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# *Simulation Experiment of 3D Digital Core Visual Modeling Based on SCILAB Software*

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***Keywords:*** Digital core, SCILAB, simulation, process method, sedimentation, rock particles

***Abstract:*** This paper briefly introduces the process of using scilab software to carry out the simulation experiment of 3D digital core modeling, expounds in detail the theoretical method of establishing 3D digital core by process method, and introduces the setting method of each parameter in the algorithm. The research shows that the 3D digital core visual modeling can be well realized by using scilab software. The rock particle skeleton is tightly packed, and the generated rock pore has good space connectivity. The algorithm model can be further improved after considering the compaction effect and cementation type of the actual formation rock, and there is room for improvement in this 3D digital core visual modeling.

## 1. Introduction

Oil and gas, as important strategic resources, affect the energy security and sustainable economic development of modern countries. Unilateral use of macro-scale geological exploration technology can no longer satisfy the fine evaluation and exploitation of oil and gas reservoirs. Multi-scale accurate analysis of core samples extracted by drilling has become increasingly important for reservoir evaluation[1,2]. Core is one of the direct and effective data to describe the structural characteristics of underground rock reservoirs. Studying the physical and chemical properties of core is of great scientific significance for the development of modern national industry.

Through the measurement of instruments and equipment in the laboratory and the numerical simulation in the simulation laboratory, the conductivity, compressibility, oil and gas content, lithology and other physical characteristics of reservoir rocks can be described, which provides important test data for finding out the geological characteristics of the reservoir, evaluating the recovery effect of oil and gas reservoirs and enhancing oil recovery[3-4]. In the long-term crustal plate movement and increasingly complex geological evolution environment, the formation and change of sedimentary rocks are often subjected to extremely complex physical, chemical and biological actions, and this series of changes is difficult to be accurately defined by simple mathematical and physical equations. To establish a model with similar pore characteristics to sedimentary rocks, existing scholars put forward a method to simulate the formation process of sedimentary rocks (i.e. process method), which can be summarized into three basic processes: deposition process, compaction process and diagenesis process. Its core modeling idea is: using small rock particles with different shapes to simulate rock mineral detritus particles, and stabilizing the deposition process one by one to realize the construction of 3D digital core model[5]. Compared with the real core, the digital core established by the process method shows many similarities in characteristics (such as porosity, permeability, connectivity, correlation function, etc.), which can better characterize its pore structure characteristics[6].

At present, the methods and techniques for establishing digital cores can be divided into two categories: physical experiment and numerical reconstruction. Both methods have their own characteristics in modeling process and results. The physical experiment method takes the real core as the basic sample, and scans and images the core with high-precision scanning and detection equipment to establish the digital core. Firstly, the digital core with appropriate size is made, and then the high-precision 2D image information of the core is acquired by some instruments (such as X-ray CT scanner, electron microscope, nuclear magnetic resonance instrument, etc.). After that the 2D images are reconstructed into 3D images through a series of editing and processing of image processing techniques, so as to construct a 3D digital core. The numerical reconstruction method mainly inputs the basic parameters of rock structure, including porosity, grain size curve, correlation function and other statistical data. In geological experiments, these data can be obtained from rock samples in a cheap and convenient manner, and then 3D digital cores can be constructed by mathematical algorithm and program simulation. Numerical reconstruction method can be divided into random method and process method.

In 1992, Bryant and Blunt[7] publicly released the computer method of reconstructing digital core by simulating diagenetic process for the first time. This method is based on high-precision scanning and imaging 2D rock images. Using binary simulation method to extract physical modeling information such as porosity and particle size distribution, and relying on computer programming simulation to realize the formation process of stratum rocks, a 3D digital core model similar to the real core pore space is finally established[6]. In 1997, Bakke and Ren[8]made a systematic and in-depth analysis and research on the process model, which not only considered the particle size distribution function of rock debris, but also simulated the growth process of silicate rock surface cement and the coverage of cemented clay between rock particles. In 2003, Øren and Bakke[9] reconstructed the digital core model of Fontainebleau sandstone by this method, which can better reflect the geometric shape and conductivity of real rocks. In 2003, Jin[10]et al. discussed in detail the geometric structure and mechanical properties of 3D digital core model established by process method. In 2012, Zhu et al.[11]used irregular clastic particles to reconstruct sandstone digital cores in the process of sedimentary diagenesis simulation. Compared with the random generation method, the sandstone model established by the process method has better effect of pore space connectivity, pore roar is easier to form a 3D seepage network, and the simulated permeability is closer to the experimental test results of rock physical properties. Compared with the digital rock constructed by CT method, the process method is economical, efficient, portable and quick, and the 3D digital core with gradually changing pore structure and porosity can be established in a systematic manner.

Based on the existing research results of the above scientists and scholars, and considering the advantages of process method in establishing 3D digital core model, the process method is adopted to carry out 3D digital core visual modeling simulation experiment based on SCILAB software.

## 2. SCILAB Software function

SCILAB is a free and open source software for all software engineers and researchers. It was born in 1994 and has been used iteratively to optimize the algorithm ever since. It has many open source versions and data packages. SCILAB's community discussion group is growing and expanding. Up to now, 100,000 new users all over the world download it every month. It is an open source scientific computing software jointly developed by outstanding scientists and scholars of the French National Institute of Information and Automation. The use, editing and iterative updating of this software are not restricted by the license of the registered place, and can be controlled independently. SCILAB provides users with the following computing and open programming environments:

(1) A variety of easy-to-operate data types;

(2) A reasonable and effective set of callable basic sub-functions as the basis of extensive computing;

(3) An open programming environment similar to MATLAB language. New functions can be easily added.

## 3. 2D digital core model

In this paper, the rock particle deposition method is adopted, and some existing cases call function programming. The 2D digital core programming algorithm steps are as follows:

(1)Setting the size of the deposition area;

(2)Setting the probability distribution function of rock particle size;

(3)Setting the position coordinate balance function of the small ball;

(4)Randomly selecting the plane coordinate position where the pellet descends;

(5) Determining one by one whether the coordinates of the small ball reach a stable equilibrium state;

(6)When the particles fill the deposition area, the deposition process is completed.

The boundary of 2D condition is set to 200*200μm, and the particle diameter distribution function F(x) adopts normal distribution (μ takes 7.75, and σ takes 14.5). The normal distribution function is shown in formula (1):

$$f(x)=\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{1}$$

Rock particles with different random particle sizes are selected to fill the 2D plane until the algorithm cycle ends. The deposition modeling results of 2D process method are shown in Figure 1. It can be seen that rock fragments with different particle sizes have completely filled the 200*200μm plane.

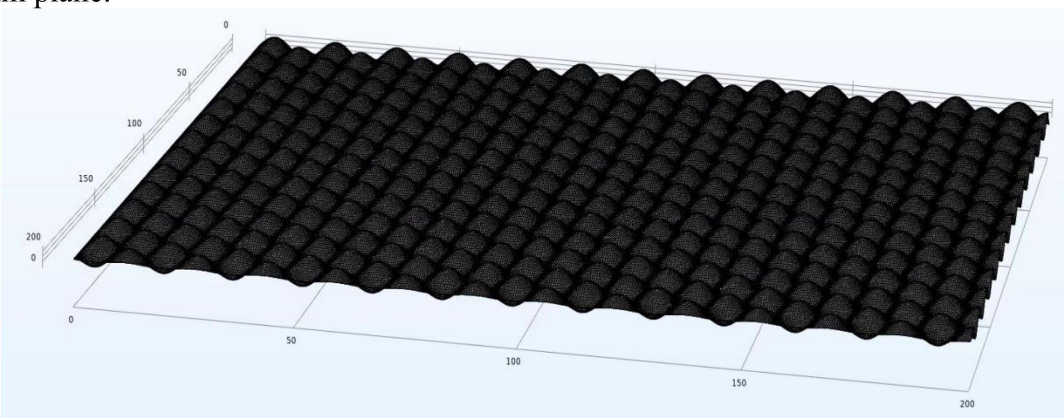

Figure 1: Simulation Results of 2D Digital Core Model.

The plane is binarized. After binarization, the image data have only two parts, namely, the skeleton part and the pore part, which are usually represented by 1 and 0 respectively. The surface of the accumulated clastic rock particles is clearly visible, and the processing results are rendered as shown in Figure 2. It is obvious that the channels between rocks are well connected and textured on the 2D plane after fitting.

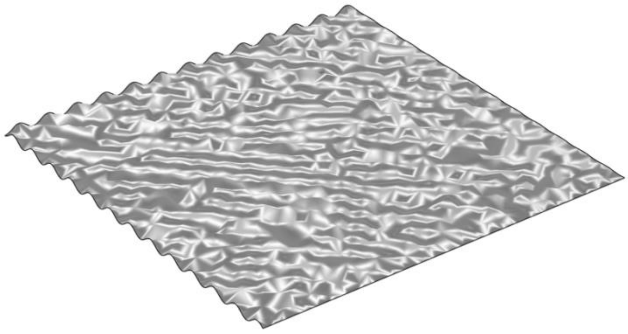

Figure 2: Chart of plane fitting results.

## 4. Three dimensional digital core model

In this paper, 3D digital core modeling follows the basic hypothesis of sedimentary process put forward by Coelho et al[12], and some improved algorithms are made:

(1)The grain size of sedimentary clastic rocks comes from the set normal distribution function;

(2)The sedimentary plane is XOY plane, which begins to accumulate along the Z direction. The initial accumulation position of rock debris particles is random;

(3)The positions of the rock particles to be deposited do not collide and overlap with all the accumulated rock particles;

(4)Rock debris particles are only affected by vertical gravity in the process of settlement and accumulation;

(5)When judging the stable position of rock debris particles, the particle movement direction is the direction with the greatest change of gravity gradient；

(6)The shape of rock debris particles does not deform under the vertical gravity;；

(7)After the rock debris particles reach the final stable equilibrium state, their 3D position coordinates remain unchanged;

(8)Rock debris particles are randomly deposited according to the normal distribution curve, and deposited one by one to reach a stable status.

The 3D box boundary condition is set to 200*200*200μm, and the particle diameter distribution function F(x) adopts normal distribution ($\mu$ is 7.75, $\sigma$ is 14.5). The 3D digital core model established is shown in Figure 3. It can be seen that the arrangement of clastic particles in the generated 3D model is stable, and the pore networks among rocks have good spatial connectivity, which has a high similarity with the real core.

The particle size and distribution frequency of all clastic rock particles in the established 3D digital core model are extracted for statistics, and the probability distribution histogram is made. Then, the set normal distribution function curve of rock clastic particles is made for comparison and verification. The results in Figure 4 show that the distribution of clastic particles in the generated 3D model has certain randomness, but basically meets the set normal distribution function, indicating that the modeling result is successful, and the process method for generating the 3D digital core model has reference value.

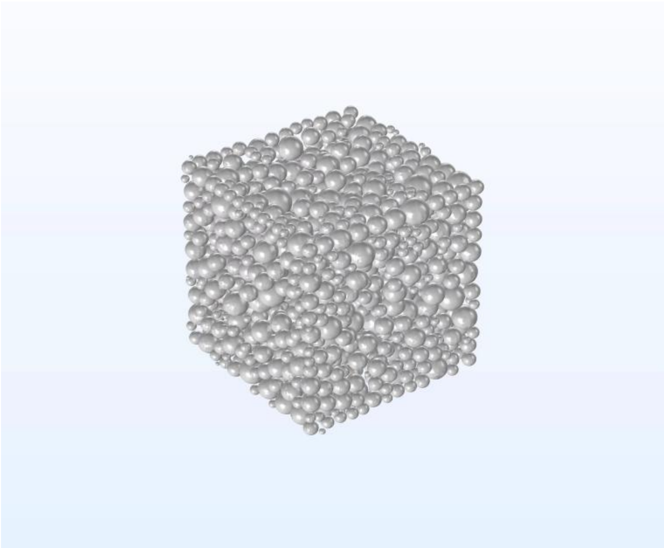

Figure 3: Three dimensional digital core model.

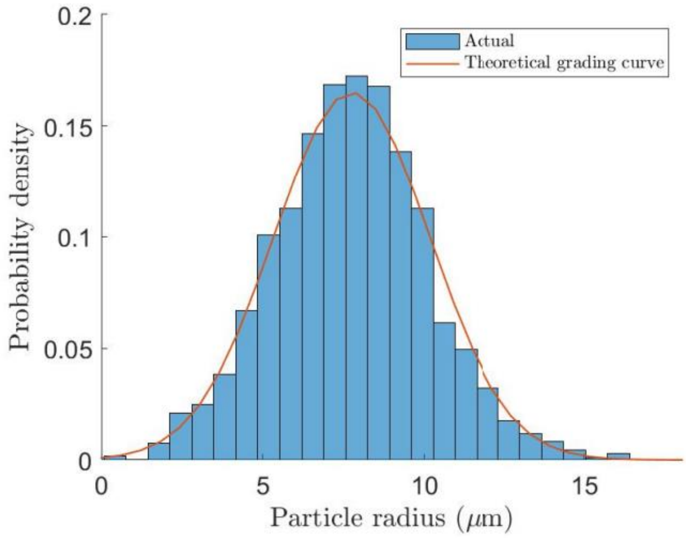


Figure 4: Comparison between theoretical value and actual value of particle size distribution.

## 5. Conclusions

(1) The 3D digital core visual modeling based on SCILAB software and process method is a convenient and reliable method to reconstruct digital core by programming, which has the advantages of low cost and fast implementation speed.

(2) Seen from the 2D pore fitting plane, the pore network generated by this 3D digital core visual modeling has good connectivity and is capable of hydrodynamic calculation.

(3) After comparison and verification, the rock particle size of this 3D digital core model accords with the normal distribution, and has a high similarity with the real core.

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