

Application of 3D Stress Model in Horizontal Well Fracturing Optimization Design

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Abstract. In the traditional optimization design of multi-stage fracturing in horizontal wells, the rock mechanics and stress profiles of the vertical section of horizontal well or other vertical wells near the perforated cluster are usually borrowed. In the strong heterogeneity reservoirs, there is a large deviation between the design results and the microseismic monitoring results. In this paper, based on the three dimensional geological model of reservoir, the stress and the rock mechanics parameter model are built, the stress and rock parameters of vertical profile at each perforation center are extracted, we can evaluate the difficulty of fracture extending in different position, by adjusting the number of perforations to achieve the best stimulation effect.

1. Introduction

The accurate stress profile and rock mechanics parameters are the basis of horizontal well fracturing design, and the fracturing design parameters such as pumping rate, fracturing pressure, fracturing fluid type, and fracturing method are closely related to stress^[1].

In the process of using the traditional fracturing design method, the stress profile and the rock mechanics parameters of the perforating section are derived from the logging data of the nearby straight wells. In the non-homogeneous stratigraphy, due to the geology and stress Conditions may change greatly, the design results may have a large deviation^[2].

For example, a horizontal well of a block of Xinjiang in China, the horizontal section of the A point near the well 1, the horizontal section of the B point near the well 2, the distance between well 1 and well 2 is 1648m, well 1 and well 2 logging curve are shown in Figure 1. It can be seen that the geological conditions are obviously different. Due to the lack of the horizontal section stress profile and the rock mechanics parameters provided by the three-dimensional stress model, it is difficult to ensure the accuracy of the design result if only the stress profile of well 1 and well 2 is used in the fracturing design process.

Therefore, it is very important for fracturing design of horizontal well to create a three-dimensional stress model and rock mechanics parameter model.



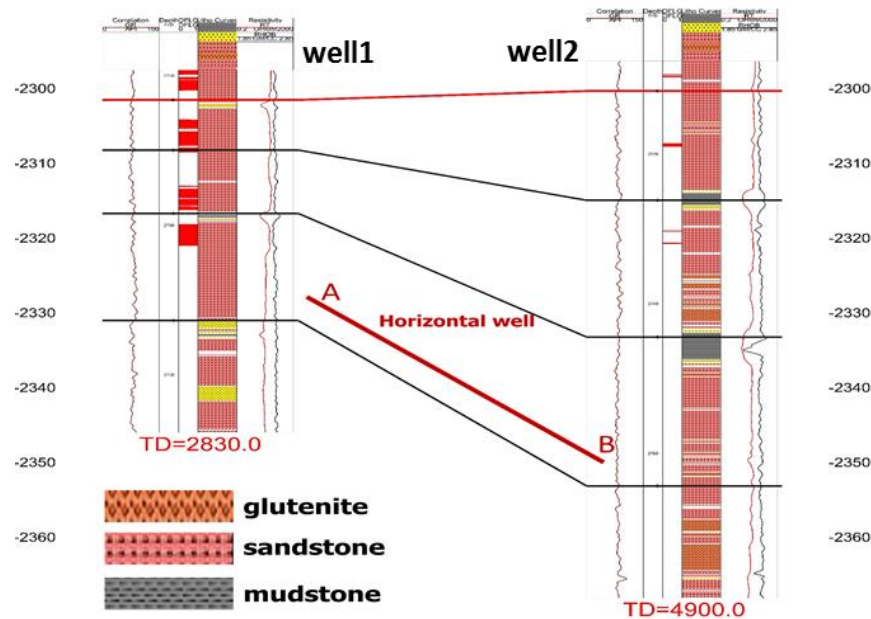


Figure 1 The position of the horizontal section of the horizontal well in the vertical section

2. Build-up of 3D stress model

The basic process to build 3D stress model is based on the stratigraphic framework model, using the single well stress profile for interpolation, showing the spatial distribution of the parameters [3]. This study has established the three-dimensional overburden pressure, pore pressure, the minimum and maximum horizontal principal stress model, and the rock mechanics parameter model, there are also large differences in the methods used to establish different parameter models.

When the three - dimensional overburden pressure is established, the three dimensional density data body is obtained by using the seismic layer velocity [4], and the overburden pressure is calculated by vertical integration. The results are shown in Figure 2 below, the overburden pressure of the target layer is about 88MPa ~ 94MPa.

The three-dimensional pore pressure is calculated by Eaton's formula using the seismic layer velocity and the overburden pressure [5]. The results are shown in Figure 3 below, the pore pressure of the target layer is about 55MPa ~ 65MPa, which is equivalent to a density of 1.5 g/cm³~1.7g/cm³.

$$P_p = S_v - (S_v - P_p) \left(\frac{v_o}{v_n} \right)^N \quad (1)$$

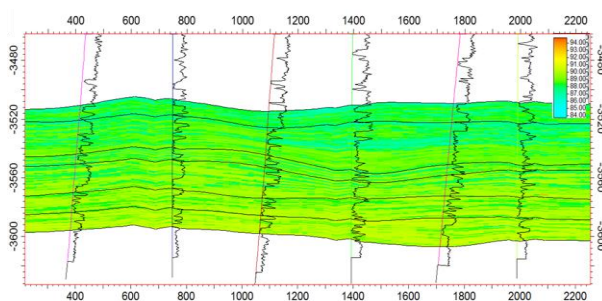


Figure 2 Overburden pressure vertical profile

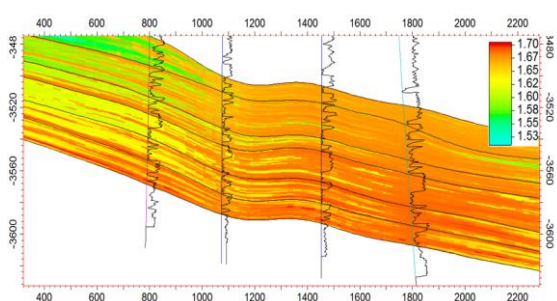


Figure 3 Pore pressure vertical profile

The three dimensional maximum and minimum horizontal stress are calculated by using the effective stress ratio method [6], the effective stress ratio model is established by using the effective stress ratio profile of the single well,. The results are shown in Figure 4 below, the minimum

horizontal principal stress of the target layer is between 66MPa and 75MPa, and the maximum horizontal principal stress is between 86MPa and 95MPa.

$$ESR_{min} = (S_{min} - P_p) / (S_v - P_p) \quad (2)$$

$$ESR_{max} = (S_{max} - P_p) / (S_v - P_p) \quad (3)$$

In the process of establishing the three-dimensional rock parameters model, the logging interpretation model is used to calculate the mechanical parameters profile of the single well, and the three-dimensional rock parameter body is obtained by using the lithologic restraining interpolation method. The results are shown in Figure 4 ~ Figure 6 below, The Young's modulus of the target layer is between 13GPa and 28GPa, and the Poisson's ratio is between 0.15 and 0.3.

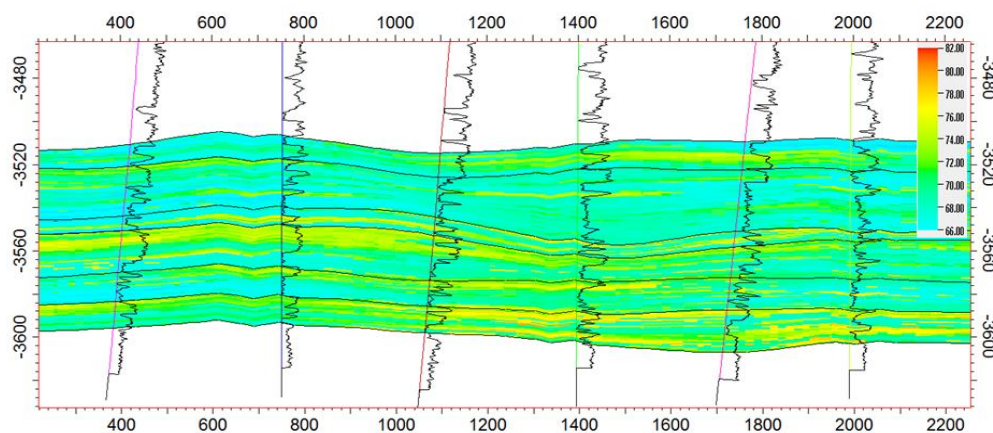


Figure 4 The minimum horizontal principal stress vertical profile

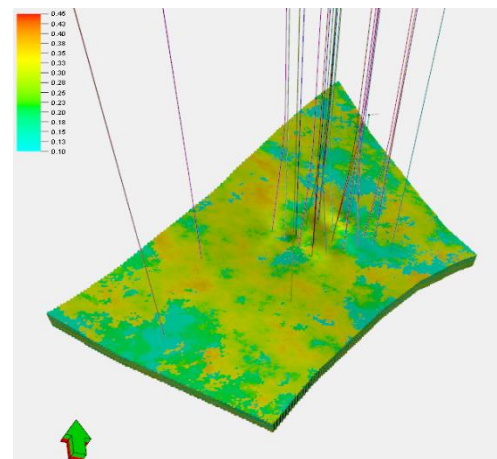
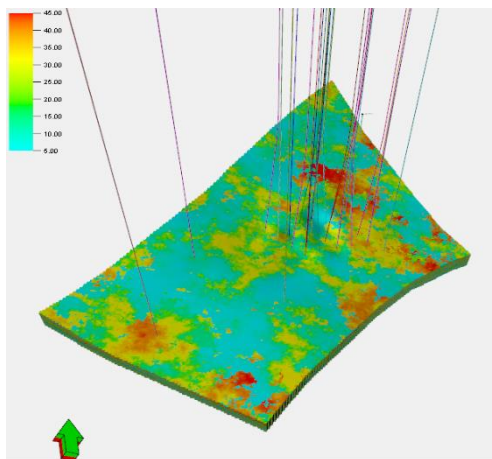


Figure 5 Three dimensional Permeability Model **Figure 6** Three dimensional Poisson's ratio Model

3. Application of 3D stress model in fracturing design

A representative horizontal well in a tight oil reservoir was chosen to verify the rationality of the method. The horizontal length of this horizontal well is about 900m, The depth of the horizontal section is about 3600 m, the reservoir porosity is about 0.08 to 0.1, the permeability is about 0.1mD to 0.5mD, the original pore pressure is about 63 MPa, the minimum horizontal stress is about 67MPa to 75MPa, and the Young's modulus is about 35GPa to 50GPa.

This horizontal well is divided into 12 stages by plug, 2 or 3 perforation clusters in each stage, and 23 clusters in total. The total design amount of single-stage total fluid is about 700m³~1200m³, the

design surface pumping rate is $4\text{m}^3/\text{min} \sim 10\text{m}^3/\text{min}$, the design surface pumping pressure is about $50\text{MPa} \sim 85\text{MPa}$.

In the design process, the geologic and stress profiles of the perforations in the horizontal section are extracted from the three-dimensional model. These parameters of one Perforation cluster are show in Figure 7 ~ Figure 10.

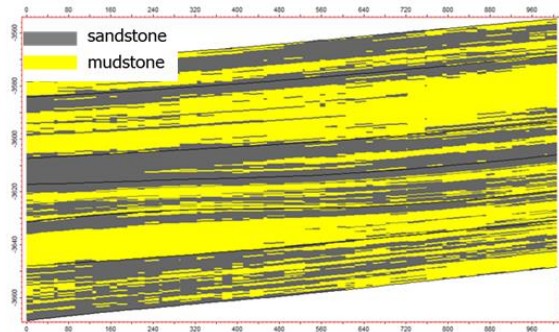


Figure 7 The vertical section of the lithology

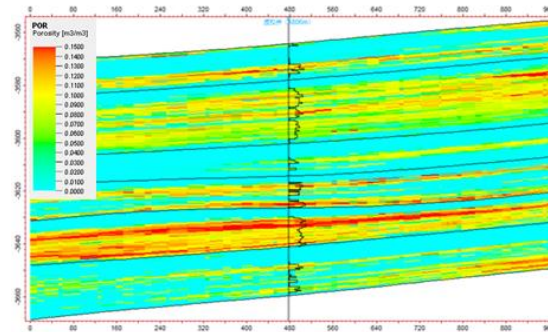


Figure 8 The vertical section of the porosity

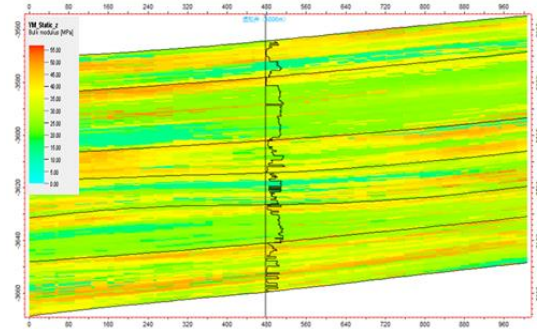


Figure 9 The vertical section of the Young's modulus

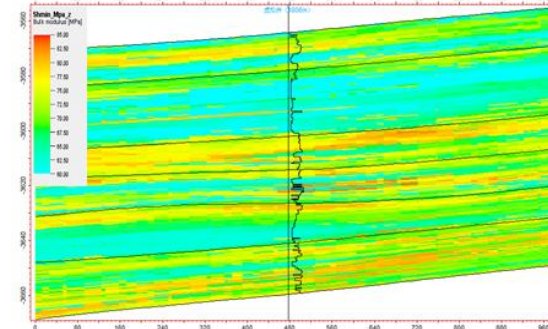


Figure 10 The vertical section of the minimum horizontal stress

According to these parameters, the size of the artificial fractures calculated by the fracturing simulation method is shown in Figure 11, it can be seen that the length of the fracture is about 120m, the length calculated by the traditional design method is about 150m, the design of the new method is closer to the Microseismic monitoring result, the fracture morphology can truly reflect the influence of the actual geological and stress conditions.

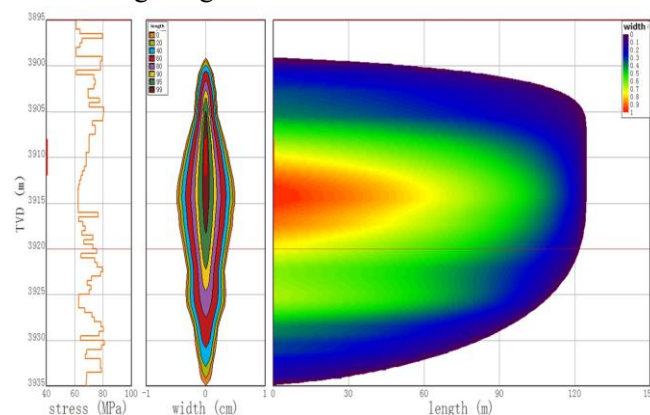


Figure 11 The actual fractal results were calculated using the actual parameters

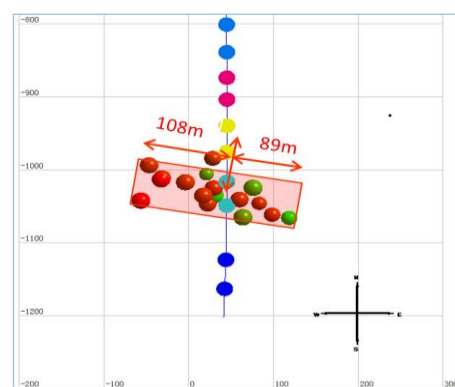


Figure 12 Microseismic monitoring of fracture morphology

4. Conclusion

(1) The high-precision three-dimensional reservoir geology, stress and petrophysical model are the basis for the accurate design of horizontal well fracturing.

(2) Using the traditional design method, the results of the fractures calculated by the nearby vertical well parameters do not match the actual geological and stress conditions. There is a large deviation in the design results. Based on the three-dimensional stress model, the horizontal well fracturing optimization design is more accurate.

(3) Through the three dimensional stress model to extract the perforation cluster geological and stress profile, you can evaluate the difficulty of fracture extending in different position, by adjusting the number of perforations to achieve the best stimulation effect.

Nomenclature

V_o = Measured seismic velocity, m/s

V_n = Normal trend seismic velocity, m/s

ESR_{min} = The effective stress ratio of the minimum horizontal stresses

ESR_{max} = The effective stress ratio of the maximum horizontal stresses

SH_{min} = the minimum horizontal stresses, MPa

SH_{max} = the maximum horizontal stresses, MPa

S_v = Overburden pressure, MPa

P_p = Pore pressure, MPa

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