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RESEARCH PAPER

Differences in formation process of tight sandstone gas reservoirs in different substructures in Changling Fault Depression, Songliao Basin, NE China

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Abstract: The tight sands reservoirs in the Lower Cretaceous Denglouku Formation in Changling Fault Depression of Songliao Basin, NE China were taken as study object. The burial history, thermal evolution history and hydrocarbon generation history of source rock, accumulation stage and porosity evolution history of typical tight sandstone reservoirs in the central deep depression belt, east slope belt and east structural belt were examined by the dissection based on the fundamental features of tight sandstone gas reservoirs, to find out the differences in their formation process, the coupling relationship between source and reservoir of different substructures, then the favorable exploration areas can be confirmed. The east structural belt has the best source rocks and reservoirs, where the Denglouku Formation tight sandstone formed reservoirs earliest when the reservoirs were not tightened yet with features of one stage accumulation. The sandstone of the Denglouku Formation in the east slope belt formed reservoirs secondly and shows one stage accumulation but two charging peaks, the first charging peak occurred when the reservoirs were not tightened, the second charging peak occurred when the sandstone was tightened already. The sandstone of the Denglouku Formation in central deep depression belt formed reservoir the latest when the reservoirs were densified already with the features of one stage accumulation. The study shows that the east structural belt has the best coupling relationship between source rocks and reservoirs, and is the most favorable exploration area for tight gas in the Changling Fault Depression.

Key words: substructural belt; tight sandstone gas reservoir; formation process; Lower Cretaceous Denglouku Formation; Changling Fault Depression; Songliao Basin

Introduction

The previous studies on tight sandstone gas reservoirs in China mainly focus on the Western Tarim Basin and Turpan-Hami Basin and the Centural Ordos Basin and Sichuan Basin[1–7], but there are few studies on rift basins in east China[8–9], meanwhile, the limited studies mostly were from the macro perspective of whole basin and lack of difference discussion on different substructure in rift basin. Rift basins feature large structural difference, where sandstone deposition and diagenesis are strongly controlled by substructures, causing tight sandstone gas reservoirs in different substructures to be different in accumulation features. Therefore, to figure out the formation process and difference of tight sandstone gas reservoirs in different substructures is of great significance for the exploration of tight sandstone gas reservoirs in rift basins.

This study takes the Lower Cretaceous Denglouku Formation in Changling Fault Depression of southern Songliao Basin as an example, and dissects the formation process and difference of tight sandstone gas reservoir from burial history, thermal evolution history, hydrocarbon generation history, accumulation stage and porosity evolution history based on the fundamental features of the tight sandstone gas reservoirs in different substructures, which can provide reference to the exploration of tight sandstone gas reservoirs in Changling Fault Depression and rift basins.

1. Geologic setting

Located in the south of Songliao Basin in NNE trend on the

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whole, with an area of about 8 500 km^2, the Changling Fault Depression is divided into west step-fault belt, central depression belt, east slope belt and east structural belt[10–11]. So far, the major gas reservoirs discovered there include the Changling I gas reservoir in the central depression belt, the Dalaoyefu gas reservoir and Shuangtuozi gas reservoir in the east slope belt and the Fulongquan gas reservoir in east structural belt (Fig. 1).

There mainly deposit Mesozoic and Cenozoic strata in Changling Fault Depression, including Lower Cretaceous Huoshiling Formation (K_1h), Shahezi Formation (K_1sh), Yingcheng Formation (K_1y), Denglouku Formation (K_1d) and Quantou Formation (K_1q), Upper Cretaceous Qingshankou Formation (K_2qn), Yaojia Formation (K_2y), Nenjiang Formation (K_2n), Sifangtai Formation (K_2s) and Mingshui Formation (K_2m), Neogene Daan Formation (Nd) and Taikang Formation (Nt) and Quaternary (Q) from bottom to top. The Changling Depression is in the rift stage from Jurassic to Lower Cretaceous Denglouku Formation and in the post rift stage from Quantou Formation to Nenjiang Formation, and then the depression becomes shrunk[12]. There mainly develops braided river, braided river delta and lacustrine and alluvial fan, fan delta and lacustrine sedimentary systems[13]. The Denglouku Formation sandstones are mostly feldspathic lithic sandstone, feldspar lithic sandstone and lithic sandstone[14], and the porosity is 2%–7% and the permeability mainly less than 0.1×10^{-3} μm^2 [15]. The dark mudstones of Shahezi Formation and Yingcheng Formation below in the deep to semi-deep lacustrine environments are the main source rock of the study area[16].

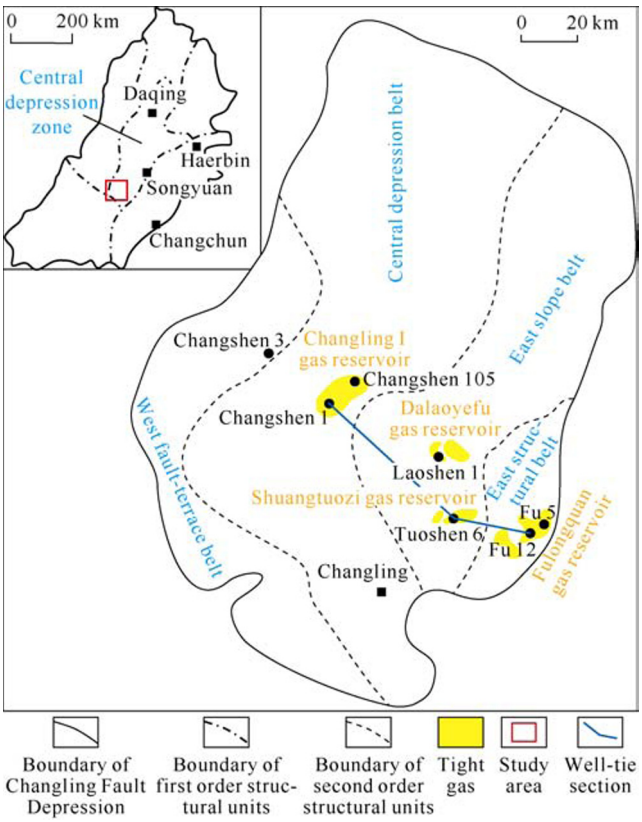

Fig. 1. Location, structural division and tight sandstone gas distribution of Changling Fault Depression.

2. The tight sandstone gas reservoirs

Combining the typical gas reservoir sections of different substructures, this study selects the Changling I gas reservoir of central depression belt, the Shuangtuozi gas reservoir of east slope belt and the Fulongquan gas reservoir of east structural belt to analyze the fundamental features of tight sandstone gas reservoirs in different substructures.

2.1. The Changling I gas reservoir in central depression belt

The Changling I gas reservoir is a cap and reservoir above source combination, where the source rock of Shahezi Formation and Yingcheng Formation have a TOC of 0.4%–2.0% and less than 0.6%, respectively. Denglouku Formation reservoir, mainly braided river sandstone, has a porosity of 3.0%–5.5% and a permeability of $(0.01–0.04)\times10^{-3}$ μm^2. The thick mudstone of Quantou Formation is the regional seal. The Denglouku Formation has an average geothermal of 140.56 °C, average geothermal gradient of 3.766 °C/100 m, average pressure of 36.8 MPa and average pressure coefficient of 1.058 at present, showing normal hydrostatic formation pressure and slightly higher geothermal gradient.

On the whole, the Changling Ⅰ gas reservoir is a tight lithologic gas reservoir on a faulted nose structure with a gas-bearing area of 94.37 km^2. Universally gas-bearing, Denglouku Formation sands are distributed in discrete layers vertically and continuous laterally (Fig. 1), saturated with gas, and have no bottom water (Fig. 2).

2.2. The Shuangtuozi gas reservoir in the east slope belt

The Shuangtuozi gas reservoir is a combination of source rock below sandstone reservoir and cap rock, where TOC of Shahezi Formation and Yingcheng Formation source rock are 0.6%–4.0% and 0.4%–2.0%, respectively. The Denglouku

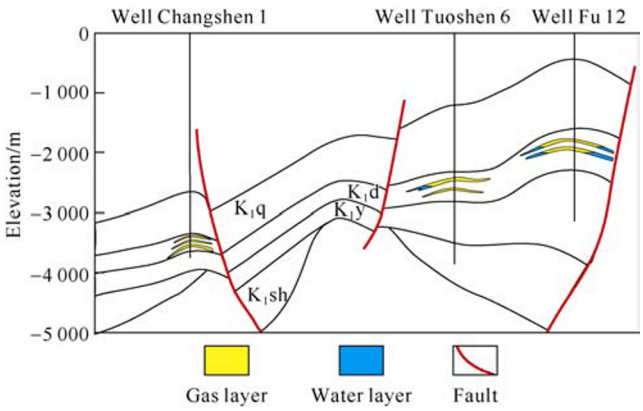

Fig. 2. Tight sandstone gas reservoir section of different substructures in Changling Fault Depression (section location is shown in Fig. 1).