

## Research Article

# Key technologies for well completion and commissioning of ultra-deep sour gas reservoirs in the Yuanba Gasfield, Sichuan Basin<sup>☆</sup>

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## Abstract

The Yuanba Gasfield is another large gas field with reserves of a hundred billion cubic meters that was discovered by Sinopec after the Puguang Gasfield in the Sichuan Basin. At present, it is the deepest marine carbonate sour gas field in China. Its principal reservoir, the Upper Permian Changxing Fm, is characterized by ultra depth, high temperature, high sulfur content, high CO<sub>2</sub> content, and complex gas–water relationship. Therefore, well completion is faced with complicated engineering geological conditions, diverse well types and well completion modes and high-difficulty operation. In view of this, Sinopec Southwest Petroleum Engineering Co., Ltd. carried out technical research and practice. As a result, a series of key well completion and commissioning technologies were developed, including well completion testing and ground control, in-depth acid fracturing stimulation, ultra-deep slim-hole wellbore processing, micro-tooth mark make-up and air tightness detection, and safety control. Based on these technologies, the worldwide technical difficulties of well completion and commissioning in the process of gas field development are settled, such as string corrosion prevention, in-depth acid fracturing, high-yield testing, and safety control. These technologies have been applied successfully in nearly 40 wells, providing an important technical support for the realization of  $34 \times 10^8 \text{ m}^3$  annual gas production capacity construction in the Yuanba Gasfield.

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**Keywords:** Sichuan Basin; Yuanba Gasfield; Late Permian; Ultra-deep; High sulfur content; Well completion; Commissioning; Acid fracturing; Gas testing

## 1. Overview of the Yuanba Gasfield and technical difficulties in well completion and commissioning

### 1.1. An overview

The Yuanba Gasfield is geographically located in Cangxi County and Bazhong City, Sichuan Province, and it is

structurally situated at the southern margin of Micangshan structural belt in South Qinling, and the southwestern flank of Dabashan arc thrust structural belt (Fig. 1). On the whole, it is a part of central gentle structural belt in the Sichuan Basin. It lies at the transitional zone between the North Sichuan depression and the Central Sichuan uplift and is characterized by a large burial depth, weak structural deformation and gentle strata attitude. In this block, natural gas resources are abundant with proved gas in place of  $2000 \times 10^8 \text{ m}^3$ . Its principal gas reservoir, the Upper Permian Changxing Fm, is a reef–beach controlled fracture-pore lithologic gas reservoir locally with edge/bottom water and it is characterized by high H<sub>2</sub>S content (4.88–5.14%), medium CO<sub>2</sub> content (6.98–7.50%), normal pressure (66.33–70.62 MPa), high temperature (145.2–157.4 °C) and ultra depth (6200–7250 m). Its proved gas in place is  $1800 \times 10^8 \text{ m}^3$ . Complex engineering geology brings about huge challenges to the operation engineering of

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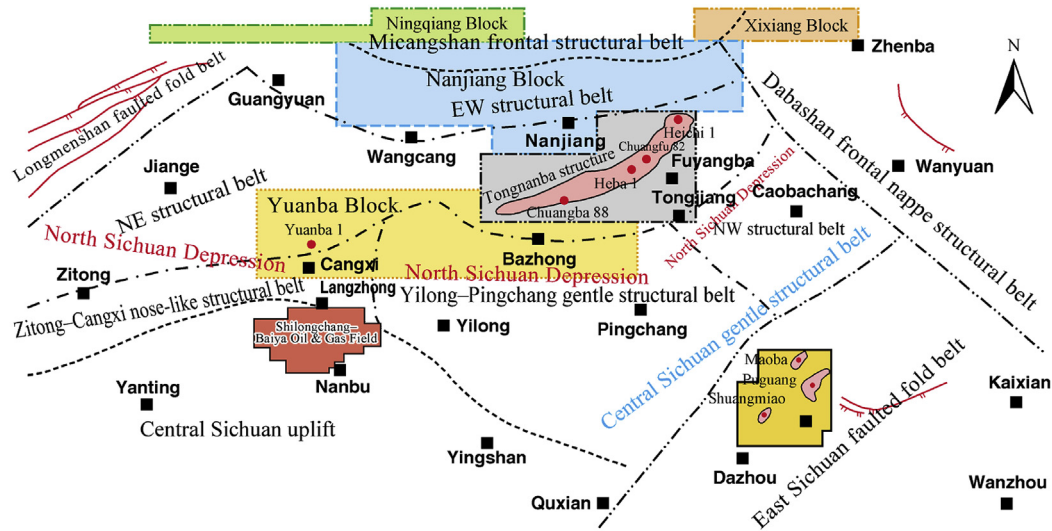


Fig. 1. Structural location of the Yuanba Block.

well completion and commissioning. Based on a systematic research, 29 key technologies of 4 types have been developed to solve effectively a large number of technical bottlenecks in the exploration and development of the Yuanba Gasfield. These technologies provide an important support for the high-efficiency safe commissioning of the Yuanba Gasfield.

## 1.2. Technical difficulties

The Changxing Fm gas reservoir in the Yuanba Gasfield is characterized by ultra-depth, high temperature, high sulfur content and high yield. These characteristics lead to a high risk of exploration and development. Besides, it is characterized by a strong heterogeneity and a complex gas–water relationship. As a result, wellbore processing, well completion testing, reservoir stimulation and safety insurance are faced with many technical difficulties as follows.

### 1.2.1. High-difficulty treatment of ultra-deep slim hole with long horizontal sections

In the Yuanba Gasfield, the gas wells in marine strata are completed mainly by using  $\varnothing 139.7$  mm,  $\varnothing 127$  mm or  $\varnothing 114.3$  mm liners or casings, and the horizontal section is

long and slim (Table 1). The commissioning string should carry large-size tools (e.g. permanent packers), but the annulus between the commissioning string and the casing is small, so the borehole preparation and treatment suffer more difficulties and risks [1].

### 1.2.2. High-difficulty commissioning testing due to high temperatures and high $H_2S$ contents

The reservoir temperature and  $H_2S$  content are high (Table 2), so downhole strings are prone to deformation, leakage and breaking due to  $H_2S$  corrosion, temperature effect and expansion effect. As a result, difficulties and risks of completion testing are exaggerated largely.

### 1.2.3. High-difficulty in-depth reservoir stimulation due to deep burial depth, high temperature and strong heterogeneity

The reservoirs are characterized by deep burial depth and high temperature (Table 3), so acid reacts fast on rocks after the conventional acid flows into the reservoirs. As a result, the etched fractures are short, and in-depth acid fracturing cannot be realized easily. The reservoirs in reef, beach and superimposed areas are strongly heterogeneous, with various

Table 1  
Well completion statistics of some wells in marine strata in the Yuanba Gasfield.

Well No.	Well type	TVD/m	Completion mode	Minimum hole size/mm	Horizontal section length/m
YB11	Vertical well	7027.00	Casing perforation	139.7	
YB122-sidetracking 1	High angle deviated well	7480.00	Casing perforation	139.7	
YB10-1H	Horizontal well	7749.00	Liner	127.0	507.0
YB103H	Horizontal well	7729.80	Liner	127.0	684.8
YB27-3H	Horizontal well	7626.0	Liner	127.0	838.0
YB102-2	Horizontal well	7802.0	Liner	127.0	782.0
YB1-sidetracking 1	Deviated well	7427.22	Casing perforation	121.4	
YB121H	Horizontal well	7786.00	Liner	114.3	873.0

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