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Overview of Study Methods of Reservoir Rock Pore Structure

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Abstract: Rock pore structure is the main factor affecting the fluid storage and hydrocarbon recovery, therefore a thorough understanding of reservoir rock pore structure is critical to improve oil and gas recovery factor. This paper introduces the study methods of reservoir rocks pore structure: laboratory experiment (capillary pressure curve method, casting sheet method, scanning electron microscope and CT scanning method), using well logging data (resistivity logging data and nuclear magnetic resonance logging data) and other methods (three dimensional pore structure simulation, neutron scattering and low pressure adsorption method) evaluation methods. The advantages and disadvantages of these methods are comprehensively analyzed. It is pointed out that the study of reservoir pore structure characteristics by using well logging data has great advantages.

Keywords: *pore structure, capillary pressure curve, well logging data, three dimensional pore structure simulation*

I. INTRODUCTION

The reservoir pore structure is the geometry, size, distribution and mutual connection of the pore and throat of the rock. For carbonate rocks, its pore structure mainly refers to the size, shape and mutually connected relation of rock with crack and hole[1]. A large number of exploration and development practice research shows that, The pore structure characteristics of reservoir rocks directly influence the reservoir and seepage flow capacity, and ultimately determine the distribution of oil and gas reservoir production capacity [2]。

The pore structure of reservoir is mainly studied by laboratory experiment, nuclear magnetic resonance log and conventional log data. The research method is gradually developed from the simple physical analysis to the advanced experimental test.The theory and method of the study also showed the characteristics of multi discipline.It is related to geology, chemistry, mathematics, physics and other disciplines[2]. Laboratory experimental methods mainly include: capillary pressure curve method, casting sheet method, scanning electron microscope and CT(Computed Tomography) scanning method. The study of micro pore structure by reservoir logging data has opened up a new way for laboratory experimental method, these analytical methods can be used to characterize the micro pore structure of the reservoir from different angles.

II. LABORATORY EXPERIMENT

2.1 Capillary pressure curve method

The capillary pressure curve of rock is the capillary pressure of reservoir rocks and wet phase (or non-wet phase) relation curves of fluid saturation[3]. Capillary pressure curve reflects the possible size and pore volume of pore throat which silver may enter under a certain displacement pressure. Therefore, the capillary pressure curves can be used to study the pore structure of the reservoir. Methods for determining capillary pressure mainly include:semi permeable diaphragm method, pressure mercury method and centrifuge method.

The semi permeable diaphragm method is considered as a capillary with different radius.The main step is to place the core of saturated wet phase fluid (water) into a core room with a semi permeable separator. After treating, the semi permeable diaphragm only allows the wet phase to pass through, the non-wet phase can’t pass. The material of semi permeable diaphragm is ceramic, glass, powder metal sintered plate, etc.A room which filled with non-wet phase fluid(oil or gas), then the non-wet phase is subjected to the pressure of displacement.The non-wet phase will overcome the capillary force into the core to drain the water in it.Record a series of pressure values and their corresponding cumulative discharge volumes.According to the initial sample saturated wet phase volume can calculate the wet phase saturationunder each pressure.According to the measured data the curve of displacement pressure and saturation of the core can be drew, namely displacement of capillary pressure curve. The advantage of the semi permeable diaphragm method is that the water and oil displacement are close to the simulated oil reservoir, measurement accuracy, simple operation，it can also measure samplesat the same time.But the drawback is that the test time is too long, it can’t obtain completecapillary pressure curve in the measurement of low permeability rock. Dong Dapeng et al.[4]studied the application of semi permeable diaphragm method in constructing capillary pressure curve.The analysis shows that using the thin film material to replace the ceramic membranecan shorten the test time of semi permeable diaphragm method to a great extent,the operation efficiency of the method can be improved.

Pressure mercury method also known as mercury porosity method. Its basic principle is: the process of non-wetphase mercury entering rock can be regarded as a process of non-wet phase displacement[5]. With increasing injection pressure, when the pressure exceeds the capillary pressure of the pore throat mercury enters the pores. At this time the injection pressure is equivalent to capillary pressure, the corresponding capillary radius is the pore throat radius, the volume of mercury in the pore is the volume of pores in the throat.Pore size distribution curve and capillary pressure curve can be obtained with changing the injection pressure constantly. The relationship between capillary pressure and the capillary diameter is:

$$P_c = \frac{2\sigma \cos\theta}{r} \quad (1)$$

where: P_c is the capillary pressure(MPa); σ is the fluid interfacial tension(N/m); θ is the wetting contact angle, r is the capillary radius. The capillary pressure curve can be obtained in the experiment. Fig.1 is a typical capillary pressure curve;Fig.2 is the frequency distribution histogram of pore radius[6]. The principle of capillary shows that the fluid permeability influences the pore size and pore throat radius, the largest diameter of the throat radius determines the size of the fluid, the higher the displacement pressure, the lower the permeability.

In recent years, the development of the constant pressure method is a new method for the determination of reservoir capillary pressure curve. Xu Ying[7]tested the core pore structure of different permeability levels by constant velocity mercury injection, studied the distribution characteristics of pore and throat at different permeability levels.It is concluded that the constant velocity mercury injection can not only provide the distribution of the pore radius, but also distinguish the pore and throat, obtain the number of pores and throats, and provide three kinds of capillary pressure curves.

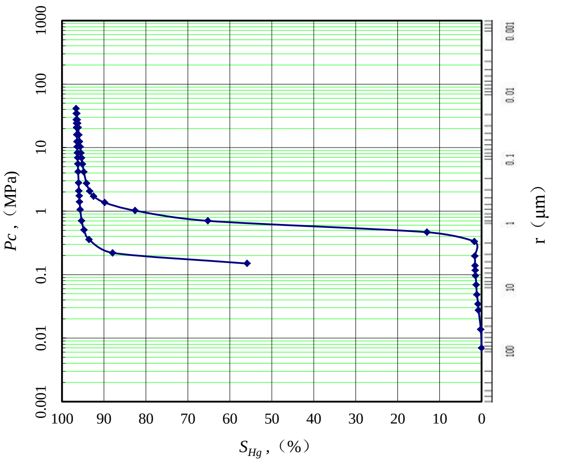

Fig1 Typical capillary pressure curve

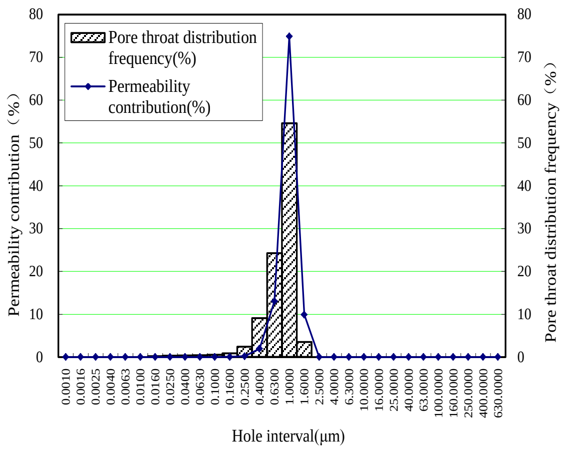

Fig 2 Frequency distribution histogram of pore radius

Centrifuge is using strong displacement pressureproduced by centrifugal force to displace the wet phase from porous medium.In the experiment, the increasing centrifugal force is obtained by gradually increasing the speed of the centrifuge namely increase the angular velocity. Thus the wetting phase of porous media which hasmany kinds of permeability is driven out.Finally draw the capillary pressure curve. The advantage of the centrifuge method is that the determination of the speed is fast.The operation is simple and the precision is high.

2.2Casting sheet method

Casting thin sheet is one of the most direct methods to analyze the characteristics of two dimensional spaces.Through the experiment, the distribution and connectivity of the pore, the mineral composition and the cementation condition can be obtained.The specific method is that the dyeing resin liquid glue is injected into the core pore under the pressure of the vacuum state, When the resin or liquid adhesive solidified grinding them into rock slices, observing under the microscope.This method provides an effective way for the study of rock pore size distribution and geometry, average pore throat ratio, average pore throat radius, throat, coordination number, length and width of crack, fracture rate and so on [8].Cast thin section has low requirement on sample,it is well favored by logging and geologists.

2.3Scanning electron microscope

The principle of scanning electron microscope is that the electron gun emits an incident beam with a certain energy, after accelerated deflection, focus on the sample surface into a very thin electron beam, the electron beam scans the surface of the sample, electrons interact with the sample to produce a variety of signals, by receiving, amplifying and displaying the information, the observation of the surface morphology of the sample was obtained.Scanning electron microscope images of minerals has the characteristics of large depth of field, higher resolution and strong sense of three-dimensional，it can also obtain the information of intergranular pore, intergranular pore, throat connection and coordination number and so on[9].

2.4CT scanning method

CT scanning method is to launch X - rays on the core for rotating scanning.A set of one-dimensional projection data can be collected at each location.In combination with rotational motion, the projection data in many directions can be obtained.Combined with these projection data, the cross section distribution of X - ray attenuation coefficient can be obtained by iterative calculation.This is the basis of the reconstruction of the CT image of the core section.Core CT scanning can provide the distribution of pore throat, connectivity and physical parameters.The advantage of the CT scanning method is that it can quickly observe the internal structure of the whole core under the condition of no damage to the core,but the disadvantage is that the measurement method is complex, and the cost is high. [10]

III. LOGGINGANALYSIS METHOD

Well logging analysis method is a powerful tool for reservoir pore structure, especially in the quantitative evaluation of pore structure.The well logging data has the advantages of "vertical" and "face", this opens up a new way to study the pore structure of the reservoir rocks in the area.The well logging data of the pore structure of the reservoir is mainly included in the data of resistivity logging and nuclear magnetic resonance logging.

3.1Study on the pore structure of rock by means of resistivity logging data

Resistivity logging data reflects the resistivity of different fluids (oil, gas, water) in the complex pore structure of rock.Therefore, the different pore structure characteristics of reservoir rock will influence the resistivity logging response.At home and abroad, the research on micro pore structure model, physical model and related theory of rock is more, including the capillary bundle model, tortuous degree model, resistor network model, percolation theory, effective medium theory, fractal theory and model etc. Mao Zhiqiang[11] establish the network model based on the effective medium and percolation theory to simulate the influences of two-phase fluid rock resistivity of the changing of rock micro pore structure characteristic parameters, such as pore throat size and distribution, water film thickness and pore connectivity.The main factors that affect the resistivity change law of oil and gas reservoir are pore connectivity, rock solid particle surface bound water film thickness, pore size and pore throat radius ratio. Yang Jinlin[12] et al.uses a simplified rock conductivity model which defines a rock pore structure parameter S. The degree and size of the pore channel of the reservoir are comprehensively reflected. Li Qiushi[13] et al. obtained thatthe resistivity factor F in the Archie formula is not only related to the porosity and the tortuous degree of the reservoir, but also related to the throat ratio of the reservoir, the smaller the pore throat ratio, the lower the F value.

3.2Study on the pore structure of rock by NMR logging data

Nuclear magnetic resonance logging technology has the characteristics of abundant information, high measurement accuracy, and sensitivity to the pore structure and pore fluid flow.Multi exponential inversion of NMR echo acquisition on can obtain NMR T_2 relaxation time spectrum.Using T_2 spectrum can evaluate reservoir pore structure qualitatively.For better reservoir with pore structure, the large pore component of T_2 distribution has the main advantage, it shows the distribution characteristics of double peaks; and the reservoir with poor pore structure, the small and medium porosity group of T_2 distributionhas the main advantage, and the relaxation time is shorter.

IV. OTHER METHODS

In addition to the above methods, the simulation method, three-dimensional pore structure of neutron scattering and low pressure adsorption method all have good effects. The difficult to study the pore structure is to obtain the three-dimensional pore structure model of whole rock. There are three kinds of methods to establish three-dimensional pore structure model at present: slice combination method, X ray imaging method and image reconstruction method based on slice analysis. Oren[14] et al. proposed a process approach to solve the above problems in 2002, the numerical model of sandstone is reconstructed by this method. This model can be used to reproduce the geometric properties and conduction properties of real rocks.

Low pressure adsorption was used in the study of nanometer materials, in recent years, it applied to study the structure of the nanometer pore throat. CO_2 low pressure adsorption is effective on the description of micro pore the (pore diameter<2 nm), low temperature adsorption of N_2 is effective for low and medium pores.[15]

Small angle and ultra-small angle neutron scattering is applied in the tight reservoir of shale gas, it is able to detect a wide range of aperture.

V. CONCLUSIONS

The pore structure of reservoir rocks is an important parameter for the evaluation of oil and gas reservoirs. It is also the key to develop the production of oil and gas reservoir and increase the recovery ratio of oil and gas.The laboratory experiment obtains the pore structure parameters of rock by researching capillary pressure curve of rock. However, each method has its own limitations.Therefore, various experimental methods should be combined.The constant velocity mercury intrusion method which determines the large pores can be combined with the low pressure adsorption experimental method for the measurement of micro pores.Nuclear magnetic resonance, electron microscope scanning and other methods can be used to validate the results of the analyzedpore structure.Through the comparison and analysis of the capillary pressure curve of rock, rock pore structure characteristics can be further studied. With the improvement of experimental method and experimental instrument,more and more methods will become more and more common, such as small angle neutron scattering and small angle neutron scattering.The pore structure of the reservoir will be more and more precise, itwill greatly enhance the fluid flow mechanism and storage research.

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