

# Exploitation Evaluation of Tight Oil Reservoirs in Yanchang Formation Using Horizontal Well: A Case Study of Some Wells from Changqing Oilfield, Ordos Basin

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**Abstract:** Horizontal wells development technology has become an important means to improve the production of a single well. In this paper, according to the reservoir characteristics of tight oil of Yanchang Formation, some optimizations of horizontal well technology were made and applied in some wells. Through evaluating the exploitation effect concluding yield evaluation, regression and water content evaluation and single well evaluation of these wells, it can be seen that the single well production is enhanced greatly.

**Keywords:** Horizontal Well, Tight Oil, Horizontal Technology, Stimulated Reservoir Volume, Exploitation Evaluation

## 1. Introduction

Tight oil is the abbreviation of tight reservoir oil. Tight oil always refers to the sandstone, limestone, reservoir etc, which overlying pressure permeability is less than or equal to the 0.1mD [1]. Oil would be transported for a short distance and become lighter. In certain economic and technical conditions, single well, without natural productivity or which natural productivity is lower than the lower limit of industrial capacity, will obtain industrial production of oil [2, 3, 4]. Combined with the actual situation of the Ordos basin, the tight oil is divided into two types (Figure 1). Based on past experience, the formation of tight oil has three key flags: large area distribution of tight reservoirs, the wide covered distribution of high quality sapropelic source beds with high maturity, continuous distribution of symbiosis between tight reservoir and source rocks [5, 6].

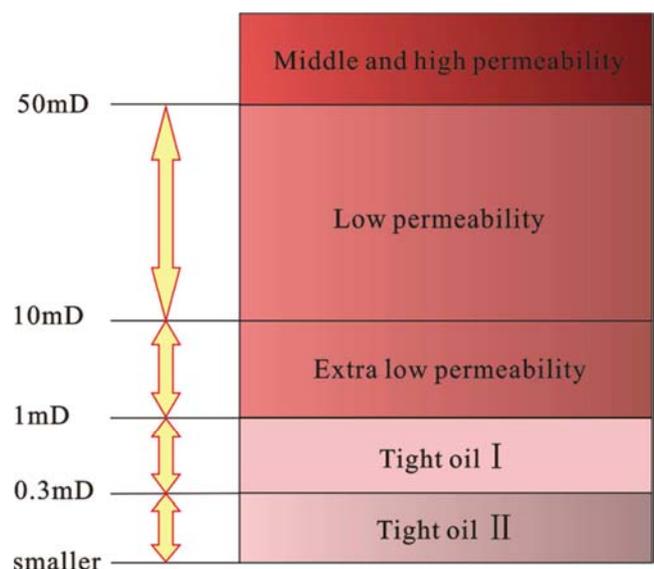


Figure 1. The division of tight oil types in Ordos basin.

The Ordos basin has a wealth of oil and gas resources. As the most important hydrocarbon source rocks and oil gas reservoir of Mesozoic in basin, Yanchang Formation is rich in oil. And semi-deep lake and delta front sedimentary sand bodies of Chang 7 and Chang 6 reservoir are the main distribution layers of tight oil. The tight sandstone and hydrocarbon source rock in these layers contact closely. The oil layers have stable distribution and good lateral continuity. The tight oil has good properties, high liquidity and high oil saturation. Because of the symbiosis between tight sandstone reservoir and hydrocarbon source rock, filling degree of oil is high. It was found that the reservoir has poor reservoir properties, more interlayer, strong heterogeneity, natural fracture [7]. In recent years, successively finding of low permeability and ultra-low permeability oilfield in the areas of Xifeng, Jiyuan and Huaqing, then major progress in exploration and research of tight oil were made [8, 9, 10, 11].

In order to realize the effective exploitation of this kind of reservoir, Changqing Oilfield actively changes the development models from directional wells to horizontal wells. With application in oil and gas field exploration and rapid development, Horizontal well technology has become one of the focuses in petroleum industries [12]. The horizontal wells have many obvious advantages, such as high output, large reserves controlled by single well, and increasing of the recoverable reserves of crude oil. However, there are many disputes about the optimization design of horizontal well and the selection of volume fracturing technology [13, 14]. In this paper, through the optimizing of the horizontal well pattern, contrastively analyzing and choosing preferable volume fracturing technology, as well as optimizing drilling technology, then it values the exploitation effects of tight oil of Yanchang Formation in Ordos basin used some wells from Changqing oilfield.

## 2. Model Optimization and Application

Horizontal well optimization includes three aspects, optimization technology of horizontal well pattern, fracturing technology and drilling technology. The key technical parameters of horizontal well pattern include well

arrangement (including design of angle between fracture and horizontal section), well spacing, row spacing, horizontal length and fracture laying patterns (fracture laying density).

### 2.1. Optimization of Horizontal Technology

#### 2.1.1. Position Optimization of Horizontal Section

The theoretical study shows that when the anisotropic horizontal section is perpendicular to the fracture direction, that is  $\alpha=0$ , the yield is the highest. When the anisotropic horizontal section is parallel to the fracture direction, that is  $\alpha=\frac{\pi}{2}$ , the yield is the lowest (Figure 2).

$$Q = \frac{542.9Kh(p_e - p_w)}{\mu \ln \frac{2r_e \sqrt{\cos^2 \theta_e + \beta^2 \sin^2 \theta_e}}{l \sqrt{\cos^2 \alpha + \beta^2 \sin^2 \alpha}}} \quad (1)$$

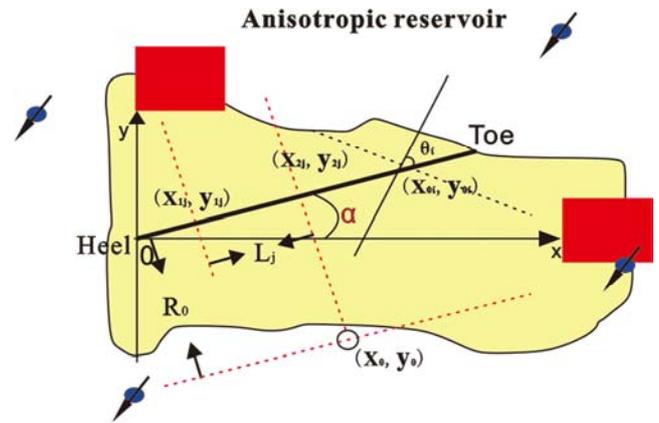


Figure 2. Diagram of angle between directions of horizontal well and fracture.

#### 2.1.2. Optimization of well Spacing and Row Spacing

Core indoors experiment from Changqing 6 oil reservoir has proved that when pressure difference with 500-meter well spacing and 200-meter row spacing is greater than starting pressure gradient (0.048MPa/m), effective pressure displacement can be established (Figure 3a, 3b).

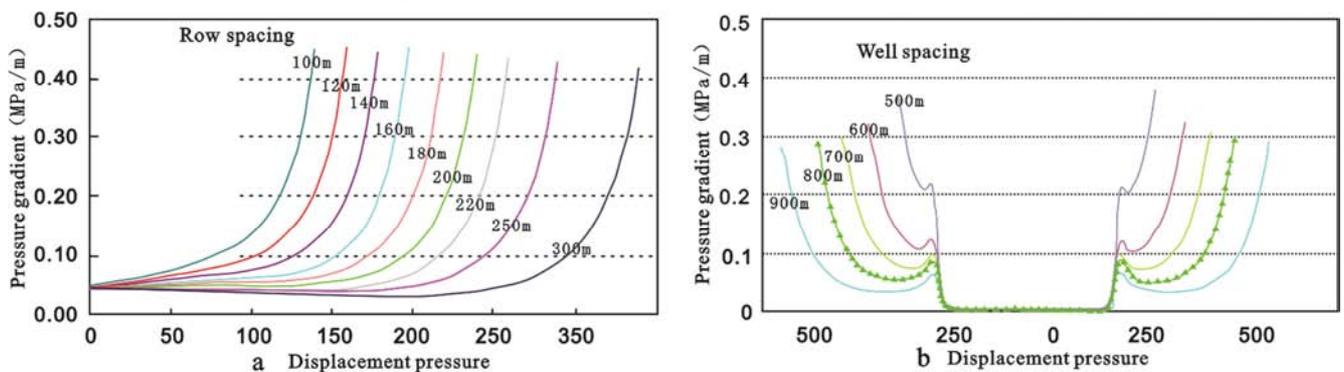


Figure 3. a. Diagram of displacement pressure and pressure gradient a: different row spacing; b: different well spacing.

**2.1.3. Optimization of Horizontal Well Pattern**

According to the numerical simulation and experience, five-point and seven-point well pattern have been adopted. About the well spacing and row spacing, 500 ×200m well pattern was used.

**2.1.4. Optimization of Horizontal Section Length**

Theoretical formulas and numerical simulations show that the longer the horizontal section, the higher the initial production of a single well.

Productivity calculation formulas of fractured horizontal well are shown as follows:

$$Q_{fmax} = \frac{2\pi Kh_0 n}{\mu_0 B_0} \cdot \frac{p_e - p_{wf}}{\sin \frac{\pi L_f}{2a} \left[ \text{arcch} \frac{ch \frac{\pi b}{2an} + \frac{Kh_0}{K_f c} \ln \frac{h_0}{2r_w}}{2a} \right]} \quad (2)$$

$$Q_{max} = \frac{8 \pi KL (p_e - p_{wf})}{\mu_0 B_0 \left[ 3 \ln \frac{h_0}{2 \pi r_w} + \frac{2 \pi a}{h_0} \right]} \quad (3)$$

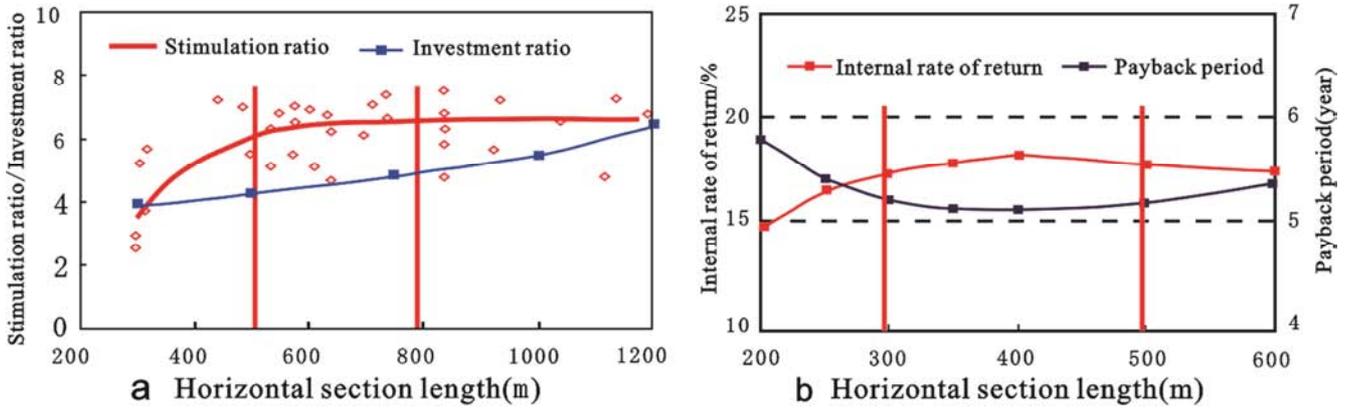


Figure 4. a. Diagram among horizontal section length, stimulation ratio and investment ratio; b. among horizontal section length, internal rate of return and payback period.

Based on comprehensive evaluation of theoretical and economic efficiency, from figure 4a and figure 4b, it can be seen that using of 500-600m horizontal section length for the five-point method and 800-1000m horizontal section length for seven-point is more reasonable.

**2.1.5. Optimization of Fracture Laying Patterns**

According to the relationship between fracture density and production of a single well and economic benefits, optimum fracture number per 100m is 1-1.5 (Figure 5).

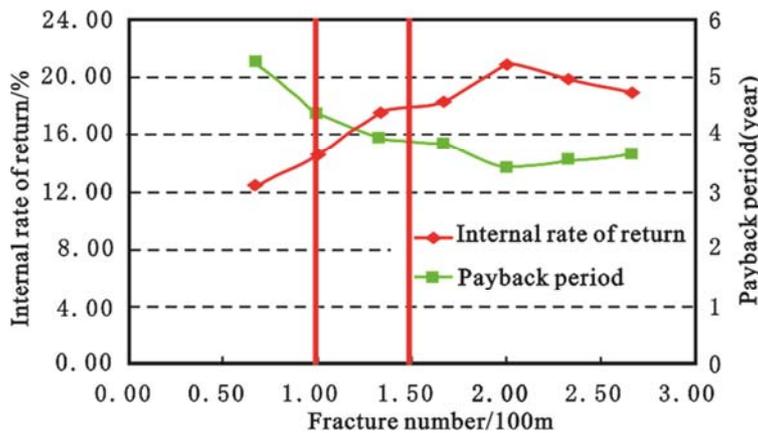


Figure 5. Diagram among fracture density, internal rate of return and payback period.

**2.2. Optimization of Stimulated Reservoir Volume**

**2.2.1. Matching Technologies and Its Characteristics**

In horizontal well development test area of Chang 8<sub>1</sub> well in the block of Huang 36, Chang 6<sub>3</sub> well in the block of Yan, Chang 7<sub>2</sub> in the block of Wu, PSK staged multi-section fracture, annuls sand fracture and normal staged fracturing technology were carried out. It was realized that making the

fracture laying dense and liberating oil layer highly. Displacement of annuls sand fracture is up to 2.5↑6m<sup>3</sup>/min. The volume increased by 50% by alteration of single stage fracture. It can be formed that Multi-direction and multi-dimension fracture and entirely breaking of reservoirs using normal staged fracturing technology.

The single well productivity of the horizontal well by

stimulated reservoir volume is 6-8 times than that by conventional development well (Figure 6).

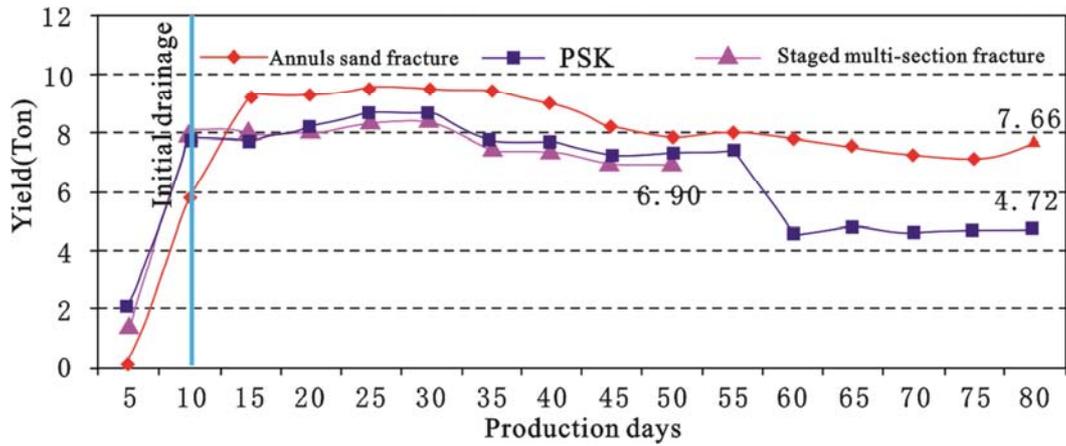


Figure 6. Production curves of different technologies well.

### 2.2.2. Optimization of Matching Technologies

By comparing the three aspects of the initial production, decline rate and construction period after renovation of three processes, it was concluded that annuls sand fracture would be more applicable with high production, low decline rate and equivalent oil-test cycle. The initial production of single well was up to 12.9 tons in the two wells in Chang 7<sub>2</sub>, Wu 464 area by annuls sand fracture. So, annuls sand fracture is better.

### 2.3. Optimization of Drilling Technology

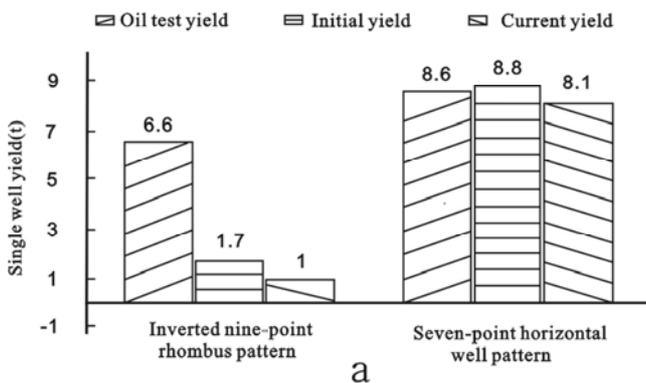
The position of entering window was optimized to the lower part of the second opening well. When well track enters into the oil layer, well deviation is less than 76°. Then the drilling cycle and reduced the drilling cost were shortened by above measures. Well construction period was reduced to 23.8 days per well.

and directional wells in blocks of Huang 36, Yan 31 and Wu 464, the former is 6-8 times than the latter. The earlier average daily oil was 1.7 tons, but now 1.0 tons by inverted nine-point rhombus pattern of horizontal wells in Huang 36 block. When the pattern was optimized to seven-point well pattern, the earlier average daily oil was 8.8 tons, but now 8.1 tons. The earlier average daily oil was 1.3 tons, but now 0.6 tons by inverted nine-point rhombus pattern of horizontal wells in Yan 31 block. When the pattern was optimized to seven-point well pattern, the earlier average daily oil was 6.5 tons, but now 6.1 tons. The earlier average daily oil was 5.1 tons, but now 1.9 tons by inverted nine-point rhombus pattern of horizontal wells in Wu 464 block. When the pattern was optimized to seven-point well pattern, the earlier average daily oil was 10.2 tons, but now 10.1 tons.

## 3. Evaluation of Exploitation Effect

### 3.1. Yield Evaluation

Comparing the single well output between horizontal wells



### 3.2. Regression and Water Content Evaluation

Contrasting decline and water content after exploitation by horizontal wells and directional wells in blocks of Huang 36, Yan 31 and Wu 464, risk of seeing water is relatively small from figure 7a and 7b. The regression was controlled among 1.9-7.9%, water content among 24.7-42.1%.

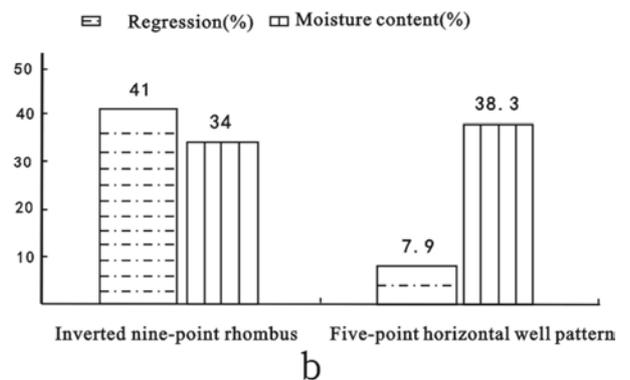


Figure 7. a. Comparison between horizontal well and directional well a: single well yield; b: water content and regression.

### 3.3. Single Well Evaluation

The well pattern was five-point, 500m of horizontal section

length with 1.3 fractures per 100m in wells of YP 32-17. Stimulated reservoir volume retention fluid was up to 2138 cubic meter showing a longer stable period and efficient

exploitation of horizontal well. Daily output of single well was 10.5 tons (Figure 8a). The well pattern of seven-point, 800m of horizontal section length, and 1.5 fractures per 100m was applied in wells of HP35-22. Stimulated reservoir volume

retention fluid was up to 6282 cubic meter. The yield and water content was stable at present. Daily oil output was kept stably at 11.5 tons (Figure 8b).

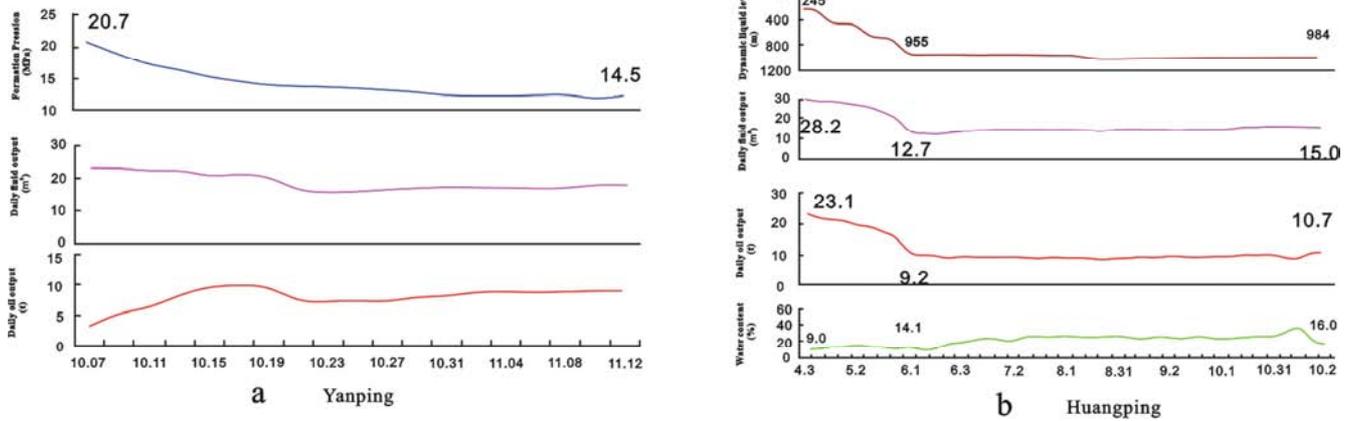


Figure 8. Daily output curve a: YP32-17 wells; b: HP 35-32 wells.

### 4. Conclusion

Through the optimized exploitation technology, single well daily oil production can reach more than 8 tons, to achieve the effective development of tight oil resources. The 500×200m well pattern was more reasonable after optimization. Horizontal section length is 500-600m for five-point. Horizontal section length is 800-1000m for seven-point. The Regression was controlled among 1.9-7.9%, water content among 24.7-42.1% by horizontal well pattern. As for development of tight oil, the technology of “horizontal well + stimulated reservoir volume” has been carried out. Retention fluid of stimulated reservoir volume can make up ability of formation and restore the original formation pressure to 131%. It has stable production period and high efficiency development of horizontal well. It was found that the yield was positively correlated with construction parameters by the field practice. The initial production of horizontal well can reach 8 tons or more with greater than or equal to 800m of horizontal section length, 4m<sup>3</sup>/min of fracturing displacement, 4000m<sup>3</sup> of amount of fluid into the ground and 1 piece per 100m of fracture laying density

### Nomenclature

$Q_{f\ max}$	horizontal section flow in the direction of substrate
$Q_{m\ max}$	horizontal section flow in the direction of fracture
n	number of fracture
c	width of fracture
$L_f$	length of fracture
$h_f$	height of fracture
$K_h$	permeability of substrate
$K_f$	permeability of fracture
$h_0$	height oil reservoir
$\beta$	anisotropy coefficient
L	length of horizontal section

$p_c$  supply edge pressure  
 $p_{wf}$  bottom hole pressure

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