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Hole throat characteristics of Chang 7 Member tight sandstone reservoir in Fuxian area

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Abstract

This paper elucidates the pore throat characteristics of tight sandstone reservoirs in Fuxian area of the southeast margin of the Ordos Basin, explore the key to affect the reservoir storage and seepage capacity, and better discover the seepage law of tight sandstone oil and gas and improve the development effect. Taking the area of Fuxian as an example, the nuclear magnetic resonance T2 spectrum, pore throat radius conversion coefficient and pore throat radius distribution were obtained by combining the high-pressure pump method and the improved method, and the pore structure characteristics of the reservoir were quantitatively studied, and the causes of the difference in the pore structure of tight sandstone and reservoir effectiveness were discussed by combining rock thin sections and scanning electron microscopy. The results show that the NMR pore throat radius curve obtained by the improved method has a high degree of agreement with the mercury pressure curve, which significantly improves the accuracy of the tight sandstone NMR test. The pore types of the Chang 7 Member reservoir were mainly residual intergranular pores and dissolution pores, and the pore throat radius was distributed in 0.003~100.000μm. According to the experiment, it can be concluded that the Chang 7 Member-section reservoir pore throat in the area of Fuxian is divided into three categories, that is, the Class A pore throat is small hole-fine throat and fine throat type, mainly micron-sized intergranular pores and large dissolution pores, and oil and gas are shown above oil spot level. Class B. pore throat is small-microlaryngeal type, mainly with larger clay intergranular pores and dissolution pores, and oil and gas are shown as oil trace grade; Class C. pore throat is fine-porous, microporous-microlaryngeal type, mainly nano-scale intergranular pores, and oil and gas are fluorescent or oil-free.

Keywords

Tight reservoirs; Foramen features; NMR method; Chang 7 Member; Fuxian.

1. Introduction

Unconventional oil and gas has always been a key link in the oil and gas exploration research and development of [1], ordos basin oil and gas resources reserves [2], which extend the key layer [3], extend the characteristics of reservoir physical poor, hole throat structure is complex, strong heterogeneity [4], therefore for the tight oil exploration in the ordos basin is still a difficult challenge [5]. Many scholars have conducted research on the extended reservoir characteristics [6-8], but there are few studies on the classification of pore and throat characteristics in Fuxian County according to the reservoir characteristics. Therefore, this paper mainly studies the characteristics of reservoir pore throat in Fuxian County. In recent years, the emerging NMR technology with the advantages of rapid, non-destructive and repeatable has entered our field. It can conduct continuous and mass testing of dense reservoir, and can also make high precision measurement of dense sandstone.Songtao Baiet al. [9] studied the physical significance of the NMR parameter rock based on the normal distribution model and the geological hybrid empirical distribution model, and demonstrated the applicability and reliability of the quantitative characterization of the microscopic pore structure of the reservoir. Hongrui Yuanet al. [10] theoretically analyzed the correlation between NMR T_2 spectrum and NMR decay signal of different pore fluids, and established the conversion method of T_2 spectrum and pore throat radius in shale reservoir in Changqing oilfield, which provided data support for the interpretation and evaluation of NMR hydrocarbon layer.Shuhui Caoet al. [11] also explored the relationship between shale nuclear magnetic pore distribution and the experimental pore distribution by applying gas adsorption method, mercury pressing method and NMR T_2 spectrum, and initially established the corresponding relationship between shale NMR T_2 spectrum and pore radius in Niuhootang group. In this paper, the combined mercury pressure method and nuclear magnetic resonance method were used to support the hole throat size and distribution characteristics of the Chang 7 Member dense sandstone reservoir in Fuxian County, in order to provide theoretical and data support in the prediction of favorable areas.

2. Rocky characteristics

Through field outcrop and core observation and scanning electron microscopy in the study, the is shows that the rock type is mainly feldspar sandstone. Rock debris group should be feldspar, quartz accounted for 84.00%-98.00%, among, Phrospar volume fraction from 47.25%-67.20%, The mean value was 53.50%; Quartz volume fraction from 18.65%-30.48%, The mean value was 24.53%; Mica volume fraction from 2.00%-14.00%, The mean value was 4.44%; The debris volume fraction is 8.00% -24.00%, The mean value was 12.38%; The number of integral als in rock is 5.00%-17.00%, The mean value was 10.91%. The main cement is calcite, followed by chlorite, hydromica and silicite, and contains a small amount of turbid zeolite, the terrigenous mud base content is very low, the volume fraction of calcalite is about 3.58%, the volume fraction of chlorite is about 3.25%, the volume fraction is about 1.25% and the volume fraction is about 1.50%, the volume fraction of trace turbid zeolite is about 1.33%. For this analysis, the porosity distribution of Chang 7 Memeber reservoirs is 1.30%-12.60%, mean is 7.13%; permeability distribution is 0.04×10-3-$6.22\times10^{-3}\mu m^2$, mean is $0.27\times10^{-3}\mu m^2$. Overall, Chang 7 Member reservoirs belong to low porosity and low permeability reservoir.

3. Traverse characteristics of reservoir hole

3.1. Pore type.

By electron microscopy, the following pore types mainly exist in the dense sandstone reservoir: residual intergranular pore, intergranular dissolved pore, intergranular dissolved pore, intercrystal hole and split hole. These pores, with the remaining intergranular pore, internal pore, and internal pore, and crack pore and intercrystal pore data is less, analysis results say Chang 7 Member reservoir average face rate is about 4.29%, according to the composition and cause to produce these pores can be divided into micro cracks, native pore and secondary pore 3 types. The residual intergranular pore is the main component of native pores, with different sizes, general connectivity, uneven distribution, and good development in the study area , and is the most important pore type with 7 long segments. The pore size distribution area is 15.00-80.00μ m. The average face rate is 1.25%, accounting for about 55.00% of the total face rate. The remaining pore edge is wrapped by chlorite film, which prevents the compaction and partial cementation. At the same time, rigid particles can also effectively prevent the compaction, so this kind of pores can be effectively preserved. Secondary pores can be divided into dissolution pores and intercrystalline pores, among which they can be subdivided into intergranular pores and intergranular pores. In the study area, large dissolution pores form into intergranular dissolution expansion pores, which are mostly feldspar, irregular clay minerals and mineral particles with blurred boundaries . Phrospar, cuttings and calcite, the pores that begin to dissolve along the internal joints are called the dissolved pores, which have the characteristics of different sizes and shapes and uneven distribution. Another kind of pore cuttings dissolution hole is formed by the dissolution of its internal unstable components including argillaceous rock and slate cuttings. In the study area, the development of such debris pores was not high, probably because of the high content of feldspar in the sandstone, resulting in the dissolution of internal pores mainly developed in feldspar. The average face rate is 0.60%, accounting for 24.00% of the total face rate. In the process of sandstone, feldspar, calcite and mica, etc. These pores are generally less than 5.50μm, and the average face rate is 0.250%, accounting for 15.00% of the total face rate. In addition, some micropores are common in the sandstone in the study area, including joints of feldase, calcite and clea of mica . Through microscopic sheet observation, the structural cracks that can significantly improve the fluid permeability were also common in the study area, with 0.5-10μm and the average face rate of 0.15%, accounting for 5.00% of the total face rate .

3.2. Size and area of distribution

By testing the core samples of F3, F28, F86, F285, the maximum mercury saturation distribution zone was 35.83%~92.20%, the mean is 65.69%, and the mean mercury withdrawal efficiency was 32.93% . Through the data analysis, it can be seen that a large amount of mercury is easy to stay in the pore under the action of the complex and small roaring throat, indicating that its seepage capacity is relatively poor. The difference in permeability will also make the distribution of the throat different. Generally speaking, the proportion of the larger throat is larger, and the radius of the sandstone is 0.0075~2.9900μm. However, large pores greater than 3.0000 μm can still be found by scanning electron microscopy, which fully proves that although the distribution range of laryngeal radius of high pressure mercury pressure method is large, the results still have a large error.

Compared with the high pressure mercury pressing method, the NMR method can accurately reflect the pore information in the sandstone, so it can quantitatively analyze the conversion coefficient of the pore throat radius calculated by the high pressure mercury pressing curve and the distribution of the pore throat radius of the T_2 spectrum. We can add up the method [14] by using the pore throat data and the maximum pore of the NMR T_2 spectra. By using the conversion coefficient of C, the relaxation time distribution of the T_2 spectrum and the T_2 conversion radius of the relaxation time , the pore radius distribution of the dense sandstone reservoir in section 7 was studied.

When the core is completely saturated with water, the NMR T_2 relaxation time distribution map can approximately represent the pore diameter distribution and pore structure. In general, the larger the core aperture, the longer the relaxation time of the NMR signal, and vice versa. However, the relative amplitude of the signal corresponding to the relaxation time can indicate the cumulative number of the corresponding size pores. Therefore, the relaxation time spectrum can be used to well reflect the pore structure characteristics of different types of core samples. Number 4 had a porosity of 6.98% with a permeability of $0.02\times10^{-3}\mu m^2$ and sample number 2 of 8.69% with a permeability of $0.06\times10^{-3}\mu m^2$. Combined with the physical properties, comparing the T_2 relaxation time distribution map of the two samples, the better the physical property of the core, the greater the porosity and permeability, the higher the amplitude of the T_2 spectrum, and the larger the area occupied by the spectrum. In addition, if the physical properties of the core are good, the change of T_2 spectrum after saturation and centrifugal action is more significant, while if the physical properties of the core are poor, the difference of T_2 spectrum between the two states is small, indicating that the content of movable water is little or difficult to separate.

According to the previous research on the NMR relaxation mechanism and the measurement principle of rock properties, the transverse relaxation time T_2 is proportional to the pore throat radius r, when the rock is basically uniform magnetic field and the water is fully saturated in the pore:

$$T_2=Cr \quad (1)$$

T_2: NMR lateral relaxation time, r: pore throat radius, C: conversion coefficient In mercury pressure experiments on dense sandstone, there is often a mercury intake saturation of less than 100% or even lower, which means that the mercury pressure data does not fully reflect many tiny pores in dense rocks. NMR T_2 spectrum technology has higher accuracy, because the two experiments have differences in the calculation of the pore throat distribution, so to accurately obtain the NMR T_2 spectrum and the pore throat radius conversion coefficient C value, it is necessary to compare the actual pore throat radius between the mercury pressure data and the T_2 spectrum. Each sample accumulated the curve from large to small pores and normalized the signal intensity of the T_2 spectrum. It can be seen that with the shortening of the T_2 relaxation time, the pore throat radius decreases. The cumulative curve of the laryngeal radius data was also obtained by the cumulative maximum of mercury corresponding to the minimum throat radius value. It is clear that the mercury pressure accumulation curve under the maximum mercury injection pressure reflects the information of the pore throat radius, while the left side of the T_2 spectrum accumulation curve represents the curve of the micropore throat radius, and the right side can be compared with the mercury pressure data. Compcompare the cumulative percentage of the T_2 spectrum on the right side of the curve. This ensures the identity between the T_2 spectrum and the radius of the mercury hole. The same physical significance is the NMR T_2 spectrum and the longitudinal mercury pressure curve accumulation, which corresponds to the percentage accumulation represented by the different throat radius of the pore. Therefore, two columns of values were obtained by interpolating the vertical axis, and the T_2 value and the equal spacing percentage represented by the radius of the mercury hole accumulated [15]. Finally, the best rotation between the T_2 value and the throat radius.

The NMR T_2 spectrum is converted into a pore throat radius distribution curve according to equation (1). Figure 7 is the distribution map of T_2 relaxation time conversion radius of sample 4 and 2. According to the curve, the pore radius is from 0.5-700 nm, both less than 1000nm, and the pore radius of sample 2 is from 5-7000 nm. Although it is more than 1000nm, the distribution is very small, mainly developing less than 1000nm. Therefore, the quantitative analysis of the pore structure by NMR combined with mercury pressure data can show that the study area mainly developed nanoscale pores, with little micrometer pore development.

3.3. Hole throat type

Because According to the distribution, size and characteristics of the study area, the length of the study area was divided into three types. Class A pore throat. According to the test results, this kind of pore throat mainly develops in the fine sandstone in the underwater diversion channel, corresponding to the reservoir with good storage and seepage function. The sandstone has low adhesive content and strong connectivity, mainly large dissolved pores and residual intergranular pores. The main distribution area of the radius of the throat is 0.35-18.00μm, and the throat is mainly micron size, which belongs to the small hole-fine throat type, and the homogeneity of the throat is good. The porosity is greater than 8.50%, the permeability is greater than $0.40\times10^{-3}\mu m^2$, and the oil spot grade is high. The discharge pressure is low, the distribution curve is 0.25-1.25MPa, the median radius of the throat is 0.05-0.25μm, the maximum mercury saturation exceeds 80%, and the mercury withdrawal efficiency is 32%-

65%. F3 well. Class B pore throat. According to the test results, this kind of pore throat is mainly developed in the very fine sandstone in the underwater diversion channel, corresponding to the reservoir with general storage and seepage functions. The sandstone has a high content of cement, mainly large clay intercrystalline pores and dissolution pores. The main distribution area of the pore throat radius is 0.15-9.55μm, which belongs to the small pore-microthroat type. The porosity distribution area is 5.0%-9.75%, the permeability distribution area is 0.23×10-3-0.42×10^{-3}μm^2, and the oil grade is oil grade. The displacement pressure is low, the distribution curve is 0.75-2.00MPa, the median throat radius distribution area of 0.08-0.25μm, the maximum mercury saturation distribution area of 55% - 85%, and the mercury withdrawal efficiency is 18%~36%. Well F28 is represented. (3) Class C pore throat. According to the test results, this kind of pore throat is mainly developed in the siltstone in the underwater natural dike, corresponding to the reservoir with poor storage and seepage function. The cement content in the sandstone is high, the pore throat is not developed, and the smaller clay mineral intercrystalline pores are mainly used. The main distribution area of the pore throat radius is 0.08-3.20μm, which belongs to the fine pore-microthroat type. Porosity less than 9.0%, permeability less than 0.15×10^{-3}μm^2, and oil level was fluorescent or oil free. The discharge pressure is high, generally greater than 2.50MPa, the median throat radius distribution area is 0.02-0.10μm, the maximum mercury saturation distribution area is 35%-75%, and the mercury withdrawal efficiency is 15%~30%. F86 well as a representative.

4. Conclusion

By applying high pressure mercury and NMR techniques to test the characteristics of the study area, we were able to fully reveal the distribution of the reservoir pore throat. Here are the key conclusions we draw: (1) The main rock type of the Chang 7 Member oil formation in Fuxian area is feldspar sandstone, containing a small amount of clastic feldspar. Overall, this is a reservoir with extremely low porosity and ultra-low permeability. There are various pore types in the dense sandstone dense reservoir in the study area, among which the residual intergranular holes and dissolution holes dominate, and a few intercrystalline holes and microcracks of clay minerals. (2) In the classification of pore throat of Chang 7 Member sandstone reservoir, we can divide it into three types: Class A is the small hole-fine throat type in the fine sandstone reservoir developed in the underwater diversion channel, and the oil and gas level is oil spot level above. Class B is the pore-microlaryngeal micron pore throat developed in the very fine sandstone reservoir at the edge of the underwater diversion channel, and the oil and gas class is the oil trace grade. Class C is the fine pore-type nano-scale pore throat in the siltstone reservoir in the developing underwater natural dike. The oil and gas level is fluorescent or without oil.

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