PS Three-Dimensional Quantitative Characterization of Pore Throat Space of Low and Ultra Low Permeability Sandstone Reservoir in Bohai Bay Basin by Combined Constant Velocity Mercury Injection and X-CT*

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Search and Discovery Article #42251 (2018)**
Posted August 6, 2018

*Adapted from poster presentation given at AAPG 2018 AAPG Annual Convention and Exhibition, Salt Lake City, Utah, May 20-23, 2018

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Abstract

The study area is located in the steep slope zone of Shijiutuo Uplift in Bohai Bay Basin. The low and ultra low permeability sandstone in the glutenite reservoir has an important influence on the overall hydrocarbon migration and accumulation. The permeability of these sandstones is distributed at $0.01\sim50\times10^{-3}\mu m^2$. Constant speed mercury injection technique and X-CT scanning technology is used to achieve quantitative characterization of microscopic pore throat distribution and fluid seepage characteristics in low and ultra low permeability sandstone reservoirs with different permeability grades and different grain sizes.

Research shows:

1. The number of primary pores in fine sandstone is large, but its pore size is relatively small. The throat is cemented by carbonate, which caused some of the primary pores to be void. The porosity distribution of the middle sandstone is the most uniform, the high porosity and high opening ratio are the most important factors for its high seepage capacity. The pore size distribution of pebbly sandstone is very heterogeneous, it shows a large number of pores and the number of effective pores connected with throat is less. Intergranular pore volume decrease of siltstone and fine sandstone is mainly due to the cementation. With the increasing of particle size, compaction porosity of medium sandstone is close to 80%.

2. Target sandstone has the characteristics of medium pore size, small throat radius, and abnormally large pore throat ratio. The number and distribution of throat with large radius are the key factors that affect the percolation capacity of reservoir. The pore controlled mercury entry zone is the most effective space for controlling fluid flow, the higher the permeability is, the larger the throat radius of the pore master zone is. In the pore throat transition mercury zone, mercury is mainly combined by pore and throat, with the decrease of throat radius, fine throat gradually becomes the main space for fluid storage and flow. The contribution of permeability in the main control area is very low, the fluid flow capacity at this stage is greatly affected by the throat radius. With the increase of permeability, the critical throat radius of low

permeability and ultra low permeability sandstone increases from 1μm~2μm to 3μm~4μm. This study fills the gap of related research in Bohai sea area and helps to realize comprehensive and accurate reservoir evaluation of this kind of reservoir.

20-23 May 2018 • Salt Lake City, Utah

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Abstract: The study area is located in the steep slope zone of Shijiutuo Uplift in Bohai Bay Basin, the low and ultra low permeability sandstone in the glutenite reservoir has an important influence on the overall hydrocarbon migration and accumulation. The permeability of these sandstones is distributed at 0.01~50×10^{-3}μm². The complex pore structure led to obvious heterogeneity of the reservoir and seepage capacity of sandstone. Using constant speed mercury injection technique and X-CT scanning technology to achieve quantitative characterization of microscopic pore throat distribution and fluid seepage characteristics in low and ultra low permeability sandstone reservoirs with different permeability grades and different grain sizes. Research shows：1.The number of primary pores in fine sandstone is large, but its pore size is relatively small. The throat is cemented by carbonate, which caused some of the primary pores to be void. The porosity distribution of the middle sandstone is the most uniform, the high porosity and high opening ratio are the most important factors for its high seepage capacity. The pore size distribution of pebbly sandstone is very heterogeneous, it shows a large number of pores and the number of effective pores connected with throat is less. Intergranular pore volume decrease of siltstone and fine sandstone is mainly due to the cementation. With the increasing of particle size, compaction porosity of medium sandstone is close to 80%. 2.Target sandstone has the characteristics of medium pore size, small throat radius and abnormally large pore throat ratio, the number and distribution of throat with large radius are the key factors that affect the percolation capacity of reservoir. The pore controlled mercury entry zone is the most effective space for controlling fluid flow, the higher the permeability is, the larger the throat radius of the pore master zone is. In the pore throat transition mercury zone, mercury is mainly combined by pore and throat, with the decrease of throat radius, fine throat gradually becomes the main space for fluid storage and flow. The contribution of permeability in the main control area is very low, the fluid flow capacity at this stage is greatly affected by the throat radius. With the increase of permeability, the critical throat radius of low permeability and ultra low permeability sandstone increases from 1μm~2μm to 3μm~4μm. This study fills the gap of related research in Bohai sea area, and helps to realize comprehensive and accurate reservoir evaluation of this kind of reservoir.

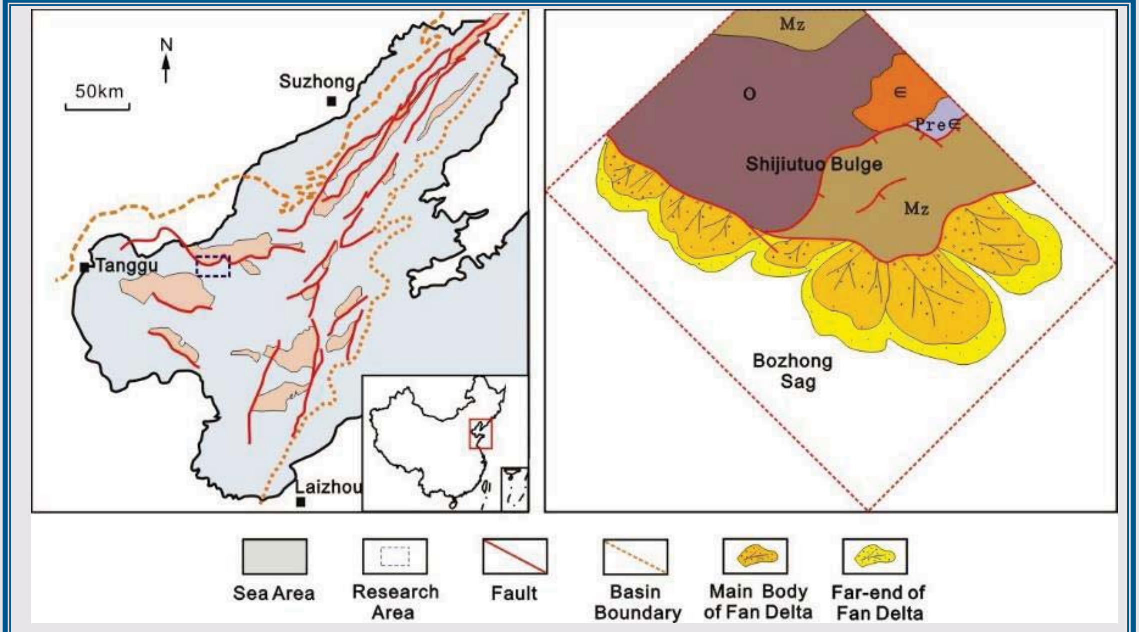

Fig 1. The tectonic position of the study area and the plane distribution of the sedimentary system

1. Geological background and sample

Table 1. Lithology, physical properties and thin section identification characteristics of low permeability- ultra low permeability sandstone samples

Groups	Sample	Depth (m)	Lithology	Porosity (%)	Permeability (10^{-3}μm²)	Particle size median (mm)	Sheet identification data (area) (%)		
							Calcite (iron)	Dolomite (iron)	clay mineral
I	Y1	2875.62	Very fine-fine sandstone	14.8	1.78	0.1	3	10	16
	Y2	3140.11	Glutenite	12.4	2.15	0.26	7	2	5
	Y3	3142.27	Medium -fine sandstone	16.3	2.88	0.2	4	3	3
II	Y4	2876.73	Medium -fine sandstone	14.1	7.63	0.14	1	3	12
	Y5	2877.79	Very fine-fine sandstone	15.1	8.14	0.12	2	8	6
	Y6	2878.44	Very fine-fine sandstone	14.6	8.38	0.15	6	5	6
III	Y7	2877.93	Very fine-fine sandstone	16.3	15.2	0.15	3	7	8

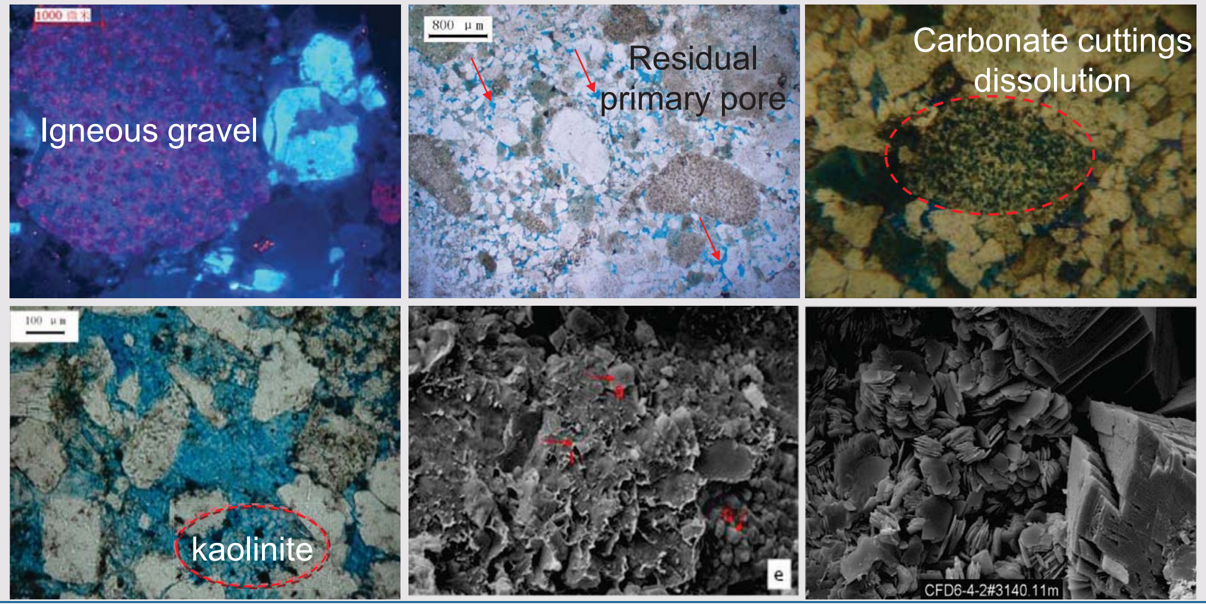

Fig.2 Characteristics of cathode luminescence, cast thin slices and SEM in sandstone samples

2.Distribution characteristics of pore and throat in constant velocity mercury pressure

2.1 Mercury entry characteristics

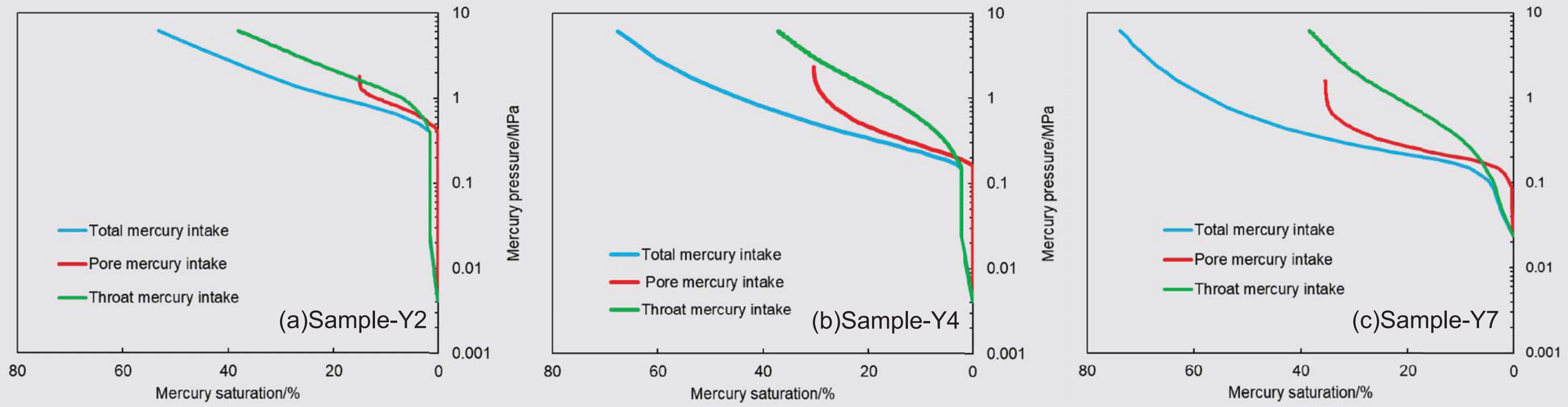

Fig.3 Characteristics of constant velocity mercury injection mercury curve of typical samples of three types of throat and throat

2.2 Pore distribution and pore-throat ratio

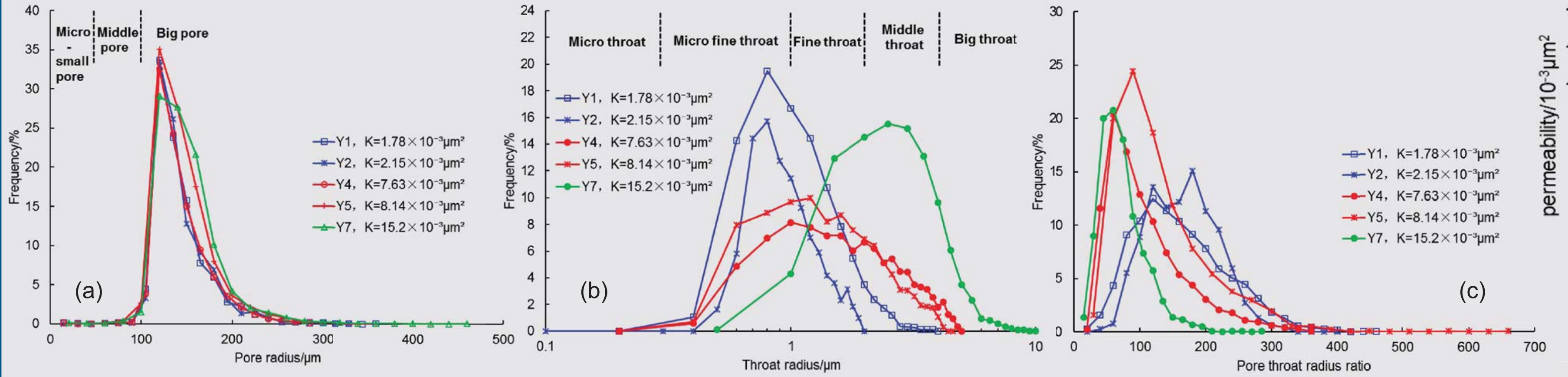

Fig.4 Pore, throat and pore throat ratio distribution of sandstone samples with low permeability and extra low permeability

2.3 Relationship between pore throat structure parameters and physical properties

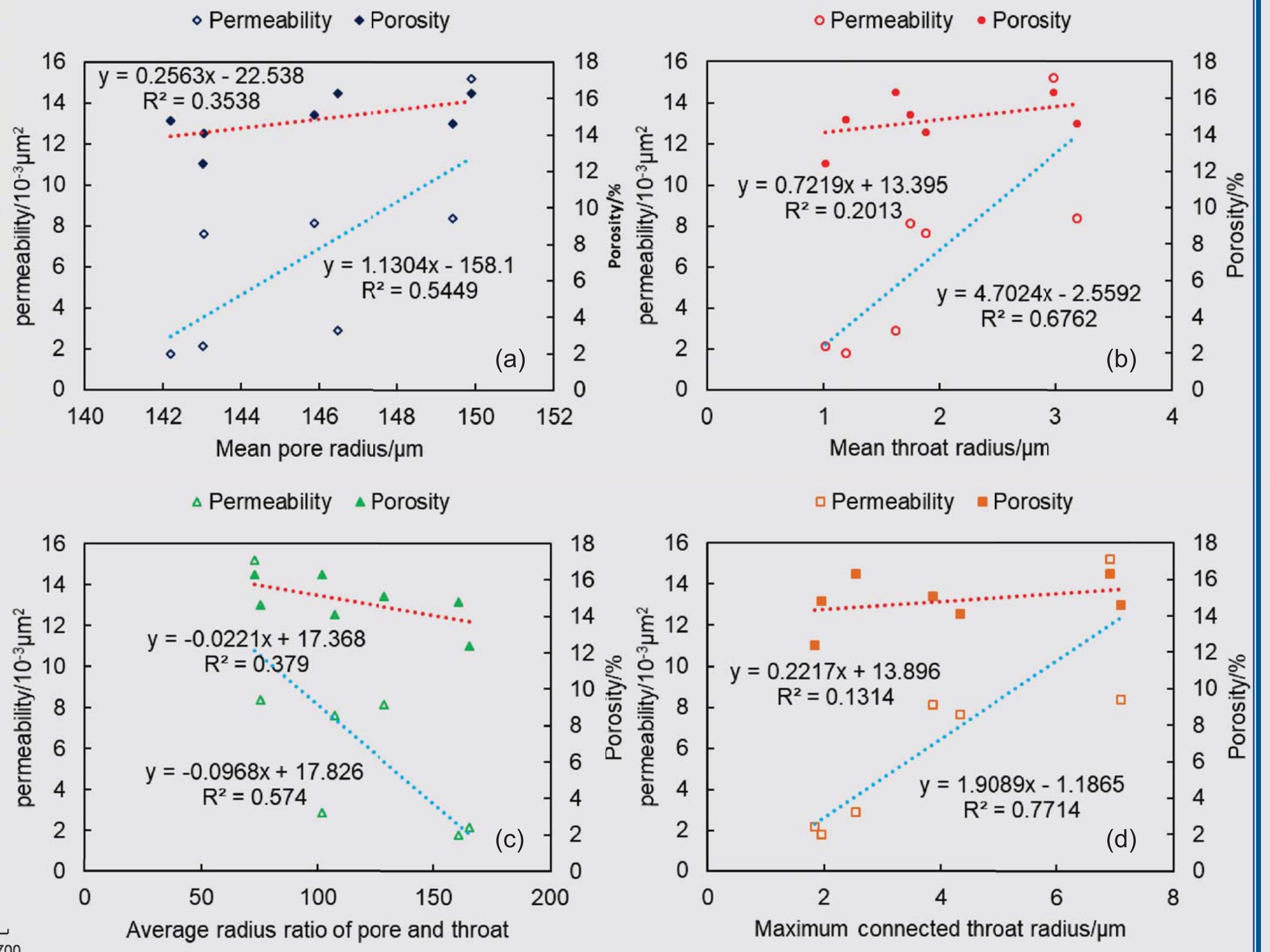

Fig.5 Relationship between pore structure parameters and physical properties