Recovering the phase diagram of condensate gas reservoir in Well TZ86, Central Tarim Basin using PVTsim with geochemical inputs

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Abstract. The phase diagram of the condensate gas reservoir in the Ordovician lithologic trap of Well TZ86 was recovered using PVTsim software with geochemical inputs (well fluid components and experiment data). The results show the error between the recovery and measured phase diagrams is within a reasonable range, indicating the reliability of the recovery result. The recovery phase diagram shows an order of CP-Pm-Tm, and the current reservoir temperature and pressure (138.49°C, 65.10MPa) confirms that the fluid belongs to the condensate gas phase currently and turns to the condensate gas-condensate oil coexistence phase when it is mined to the surface condition. The components rich in gaseous hydrocarbons caused by the gas charging in the Late Himalayan and the temperature and pressure condition determined the formation of condensate gas reservoirs in the Tazhong Uplift.

1. Introduction
The Tarim Basin is the largest petroleum-bearing basin in China, covering an area of 56x10⁴ km². The development of two sets of hydrocarbon source rocks, multiple oil and gas charging, and multiple adjustments after accumulation, all made the distribution of oil and gas phase state complicated[1, 2]. There are solid bitumens, heavy oil reservoirs, normal oil reservoirs, light oil reservoirs, condensate gas reservoirs, wet gas reservoirs, and dry gas reservoirs in the Tarim Basin[3]. Among all these reservoirs, condensate gas reservoirs have a particular retrograde condensate phenomenon, so they are special, valuable, and have research significance[4]. Therefore, in this paper, the phase diagram of the condensate gas reservoir in the Ordovician lithologic trap of Well Tazhong 86 (TZ86) was recovered using PVTsim software with geochemical inputs (well fluid components and experiment data), to characterize the fluid phase state and explore the possible formation mechanism of condensate gas reservoirs in the Tazhong Uplift.

2. Geological Setting
The Tarim Basin is the largest superimposed basin in China, containing three uplifts and four depressions. The Tazhong Uplift is in the central Tarim Basin, near the Manjiaer hydrocarbon generation depression, and has favorable conditions for long-term migration and accumulation of oil and gas[5]. It was formed in the Ordovician, developed in the Silurian and Devonian, and its structure
was finalized at the end of Devonian, and then developed steadily after the Late Paleozoic[6]. The Tazhong Uplift included the Tazhong No.1 fault zone, Tazhong No.10 structural belt, Tazhong central horst belt, and Tazhong 1-8 buried hill belt [7]. The Tazhong North Slope is sited between the Tazhong central horst belt and Tazhong No.1 fault zone. Well TZ86 is located in the northwestern of the Tazhong North Slope (Figure 1). The condensate gas reservoir was discovered in the Ordovician lithologic trap, with a burial depth of 6273-6320m. The measured temperature and pressure of the in-situ gas reservoir are 138.49°C and 65.1 MPa.

![Figure 1. Map showing the location of Well TZ86 and the geological structures of the Tazhong Uplift (modified from Reference [8]).](image)

3. Methods and Data

3.1. Input data for recovering the phase diagram

The input data needed for recovering the phase diagram of the Ordovician reservoir in Well TZ86 include the well fluid components, constant volume depletion (CVD) experimental data, and constant mass expansion (CME) experimental data. These data were all derived from the PVT analysis report (inner report of the Tarim Oil Company, 2014) and the concrete values are shown in Table 1 and Table 2. The well fluid components of the Ordovician reservoir in Well TZ86 is dominated by methane, which accounts for 83.366%, and the total of gaseous hydrocarbons account for 86.679%. The contents of light hydrocarbons and heavy hydrocarbons are 3.456% and 0.301%. The specific contents were all measured using the gas chromatography (Agilent 7890A, 6890N).

| Reservoir | Components/% |
|-----------|--------------|
| TZ86(O)   | N₂ 4.656     |
|           | CO₂ 4.909    |
|           | C₁ 83.366    |
|           | C₂ 1.746     |
|           | C₃ 0.693     |
|           | iC₄ 0.168    |
|           | nC₄ 0.359    |
|           | iC₅ 0.142    |
|           | nC₅ 0.205    |
|           | C₆ 0.328     |
|           | C₇⁺ 3.429    |

**Table 1.** Well fluid components (C₁⁻C₇⁺) of the Ordovician reservoir in Well TZ86.

| Well   | Constant Mass Expansion Experiment | Constant Volume Depletion Experiment |
|--------|------------------------------------|--------------------------------------|
|        | Pressure (MPa) | Temperature (°C) | Liquid vol% of Vd | Pressure (MPa) | Temperature (°C) | Z factor gas |
|        | *61.44     | 98.50       | 0.00            | *56.08    | 138.50       | 1.336        |
| TZ86   | *58.61     | 118.50      | 0.00            |            |              |              |
|        | *56.08     | 138.50      | 0.00            |            |              |              |

**Table 2.** Constant mass expansion and constant volume depletion experimental data.
Dew point pressure

3.2. The method of recovering the phase diagram

The PVTsim commercial software developed by Calsep Co. in Denmark specializes in the calculations of fluid properties and has been extensively used in the study of oil and gas reservoirs[9]. The phase diagram simulation steps are as follows: First, the well fluid components of the Ordovician reservoir in Well TZ86 were entered into the PVTsim software. Then the original phase envelope was obtained after calculated with the Peng-Robinson equation of state. Check the deviation between the calculated phase envelope and the measured phase envelope getting from the PVT analysis report, and input appropriate experiment data (CME, CVD) to do regression calculation until the deviation between two was small enough. Then the final phase model can be regarded as the actual fluid in the reservoir.

4. Results and Discussion

4.1. The phase diagram recovery results

After several rounds of calculation and regression, the final recovery phase envelope and the measured phase envelope getting from the PVT analysis report are shown in Figure 2. The concrete comparison results of the characteristics of two phase envelopes are listed in Table 3. The results show that the deviations between the recovery and measured phase envelope are within a reasonable range and the recovery result is valid. There are three basic elements in the phase envelope, which are the critical point (CP), cricondentherm (Tm), and cricondenbar (Pm). The recovery result shows that the temperature and pressure of the critical point (CP) are -87.8°C and 48.98 MPa, and the cricondentherm (Tm) and cricondenbar (Pm) are 324.73°C and 62.39 MPa, respectively.

The phase diagram can be divided into the gas-liquid coexistence phase zone, liquid phase zone, condensate gas phase zone, and gas phase zone by the positional order of the critical point (CP), cricondentherm (Tm) and cricondenbar (Pm) (Figure 3). According to the PVT analysis report, the reservoir temperature and pressure are 138.49°C and 65.10MPa, which indicates the fluid belongs to the condensate gas phase currently. The difference between reservoir pressure and starvation pressure is small which illustrates the fluid saturation is relatively high. When the fluid is mined to the surface condition, it turns to the condensate gas-condensate oil coexistence phase. The production gas-oil ratio is 5231.6 m³/m³, and the condensate oil content of the reservoir is 146.062 g/m³, which is a condensate gas reservoir fluid with medium liquid hydrocarbon content. The condensate oil density is relatively light with good quality.

![Figure 2. The recovery and measured phase envelope.](image-url)
Table 3. The comparison between recovery and measured features of the fluid.

| Items                      | Recovery Values | Measured Values |
|----------------------------|-----------------|-----------------|
| Critical Temperature (°C)  | -87.80          | -82.10          |
| Critical Pressure (MPa)    | 48.98           | 45.67           |
| Cricondentherm (°C)        | 324.73          | 329.5           |
| Cricondenbar (MPa)         | 62.39           | 62.32           |
| Dew point pressure (138.5°C) (MPa) | 56.43       | 56.08           |
| Oil density at ground (20°C) (g/cm³) | 0.7384       | 0.7686           |

![Figure 3](image.png)

**Figure 3.** The recovery phase diagram of the condensate gas reservoir in Well TZ86.

4.2. *Forming conditions of the condensate gas reservoir in the Tazhong Uplift*

The main source rocks in the Tarim Basin are the Cambrian-Lower Ordovician source rock and the Middle-Upper Ordovician source rock. Their main hydrocarbon generation stages include the Late Caledonian, Late Hercynian, and Late Himalayan. The first two stages are dominated by oil charge, and the last stage is dominated by gas charge. The strike-slip faults provide the main pathway for oil and gas migration. The gas charging happened in the Late Himalayan is the main reason for the condensate gas reservoir in Well TZ86 being rich in gaseous hydrocarbons. The thick sedimentation of Neogene (more than 2000m) in the Himalayan makes the strata temperature and pressure increased to a suitable range for the formation of condensate gas reservoirs. The components rich in gaseous hydrocarbons and the temperature and pressure condition determined the formation of condensate gas reservoirs in the Tazhong Uplift.
5. Conclusions
The phase diagram recovery result of the condensate gas reservoir in the Ordovician lithologic trap of Well TZ86 shows the error between the recovery and measured phase diagrams is within a reasonable range, indicating the reliability of the recovery result. The recovery phase diagram shows an order of CP-Pm-Tm, and the current reservoir temperature and pressure (138.49°C, 65.10MPa) confirms that the fluid belongs to the condensate gas phase currently and turns to the condensate gas-condensate oil coexistence phase when it is mined to the surface condition. The components rich in gaseous hydrocarbons caused by the gas charging in the Late Himalayan and the temperature and pressure condition determined the formation of condensate gas reservoirs in the Tazhong Uplift.

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