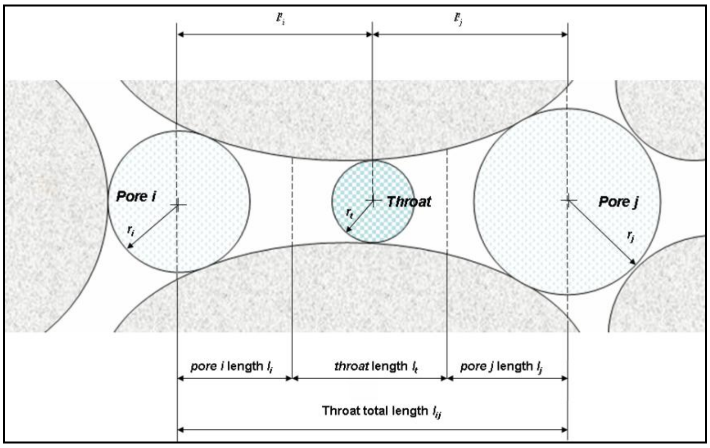


Fig. 10 Pore and throat schematic diagram

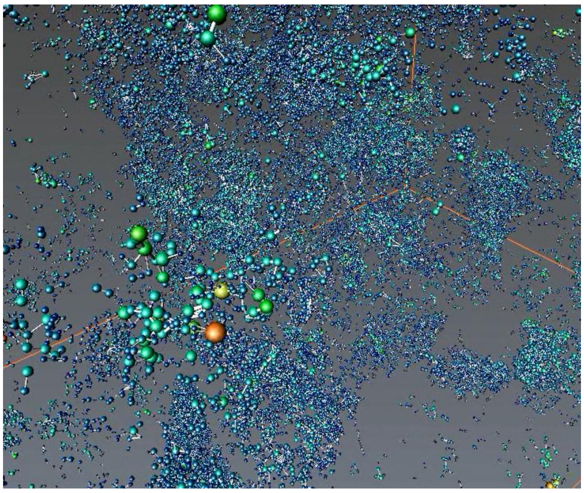


Fig. 11 3D pore network structure model (ball for pore, tube for throat)

VI. THE RESULTS AND ANAILSIS

Through the establishment of 3D pore network model, quantitative characterization of pore and throat, pore, We identified 71881 pore and 78869 throat, maximum pore radius is 7.86 um, minimum pore radius is 0.11 um, the average pore radius is 1.89 um (fig.12), the largest throat radius is 6.33 um, minimum throat radius is 0.11 um, the average throat radius is 1.01 um (fig.13), image computing porosity is 0.5%, whole pore connectivity is poor, pore types are mainly dissolution pores in the granules (fig.14).

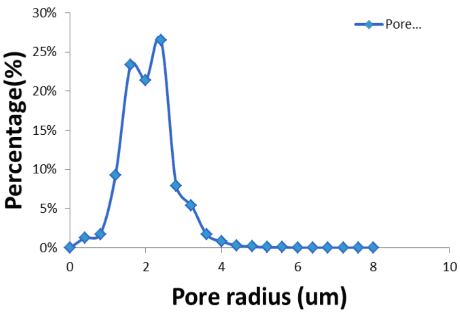


Fig. 12

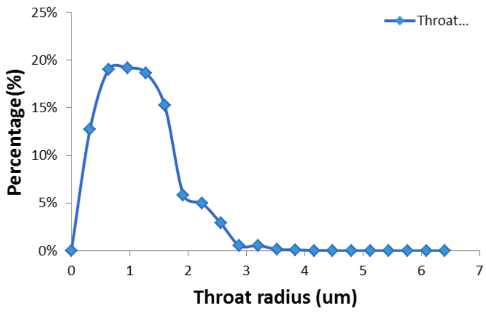


Fig. 13

Fig. 12 Pore radius distribution frequency diagram

Fig. 13 Throat radius distribution frequency diagram

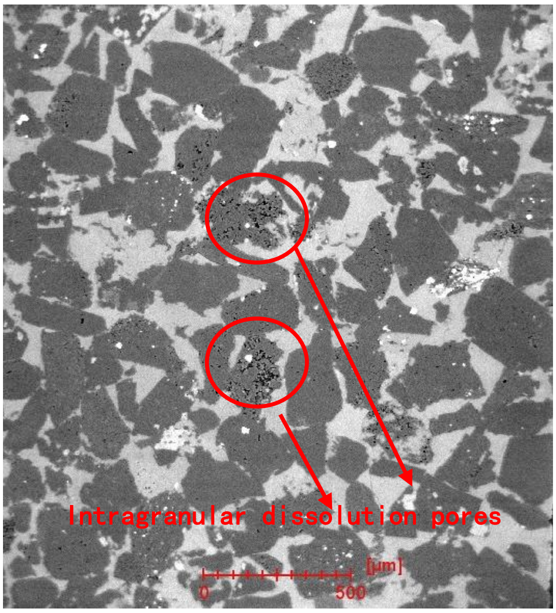


Fig. 14 Types of reservoir space under 2D gray scale images (resolution 1.0664 um)

VII. THE EXPEREMENTAL RESULTS AND ANALYSIS

1 .In this paper, using X-ray CT imaging technology combined with advanced " Maxima-Ball" method，we established the micro scale real 3D pore model of pore throat structure, CT scanning experiment results show that the samples of argillaceous siltstone has poor connectivity, reservoir space is mainly intergranular dissolved pore.

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 laid a foundation for further study of multi-scale dense sandstone pore structure characteristic.

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