Formation Conditions of the Dolomite Tight Oil in Fengcheng Formation of Fengcheng Area, Junggar Basin, Northwest China

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1 Introduction

Combined with the actual geological settings, this paper defines that the dolomite tight oil is the oil that occurs in tight reservoirs which have permeability less than 1mD, which is interbeded with or closed to shale (Energy Information Administration, 2012; National Energy Board, 2011; Canadian Society for Unconventional Resources, 2011; Jia et al., 2012; Zhou et al., 2012).

The Fengcheng area (FA), at the northwest margin of the Junggar Basin, northwest China, has made significant progress in the tight oil exploration of the Fengcheng Formation (P1f), recently, which indicates that the tight oil resources have good exploration prospects (Kuang, et al., 2012). However, the researches of the dolomite tight oil formation conditions in the FA are quite weak, and most of them focus only on the reservoir (Zhu et al., 2013; Liu et al., 2014; Pan et al., 2013; Feng et al., 2011; Zhu et al., 2014). The lack of knowledge of the formation conditions and the lack of systematic researches were the key restrictions on progress in the tight dolomite oil prospecting. This is of great practical significance and in this article, we analyse the formation conditions of the dolomite tight oil by combining geologic, geochemical, well test, well drilling and well logging data, attempting to provide geological evidence for the tight dolomite oil prospecting. Results show that there are four favourable conditions for the formation of the tight dolomite oil in the FA, which are high quality source rocks, tight reservoirs, excellent source - reservoir combinations and Formation pressure.

2 Formation Conditions

2.1 Source rock

The tight dolomite oil was sourced from the P1f source rocks (Zhang et al., 2012), which distribute widely, are thick, have high total organic content, are dominated by type II kerogen and have entered into low mature - mature stage.

Combined with the comprehensive analysis of seismic inversion results, sedimentary facies and structural contour, the distribution area of TOC >1.0% of the P1f source rocks is nearly 2039km², which covers the whole FA. The thickness of TOC >1.0% of the P1f source rocks is with an average value of 119m, and the thickness of the P1f source rocks has the obvious characteristics of decrease from northwest to southeast, horizontally, with thicker accumulations in the Fc011 well block and Bq1 well block, exceeding 250m.

The TOC of the P1f source rocks ranges from 0.14% - 3.19% and the average value is 1.13%, with 83.69% of 129 samples exceeding 0.6%. The S1+S2 of the source rocks ranges from 0.09 mg HC/g rock~18.31 mg HC/g rock and the average value is 4.67 mg HC/g rock, with 78.26% of 129 samples exceeding 2 mg HC/g rock. The chloroform bitumen “A” of the P1f source rocks ranges from 29ppm - 16185ppm and the average value is 3357.37ppm, with 81.91% of 94 samples exceeding 500ppm. According to the evaluation standards proposed by Huang et al. (1984), all of the organic matter abundance indicators suggest that the P1f source rocks are mainly fair - good source rocks.

The P1f source rocks are dominated by Type II kerogen, with less common type III kerogen.

The VR data obtained from 20 samples generally Rock-Eval pyrolysis were < 470 °C. The distribution of
cluster between 0.6% and 1.4%, with one sample over 1.4%. And the sample Tmax values (99.18%) from VR and Tmax values suggest that P1f samples are still in the low mature - mature stage (Table 1).

2.2 Reservoir
The P1f reservoirs distribute widely, are thick, vary in reservoir space types, and are characterized by strong heterogeneity and low porosity and permeability, belonging in a set of typical tight reservoir.

The main rock types of the P1f reservoirs are dolomitic siltstone, tuffaceous dolomite and dolomitic mudstone, which distribute widely (up to 2039 km²), are deeply buried (3000m~5000m) and the thickness ranges from 120m to 500m.

The microfracture is the main reservoir space of the P1f reservoirs, which accounted for more than 50% of the space, and the rest is composed of dissolved pore and intracrystalline pore.

Even though there exist some differences in pore structure of different rock types in the FA, the mercury injection curves of which display the similar features with steep slopes, small slanting degrees, high replacement pressure and low efficiency of mercury ejection, indicating the strong heterogeneity of the tight reservoir.

According to reservoir evaluation criterion proposed by Jia et al. (2012), the P1f strata belongs to typical low-air permeability (400 out of 430 analyses are less than 1 mD) and low-porosity (6,364 out of 430 analyses are less than 10%) tight dolomitic reservoirs, and most of them are III-type reservoir, exceeding 65% (Table 1).

2.3 Source – reservoir combination
The excellent source - reservoir combination is one of key condition for the formation of the dolomite tight oil.

The P1f source rocks and reservoirs are both large in total thickness, wide in lateral distribution and good in continuity. The analysis of single well and connecting-well section suggests that the high-quality mudstone source rocks and the dolomite reservoirs are alternated, constituting good source-reservoir combinations. The tight oil occurs in the entire strata vertically and spreads across large continuous areas horizontally (Fig. 1).

2.4 Formation pressure
The P1f formation is generally develop abnormal overpressure with pressure factor of 1.22-1.74, which is a significant condition for the accumulation of dolomite tight oil.

The abnormal overpressure provided the drive force for tight oil migration and charging, and also, the abnormal overpressure is favorable for the preservation of secondary pore and the formation of the microfractures, which could enhance the porosity and permeability of the reservoir.

References
main types, basic features and resource prospects of the tight oil in China [J]. Acta Petrolei Sinica. 33 (03): 343-350

<table>
<thead>
<tr>
<th>Source-rock</th>
<th>Reservoir</th>
<th>Depth (m)</th>
<th>TOC (%)</th>
<th>Rock thickness (m)</th>
<th>Rock types</th>
<th>Porosity (%)</th>
<th>Permeability (10^-3 μm²)</th>
<th>Oil density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muddy dolomite; Dolomitic mudstone; Dolomitic siltstone</td>
<td>Lower Permian</td>
<td>3000~5500</td>
<td>10.0~260</td>
<td>40~300</td>
<td>Dolomite, dolomite-siltstone</td>
<td>6.0~14</td>
<td>2.0~6.0</td>
<td>1.35~1.58</td>
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<tr>
<td>Dolomitic siltstone; Silty dolomite</td>
<td>Upper Devonian</td>
<td>2903~3203</td>
<td>10~18</td>
<td>20~50</td>
<td>Dolomite, dolomite-siltstone</td>
<td>1~5</td>
<td>0.01~1</td>
<td>1.76~1.87</td>
</tr>
<tr>
<td>Interbedded or adjacent</td>
<td>Carboniferous</td>
<td>Lower and shallow-water delta</td>
<td>3000~3200</td>
<td>10~18</td>
<td>Dolomite, dolomite-siltstone</td>
<td>1~5</td>
<td>0.01~1</td>
<td>1.76~1.87</td>
</tr>
</tbody>
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Table 1 The characteristic contrast of tight oil between P1f Formation in FA, Junggar Basin and Bakken Formation, Williston Basin