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Research article

Significance of new breakthrough in and favorable targets of gas exploration in the Middle Permian system, Sichuan Basin

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Abstract

The Middle Permian system in the Sichuan Basin represents favorable conditions for the formation of natural gas reservoirs. However, only fracture-vuggy limestone gas reservoirs were discovered in early exploration, whose scales and results were limited. In 2014, a high-yield industrial gas flow was produced there in Well Shuangtan 1, the major risk-exploration well, which means a great breakthrough in natural gas exploration in the Middle Permian system, Sichuan Basin. This plays a strategically important and guiding role in oil and gas exploration in ultra-deep marine formations. This paper illustrates the deployment background of Well Shuangtan 1, major exploration achievements and its significance in the gas exploration in the Middle Permian system, Sichuan Basin. Moreover, exploration potential and subsequent exploration targets of Middle Permian are analyzed in terms of its hydrocarbon source conditions, sedimentary characteristics, reservoir characteristics and areal extension, resources and favorable exploration zones. It is concluded that the Middle Permian system in the Sichuan Basin is a continent-connected carbonate platform with carbonate deposits being dominant. There are three types of reservoirs, including pore dolomite, karst fracture-vuggy, and fracture, which present considerable natural gas resources and huge exploration potential. Favorable exploration zones classification of Middle Permian in the Sichuan Basin indicates that the most favorable exploration zones are mainly distributed in the central-western Sichuan Basin. In particular, the northwestern Sichuan Basin is the most favorable exploration area which is characterized by the most excellent hydrocarbon source conditions, developed dolomite reservoirs and zonal distribution of structures.

Keywords: Sichuan Basin; Well Shuangtan 1; Risk-exploration; Middle Permian; Natural gas exploration; Breakthrough; Favorable zone; Hydrocarbon source conditions; Dolomite; Reservoirs

1. Overview of natural gas exploration

1.1. General situation

With a long natural gas exploration history, the Middle Permian has always been an important stratum for natural gas exploration and development in the Sichuan Basin. The exploration of this stratum started over 60 years ago, when the first well (Long 10) produced gas from the Middle Permian Maokou Formation in 1955. At early stage, exploration activities in the southern Sichuan region mainly focused on the Middle Permian, aiming to find karst fracture-cave gas reservoirs. To date, proved natural gas reserves of the Middle Permian over the whole basin total 852.03×10^8 m^3, of which 87.7% (746.9×10^8 m^3) is produced in the southern Sichuan region. These reserves are distributed within a total of 325 fracture-cave systems of varying sizes. Scale layered reservoirs are absent in this region.

Field workers have long noted that, the Middle Permian Qixia Formation in local area of the northern part of the western

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Sichuan region contains layered "saccharoidal" dolomite and "leopard" limestone, which are 30−40 m thick, exhibit good physical properties and can act as a favorable reservoir. Yet, a long-standing question is whether or not this dolomite can be present at subsurface. Kuang 2, a well drilled in the northern part of the western Sichuan region targeting the Kuangshanliang structure, reveals the presence of thick-bedded pore-type dolomite inside the basin. This triggered considerable interest in prospecting the Middle Permian pore-type large-scale gas reservoirs. Then Well Kuang 3 was subsequently drilled to the north of Well Kuang 2, targeting the Baolunzhen structure in the Kuangshanliang structural belt. According to the completion well-log interpretation, the Qixia Formation reservoir is absent in this well. This has initially demonstrated that the Qixia Formation pore-type dolomite reservoir in the northern part of the western Sichuan region is characterized by rapidly changed lateral distribution and high heterogeneity.

In order to achieve breakthrough in natural gas exploration of marine strata in the western Sichuan region, PetroChina Southwest Oil & Gas Field Company (hereinafter referred to as PetroChina Southwest) accelerates the exploration process of the Middle Permian in the western Sichuan region, and places much emphasis on integrated geological study and 2D seismic survey during the 10th and 11th Five-Year Plan. Although some wells have been drilled to test some favorable structures and the Middle Permian reservoir facies belt, including some small-scale high-pressure and extra-high-pressure gas reservoirs (e.g., Hewanchang and Jiulongshan) and gas-bearing structures (e.g., Shejianhe, Zhangjiabian and Xiasi), the discoveries are considered less significant, because there is no substantial breakthrough.

1.2. New breakthrough in recent natural gas exploration

1.2.1. Deployment of Well Shuangtan 1

Continuous drilling and geological study results at early stage suggest that the Middle Permian in the northern part of the western Sichuan region possesses a favorable condition for natural gas accumulation, and numerous wells producing gas from the Middle Permian Maokou Formation through testing have preliminarily proved to have the superiority of preservation condition of this region [1−7]. All these jobs and understandings have further strengthened our confidence and determination to find large- to medium-sized gas fields in the northern part of the western Sichuan region.

In the western Sichuan region, PetroChina Southwest has selected the Shuangyushi-Hewanchang structural belt (Fig. 1) in the northern part to seek a breakthrough in prospecting the marine strata, deployed 1140 km of 2D seismic survey in 2010 and 2011, and invited numerous companies to systematically conduct the integrated geological study and seismic processing & interpretation since the 11th Five-Year Plan, in order to determine the reservoir development degree and gas-bearing capacity of the Permian and Triassic strata and open up a new territory for natural gas exploration. Based on these results, the exploration Well Shuangtan 1 was designed and drilled in 2012, targeting the Shuangyushi structure (Fig. 1). This well is located in the northwestern part of the Sichuan Basin, within Jiange County, Guanyuan City. Regionally, it structurally lies at the joint part of the Longmenshan nappe structural belt and the Zitong syncline, which is bordered by the Ganzi-Songpan structural belt to the west, to the east by the front of the Micangshan platform marginal uplift belt, and

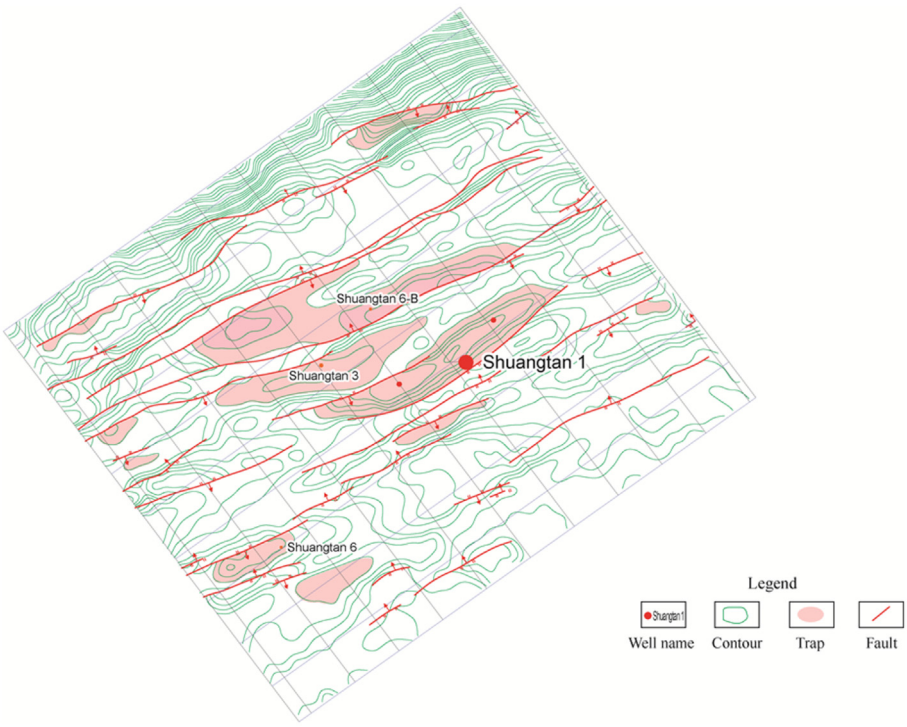

Fig. 1. Structural map of the Upper Permian base floor in the Shuangyushi structure in the northwestern part of the Sichuan Basin.