PETROLEUM EXPLORATION AND DEVELOPMENT
Volume 40, Issue 2, April 2013
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: PETROL. EXPLOR. DEVELOP., 2013, 40(2): 161–169.

RESEARCH PAPER

Characteristics of tight oil in Triassic Yanchang Formation, Ordos Basin

YAO Jingli[1,2,*], DENG Xiuqin[1,2], ZHAO Yande[1,2], HAN Tianyou[1,2], CHU Meijuan[1,2], PANG Jinlian[1,2]

1. Exploration & Development Research Institute of PetroChina Changqing Oilfield Company, Xi'an 710018, China;
2. National Engineering Laboratory for Exploration and Development of Low-Permeability Oil Fields, Xi'an 710018, China

Abstract: By comprehensive study of reservoir and source rock distribution, petrology and geochemistry, the tight oil and its exploration potential was analyzed in the Triassic Yanchang Formation, Ordos Basin. The Triassic Yanchang Formation is rich in low permeability reservoirs. The proved geological reserves of tight oil, with the permeability less than 2×10^{-3} μm^2, is about two billion tons by now. The tight oil mainly occurs in tight sandstone reservoirs of Chang6-Chang8 oil-bearing members which are close to or interbedded with the oil shale layers, without long-distance migration. The large-scale gravity flow sandstone reservoirs of Chang7 and Chang6 oil-bearing members in the center of the lacustrine basin are particularly tight, with the permeability less than 0.3×10^{-3} μm^2 in general. The tight oil in the Yanchang Formation features large scale in sand body complex, tight reservoir, complicated pore throat structure, high content of rigid components, abundant fractures and saturation, good crude property, low fluid pressure and low oil yield. The formation of large-scale superimposed tight oil reservoirs is controlled by the interbeded lithologic combination of extensive source rocks and reservoirs and the strong hydrocarbon generation and expulsion during geological history. This type of pools is an important potential resource for future oil exploration and development.

Key words: tight oil; Yanchang Formation; Ordos Basin; potential resource

Introduction

In recent years, unconventional oil and gas resources such as tight gas, tight oil and shale oil, have successfully obtained commercial development in the United States, Canada, Australia and other countries, playing an important role in the global energy structure [1]. Although tight sandstone gas, tight oil, shale oil, and coal bed methane and other unconventional oil and gas resources are abundant in China, their exploration and development is still in the initial stage. The reservoirs in the Triassic Yanchang Formation of the Ordos Basin have a low maturity, strong diagenesis, with fine particles of rock, poor sorting, high cement content, considerable variation in the reservoir space, and great heterogeneity [2]. The reservoirs take on characteristics such as tight reservoirs, being difficult to predict, complex mechanism of accumulation, low production rate per well [3]. They are typical areas in which low permeability reservoirs developed in China. In recent years, many new understandings have been obtained through comprehensive research on favorable sedimentary-diagenetic facies of the clastic rocks, relationship between the reservoir tightening history and hydrocarbon accumulation history, reservoir formation mechanism and the oil accumulation patterns, etc. [4–15] It also effectively guides the exploration and development of the Mesozoic reservoirs in the Ordos Basin. Consequently, large oil fields with reserves of more than a giga-ton-class (10^9t) have been discovered in Xifeng, Jiyuan, and Hua(chi)-Qing(cheng) [16–19], in which tight oil and gas resources are abundant. Until now, the proved reserves of tight oil with air permeability of less than 2×10^{-3} μm^2 are about 2×10^9t. Therefore, there is a great potential for exploration and development. The tight oil has now become an important domain for petroleum exploration and development in the Ordos Basin. To strengthen the tight oil study of the Ordos Basin is a great significance for exploration and development of tight oil resources in China.

1 Concept of tight oil

Tight oil is a kind of unconventional petroleum resource. At present, there is no uniform definition at home or abroad. In recent years, tight oil has been rapidly developing in the United States, especially the Bakken tight oil in the Williston Basin. It mainly developed in the depression of the Basin,

Received date: 22 May 2012; **Revised date:** 16 Jan. 2013.
*** Corresponding author.** E-mail: yjl_cq@petrochina.com.cn
Foundation item: Supported by the National Science and Technology Major Project "Large Oil and Gas Fields and Coalbed Methane Development" (2011ZX05044; 2011ZX05001-004)

Table 1 Comparison of characteristics of the tight oil in the Ordos Basin and the Bakken Basin [20–27]

Tight oil reservoirs	Stratum	Depositional environment	Depth/m	Shale thickness/m	Reservoir rock types	Minerals/%			Physical properties*		Formation pressure factor	Kerogen type	*TOC*/%	R_o/%	Maximum pyrolysis temperature/°C	Source-reservoir relationship
						Quartz	Feldspar	Clay	Porosity/%	Perm./10^{-3} μm²						
Bakken Formation	Upper Devonian—Lower Carboniferous	Shallow marine	2 593–3 203	2.4–4.9	Silty dolomites, dolomitic siltstones	47.5	18.9	21.5	6.0	0.04	1.2–1.5	I+II	11.30	0.7–1.0	443–447	interbedded
Yanchang Formation	Triassic	Lacustrine	1 000–2 800	20–60	Fine-grained sandstones, siltstones	41.8	23.5	17.4	9.2	0.43	0.64–0.87	$I+II_1$	13.75	0.9–1.16	440–455	interbedded or immediately adjacent

Note: The physical property of tight oil reservoirs of the Bakken Formation and the Yanchang Formation are subsurface conditions and surface conditions respectively. All statistics are averages.

with a porosity of generally less than 10% and the in-situ permeability of generally between 0.001 and 0.1 × 10^{-3} μm² [20–27] (Table 1).

LIN Senhu [28] and JING Dongsheng [29] et al. defined the tight oil as a continuously distributed oil accumulation with self-source-reservoir in the organic-rich and extremely low permeability dark-colored shales, argillaceous siltstones, or sandstone intervals, in an adsorbed or free state. A large amount of stagnant shale-generated oil and gas occur in the nano-scale pores or micro fractures in the form of free hydrocarbon and absorption hydrocarbon, forming tight oil (gas) available for commercial exploitation, with the exception of parts of the shale-generated petroleum being discharged and migrated into the permeable rocks such as sandstones or carbonate rocks to form conventional oil and gas reservoirs.

In order to meet the needs of the development of unconventional oil and gas resources in China, according to the status quo of China's oil and gas fields, it has been clarified that the tight oil usually refers to the sandstone and carbonate reservoirs with in-situ matrix permeability of less than 0.2 × 10^{-3} μm² or air permeability of less than 2 × 10^{-3} μm². Generally the single well has no natural production capacity or the natural productivity is lower than the minimum commercial hydrocarbon flow, but could obtain commercial oil production [30] through techniques like fracturing, horizontal wells, multilateral wells etc. under certain economic conditions.

2 Tight oil distribution

The Mesozoic Yanchang Formation in the Ordos Basin is rich in tight oil resources. Proven geological reserves of about 2 giga tons (10^9 t) has been submitted from the reservoirs with air permeability of less than 2 × 10^{-3} μm², of which the proven geological reserves of tight oil reservoirs with air permeability of less than 1 × 10^{-3} μm² outnumber one giga tons. The giga-ton-class tight oil reserves in the Xifeng, Jiyuan, Hua-Qing oilfields with average air-permeability of less than 2 × 10^{-3} μm² have been discovered. The Yanchang Formation tight oil is distributed in the "core area" of the play: on plan, in the middle of the lake basin, that is, the range delineated by Huanxian - Wuqi-Zhidan-Zhengning-Ningxian-Qingyang

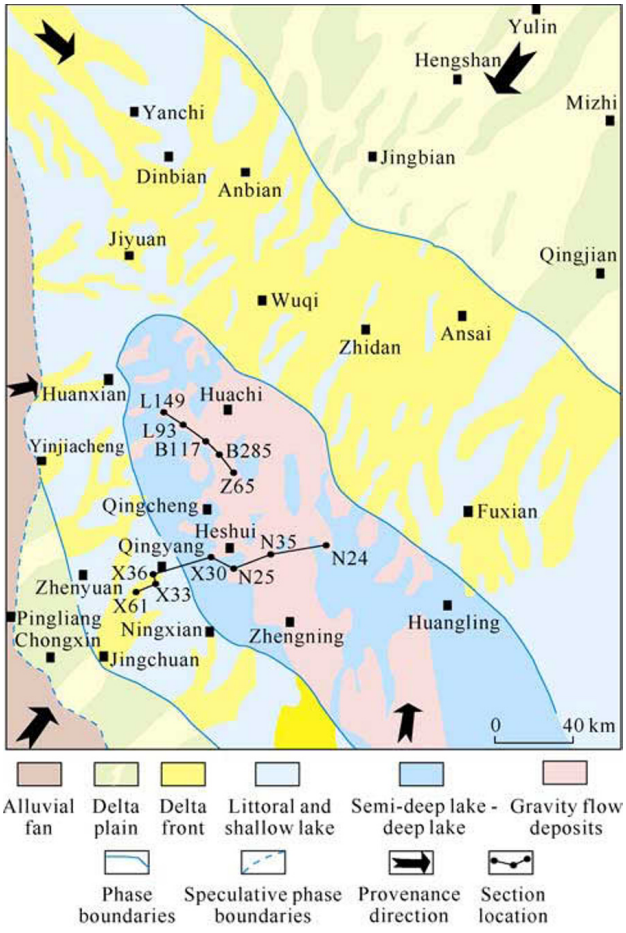

Fig. 1 The sedimentary facies map of Triassic Chang 6 Formation, Ordos Basin.

(Figure 1), as a depocenter in the Mid-Late Triassic; vertically, it's located in the middle of the Yanchang Formation, that is, in the tight sandstone reservoirs interbedded and associated with or immediately adjacent to the oil shale. The oil is without large- scale long-distance migration (Figure 2), mainly distributed in Chang 6 – Chang 8 oil reservoir group. The Chang 8 and Chang 6 reservoirs and the Chang 6 oil reservoir in the northern Hua-Qing oilfield are mainly composed of delta front and prodelta sediments, dominated by fine sandstone, and