Evaluation criteria, major types, characteristics and resource prospects of tight oil in China

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***Abstract*:** Tight oil refers to a petroleum play that occurs in a free or adsorbed state in source rocks or tight reservoir rocks (e.g., sandstone and carbonate rock) interbedded with or close to source rocks. Tight oil has generally not experienced large-scale, long-distance migration. According to such a definition and its characteristics, 10 key indices are proposed for tight oil resource evaluation in China. Tight oil reservoirs are divided into three groups in terms of porosity and permeability. Tight oil can be classified into three types according to the contact relationship between the tight oil reservoirs and source rocks, i.e., tight lacustrine carbonate oil, tight deep-lake gravity flow sandstones oil, and tight deep-lake deltaic sandstones oil. In China, tight oil resources are widely distributed and significant exploration discoveries have been achieved in the sixth member and seventh member of the Triassic Yanchang Formation in the Ordos Basin, the Permian Lucaogou Formation in the Junggar Basin, the Middle-Lower Jurassic strata of the Sichuan Basin, and the Cretaceous Qingshankou and Quantou Formations in the Songliao Basin. The total geological resources of tight oil in China assessed by using the "analog" method are estimated to be (10.67–11.15) $\times 10^9$ tones. Taking into account of the future prospects of petroleum development, tight oil may become a realistic alternative to the conventional oil resources in China.

Key words: *tight oil; evaluation criteria; classification; reservoir characteristics; resource potential*

1 Introduction

Tight oil is a new focal resource type of the global unconventional oil and gas resources following shale gas (Sun et al., 2011; Zou et al., 2011). The United States has attached great importance to the exploration of tight oil (Daniel et al., 2009) and attempts to replicate the shale gas development model to achieve crude oil self-sufficiency. In 2006, a breakthrough of tight oil production (over 7950 m^3/d) was made in the Elm Coulee Oilfield from the Bakken Formation in the Williston Basin, which significantly increased the confidence of tight oil exploration and attracted substantial investment. In 2008, large-scale tight oil development was achieved in the Bakken Formation. This progress was considered to be one of the global top 10 discoveries for the year(Zou et al., 2011). In 2009, the U.S. tight oil exploration and development investment reached at $ 51.4 billion(Lu, 2011). In the following year, the U.S. tight oil production exceeded 30×10^6 t, which for the first time reversed its decreasing trend in oil production that had lasted for 24 years. In 2012 there were over 2000 tight oil wells in the U.S. with an average single well oil production of 12 t/d(Zou et al., 2011). Total tight oil production forecast of the U.S. is 150×10^6t in 2010 (Zou et al., 2011), which will increase the nation's total crude oil production by 1/3 and thus greatly reduce its dependence on foreign oil resources and to some extent change the global energy structure.

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In China, tight oil exploration was started relatively late and the concept of tight oil has now been widely accepted in recent years. Tight oil resources are widespread in China and particularly rich in the sixth member and seventh member of the Triassic Yanchang Formation in the Ordos Basin, the Permian Lucaogou Formation in the Junggar Basin, the Middle to Lower Jurassic strata in the Sichuan Basin, and the Cretaceous Qingshankou and Quantou Formations in the Songliao Basin. To date, great exploration discoveries have been achieved in the above tight-oil-rich formations that have the potential for large-scale accumulation and effective development. Through research and deployment of tight oil, the industrial capacity can be improved with the progress of exploitation technologies, enabling tight oil to be an important alternative for future replacement of oil resources in China.

Presently, tight oil exploration and development in China as well as related research remain at an early preparation stage. Overall, the levels of exploration and geological understanding of tight oil are low, and a number of questions exist in the basic geological theory, evaluation criteria, controlling factors, resource potential, and exploration direction of tight oil plays. Based on the most recent progress of tight oil exploration in different tight-oil-rich formations in China, this study proposes evaluation criteria for tight oil classification in China. The key geological characteristics of tight oil are elucidated and the resource prospects of tight oil are preliminarily evaluated and forecasted. The work will provide supporting data for exploration and continuous in-depth geological research of tight oil in China.

2 Concept and evaluation criteria for tight oil

2.1 Concept of tight oil

Tight oil is a petroleum that occurs in a free or adsorbed state in source rocks or tight reservoir rocks (e.g., sandstone and carbonate rock) interbedded with or close to source rocks, and has not experienced large-scale long-distance migration (Fig. 1). In general, tight oil has the following characteristics: (1) a large area of tight reservoirs with porosity < 10%, in-situ matrix permeability > 0.1 mD, and pore throat diameter <1μm (Zou et al., 2012); (2) widespread, overlapped, mature high-quality source beds (kerogen type I or II, average total organic carbon >1.0%, and R_o from 0.6% to 1.0%); (3) the coexisting relationship of continuously distributed tight reservoirs and source rocks that are in close contact, with no obvious trap boundary or oil reservoir(Zou et al., 2012); (4) the density of crude oil in tight reservoirs >40°API or <0.83 g/cm^3, i.e., relatively light oil.

2.2 Tight oil evaluation criteria

Large-scale exploration and efficient development of tight oil mainly depend on following evaluation criteria: (1) Porosity and permeability are two physical parameters that respectively describe reserve and percolation capabilities of reservoir, in accordance with the existing reservoir classification standards and relevant exploration and development experiences, the porosity of tight oil reservoirs under normal circumstances is <10% and the in-situ matrix permeability is <0.1 mD. (2) Tight

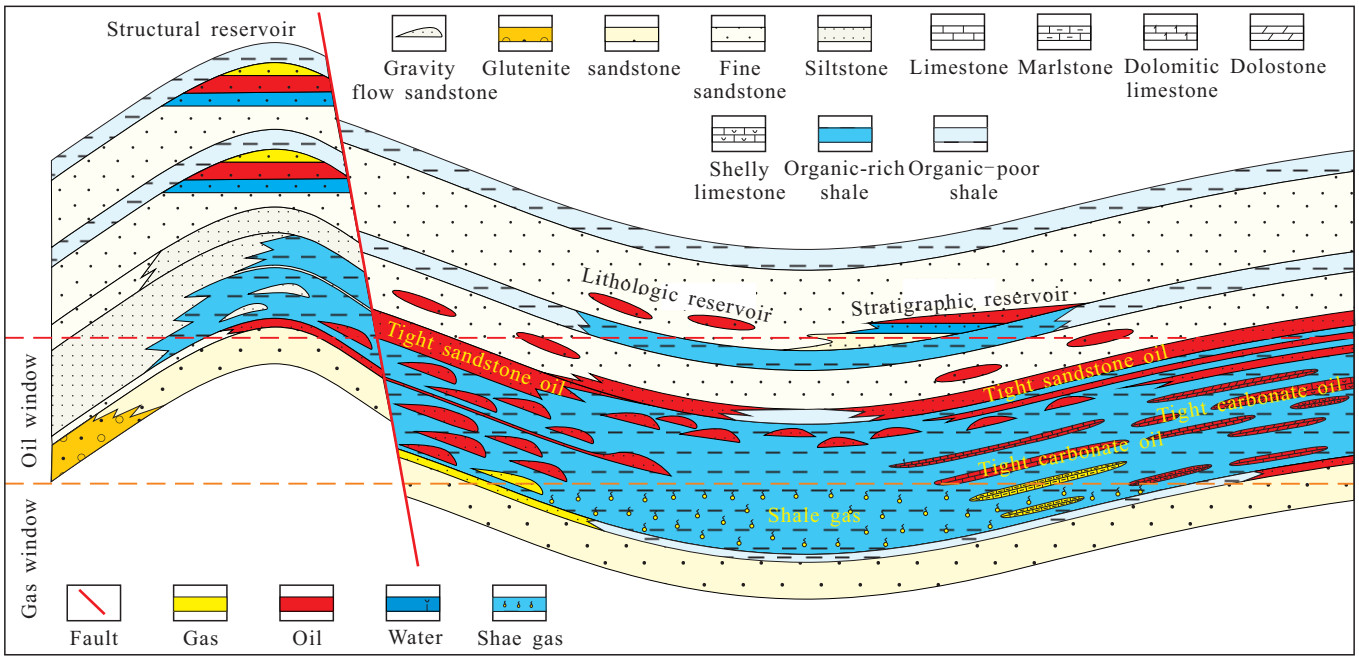

Fig. 1 Spatial distribution of tight oil in relation to source rocks and reservoirs