

Research Article

A golden era for natural gas development in the Sichuan Basin

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Abstract

Owing to the technical innovation as well as a better understanding of gas exploration, nine giant gas fields have been successively discovered in the Sichuan Basin with cumulative proven gas reserves of 3.69 trillion cubic meters, where the annual natural gas productivity ranks the second in China. The CNPC latest oil & gas resources evaluation results demonstrate that natural gas resources in the Sichuan Basin takes the first place among those petroliferous basins all over China, but its proved gas reserves is only 10%, so the exploration prospect is bright. Over the past decades, PetroChina Southwest Oil & Gas Field Company has made great efforts to complete its technical systems, improve gas pipeline networks, and streamline gas markets, laying a robust foundation for the natural gas development in the Sichuan Basin. To further enhance the natural gas reserves and productivity in this basin and to achieve the biggest gas province in China, this company presents the following major projects: progressive multi-strata exploration and development in the central Sichuan area, Safe and efficient development of high-sulfur gas fields in the northeastern Sichuan area, Demonstrative exploration and development of deep marine carbonate gas reservoirs in the northwestern Sichuan area, Exploitation and development of large Cambrian pre-salt structural gas reservoirs in the eastern Sichuan area, and Extensive and beneficial development of shale gas in southern Sichuan. As the key to the Southwest growth pole, the above projects cover all the important, hard and hot fields of the whole basin and multiple gas-bearing strata and layers. With all the projects fulfilled, natural gas productivity will be 25–29 billion cubic meters (bcm) in 2020, accounting for most parts of this company's whole planning production (30 bcm in total), and will reach up to 50–70 bcm in 2030. It is predicted that natural gas development in the Sichuan Basin will be in a golden era in the long term.

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Keywords: Sichuan Basin; Natural gas; Golden era; Resources; Exploration rate; Reserves; Production rate; Five major projects for enhancing both natural gas reserves and productivity; PetroChina Southwest Oil & Gas Field Company

Owing to the technical innovation as well as a better understanding of gas exploration, the Sichuan Basin has witnessed a rapid growth period of natural gas reserves and production rate. The latest oil & gas resources evaluation initiated by CNPC demonstrated that the Sichuan Basin takes the first place among the petroliferous basins in China for its gas resources, of which only 10% has been proved as reserves. In this basin, the exploration is in the early-middle stage, so its exploration prospect is bright. Over years of development,

advanced technical systems, perfect gas pipeline networks, and mature gas markets have been established in the Sichuan Basin. Furthermore, the basin will play an important role in developing the “Southwest Growth Pole” under the 13th Five-Year Plan of PetroChina Southwest Oil & Gas Field Company (“Southwest Oil & Gas Field”). Southwest Oil & Gas Field has proposed five major projects for enhancing natural gas reserves and productivity to ensure that a large gas province of $300 \times 10^8 \text{ m}^3$ will be completely built by 2020 and the gas production rate will reach $500 \times 10^8 \text{ m}^3$ by 2030. It can be said that the natural gas development in the Sichuan Basin has entered a golden era.

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1. The Sichuan Basin with the richest natural gas resources and the largest exploration potential

1.1. Geology

The Sichuan Basin is a typical superimposed basin characterized by a large oil and gas exploration area and dominated by gas production. The favorable exploration area in the basin and its periphery is more than $30 \times 10^4 \text{ km}^2$, among which the licensed area of PetroChina is $16.67 \times 10^4 \text{ km}^2$. There are thick strata, with both marine and continental formations up to 6000–12000 m thick. Specifically, the Late Proterozoic Sinian–Middle Triassic formations present a set of marine platform sedimentary sequence dominated by carbonate, with a thickness of 4000–7000 m. Above the Middle Triassic, there are continental classic rocks, with a thickness of 2000–5000 m. Vertically, 6 sets of source rocks are developed, including 4 sets of marine source rocks (Lower Cambrian, Lower Silurian, Lower Permian, and Upper Permian) and 2 sets of continental source rocks (Upper Triassic and Lower Jurassic). By far, 25 gas-dominated commercial hydrocarbon strata have been obtained from Sinian to Jurassic.

1.2. Rich gas resources and large exploration and development potential

1.2.1. Ranking the first in gas resources in China, and being in the early-middle exploration stage

According to the results of PetroChina's latest oil & gas resources evaluation, the Sichuan Basin contains total natural gas resources of $38.18 \times 10^{12} \text{ m}^3$, including $12.47 \times 10^{12} \text{ m}^3$ conventional gas, $3.98 \times 10^{12} \text{ m}^3$ tight gas, and $21.73 \times 10^{12} \text{ m}^3$ shale gas under 4500 m. At present, the favorable shale gas area is $2 \times 10^4 \text{ km}^2$, with recoverable resources of $10 \times 10^{12} \text{ m}^3$. The sum of conventional gas, tight gas and recoverable shale gas resources is $26.45 \times 10^{12} \text{ m}^3$, ranking the first in China (Fig. 1) [1].

In view of the proved rate of natural gas, the Sichuan Basin demonstrates only 10%, lower than that in mature basins in

other countries (generally 30%–60%). Assuming the rate is 30%, the proved natural gas reserves in the Sichuan Basin would expected to reach $10 \times 10^{12} \text{ m}^3$ (Table 1).

1.2.2. A rapid growth stage of both natural gas reserves and production

After more than 60 years of operations, valuable breakthroughs in gas exploration have been made successively in Southern Sichuan fracture system, Carboniferous in eastern Sichuan Basin, Lower Triassic Feixianguan Fm in eastern Sichuan Basin – central Sichuan Basin, and Upper Triassic Xujiahe Fm and Lower Paleozoic–Sinian in central Sichuan Basin. The exploration initially focused on surface structures and small gas reservoirs like fractured reservoirs, but later turned to medium–large layered fracture–pore/cavity gas reservoirs. By the end of 2015, PetroChina and Sinopec totally had proved natural gas reserves of $3.69 \times 10^{12} \text{ m}^3$ in the Sichuan Basin. All large gas fields with reserves of more than $1000 \times 10^8 \text{ m}^3$ were discovered in the past decade. Since 2005, with the advancement of engineering technologies and more knowledge about geology, the Sichuan Basin has entered a rapid growth period of natural gas. Nine large and super-large gas fields with individual reserves of more than $1000 \times 10^8 \text{ m}^3$ have been successively discovered (Table 2), contributing additional proved gas reserves of more than $2.4 \times 10^{12} \text{ m}^3$, accounting for 65% of the accumulative proved gas reserves of the basin.

Natural gas production in the Sichuan Basin has been continuously and stably increasing – up to $50 \times 10^8 \text{ m}^3$ in 1977, $100 \times 10^8 \text{ m}^3$ in 2004, more than $200 \times 10^8 \text{ m}^3$ in 2010 and $300 \times 10^8 \text{ m}^3$ in 2015. By the end of 2015, PetroChina and Sinopec's accumulative gas production in this basin was about $4000 \times 10^8 \text{ m}^3$ and $1000 \times 10^8 \text{ m}^3$ respectively.

1.2.3. Reappearance as the largest gas production province in China in the late period of the 13th Five-Year Plan

The Sichuan Basin represents the earliest area around the world where natural gas was discovered and utilized. The Sichuan–Chongqing area, structurally as a part of the Sichuan Basin, has a long history of natural gas exploitation, since Sichuan ancestors discovered and utilized natural gas in the present Qionglai belt as early as 2000 years ago [2]. The Chinese modern natural gas industry is originated from the Sichuan Basin. In 1937, Well Ba1 was drilled in the Shiyougou structure in Baxian County (present-day Banan District of Chongqing City). It was the first natural gas well drilled by rotary drilling rig in the modern oil and gas drilling history and also the first well for geophysical logging in China. After the foundation of New China, the first petroleum campaign was initiated in Sichuan. In the 1950s–1960s, two rounds of petroleum campaigns were carried out, helping to deepen the understanding of oil and gas resources in the basin and uncover a natural gas industrial age in China. In 1965, the first large gas field–Weiyuan gas field was discovered. Before 2009, gas production in the Sichuan Basin always stayed at the first place in China (Fig. 2). In 2015, gas production in the Sichuan Basin was about $300 \times 10^8 \text{ m}^3$, ranking the second in

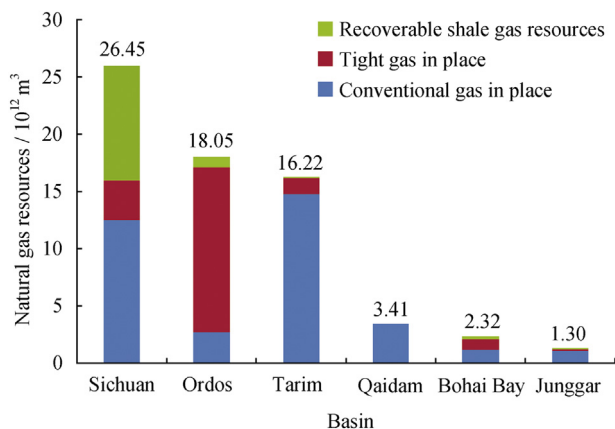


Fig. 1. Histogram of natural gas resources in major petroliferous basins in China.

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