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Full Length Article

Formation characteristics and resource potential of Jurassic tight oil in Sichuan Basin

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ABSTRACT

Through test analysis of large amount of cores, rock fragments and crude oil samples, and in combination with dynamic data of production from 456 oil wells, hydrocarbon generation potentials of four major source rocks and accumulation characteristics of three major pay layers in the Jurassic of Sichun Basin were well investigated. Results indicated that source rocks in the Lianggaoshan Formation, the Da'anzhai Member and the Dongyuemiao Member mainly generated oil, and those in the Zhenzhuchong Member dominantly generated gas; the organic-rich source rocks controlled distribution of sweet spots of tight oil, and most industrial oil wells were located at the area with high-quality source rocks (TOC > 1.2%); and micron-sized pore throats were effective storage space, and fractures played a key role in initial high yield. Jurassic tight oil in the Sichuan Basin was characterized by light oil, high gas-oil ratio and abnormal high pressure, which were favorable for tight oil flow and output. Four methods (i.e., small bin method, resource abundance analogy method, EUR analogy method and total organic carbon method) were used to estimate Jurassic oil in-place in the Sichuan Basin which ranged from 2×10^9 to 3×10^9 t. Through analysis of main controlling factors of resource enrichment, the grading criteria were established for the evaluation of oil in-place in the Sichuan Basin. Through the small bin method, the oil in-place of Type I, Type II and Type III was 1.611×10^9 t, 0.477×10^9 t and 0.289×10^9 t, respectively. It was predicted that the largest exploration potential of the Da'anzhai Member was in the Nanchong-Suining area and the east of Liangping area, the most favorable exploration area of the Lianggaoshan Formation was in the Guang'an-Nanchong-Suining-Yilong area, and the good exploration prospect of the Dongyuemiao Member was in the south of the Guang'an-Suining area.

1. Introduction

The Jurassic strata is the only formation containing oil reserves in the Sichuan Basin and also one of the earliest areas for large-scale oil exploration in China. Since 1958, more than 1200 wells were drilled in the Jurassic formation in the Sichuan Basin, and five oilfields (e.g., Guihua oilfield, Jinhua oilfield) and five sets of oil reservoirs (e.g., Da'anzhai Member, Lianggaoshan Formation) have been discovered, the proven oil reserves in place were about 0.08×10^9t and the cumulative oil production was more than 5×10^6t (Yang et al., 2016b). The favorable oil exploration area of the Jurassic in Sichuan Basin is more than 40×10^3 km^2. The oil resources evaluated in 1984 and 1985 were both more than 1×10^9 t, but major breakthroughs still have not been achieved. Exploration practices in past 60 years proved that the Jurassic reservoirs in the Sichuan Basin had poor physical properties, and lacked basic reservoir conditions for formation of conventional large oil fields. Fractures-controlled reservoirs and well deployment near fracture zones were main basis and basic principles in previous exploration and deployment (Liang et al., 2011). Since the 21st century, the introduction and widespread acceptance of the concept of continuous oil and gas accumulation, as well as industrial breakthroughs in tight oil exploration and development in North American (Liao et al., 2011; Jia et al., 2012; Zhou and Yang, 2012; Zou et al., 2013a, b; Lu et al., 2016; Yang et al., 2016a; Zhao et al., 2016; Wu et al., 2016) provided the direction for re-understanding of the Jurassic exploration potential in the Sichuan Basin. In recent years, high oil production is obtained in wells (e.g.,

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Well GQ1H) through tight oil exploration techniques (such as horizontal drilling and staged fracturing). However, compared with other Mesozoic and Cenozoic continental basins in China, the Jurassic petroleum geological condition in the Sichuan Basin is special, and there is a different understanding that whether it could form massive tight oil resources and had the prospect of industrial exploration and development. In this paper, based on the research result of Jurassic oil resources evaluation, formation condition of Jurassic tight oil in Sichuan Basin was investigated, and potential sweet-spot areas were predicted.

2. Tectonic and sedimentary background

The Sichuan Basin is located in the east Sichuan Province and Chongqing City, and it is surrounded by mountains such as Longmen Mountain, Micang Mountain and Daba Mountain. The landform of the basin interior mainly is hill and plain, and the area of the basin is about 0.2×10^6 km^2. Tectonically, the basin is located in the northern part of the Yangtze plate, and is a large petroliferous superimposed basin formed on the basement of the Pre-Sinian metamorphic rocks.

Since the Sinian, the Sichuan Basin experienced five major sedimentary and tectonic evolution stages, i.e., the craton depression basin (Z_1-S), the craton rift basin (D-T_2), the foreland basin (T_3), the intracontinental depression basin (J-N_1) and the basin finalization (Q) (Wang et al., 2015, 2016b; Liu et al., 2016). Thick sedimentary rocks were developed in the basin, and vertically multiple sets of source rock-reservoir-caprock assemblages were formed. Industrial producing gas intervals were discovered from the Sinian to the Jurassic strata (Zhao et al., 2014), but oil producing intervals only occurred in the Jurassic.

In the Early Jurassic, the basin was dominated by the shore shallow lacustrine sedimentary environment, but in the Middle to Late Jurassic, it was dominated by the river-delta sedimentary environment. The sedimentation center of the Early Jurassic lacustrine basin migrated from the northern Sichuan to the eastern Sichuan. During the depositional period of Zhenzhuchong Member, area of the lacustrine basin was the smallest, and the depocenter was located at the Yilong-Tongjiang-Dazhou area in the northern Sichuan, thickness of source rock was up to 80 m (Fig. 1a). Area of the lacustrine basin slightly enlarged during the depositional period of Dongyuemiao Member, the depocenter migrated to the Liangping-Guang'an-Fuling area in the eastern Sichuan, and thickness of source rock was generally less than 30 m (Fig. 1b). Area of the lacustrine basin was largest during the depositional period of Da'anzhai Member, the depocenter was located at the Nanchong-

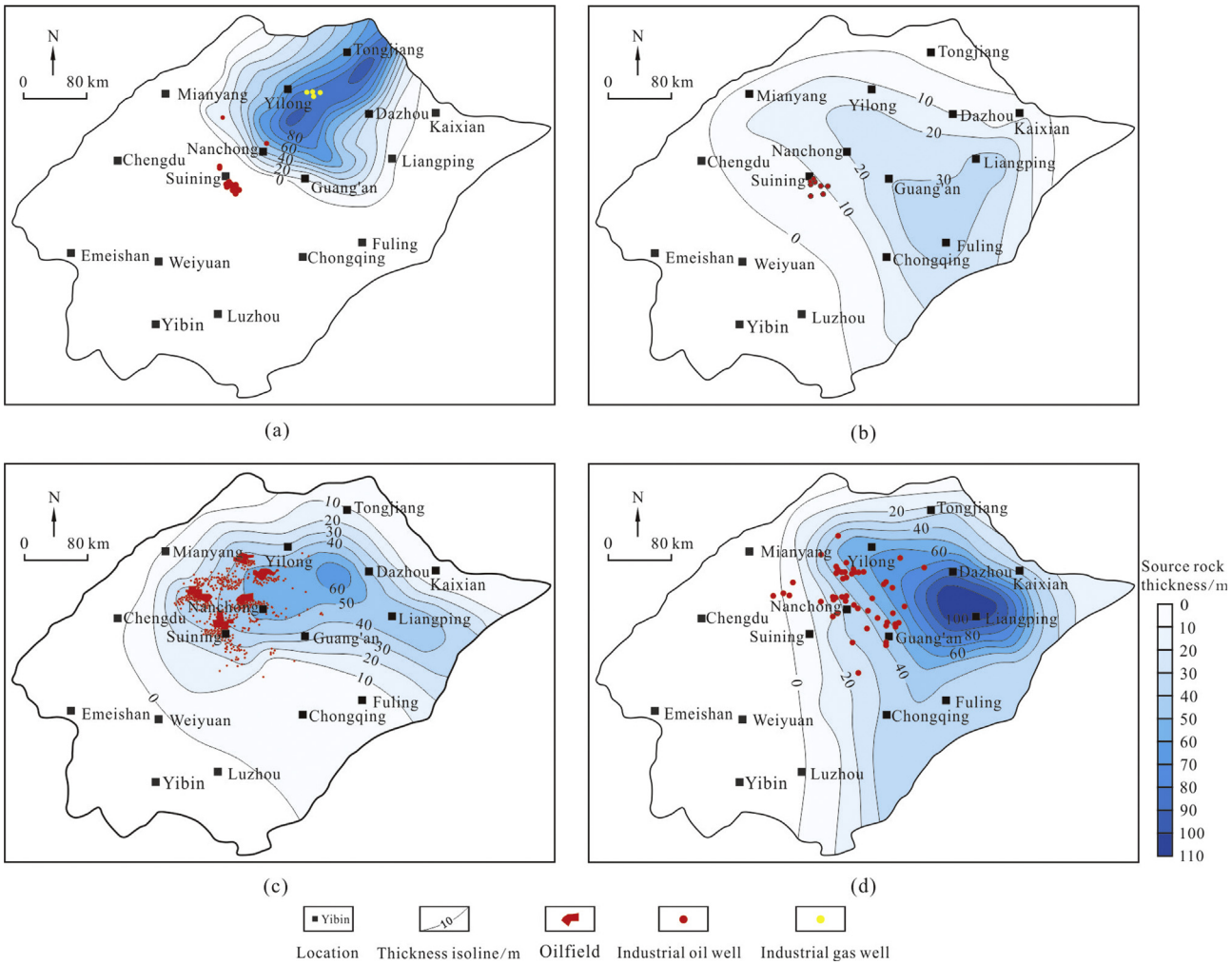

Fig. 1. Thickness distribution of Jurassic main source rocks in Sichuan Basin. (a) Thickness distribution of source rock in the Zhenzhuchong Member showing that thickness of source rock was up to 80 m; (b) thickness distribution of source rock in the Dongyuemiao Member showing that thickness of source rock was generally not more than 30 m; (c) thickness distribution of source rock in the Da'anzhai Member showing that thickness of source rock was more than 50 m; (d) thickness distribution of source rock in the Lianggaoshan Formation showing that thickness of source rock was up to 100 m.

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