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Research on digital core reconstruction and micro water saturation

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Abstract: Rock physics experiment cost is high, long cycle.Based on 3D digital core tocarry out rock physics numerical simulation experiments will make up for its shortcomings.Introduce the basic principle of simulated annealing method, modeling reference function, using simulated annealing method to reconstruct the 3D digital cores, and the use of mathematical morphology simulation methodology to simulate digital core pore fluid distribution.Studies have shown that 3D digital core reconstruction based on the simulated annealing method is convenient and feasible modeling method based on a two-dimensional image of a core, using mathematical morphology method can determine the pore space fluid distribution of different water saturation of digital cores.

Keywords: *simulated annealing; digital core; water saturation*

I. INTRODUCTION

With the development of unconventional oil and gas resources, rock physics research in the evaluation of oil and gas accumulation has the increasingly important status. The unconventional reservoir, rock physics experiment has encountered many difficulties, such as low porosity and low permeability rock displacement, carbonate rock fracture is difficult to get a representative core, and oil shale rock physical experiment is difficult to carry out; at the same time, rock physics experiment cannot be quantitatively studying reservoir microscopic parameters on macroscopic physical properties of rocks,the capillary model, network model and percolation network model of reflecting the rock microstructure are all simplified. Therefore, based on the 3D digital the core to carry out numerical simulation of rock physics experiment will make up for the shortages [1-4]. Digital core reconstruction method mainly has two kinds: physical experiment method and numerical reconstruction method.Physical experiment method is based on the high accuracy of the experimental equipment to obtain the core of plane or three-dimensional data, so as to build a digital core; numerical method to reconstruct the digital core is usually based on the core slice images with a variety of statistical methods or simulation of the formation process of rock to establish digital cores.The physical methods used to construct the digital core include: sequence imaging, focusing scanning, magnetic resonance imaging, scanning;at present, the widely used numerical reconstruction method includes: Gauss simulation method, simulated annealing method, process simulation method, multi point statistics method, sequential indicator simulation method and Markov random reconstruction method[5-6].The author takes simulated annealing as an example to set up 3D digital cores, and uses mathematical morphology to simulate the distribution of fluid in the pore space, which provides an important guiding significance for solving many difficulties in rock physics experiment.

II. THREE DIMENSIONAL DIGITAL CORE RECONSTRUCTIONS

2.1 Basic principle of simulated annealing method

The basic idea of the simulated annealing method is to generate a series of parameter vectors to simulate the thermal motion of particles, and to reduce the control parameters of a simulated temperature slowly, so that the final cooling crystallization of the system reaches the minimum value of the system energy.

According to the laws of thermodynamics, a molecule is in a state of *i* when the temperatureis *T*, which meet Boltzmann probability distributions [7]:

$$P = \frac{\exp(-\frac{E_i}{k_B T})}{\sum_l \exp(-\frac{E_l}{k_B T})} = \frac{1}{Z(T)} \exp(-\frac{E_i}{k_B T}) \tag{1}$$

Formula: T is the absolute temperature, k_B expresses Boltzmann constant,$E_i$expressessystem energyin a state of *i* when the temperatureis T, $Z(T)$represents the probability distribution of the normalization factor, which indicates the relative probability of each state of the sum:

$$Z(T) = \sum_{l} \exp(-\frac{E_l}{k_B T}) \tag{2}$$

Assuming that the system enters a new state from the state i to the state j due to a random disturbance, the energy of the new state system isE_j . From the formula (2)can be seen that the probability of the object from the state*i*to the state *j*is:

$$P = \exp(\frac{E_i - E_j}{k_B T}) \tag{3}$$

If$E_i < E_j$, then accept the new state *j* as the current state; if $E_i \geq E_j$ then between [0, 1]generates a random numberλ, if $P > \lambda$ then accept the new state *j*, otherwise discarded.That Metropolis guideline [8]:

$$P(E_i \to E_j) = \begin{cases} 1 & if \quad E_j < E_i \\ \exp(\frac{E_i - E_j}{k_B T}) & if \quad E_j \geq E_i \end{cases} \tag{4}$$

With the decreasing of the temperature T, that is the annealing process, the object finally reachesthe minimum energy balance state, and the global optimal solution is obtained.

2.2 Modeling reference function

The reference function of the simulated annealing method is mainly the porosity, the autocorrelation function and the linear path function. These functions can be obtained from a core fault image, and the simulated annealing algorithm has a low requirement for the modeling data, one or more fault images can be. The modeling functions are as follows [3、8]:

$$Z(\vec{r}) = \begin{cases} 1, & \vec{r} \in \text{pore} \\ 0, & \vec{r} \notin \text{pore} \end{cases} \tag{5}$$

$$\phi = \overline{Z(\vec{r})} \tag{6}$$

$$S(r) = \overline{Z(\vec{r}) \times Z(\vec{r} + r)} \tag{7}$$

$$L(r) = P(\vec{r},\ \vec{r} + r) \tag{8}$$

$$P(\vec{r},\ \vec{r} + r) = \begin{cases} 1, & r_x \in \text{pore} \\ 0, & r_x \notin \text{pore} \end{cases} \tag{9}$$

In the formula, $Z(\vec{r})$ represents the phase function; ϕ represents porosity; $S(r)$ represents the autocorrelation function; $L(r)$represents a linear path function; $\vec{r}$represents any position of a point; r_x represents any point at$(\vec{r},\ \vec{r} + r)$; $\overline{\ \ }$ representsstatistics average.

The self-correlation function is characterized by probability of the two points in the same phase (pore or skeleton), which random selection of two points in the system. Blair et alproved that the image autocorrelation function has two important properties [9]:

$$S(r = 0) = \phi \tag{10}$$

$$S(r \geq a) = \phi^2 \tag{11}$$

Where $a$is the distance corresponding to the self-correlation function curves reach a stable valueϕ^2, which is the autocorrelation length. Linear path function is important function, which described in porous media the same locally connected performance.

2.3 The reconstruction process

First porosity α randomly generated three-dimensional mathematical core[8], in the pore space and rock skeleton space were randomly selected a pore and skeleton points, their positions werereversed by a new system, calculation of the energy of the new system, the Metropolis criterion to judge whether the new system is accepted, if the new system is accepted, then the update of the original system, otherwise the new system was abandoned and the original system is retained, so that the system optimize, eventually the runtime to terminate to obtain the 3D digital cores.

III. DISTRIBUTION OF PORE SPACE FLUID

Mathematical morphology is composed of a set of algebraic morphology [10-11]. There are 4 basic operations: expansion (or expansion), corrosion (or erosion), open and close operation. They are of different characteristics in the two value image and gray image.These basic operations can be derived and combined into various mathematical morphology algorithm, they can analyze and deal with shape and structure of the image, including image segmentation, feature extraction, edge detection, image filtering, image enhancement and restoration. Dilation and erosion operation is the basis of mathematical morphology; many morphological algorithms are based on the two basic operations.

3.1 Dilation and erosion

Dilation can expand image and make the lines thicker, the particles become larger, the gaps and holes become smaller or disappear and erosion operation can shrink the image lines thinner, the particles become small, slit and holeenlargement [10].

3.2 Open and close operation

Open and close operation two kinds of operation can remove a particular image details which is smaller than the structural elements, while ensuring the geometry does not produce global distortion. The opening operation is equivalent to the corrosion and expansion of the cascade, can filter out thrusting which is smaller than the structure element and cut off the long lap and play separation effect.Close operation is equivalent toexpansion and corrosion cascade, it can fill notch or hole which is smaller than the structure element, lap the short Intermittent and play connect function [10-11].

3.3 The pore space distribution of oil and water under different saturation

If only the rock skeleton and the pore space are considered, the 3D digital cores can be regarded as the 3D digital image of binarization.The rock skeleton is expressed in 0, and the pore space of the rock is expressed by 1.The mathematical morphology method is suitable for 3D digital cores.In order to visually display the result of mathematical morphology operation, taking a section of three dimensional digital cores as an example tointroduce the image of corrosion, expansion and open operation, as shown in Figure 1.Assumingresults of open operation characterize oil in the process of water driving oil, the remaining pore space is the characterization of formation water, the process is similar to displacement process of water wet rock.In water wet rock, non-wetting phase oil first to occupy large pores in the pore space, with the driving pressure increases, oil followed by invasion according to the pore radius from big to small order.Therefore, using of the pore space opening operation can simulate displacement process of water wet rock, then determined oil and water distribution in the pore space at different water saturation[6].

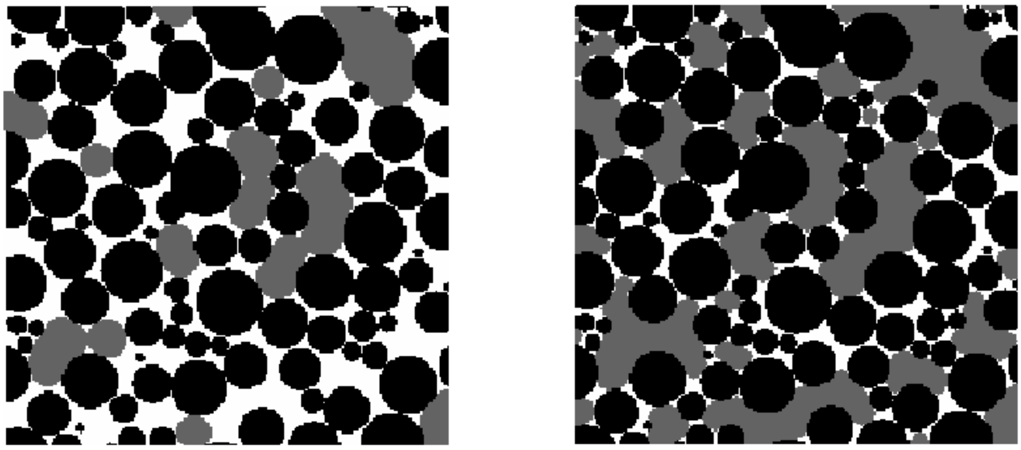

Figure 1 The displacement process

IV. CONCLUSIONS

3D digital core reconstruction based on the simulated annealing method is convenient and feasible modeling method based on a two-dimensional image of a core, using mathematical morphology method can determine the pore space fluid distribution of different water saturation of digital cores.

REFERENCES

[1] Jun Yao, Xiucai Zhao, Yanjing Yi, et al. The current situation and prospect on digital core technology[J]. Petroleum Geology and Recovery Efficiency, 2005, 12(6) : 52-55+86.

[2] XuefengLiu, Weiwei Zhang, Jianmeng Sun. Methods of constructing 3-D digital cores : A review[J]. Progress in Geophysics, 2013, 28(6) : 3066-3072.

[3] Jianmeng Sun, Liming Jiang, Xuefeng Liu, et al. Log application and prospect of digital core technology[J]. Well Logging Technology, 2013, 36(1) : 1-7.

[4] Jinbin Wan, Baodian Sun, Shoujun Chen, et al. Digital core technology research and its applications[J]. Well Logging Technology, 2012, 36(2) : 154-159.

[5] Xiucai Zhao. Numerical rock construction and pore network extraction [D]. China University of Petroleum(East China), 2009.

[6] Xuefeng Liu. Numerical simulation of elastic and electrical properties of rock based on digital cores[D]. China University of Petroleum(East China), 2010.

[7] Xueming Shi, Jiaying Wang. Lecture on non-linear inverse methods in geophysics (3) Simulated Annealing Method[J]. Chinese Journal of Engineering Geophysics, 2007, 4(3) : 165-174.

[8] Xiucai Zhao Jun Yao, Jun Tao, et al. A method of constructing digital core by simulated annealing algorithm[J]. Applied Mathematics A Journal of Chinese Universities, 2007, 22(2) : 127-133.

[9] Blair S C, Berge P A, Berryman J G. . Two-point correlation functions to characterize microgeometry and estimate permeabilities of synthetic and natural sandstones [C]. Lawrence Livermore National Laboratory Report, Livermore, 1993.

[10] Hua Wen. Research of image processing algorithm based on mathematic morphology[D]. Harbin Engineering University, 2007.

[11] RonghuaRen. Mathematical morphology and its application[D]. Xidian University, 2004.