Study on Rock Stress Sensitivity of Chang 8 Tight Oil Reservoir in Fuxian Block

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Abstract: The combined oil reservoir under the Yanchang Formation has been proven to have approximately 340 million tons of oil geological reserves, which is an important resource guarantee for Yanchang Oil to achieve the stable production target of 10 million tons. The development and research of oil reservoirs are in the initial stage, and there are many technical difficulties in the overall development, which seriously affect the sustained high and stable production of the lower combination reservoir. Therefore, nuclear magnetic resonance technology was used to conduct stress sensitivity testing on the pore structure of the Chang-8 reservoir in Fuxian County, Ordos Basin. It was recognized that large-diameter pores are easily compressed, but porosity accounts for a relatively small proportion, so the influence of confining pressure on permeability is greater.

1. Introduction

Nuclear magnetic resonance refers to the interaction between hydrogen nuclei and a magnetic field. Formation fluids (oil, gas, water) are rich in hydrogen nuclei. The speed of fluid relaxation in rock pores, i.e. the magnitude of relaxation time, depends on the strength of the force exerted by the solid surface on the fluid molecules. The internal mechanism of the strength of this force depends on three aspects: firstly, the pore size within the rock sample, secondly, the solid surface properties within the rock sample, and thirdly, the fluid type and properties of the saturated fluid within the rock sample. The size of the relaxation time implies information such as pore size, solid surface properties, and fluid properties. Therefore, conversely, after measuring the relaxation time, analysis can be conducted on the pore size, solid surface properties, fluid type, and fluid properties within the rock sample.

When the core is vacuumed and saturated with saline water, the T2 relaxation time of saline water in the core pores mainly depends on the strength of the water molecules subjected to the surface forces of the pore solid[1,2]. When water molecules are subjected to strong forces on the surface of porous solids, this portion of water exhibits a smaller T2 relaxation time on nuclear magnetic resonance. When the force of water molecules on the porous solid surface is weak, the T2 relaxation time of this part of water is relatively long. There is a significant difference in the relaxation time of nuclear magnetic resonance T2 between the bound fluid and the movable fluid in the core pores. Therefore, the occurrence state of saline water in the core pores can be analyzed using nuclear magnetic resonance T2 spectrum[3].

2. Experimental setup

The experimental instruments used in the experiment are shown in the figure 1, consisting of Oxford MARAN DRX 2 nuclear magnetic resonance instrument, nuclear magnetic core gripper, ISCO confining pressure pump, etc. in the UK .

Figure 1 Stress sensitive nuclear magnetic resonance testing device

3. Experimental process

The experimental process involves extracting and cleaning the rock sample, drying it to test its porosity and permeability, and vacuuming for 8 hours until the vacuum reaches 50mto[4]. The sample is saturated with 65000mg/L of standard salt water with mineralization degree, and is placed in a pressurized tank. The pressure is applied to 20 MPa for 24 hours before being taken out for the experiment. Perform nuclear magnetic resonance T2 testing using saturated samples. Place the sample in the holder, apply a 45MPa confining pressure, and test the T2 spectrum under stable confining pressure conditions. Executive standard: SY/T 6490-2007

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<Laboratory Measurement Specification for Nuclear Magnetic Resonance Parameters of Rock Samples>[5].

4. Experimental results and analysis

Four rock samples (four wells) from the Chang 8 reservoir were selected for nuclear magnetic resonance testing, and four sets of nuclear magnetic resonance tests were conducted. The basic parameters of the rock sample are shown in Table 1.

Table 1 Basic parameters of testing rock samples

Serial Number	Well No	Coring segment number	Well depth/m	length/mm	diameter/mm
1	L231	7-12	1640.9	50.38	25.2
2	L242	35-40	1695.2	50.58	25.2
3	L338	29-34	1719.5	49.32	25.2
4	L352	59-64	1664.0	50.32	25.2

4.1.Analytical methods

By analyzing the nuclear magnetic resonance T2 spectra of the tested rock core under confining pressures of 0MPa and 45MPa, the cumulative porosity, porosity components, and permeability parameters of the rock sample can be obtained.

The experimental instruments used in the experiment are shown in the figure, consisting of Oxford MARAN DRX 2 nuclear magnetic resonance instrument, nuclear magnetic core gripper, ISCO confining pressure pump, etc. in the UK[6].

The cumulative porosity of the L231 well rock sample tested without confining pressure is 1.78%, while under a confining pressure of 45MPa, the cumulative porosity of the core is 1.62%[7]. The test results of T2 spectra and pore distribution maps for the two states are shown in Figures 2. Comparing the curves under the two states, it can be seen that the areas with significant changes in pore structure appear in the peak and valley regions of the curve, indicating that confining pressure has a greater impact on larger pore sizes and a minimal impact on smaller pore sizes[8,9].

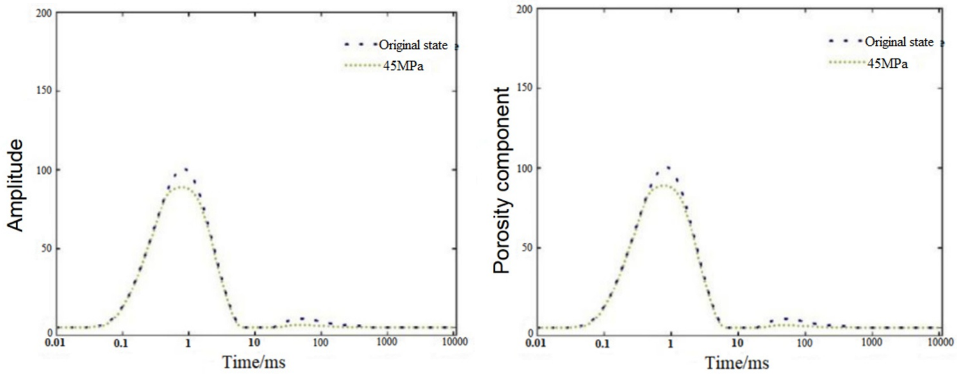

Figure 2 T2 Spectrum (Left) and Porosity Component Distribution (Right) of Core Section 2-2/46 in Well L231

The calculation of permeability adopts the SDR model, and the expression is as follows:,

$$K = A\varphi^{c}(\overline{T}_{2gm})^{B} \tag{1}$$

In the formula, A is the permeability product factor of the SDR model, taking A=4mD; B is the logarithmic mean index of the SDR model T2, taken as B=2; C is the porosity index of the SDR model, taking C=4; φ is the porosity of the rock sample; Is the geometric mean of T2[9].

4.2. Analysis results

Analyze the T2 spectra of four sets of experiments, and the obtained experimental results are shown in Table 2, Figure 4 and Figure 5 For the Chang 8 reservoir, under a confining pressure of 45MPa, the range of rock porosity reduction is about 5% to 22%, with an average of 14%[10,11]. The permeability ratio (the ratio of permeability under 45MPa confining pressure to permeability under 0MPa confining pressure) was calculated using the SDR model. The permeability of rocks under 45MPa confining pressure decreased to 9%~66% of the initial value, with an average of 36%. From Figure 3, it can be seen that in the same rock sample, confining pressure mainly compresses larger pore sizes, while smaller pore structures remain almost unchanged[12]. The above results indicate that confining pressure has a greater impact on permeability, as larger pore sizes are easily compressed, but porosity accounts for a relatively small proportion[13,14].

Table 2 Changes in Porosity and Permeability of Test Rock Samples

Serial Number	Well No	Coring segment number	Well depth (m)	Original porosity (%)	Porosity at 45MPa（%）	Reduction amplitude of porosity（%）	Permeability ratio（%）
1	L231	7-12	1640.9	1.78	1.62	8.75	51.96
2	L242	35-40	1695.2	4.16	3.38	22.33	9.47
3	L338	29-34	1719.5	3.03	2.46	19.00	16.71
4	L352	59-64	1664.0	1.78	1.62	4.71	66.16

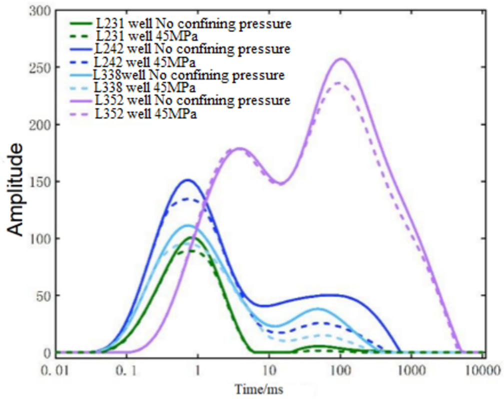

Figure 3 T2 Spectra of Rock under Unconfined Confinement Pressure/45MPa Confinement Pressure

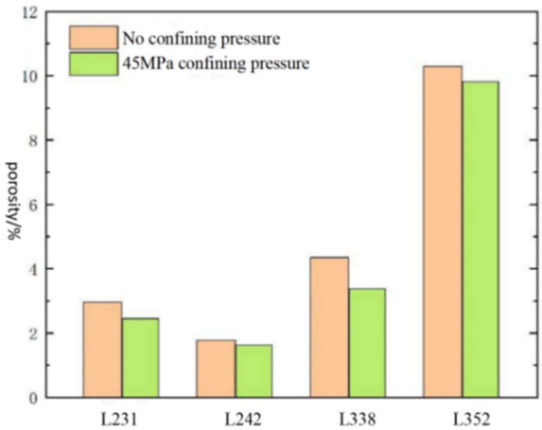

Figure 4 Comparison of Pores in Rocks under No Pressure 45MPa

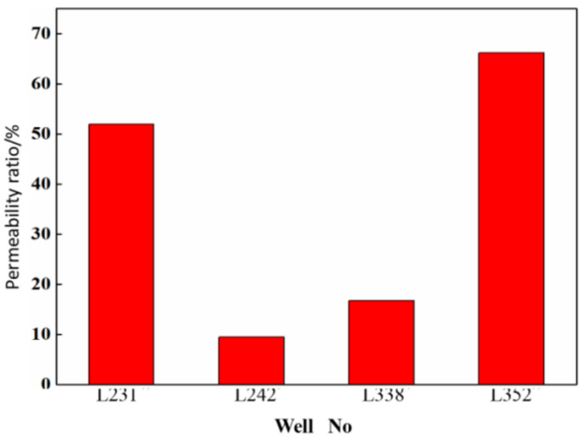

Figure 5 Permeability ratio of rocks under 45MPa confining pressure

5. Conclusions

1. For the Chang 8 reservoir, under a confining pressure of 45MPa, the range of rock porosity reduction is about 5% to 22%, with an average of 14%.

2.The permeability of rocks under a confining pressure of 45 MPa decreases to 9%~66% of the initial value, with an average of 36%.

3.In the same rock sample, confining pressure mainly compresses larger pore sizes, while the smaller pore structure remains almost unchanged.

4.The influence of confining pressure on permeability is greater because larger pore sizes are easily compressed, but the proportion of porosity is relatively small.

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