

Research article

Discussion on the exploration & development prospect of shale gas in the Sichuan Basin

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Abstract

The Sichuan Basin, a hotspot and one of the most successful areas for shale gas exploration and development, can largely reflect and have a big say in the future prospect of shale gas in China. Through an overall review on the progress in shale gas exploration and development in the Sichuan Basin, we obtained the following findings: (1) the Sichuan Basin has experienced the marine and terrestrial depositional evolution, resulting in the deposition of three types of organic-matter-rich shales (i.e. marine, transitional, and terrestrial), and the occurrence of six sets of favorable shale gas enrichment strata (i.e. the Sinian Doushantuo Fm, the Cambrian Qiongzhusi Fm, the Ordovician Wufeng–Silurian Longmaxi Fm, the Permian Longtan Fm, the Triassic Xujiahe Fm, and the Jurassic Zhiliujing Fm); (2) the five key elements for shale gas accumulation in the Wufeng–Longmaxi Fm are deep-water shelf facies, greater thickness of organic-rich shales, moderate thermal evolution, abundant structural fractures, reservoir overpressure; and (3) the exploration and development of shale gas in this basin still confronts two major challenges, namely, uncertain sweet spots and potential prospect of shale gas, and the immature technologies in the development of shale gas resources at a depth of more than 3500 m. In conclusion, shale gas has been discovered in the Jurassic, Triassic and Cambrian, and preliminary industrial-scale gas has been produced in the Ordovician–Silurian Fm in the Sichuan Basin, indicating a promising prospect there; commercial shale gas can be produced there with an estimated annual gas output of 30–60 billion m³; and shale gas exploration and production experiences in this basin will provide valuable theoretical and technical support for commercial shale gas development in China.

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Keywords: Sichuan Basin; Shale gas; Exploration and development; New progress; Enrichment condition; Prospect; Challenge; Annual gas output

1. Introduction

The exploration and development of shale gas has a long history of about 200 years since the first discovery of shale gas in North America in 1821. However, the rapid development has just been seen in the recent decade. According to EIA, in 2013, the shale gas production in North America was more than 350×10^9 m³ [1], with more than 320×10^9 m³ in the U.S, and approximately 30×10^9 m³ in Canada. China is also

abundant in shale gas resources, with a geologic resource volume of 134.4×10^{12} m³, and a technologically recoverable resource volume of 25.08×10^{12} m³, according to the prediction of the Ministry of Land and Resources in 2012 [2], indicating a broad development prospect of shale gas in China. To promote the exploration and development of shale gas in China, a pilot test of shale gas exploration and development was carried out first in the Sichuan Basin due to the two unique advantages of the Sichuan Basin — abundant organic-rich shales and great potential of shale gas resources [3,4].

The Sichuan Basin has always been the area with the greatest potential of natural gas in China, where there are both conventional gas fields such as Puguang gas field discovered in

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2003 and Anyue-Longwangmiao gas field discovered in 2012, and abundant unconventional natural gas resources such as commercial tight gas in eastern Sichuan and western Sichuan. Shale gas was discovered in the Qiongzhusi (Qz) Fm in Well Wei 5 in 1966, and then in the Wufeng-Longmaxi (WL) Fm in Well Yang 63 in the 1980s. After the introduction of the new concept of shale gas from North America in 2005, a strategic breakthrough of shale gas exploration and development was made in Well Wei 201 with the discovery of the Qz and WL Fms shale gas reservoirs, which marked a new historic beginning and brought about a craze of shale gas exploration and development in China. Four years later, the first large-scale shale gas field of 100 bcm was discovered in Jiaoshiba, Fuling, in 2014 [5] with a productivity of $5 \times 10^9 \text{ m}^3$ per year, marking a historic turning-point of commercial production of shale gas in the Sichuan Basin, with it comes a big boom of shale gas exploration and development in China presently [6–8].

Shale gas exploration and development in the Sichuan Basin will have a great influence to some degree on the future shale gas development in China. For speeding up the process of shale gas exploration and development in China, the sedimentary evolution and characteristics of organic-rich shales in the Sichuan Basin are analyzed, and the enrichment conditions and key control factors of marine shale gas are elucidated. The main challenges the exploration and development of shale gas confronts are also pointed out. And the development prospect of shale gas in the Sichuan Basin is predicted in the paper as well based on an overall review on the latest progress of shale gas exploration and development there. Hopefully, this paper

will provide valuable theoretical and technical support for commercial shale gas exploitation in China.

2. Geologic setting

The Sichuan Basin, covering Sichuan Province and Chongqing city, is bordered by Micang Mountain and Daba Mountain in the north, Daliang Mountain and Lou Mountain in the south, Longmen Mountain and Qionglai Mountain in the west, and Qiyao Mountain in the east, with a total area of approximately $190 \times 10^3 \text{ km}^2$ (Fig. 1). After over 6 decades of unremitting exploration and development, 115 gas fields have been discovered, and 110 gas fields have been developed in the Sichuan Basin. The production of natural gas there in 2013 was $24.3 \times 10^9 \text{ m}^3$, accounting for 20% of the total in China, demonstrating an indisputable place of the basin in natural gas production of China.

The Sichuan Basin is an important primary structural unit in the west of Yangtze platform and a large ancient super-imposed sedimentary basin, with Presinian metamorphic and igneous rocks as its basement. Influenced by Tethyan and Pacific structural domains, this basin has experienced two stages of sedimentary evolution: Sinian-Middle Triassic cratonic platform deposition, and Late Triassic-Cenozoic foreland basin deposition. Before Indo-China movement, as a part of Yangtze palaeo-ocean basin, the Sichuan Basin was dominantly affected by the development of Yangtze platform, abundant organic-rich shales deposited in half-deep to deep water shelf facies during Sinian, Cambrian, Ordovician, and Silurian. Influenced by Caledonian and Hercynian movements,

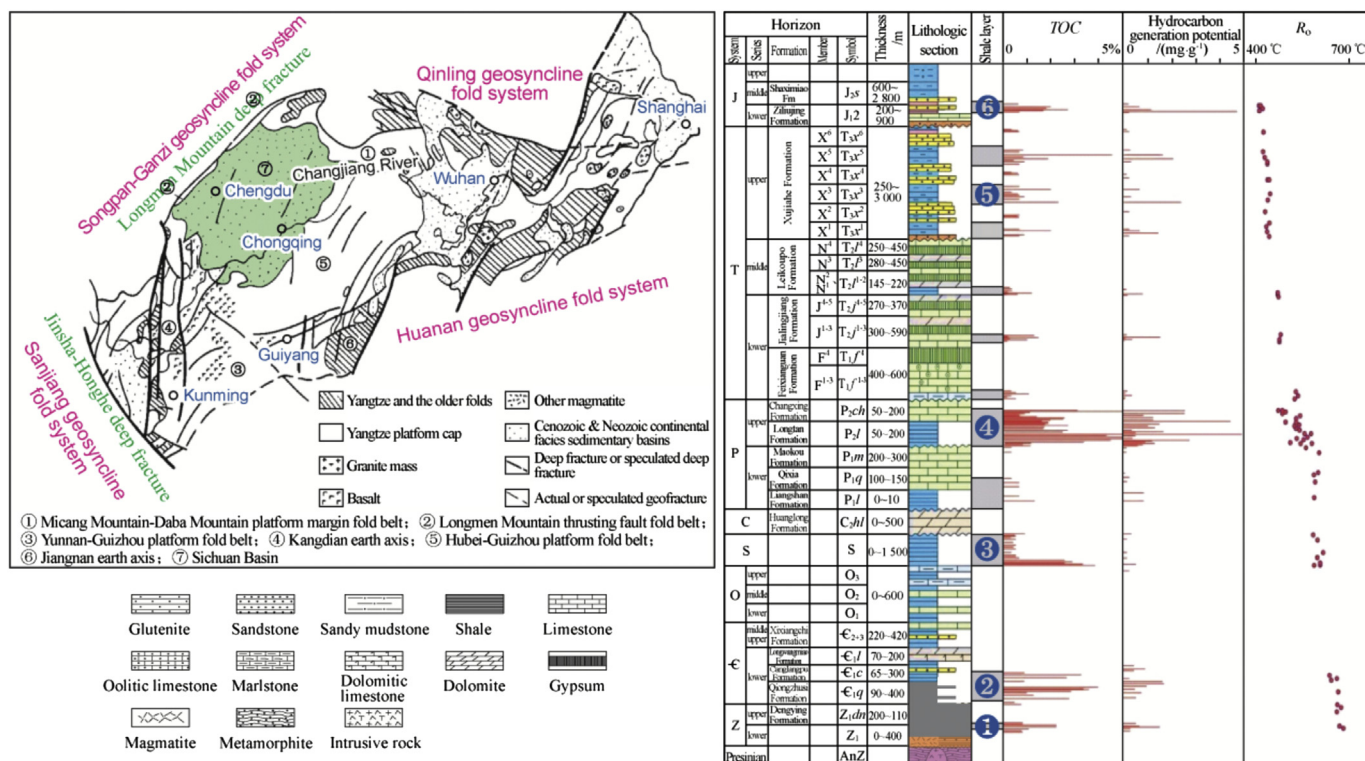


Fig. 1. Tectonic position and stratigraphic structure of the Sichuan Basin.

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