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Formation Selection Criteria for Volume Fracturing in Chang 7 Tight Reservoir in the Ordos Basin

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Abstract

The Ordos basin possesses abundance of tight oil and it has huge commercial potential. Volume fracturing is an effective means for the exploitation of tight oil which is a significant impact by geological conditions. So far, the formation selection criteria targeting on volume fracturing of Chang 7 tight reservoir in the Ordos basin have not been established. This paper combined the experiments of rock mechanics and the fracturing simulating software Meyer, and built the selection criteria of Chang 7 tight reservoir in terms of the horizontal stress difference, the brittle index and the natural fractures. It is shown that the horizontal stress difference in Chang 7 tight reservoir is 6-12 MPa, the brittle index based on elastic parameters is 30-48, with strikingly regional natural fracture growth. The fracture geometry induced by volume fracturing is affected by the horizontal stress difference, the brittle index and the natural fracture numbers together. Complex fracture networks are likely to form in a highly naturally fractured section with the in-situ stress difference below 8 MPa and the brittle index over 40. The selection criteria is adequate for optimum formation selection and it has guide function in fieldwork which proved by field practice.

Key words: Ordos basin; Tight oil; Volume fracturing; Formation selection criteria; Stimulated reservoir volume; Horizontal stress difference; Brittle index; Natural fracture

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INTRODUCTION

Unconventionality oil & gas (for example tight oil and so on) reserves abundance. At present, many countries have conducted a large-scale commercial development like USA and Canada[1-2]. In China, Changqing oilfield Chang 7 Tight Reservoir has rich tight oil reserves in the Ordos basin and it has a great potential for commercial development[3-5].

Volume fracturing is a means of increase production with the purpose to form complex fracture networks in stratum and it is also the key technology to realize commercial exploitation of tight oil[6-8]. Geological conditions are a significant factor to restrict volume fracturing. The horizontal stress difference, the brittle index and the natural fractures growth are key factors to decide if can realize volume fracturing in stratum take example by experience of shale gas volume fracturing in USA[9-10]. But the existing evaluate criteria based on the three factors what are said above can not apply to formation selection of tight oil. So formation selection criteria which aimed at Chang 7 Tight Reservoir in the Ordos basin had oilfield guide significant.

This paper combined rock mechanics experiments and the fracturing simulating Meyer software, and proposed the formation selection criteria of Chang 7 tight reservoir in terms of the horizontal stress difference, the brittle index and the natural fractures. And formation selection criteria are verified through the practice of field.

1. THE BASIC PHYSICAL PARAMETERS OF CHANG 7 TIGHT RESERVOIR

First we should know the basic physical parameters of Chang 7 tight reservoir to build the new formation selection criteria of Chang 7 Tight Reservoir in the Ordos basin. This paper acquire regularities of distribution of the horizontal stress difference, the brittle index and the natural fractures growth of Chang 7 tight reservoir partly by means of literature research and indoor simulation experiment.

1.1 Horizontal Stress Difference

Through the differential strain experiment of Core sample which from 8 wells of Chang 7 Tight Reservoir in the Ordos basin, we got 7 layers of in-situ stress gradient in this area (Table 1).

The results show that Chang 7 layers of in-situ stress gradient value ranges from 0.005058 MPa/m to 0.002910 MPa/m in Ordos basin and so the horizontal stress difference in Chang 7 tight reservoir in the Ordos basin ranges from 6.1 MPa to 12.1 Mpa.

Table 1
Stress Gradient of Chang 7 Layer

Well	The vertical stress gradient MPa/m	The maximum horizontal principal stress gradient MPa/m	The minimum horizontal principal stress gradient MPa/m	The horizontal stress difference gradient MPa/m
Well 1	0.022508	0.018849	0.015028	0.003821
Well 2	0.022409	0.019826	0.014768	0.005058
Well 3	0.022560	0.018505	0.015436	0.003069
Well 4	0.022453	0.018749	0.015247	0.003502
Well 5	0.022538	0.017317	0.014407	0.002910
Well 6	0.022516	0.018227	0.015057	0.003170
Well 7	0.022366	0.019227	0.016027	0.003200
Well 8	0.023060	0.018961	0.015330	0.003631

1.2 Brittle Index

There are two common methods to compute brittle index, one is the elastic parameter method (Equation 1) and another is mineral composition analysis method (Equation 2).

$$B_1 = \frac{(0.6895E - 28\mu - 1)}{14} \times 10^2 + 80, \quad (1)$$

$$B_2 = \frac{C_{\text{Quartzite}} + C_{\text{Carbonatite}}}{C_{\text{Quartzite}} + C_{\text{Carbonatite}} + C_{\text{Clay}}} \times 100. \quad (2)$$

In order to get accurately brittle index of Chang 7 layer in Ordos basin which base on the logging data results interpretation and drilling cuttings mineral composition analysis experimental result of Chang 7 layer horizontal segments, we use the two methods which mentioned above to compute respectively and then we got brittle index profile of Chang 7 layer (Figure 1).

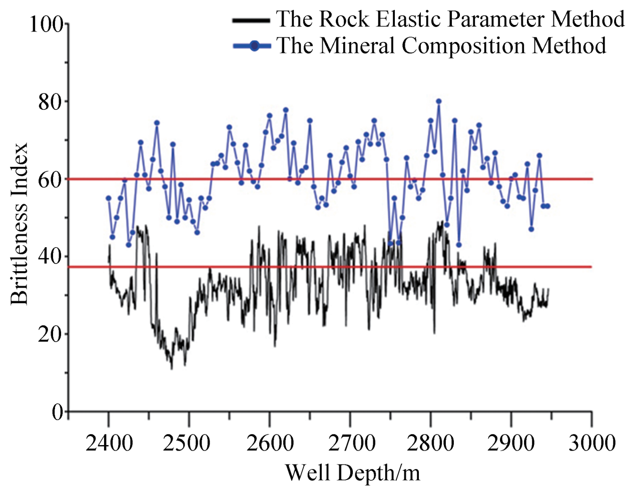


Figure 1
Brittle Index Profile of Chang 7 Layer

From the figure, we can know the value of brittle index of Chang 7 tight layer ranges from 30 to 48 and mean value is 38 with the elastic parameter method, but the value ranges from 52 to 80 and mean value is 60 with the mineral composition analysis method. The result shows that the brittle index which was received from the mineral composition analysis method is much higher than the brittle index which was received from the elastic parameter method, but both of them had the similar change rule, so the both brittle indexes can represent layer brittleness affectivity.

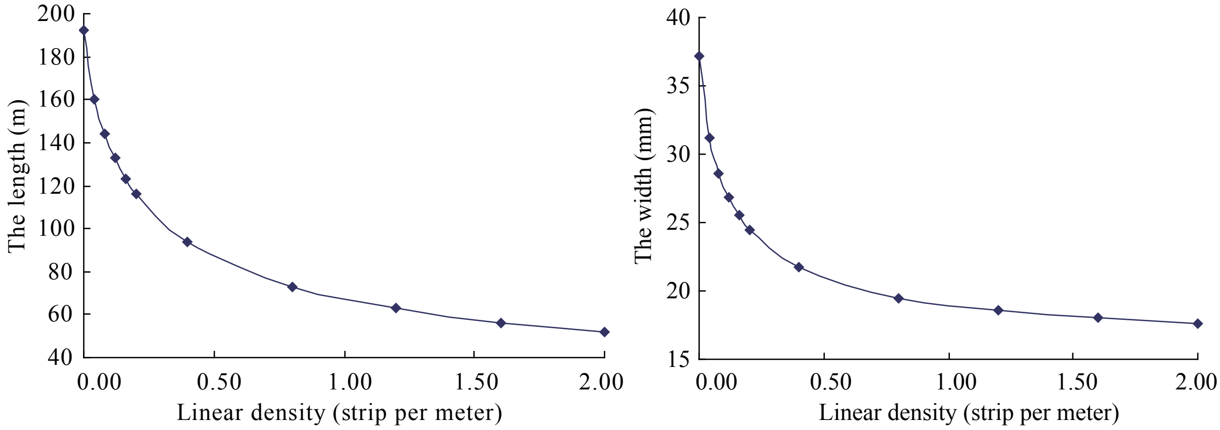
Brittle index is not the intrinsic nature of rock and so we can receive the different brittle index through different methods. So it is necessary to point out the data sources of brittle index when we use it evaluate the compressibility of layer and give different evaluation criteria aim to different computing methods. Volume fracturing of formation selection criteria was built on the elastic parameter method to receive brittle index in this paper.

1.3 Natural Fracture Abundance

Natural fracture abundance is the number of branches of natural fracture per unit length in layers. It is the most important parameter of degree of natural fracture abundance. As can be seen from the Figure 2 that, with the increase of linear density, the length and the width of the fracture are falling significantly.

It is indicated that nature fracture abundance of Chang 7 layers in Ordos basin has evident regional through survey a large number of rock core. The degree of nature fracture abundance was poor in the middle block of Ordos basin whose mean linear density was 0.58 strip/m, and the degree of nature fracture growth was well in the southwest of Ordos basin whose mean linear density was 1.25 strip/m and maximum linear density was 1.87 strip/m[11-12].

In consideration of the evident difference between regions of nature fracture abundance of Chang 7 layers in Ordos basin, formation selection criteria are necessary which aim at different regions.



(a) The Fracture Length-Line Density (b) The Fracture Width-Line Density

Figure 2
The Influence of Line Density to the Length and Width of the Fracture

2. FORMATION SELECTION CRITERIA FOR VOLUME FRACTURING IN CHANG 7 TIGHT RESERVOIR

Fracturing volume is acquired by microseismic surveillance through the scope of oil deposit fracturing transformation, its size could reflect whether success to get complex fracture network. And build formation selection criteria for volume fracturing in Chang 7 tight reservoir in the Ordos basin through summary formation condition of seam which base on the basic physical parameters in Chang 7 tight reservoir in the Ordos basin and use the fracturing simulating software Meyer to study the relationship between stimulated reservoir volume and the horizontal stress difference, the brittle index, the natural fractures.

The fracturing slurry rate which is an important human factor in forming fracture networks could influent formation selection criteria for volume fracturing. We can know the fracture construction for volume fracturing of tight reservoir in the Ordos basin in common based on 8 m^3/min through investigation and survey, so we built formation selection criteria for volume fracturing in the Ordos basin based on it.

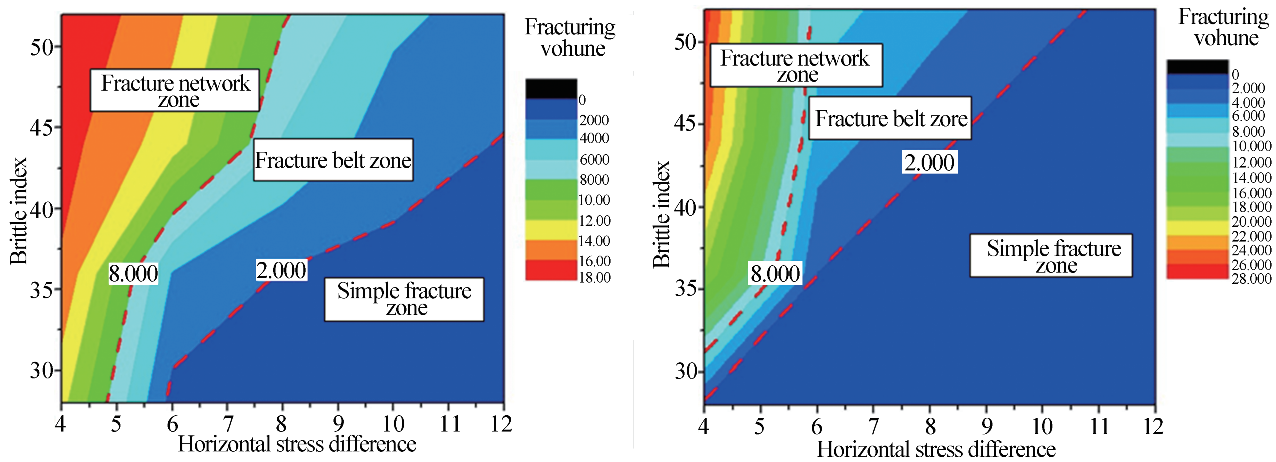
First, through investigation and survey and indoor simulation experiment ,we can divide Ordos basin into two types which called natural fracture developed region and natural fracture underdeveloped region. We could hypothesize that the natural fracture liner density was 1.25 strip/m in natural fracture developed region and the natural fracture liner density was 0.58 strip/m in natural fracture underdeveloped region. Then we use the fracture simulation software Meyer to study the regular change of stimulated reservoir volume which changed with horizontal stress in two different natural fracture regions respectively when brittle index is 28, 36, 44, 52 and base on the basic physical parameters in Chang 7 tight reservoir in the Ordos basin.

We make nephogram of Fracturing volume, horizontal stress and brittle index in different natural fracture development region according to analog computation data (Figure 3). We can get greater Fracturing volume from fragile layer at will when horizontal stress difference less than 4.8 MPa in natural fracture developed regions. But we can't get a ideal Fracturing volume even in the layer has major brittle fracture when horizontal stress difference greater than 8 MPa. A greater Fracturing volume was received when the horizontal stress difference is between 4.8-8 MPa and brittle index greater than 44 and it is also received when the horizontal stress difference less than 6 MPa and brittle index greater than 36.

Simple fracture zone is formed when Fracturing volume is less than 2×10^5 m^3 through the analysis of relations between Fracturing volume and geometric configuration of ultimate network. Complex fracture network zone is formed when Fracturing volume is greater than 8×10^5 m^3. And certainly fracture belt zone is formed when stimulated reservoir volume is between 2×10^5 m^3 to 8×10^5 m^3. We use the standard which is mentioned above to divide Figure 3 into difference fracture morphology zone, then we can get formation selection criteria for volume fracturing in Chang 7 tight reservoir in the Ordos basin.

The horizontal stress difference in the Ordos basin is between 6 MPa to 12 MPa and the brittle index is between 30 to 48, so we can know from Figure 3 that the feasibility of fracture network formation is zero in natural fracture underdeveloped regions and complex fracture network formation build when horizontal stress difference is less than 8 MPa in the layer and volume fracturing proceed with optimization brittle index is greater than 40 in the layer in natural fracture developed regions.

For the formation selection criteria was based on the fracturing slurry rate is 8 m^3/min, so the formation selection criteria for volume fracturing will reduce with change of geological condition which satisfied formation of fracture network by the development of fracture construction technology. Therefore, the formation selection criteria for volume fracturing is only suitable for situation in Chang 7 tight reservoir in the Ordos basin now.



(a)Natural Fracture Developed Regions (b) Natural Fracture Underdeveloped Regions

Figure 3
Criterion of Volume Fracturing in Chang 7 Layer

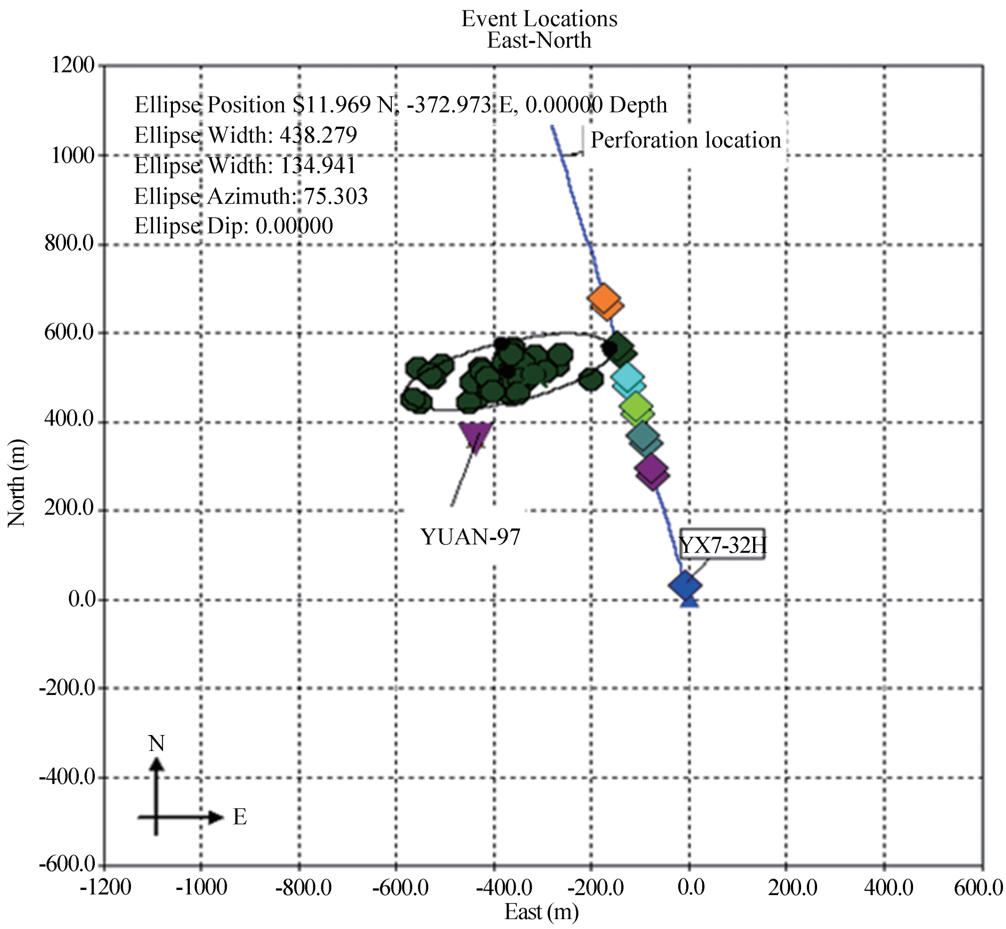


Figure 4
Microseismic Map of the 6th Stage Fracturing in Well A

3. FIELD APPLICATION

The stratum has well natural fracture development and lesser horizontal stress difference in Changqing oilfield Longdong region H area and it could use the formation selection criteria for volume fracturing in Chang 7 tight reservoir in the Ordos basin to optimize the layer. Optimize horizontal A well in this region as object of study and proceed on volume fracture and microseismic surveillance.

The TVD of well A is 2,230 m and its horizontal segment length is 824 m,and its target layer is 2,221-2,237 m with stratum depth is 16 m, which belongs to Chang 7 tight reservoir with well natural fracture development and its average fracture linear density is 1.4 strip/m. Minimum horizontal crustal stress is 34 Mpa and maximum horizontal crustal stress is 40.5 Mpa so that the stress difference is 6.5 Mpa. There are seven positions whose brittle index greater than 40 in Well A through the data interpretation of log, and we select the sixth layer as the example to confirm.

Through the data interpretation of log can also find Young's modulus is 24,138 Mpa, Poisson ratio is 0.22, brittle index is 46, and the fracturing slurry rate is 8 m^3/min, fracturing fluid is clean fracturing fluid ,and its volume is 721 m^3.

We detect the sixth layer fracture in Well A through microseismic surveillance and result as shown in Figure 4.

The result show that complex fracture network is built in the layer with the length of fracture network is 438 m, width is 135 m, height is 40 m. The equivalent volume of fracturing transformation is 1.238×10^6 m^3. So we can know the selection criteria adequate for optimum formation selection and it has guide function in fieldwork which proved by field practice.

CONCLUSION

The following conclusions can be drawn as the results of this study:

(a) The horizontal stress difference in Chang 7 layers in the Ordos basin between 6 MPa to 12 MPa and the brittle index between 30 and 48 which can get through the method of elasticity parameter. Nature fracture growth has obvious regionalism with the degree of nature fracture growth poor in the middle block of Ordos basin and the degree of nature fracture growth well in the southwest of Ordos basin.

(b) To get complex fracture network, volume fracturing should proceed with horizontal stress difference is less than 8 MPa and brittle index is greater than 40 in the layer in natural fracture developed regions in the southwest of Ordos basin to aim the Chang 7 tight reservoir in the Ordos basin.

(c) Horizontal stress difference is the first important factor to influent the form of fracture network and the brittle index is the second one and the natural fracture is the requirement. So we should select lesser horizontal stress difference in natural fracture developed regions first and then select greater brittle index in layer to realize the optimization of volume fracture layer.

(d) The selection criteria adequate for optimum formation selection and it has guide function in fieldwork which proved by field practice and it will reduce with change of geological condition which satisfied formation of fracture network by the development of fracture construction technology.

REFERENCES

[1] Lin, S. H., Zou, C. N., & Yuan, X. J. (2011). Status quo of tight oil exploitation in the United States and its implication. *Lithologic Reservoirs*, *23*(4), 25-30.

[2] Li, X. J., Hu, S. Y., & Cheng, K. M. (2007). Suggestions from the development of fractured shale gas in North America. *Petroleum Exploration and Development*, *34*(4), 392-400.

[3] Jia, C. Z., Zheng, M., & Zhang, Y. F. (2012). Unconventional hydrocarbon resources in China and the prospect of exploration and development. *Petroleum Exploration and Development*, *39*(2), 129-136.

[4] Qiu, Z., Zou, C. N., & Li, J. Z. (2013). Unconventional petroleum resources assessment: Progress and future prospects. *Natural Gas Geoscience*, *24*(2), 238-246.

[5] Zhang, H. (2013). Lessons for shale oil & gas development from that of tight oil & gas and coalbed methane gas in China. *Natural Gas Industry*, *33*(4), 18-25.

[6] Wang, S. F., An, W. H., & Chen, P. (2013). Characteristic and development techniques of Sulige tight gas pool. *Natural Gas Geoscience*, *24*(1), 138-145.

[7] Cheng, Y. F., Li, Y. Z., & Shi, X. (2013). Analysis and application of fracture network models of volume fracturing in shale gas reservoirs. *Natural Gas Industry*, *33*(9), 53-59.

[8] Chen, F. J., Yang, Y., Liu, S. F. (2012). Study on the optimization of staged fracturing of a horizontal well in a tight gas reservoir with low permeability. *Special Oil & Gas Reservoir*, *19*(6), 85-87.

[9] Li, J. B., Bai, J. W., & Zhu, L. (2013). Volume fracturing and its practices in Sulige tight sandstone gas reservoirs. *Natural Gas Industry*, *33*(9), 1-5.

[10] Weng, D. W., Lei, Q., & Xu, Y. (2011). Network fracturing techniques and its application in the field. *Acta Petrol EI Sinical*, *32*(2), 280-284.

[11] Zeng, L. B., Li, Z. X., & Shi, C. G. (2007). Characteristics and origin of the fracture in the extra low permeability sandstone reservoirs of the upper Triassic Yanchang Formation in the Ordos basin. *Acta Geologica Sinica*, *81*(2), 174-180.

[12] Zeng, L. B. (2008). *Generation and distribution of the fracture in the extra low permeability sandstone reservoirs* (pp.75-83). Beijing, China: Science Press.