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Reservoir Characteristics of Tight Sandstone of Shanxi Formation in Linxing Area in the North of Ordos Basin

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1 Introduction

The sandstone of Shanxi formation in Upper Paleozoic in the north of Ordos basin is very tight, thin, quick lateral changes and strong heterogeneity. It is a lithologic trap and subtle gas reservoir. It is very difficult to analyze gas enrichment factors and predict high yield zone(Hao et al., 2011; Zhao et al., 2012). The tight sandstone of Shanxi formation in Upper Paleozoic Permian in Linxing area in the north of Ordos basin is research target in this article. Base on identification of petrographic thin section, the data of X-ray diffraction and mercury penetration experiment and so on, it is necessary to analyse the reservoir characteristics and its influence factors of tight sandstone of Shanxi formation in the north of Ordos basin.

This article is mainly describe the above two issues.

2 Reservoir Characteristics

2.1 Petrological characteristics

Base on identification report of petrographic thin section, the sandstone tpyes of Shanxi formation in Upper Paleozoic Permian in Linxing area are mainly fine grain lithic-quartz sandstone and middle grain lithic sandstone. The quartz component is 32% ~ 75% and the average component is 52%. The lithic component is 26% ~ 63% and the average component is 46%. The feldspar is not totally developed in the pore of sandstone reservoir. Observation from these thin sections indicates that sandstones are medium sorting and rounding, grains are mainly semi-edge-angle and semi-round-angle, intergranular space is line contact and concavo-convex contact, cementation type is pack-pore cementation, and the quartz overgrowth is well developed. The content of lithic varies with the grain size, it is gradually increased with the fine grain size, and the maximum of the content of lithic is over 60%.

2.2 Sedimentology characteristics

Shanxi formation was overlying on Taiyuan formation in marine regression background, as sedimentary environment was a typical continental delta. The deltaic sedimentary systems consist mainly delta plain and delta front. Base on lithology, paleontology and well logging, sedimentary micro-facies units of Shanxi formation is divided into distributary channel, interdistributary bay, flood plain, underwater distributary channel, underwater interdistributary bay, river mouth bar and so on.

2.3 Physical property

The results of core helium porosity and permeability test show that the porosity of tight sandstone of Shanxi formation in Linxing area of Ordos basin is 1.44% ~ 10.23% and the average is 6.57%, porosity distribution range is from 4% ~ 8%, the proportion is 71%. The permeability is 0.01 ~ 5.05 mD and the average is 0.35 mD, permeability distribution range is less than 1 mD, the proportion is 92%. Therefore, the reservoir of tight sandstone of Shanxi formation in Linxing area has these characteristics of low porosity and low permeability, while the development of micro nature fracture makes the correlation between porosity and permeability worse, the correlation factor is less than 0.5.

2.4 Pore throat distribution

From experiment data of mercury penetration, the displacement pressure of tight sandstone of Shanxi formation is 0.674 ~ 13.78 MPa and the average is 2.584 MPa. The saturation median pressure is 6.179 ~ 63.166 MPa and the average is 24.926 MPa. The median pore

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throat radius is 0.012 ~ 0.124 μm and the average is 0.05 μm. The sorting factor is 1.042 ~ 2.623 and the average is 2.127. The maximum entry mercury saturation is 54.9% ~ 90.47% and the average is 79.13%. The efficiency of mercury withdrawal is 32.02% ~ 42.21% and the average is 37.08%. The displacement pressure of tight sandstone of Shanxi formation in Linxing area of Ordos basin is high, pore space is poor, small pore throat, which belongs to the micro pore and micro throat type. The pore permeability and pore throat connectivity is poor, resulting in hydrocarbon expulsion efficiency is low, oil and gas migration is blocked, making the reservoir of tight sandstone of Shanxi formation in Linxing area has these characteristics of low porosity and low permeability.

2.5 Reservoir space type

Base on identification of petrographic thin section and SEM, reservoir space types of tight sandstone of Shanxi formation in Linxing area of Ordos basin are mainly four kinds: (1) intergranular pore, kaolinite aggregates filled in intergranular pore, filamentous illite attached to clastic grain surface; (2) intergranular secondary dissolution pore, filamentous illite aggregates filled in intergranular pores, feldspar grain was dissolved and broken up to form secondary dissolution pore; (3) intragranular secondary dissolution pore, feldspar grain along the cleavage is dissolved easily form intragranular secondary dissolution pore; (4) intergranular micropore, filamentous illite and secondary quartz crystal filled in intergranular pore.

3 Reservoir Influence Factors

3.1 Sedimentary environment

Sedimentary environment from Benxi formation to Shihezi formation in Upper Paleozoic in Linxing area of Ordos basin have huge changes of from marine environment to continental environment, such as Benxi formation and Taiyuan formation are a classical tidal flat depositional system, Shanxi formation is a delta plain depositional system, Shihezi formation is a meandering fluvial and braided fluvial depositional system, finally at the top of Shihezi formation is a alluvial fan depositional system(Xie et al., 2013). Therefore, different lithological characteristics formed in different sedimentary environments, which leads to different reservoir physical properties; if in the same sedimentary environment, distribution in different sedimentary micro facies lead to more different reservoir physical properties.

3.2 Compaction

Compaction is a main reason for the reservoir tighten in Linxing area of Ordos basin. The depth and plastic materiel is the direct factor of stronger compaction. The reservoir depth of Shanxi formation in Linxing area of Ordos basin is more than 2000m, the maximum of depth is over 2200m. To compaction, the depth is deeper, compaction is stronger, which makes tight sandstone lose more than 50% primary pores. After a strong compaction, sandstone grains of reservoir are more line contact than concavo-convex contact, fracture joint of the quartz is well developed. The plastic materiel of reservoir in Linxing area is more than rigid materiel. The rock in lithic sandstone is mainly the phyllite of low-grade metamorphic rock. It is a plastic materiel and difficult to resist strong compaction, so the total reservoir space is compressed and the pore volume is reduced.

3.3 Cementation

Cementation is also an important reason for the reservoir tighten in Linxing area of Ordos basin. The cement of reservoir sandstone in Shanxi formation is mainly calcite, kaolinite, siliceous and mud cementation. Calcite cementation makes the reservoir tighter, due to the stable tectonic, limited pore fluid and poor pore connectivity in Linxing area, calcite dissolution hardly occurs. In the later stage of diagenesis, the iron calcite cementation makes the reservoir more tight, and is incompatible with the oil gas filling, and the quartz overgrowth is well developed, resulting in the reservoir is more tight.

3.4 Dissolution

In the stage of diagenesis, dissolution is not developed until natural fracture system improves the percolation ability of tight sandstone. After dissolution begins to develop, intragranular dissolution pore and intergranular dissolution pore in the clastic grain improve physical properties of tight sandstone reservoir and reservoir capability of oil and gas. As a cold basin during the geological history, paleo-geothermal gradient in Linxing area of Ordos basin is always low, which leads to the mature hydrocarbon is formed later at this stage. Although in organic acid environment, but the sandstone has already been tight, its percolation ability is poor and dissolution is limited. Because the acidic environment of become weak in the later stage of diagenesis, carbonate cementation is developed, the sandstone is more tight. Natural fracture system improves effectively the permeability of tight sandstone, making the acidic fluid begin to flow, so a few intragranular dissolution pore and intergranular dissolution pore improve totally physical properties of reservoir.

3.5 Micro fractures

Although reservoir sandstone of Shanxi formation in Linxing area of Ordos basin is really tight, its brittleness is

Table 1 Data of porosity, permeability and depth of LX-3 Well

Sample	Depth (m)	Porosity (%)	Permeability (mD)	Density (g/cm^3)	Remark
7-2	753.11	11.98	33.25	2.36	Micro fracture
16-4-2	751.80	12.88	35.01	2.30	Micro fracture
16-3	751.64	13.29	53.07	2.34	Micro fracture

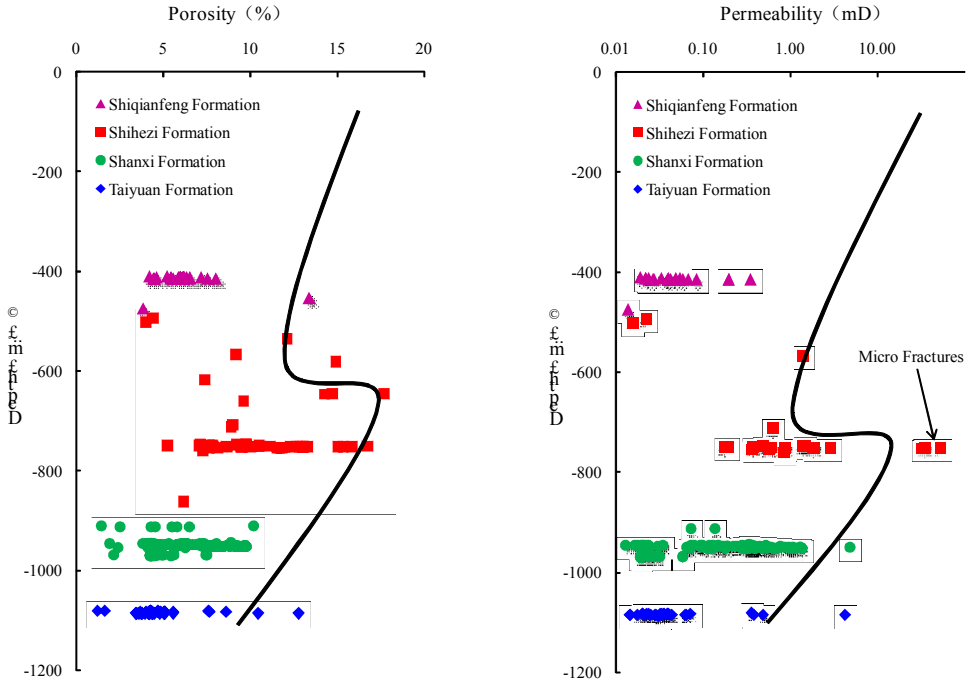

Fig. 1 Relation diagram of porosity, permeability and depth of LX-3 Well

well, and it is easy to micro fractures in the weak ground stress. From microscope observation, micro fractures in Lower Shihezi formation and Shanxi formation are relatively well developed, they are mainly micro cracks, vertical cracks, horizontal cracks and effective fractures system. They can increase effectively the permeability and liquidity of tight sandstone and improve the percolation capacity of reservoir in Linxing area. The data of core permeability test shows that 92% permeability of tight sandstone are less than 1 mD, but after micro fractures system reconstruction, reservoir permeability increases suddenly for several times and even dozens of times than the original permeability (Table 1). In addition, the micro fractures are the secondary reservoir space type in t Linxing area, and the existence of micro fractures can improve effectively reservoir physical properties in Lower Shihezi formation. The relation diagram of porosity, permeability and depth of LX-3 Well indicates that the depth is deeper, compaction is stronger, porosity and permeability are worse, but dissolution and micro fractures system improve effectively porosity and permeability in Lower Shihezi formation(Fig. 1).

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