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The research of the Pore structure characteristics of ultra-low permeability reservoir based on constant velocity mercury intrusion in X group,Jimsar sag, Junggar Basin

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Abstract: The Junggar basin in Jimsar depression X group's lithology give priority to fine siltstone, micritic dolomite and transition rocks, the average porosity is 9.17%, the average permeability is 0.15 mD, belongs to low porosity, low permeability reservoir. With the method of conventional high pressure mercury injection experiment we find out that, Reservoir microscopic pore structure change is poor; with the method of Constant velocity mercury injection experiment learned that, Reservoir percolation ability is mainly composed of throat radius distribution and pore throat radius ratio distribution.

Keywords: Pore structure; conventional high pressure mercury; Constant velocity mercury; Lucaogou formation.

INTRODUCTION

The research of oil and gas reservoir has always been the focus of petroleum geology and oil field exploration, along with the development of reservoir intricacy research and the continuous progress of unconventional oil and gas development technology, and the study on reservoir pore structure characteristics will also serve to guide the improvement of productivity of oil wells and oil recovery. At present, the main way to obtain the quantitative data of micro pore structure of reservoir is the technology of mercury injection. Constant velocity mercury injection is a porous medium formed by the combination of different diameter pore and throat, which can provide the distribution of micro pore and throat of tight oil reservoir and the correlation between them, in order to acquire more detailed physical parameters. In this experiment, the method of constant velocity mercury injection is used to study the micro pore structure of tight oil reservoir.

Regional overview

Jimsar depression is located in the southwest of Junggar basin. The X group is the main formation of tight oil in this depression, with strong compaction and cementation action for medfine lithology such as siltstone class (dolomitic Silty sandstone, calcareous sandstone, etc.), dolomite (dolomicrite, arene dolomite) and mudstone class (silty mudstone, dolomitic mudstone, etc.) [1], reservoir physical property is poor, the average porosity is 9.17%, the average permeability is 0.15 mD, belongs to low porosity, low permeability reservoir.

Constant velocity mercury injection

Conventional mercury injection can only be given a certain level of pore throat radius and the pore volume under its control, while the distribution of pore and throat cannot be distinguished[2,3].Constant velocity mercury injection set the porous medium as the model which formed by different diameter size of pore and throat combination ,can be given microscopic pore and throat distribution and pore configuration relationship, acquire more detailed physical parameters, so as to distinguish different pore structures[4-6].

Pore radius distribution characteristics

Through the analysis of 13 constant velocity mercury data, the pore radius of the study area is mainly distributed in 100~200μm, the weighted average value is 122.48~129.64. From the five pieces of typical samples' pore radius distribution curves (Fig.1), under the conditions of different permeability curve distribution characteristics are similar, presenting typical unimodal distribution, and the peak values are closed at about 125μm. Through the correlation between pore radius weighted value and the porosity, permeability (Fig.2) shows, the regression coefficient is low (R^2 = 0.098, 0.099), there is no obvious correlation between pore radius and permeability, which shows that the pore radius distribution is not a conclusiveness factor for the reservoir quality.

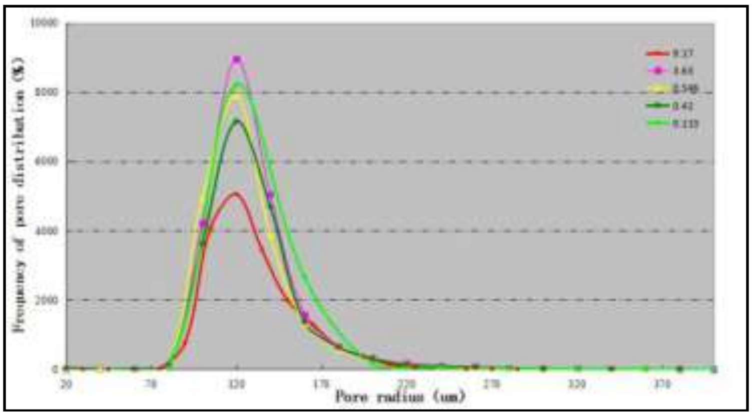

Fig-1: frequency of pore radius distribution

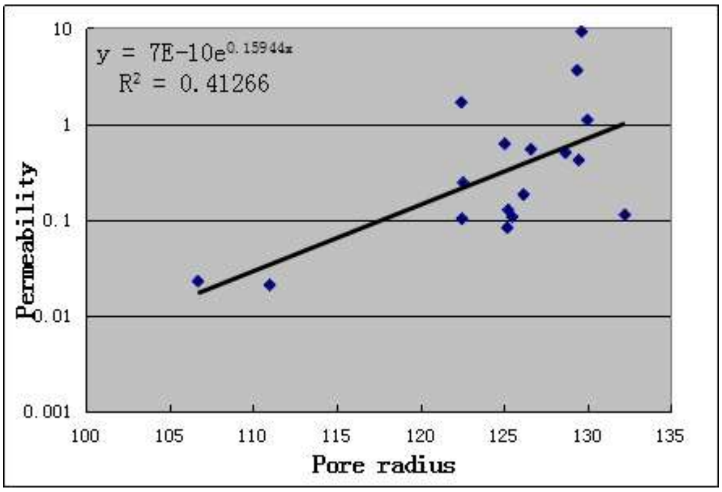

Fig-2: scatter plots of weighted pore radius and permeability

The distribution characteristics of the radius of the throat

The study shows that the distribution of the dense oil's throat radius in Jimsar is not similar to that of the conventional reservoir, the throat is very narrow, and the radius is mainly distributed in the range of less than 0.2μm, accounting for more than 90% of the throat. Throat radius' weighted average in the range of 0.1~0.21 μm, belong to nano grade throat.

According to permeability, the constant velocity mercury sample data is divided into three categories(Fig. 3): the first category is the sample more than 1mD of the permeability, which belongs to the conventional reservoir, that take a small amount of existing, average of throat radius weighted is 0.11~0.186μm. With the decrease of permeability, the curve shape presents a peak curve which peak value is 0.2 μm move to the left,. The permeability of the second kinds of samples is less than 1mD, more than 0.3mD, and is a kind of tight oil reservoir. The weighted value of throat radius is relatively small, give priority to0.131~0.158μm. Compared to the first class, the throat curve is more convergence to the left lower corner, showing a decrease in the throat channel of 0.1~0.2 m. The third kind is the sample which permeability is less than 0.3mD, that is another kind of tight oil reservoir. These samples accounted for 53.4% of all samples, the main types of reservoir distribution in the local area. The throat curve is located at the lower right end, which has most narrowthroat among the reservoir.

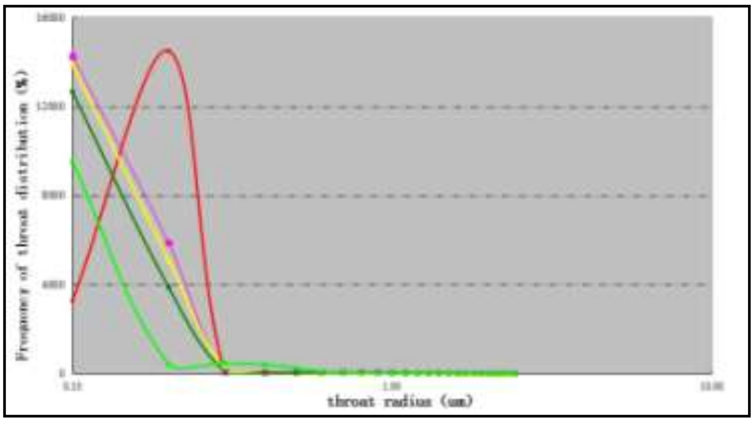

Fig-3: Frequency of throat radius

Because the maximum test pressure of the constant velocity mercury injection instrument is only 6.2MPa, it is hard to enter the throat with small radius at such low pressure, which leads to the absence of reservoir data in extra low permeability. In this experiment, due to the measurable minimum throat radius is 0.1 μm, and for less than 0.1 μm throat data is not available, makes the second and third sample throat weighted radius and related appearance produce error, throat radius is larger than the real, and with the decrease of permeability, the correlation between throat and permeability becomes less obvious. Unlike second and three types of samples, there is a strong positive correlation between the throat channel and the permeability (Figure 4A, 4B).

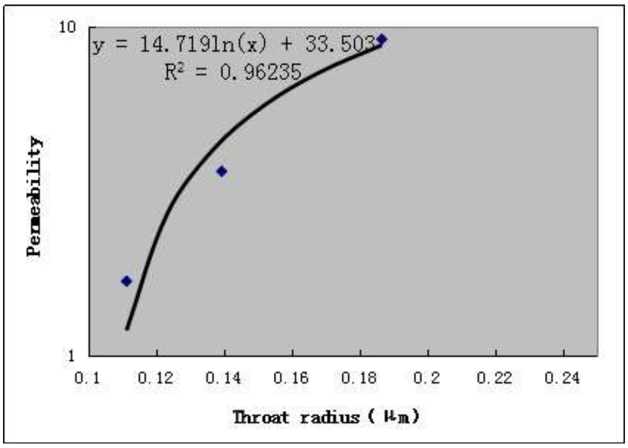

Fig-4A: Scatter plots of weighted throat radius and permeability of first kind of sample

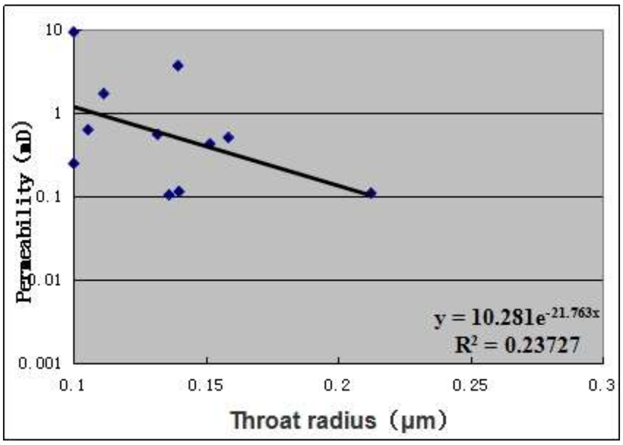

Fig- 4B: Scatter plot of weighted throat radius and permeability of second and third kinds of sample

Through analyzing the number of throat channel in the radius of 0.1μm in second, third types of samples finding out that there is a positive correlation between the number of throat and permeability. We assume that, if the second and the third sample throat radius curve is still showing like conventional reservoir of normal distribution, with the decrease of permeability , curve gradually moving to the left, and the number of throat in 0.1μm radius will gradually decreased As the curve shift to the left (Fig. 5). Through this method, it can be inferred indirectly that the size of the throat channel has a certain control effect on the permeability of the reservoir. According to the analyzing of correlation between the permeability and the minimum throat radius in the second and the third samples (Figure 6), we can come to the conclusion that the throat radius size can control the flow of the reservoir.

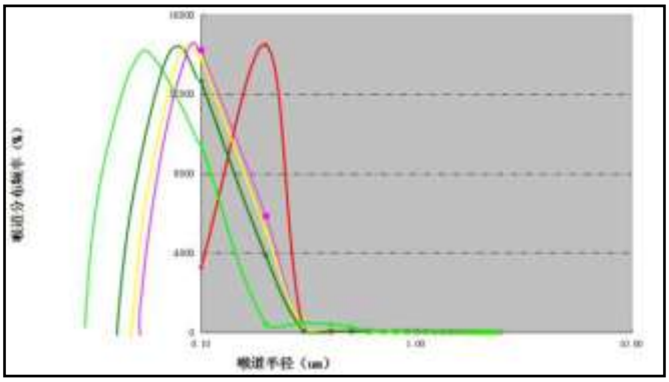

Fig-5: frequency prediction of throatl radius

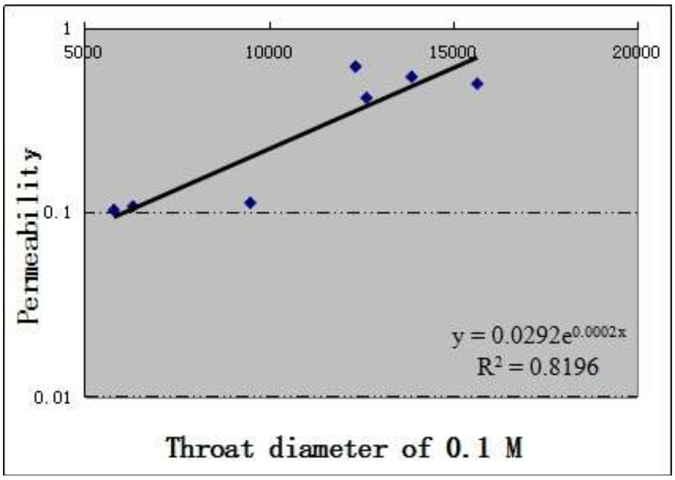

Fig-6: The radius is0.1μm throat number and permeability scatter correlation

Pore throat ratio distribution

Analyzing the data of pore throat radius ratio obtained from constant velocity mercury injection technique, we can find that the pore throat ratio curves of the first and second kinds of samples are all in normal distribution, with the decrease of permeability, the curve shifts to the right, the ratio of pore throat radius in the smaller area is relatively reduced, increasing the ratio in large area, and the peak value of the curve decreases with the decrease of permeability. As shown in Figure 7, the pore throat radius ratio of first kind of samples is mainly distributed in the range of 60~210, the peak values are 105 and 135 respectively. The throat radius of second kind of reservoir is mainly distributed in 45~675, and the peak value is 155 and 160 as typical double peak features, the first peak is generally distributed in the range of 50~65, and the second peak are distributed between 550~800.As all kinds of samples' pore radius made little difference to the case, pore throat radius ratio distributions show for this unusual form, the author thinks that is rock samples go through two different digenesis and formed two kinds of radius which have a big difference, leading to produce two pore throat distribution correlation.

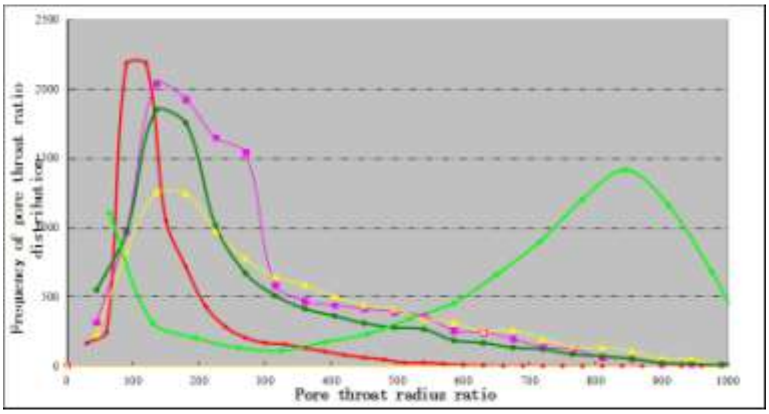

Fig-7: frequency of pore throat radius ratio

From the correlation between the pore throat ratio and the porosity and permeability (Fig. 8, Fig. 9) , we can know that the pore throat radius is negatively correlated with both the porosity and permeability, and the correlation coefficient with permeability is higher (R^2=0.62811).The permeability of the reservoir is also controlled by the connection relation between the pore and the throat.

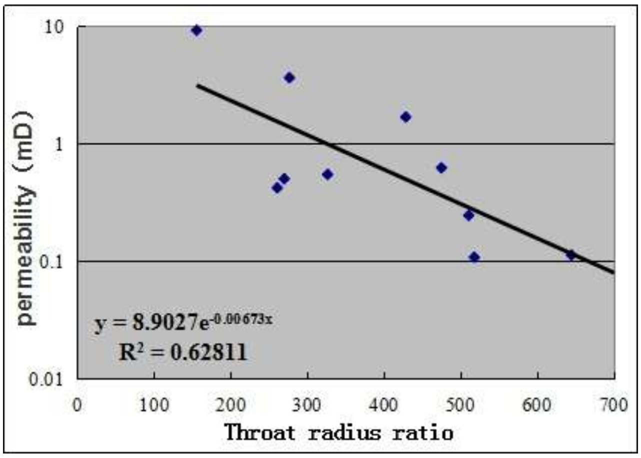

Fig-8: Correlation between pore throat radius ratio and permeability

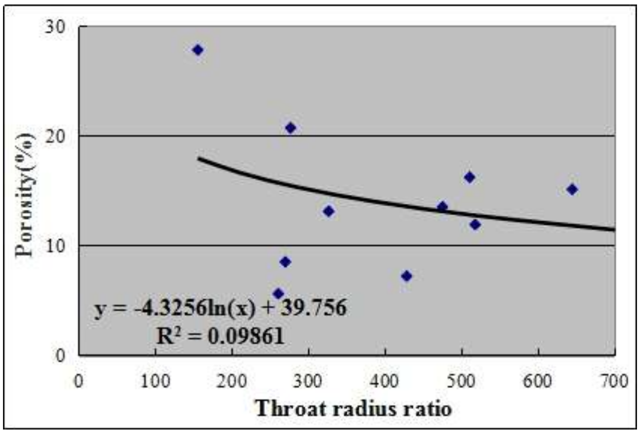

Fig-9: Correlation between pore throat radius ratio and porosity

CONCLUSION

Through the research and analysis of the constant velocity mercury injection experiment, the reservoir percolation ability of the study area is controlled by the throat radius distribution and the pore throat ratio, and the throat channel radius is stronger control ability to the permeability.

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