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Research Article

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The micro-structure and seepage characteristics of Shale reservoir

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ABSTRACT

Micro porosity and percolation rules by mercury pressure and seepage experiment of Shengli Oilfield low permeability shale cores. Because of the special characteristics of shale bedding structure, resulting in poor correlation with permeability shale hole. Mercury pressure experiment show that interval shale reservoir capillary radius distribution is low, poor sorting pores smaller, rate of permeability contribution. Because the gas slippage effect, generally in low permeability reservoir is nonlinear. The shale reservoir of low permeability, single-phase flow experiments show that shale has obvious characteristics of non-Darcy flow, starting pressure gradient magnitude and permeability, single-phase flow experiments show that shale has obvious characteristics of non-Darcy flow, starting pressure gradient magnitude and permeability negative correlation significantly

Key words: shale reservoir; Ultra-low permeability reservoir; Micro-pore structure; Seepage.

INTRODUCTION

Shale reservoir has considerable amount of gas or oil resources. Our organic-rich shale oil and gas basins in many ways have some comparability with the United States[1,2]. China also has a large potential of shale gas/oil exploration and development. Microscopic pore structure directly affects the reservoir capacity and flow capacity[3]. Therefore, studies on microscopic pore structure characteristics of ultra-low permeability shale reservoirs and its impact on flow characteristics is very important to rational development of shale reservoir.

MICRO-STRUCTURE OF SHALE RESERVOIR

Materials and methods: Methods to investigate pore structure can be divided into two types: one is the experimental statistical method, mainly through experiments such as microscope, cast sheet, conventional mercury, and constant pressure mercury, and data analysis; the other is to establish models, including physical models and fractal models. The paper used the conventional mercury experiment to investigate pore structure of shale reservoir[4-8].

Analysis of micro-structure: Micro-structure characteristics were analyzed through conventional mercury[9,10]. Core samples with length of about 2.5cm and diameter of 2.5cm were used. Porosity distribution is between 0.236% -2.959%, with an average of 1.377%. Permeability distribution is between 0.00004 x10-3 um2 and 0.018169 x10-3 um2, with an average of 0.000458 x10-3 um2. Based on current classification criterion, shale gas reservoir is low porosity and ultra-low permeability, and correlation between porosity and permeability is poor, as shown in Figure 1.

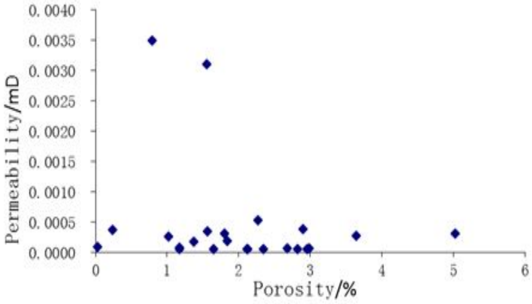
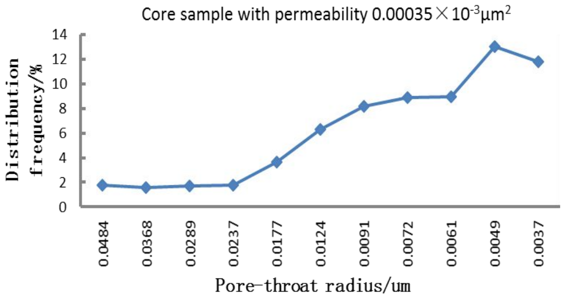
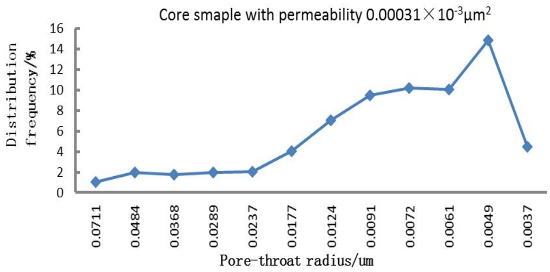


Fig.1 Correlation between porosity and permeability of shale reservoir

Pore radius distribution is the main factor affecting the reservoir properties, and subsequent reservoir permeability and ultimate recovery[11,12]. Mercury experiment could reflect the degree of reservoir development difficulty. Figure 2 shows capillary radius distribution curves of two rock samples.



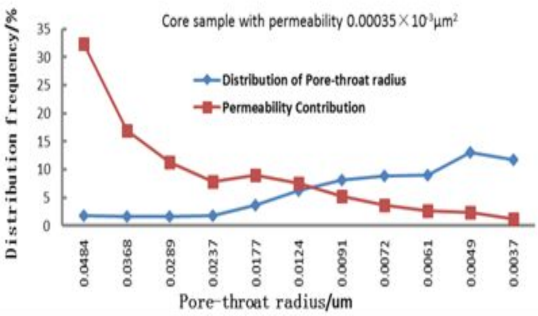
(a)



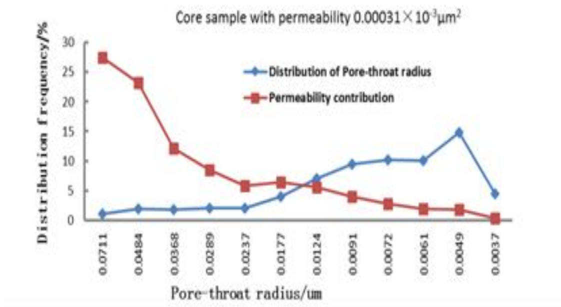
(b)

Fig.2 Correlation between Pore-throat radius and permeability of shale reservoir

As seen in the figures, size of pore radius of the samples mainly lies between 0.0177-0.0037um, with frequency of 13% -19%. The distribution curves have one single peak respectively and narrow pore radius distribution.



(a)



(b)
Fig.3 Relationship between pore radius and permeability

Capillary radius distribution of the core samples mainly ranges from 0.0177 to 0.0037um. However, pores which contribute to permeability mainly have radius between 0.0712-0.0237um.

Flow Characteristic: Numerous indoor flow experiments of low permeability reservoirs show that, when velocity is small enough, fluid flow in porous media follows nonlinear law. With increase of pressure gradient, flow follows Darcy's law. Similarly, single-phase flow experiments were carried out to investigate fluid dynamics in shale reservoir.

Six core samples were selected to perform single-phase flow experiments. Porosity distribution is 0.236%—5.026%, and permeability distribution is (0.018169-0.000052) x10-3 um2. Data describing the core samples were listed in tab. 1.

Tab. 1 Core sample data

Core no.	Depth/m	Well section	Length/cm	Diameter/cm	Permeability/mD	Porosity/%
4--1	3400.15-3400.35	15-16/27	6	2.51	0.000052	2.678
4--2	3403.6-3403.8	15-25/27	6.01	2.5	0.000086	2.112
4--3	3400.15-3400.35	15-16/27	6	2.5	0.000201	5.026
4--4	3402.6-3402.8	15-22/27	6	2.5	0.000458	2.267
4--5	3403.3-3403.6	15-24/27	6.01	2.52	0.007148	0.236
4--6	3400.15-3400.35	15-16/27	6	2.5	0.018169	1.556

Figure 4 shows flow rate curves of all the samples. As seen, under certain injection rate, with lower permeability, the differential pressure across the core increases.

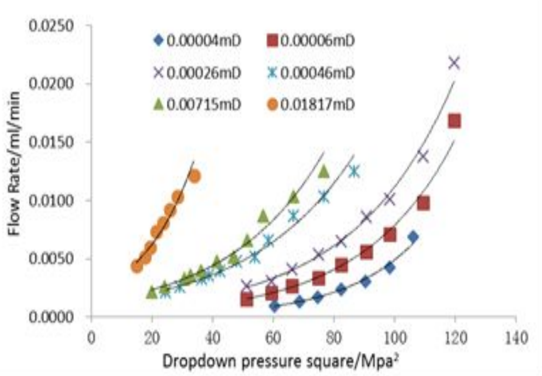


Fig. 4 Flow rate curves

The following rules could be drawn:
(1) Flow curve is obviously nonlinear and fluid flow in shale reservoir shows non-Darcy flow characteristics.
(2) Threshold pressure gradient could be obtained by extending straight line segment to abscissa.
(3) As the pressure increases, the seepage flow increases. The higher the permeability, the larger increment of seepage flow rate.

Fitting flow rate curve, threshold pressure gradient can be obtained from the graph as intercept in abscissa. As seen in the figure 5, threshold pressure gradient was negatively correlated with permeability.

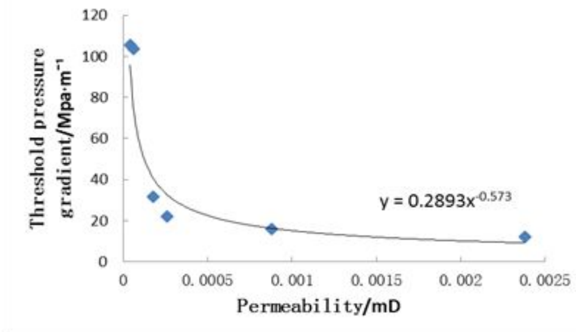


Fig. 5 relationship between threshold pressure gradient and permeability

CONCLUSION

1. There is little correlation between porosity and permeability in shale reservoir. Porosity has little effect on shale permeability which is mainly determined by micro-pore structure of shale.

2. Mercury curve has only one single peak, indicating that the reservoir pore distribution is unimodal and relatively concentrated. However pores with radius of higher frequency are not main contribution of permeability.

3. For ultra-low permeability cores, flow follows nonlinear law as seen in the flow rate curves. There exists threshold pressure gradient, smaller than which flow rate is nearly zero. Pseudo-threshold pressure gradient could be obtained through intercept of extending straight line segment and abscissa.

4. Pseudo-threshold pressure gradient decreases with the increase of permeability. When permeability is smaller than critical value, pseudo-threshold pressure gradient increases rapidly.

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