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3D Development Technology of Deep Shale Gas

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Abstract: ***In order to improve the production rate and recovery rate of reserves in deep shale gas area, based on the geological conditions of Yongchuan area, the well pattern and well spacing are studied. At the same time, the well spacing design of deep shale gas is the key to the technical policy design of gas field development, which is related to the maximum utilization of resources. The well spacing design is closely related to geological characteristics and fracturing technology.***

Keyword: Deep shale gas; Three - dimensional well network; Well spacing

1. Introduction

China is rich in shale gas resources, with a favorable exploration area of 43 × 10^4 km^2 [1]. According to the evaluation results of the United States Information and Energy Administration, the Ministry of Land and Resources of China, China Petroleum Exploration and Development Research Institute and other institutions, the recoverable resources of shale gas in China are 11.5 × 10^{12}～ 36.1 × 10^{12} m^3, ranking first in the world, and mainly marine shale gas. Among them, deep shale gas is an important successor field of China's shale gas development [2], and increasing its exploration and development efforts has important strategic significance for ensuring national energy security. In order to improve the production rate and recovery rate of reserves in shale gas area, the author combed the progress and main geological understanding of shale gas exploration and development in the United States and China. Taking the shale reservoir block in South Yongchuan District as an example, starting from manual intervention to improve the effective liquidity and development integrity of shale gas, the theoretical connotation and core technology of "volume development" in shale gas sweet spot area were proposed, Furthermore, the development prospect of "volume development" of shale gas resources in China is evaluated and prospected.

2. Overview of Gas Reservoir

The mining rights area of Yongchuan Block is 215.37km^2, located in Chongqing City, with hilly terrain; The structural location of the southern region is located on the northwest wing of the Laisu syncline between the Xindianzi anticline and the Cucumber Mountain anticline in the southern Sichuan broom shaped structural belt. In 2016, the test of Yongye 1HF well produced 136600 m3/day, making breakthrough in Yongchuan deep shale gas exploration 2016 - 2018. Two sets of five wells were deployed, and the well spacing and productivity test were carried out. The productivity was improved. Since 2019, the first two rounds of evaluations have identified the potential for 500 million cubic meters of production in the southern region. In order to further accelerate, increase production, reduce costs, and increase efficiency, three 11 well group tests have been carried out. Currently, the Yongye 5 - 2HF has achieved significant results, laying the foundation for the rolling production in the southern region. Yongchuan South District has submitted a proven reserve of 23.453 billion cubic meters (layers ① - ⑦), with a gas bearing area of 26.51 km2. The burial depth is 3700 - 4300m, which is deep shale gas. The burial depth of syncline wing and northeast uplift is 3700 - 4000m (55%), and the burial depth of core is 4000 - 4300m (45%). The shale quality and gas bearing capacity of the development layers ① to ⑦ are relatively good, with a thickness of 35 - 45 meters and stable distribution. They have the characteristics of high TOC (average 2.32%), high porosity (average 5.01%), high brittleness (average 60%), and high gas content (average 3.88 m3/t), characterized by "four highs and one low".

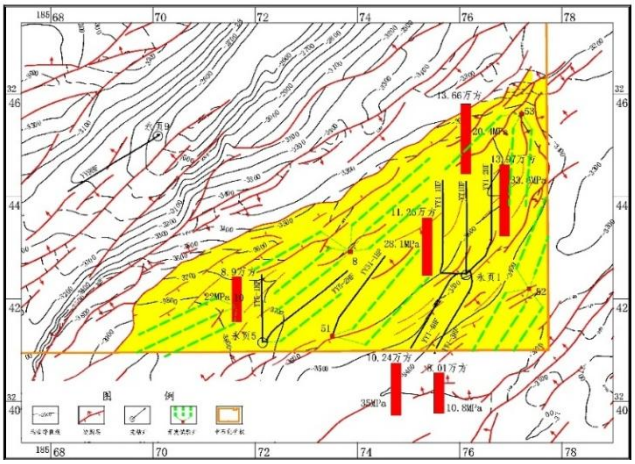

Figure 1: Gas containing area chart

3. Volume Development Theory

"Volumetric development" of shale gas refers to the development method of establishing an artificial volumetric fracture network system of shale gas reservoir through horizontal well drilling and large - scale staged and clustered fracturing, so that the reserves in the affected volume can be used as commercial development reserves, and then shale gas resources can be used on an effective scale. Compared with the development of conventional layered gas reservoirs, the commercial development of shale gas reservoirs cannot be realized by using conventional engineering technologies. Long horizontal wells, staged and clustered fracturing and

other core technologies are used, and the fluid flow mode in the reservoir has also changed from the horizontal flow dominated by conventional layered oil and gas reservoirs to the "composite volume flow" mode coupled with multiple flows such as horizontal flow of layered fractures in shale gas reservoirs and vertical flow of vertical fractures. The important condition for "volume development" of shale gas is to form a large - scale fracture network system. The main fracture of hydraulic fracturing extends along the direction of the maximum horizontal principal stress, forming secondary fractures at weak interlayer bonding or closed natural fractures, and ultimately coupling with natural fractures to form a fracture network system [3]. Compared with North America, the difference of horizontal principal stress in the "sweet spot area" of shale gas in southern China is large, which tends to form a fracture network system dominated by main fractures [4]. By combining the scale of artificial fractures and the morphology of main fractures, a multi - layer staggered well layout is adopted in high - quality shale sections. The volume fracture network formed after hydraulic fracturing can maximize the volume of transformation. The "volume development" of shale gas is to fully understand the shale reservoir, and through manual measures, to open up the flow channels from the matrix pores to the volume fracture network, and from the fracture network to the wellbore in the maximum range from vertical and horizontal, so as to maximize the liberation of natural gas in the shale reservoir, form commercial production capacity under natural energy, and achieve an effective drilling, transformation and development of gas bearing shale relative homogeneous body. To sum up, understanding shale reservoir is the foundation, forming three - dimensional fracture network system and composite seepage mode is the core, promoting geological engineering integration is the key, and implementing well factory management is the key.

4. Evaluation of Volume Development Mode

Previous studies have suggested that hydraulic fractures are distributed in a "star" shape; In the vertical direction, the maximum height of the support fractures distributed above and below the perforation position is between 10 - 25 meters, while the reservoir thickness in the southern Yongchuan area is between 60 - 70 meters. On a flat surface, the length of the support joint ranges from 150 to 280 meters. And the farther away from the perforation position, the lower the conductivity of the support fracture; It can be concluded that this area has the potential for three - dimensional development.

The essence of well network deployment is to increase the renovation area of reservoirs and how to utilize more reserve resources.

The red area represents the simulation of artificial cracks, with 100m as the half length of the crack for the first time.

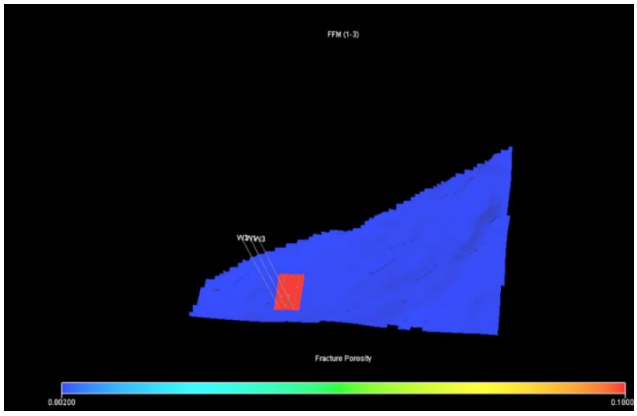

Figure 2: Artificial Crack Simulation Diagram

Right - angle grid refinement was carried out in the area around the wellbore, which can change the permeability in the refinement grid to simulate artificial fractures, which is relatively more refined (Figure 3).

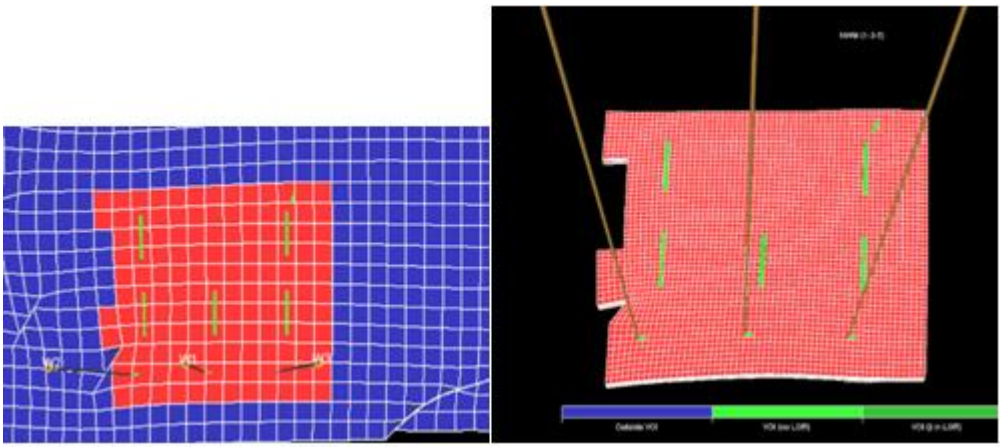

Figure 3: Schematic diagram of grid encryption

The wells are arranged vertically in two types of well network deployment, namely the same layer arrangement and staggered deployment.

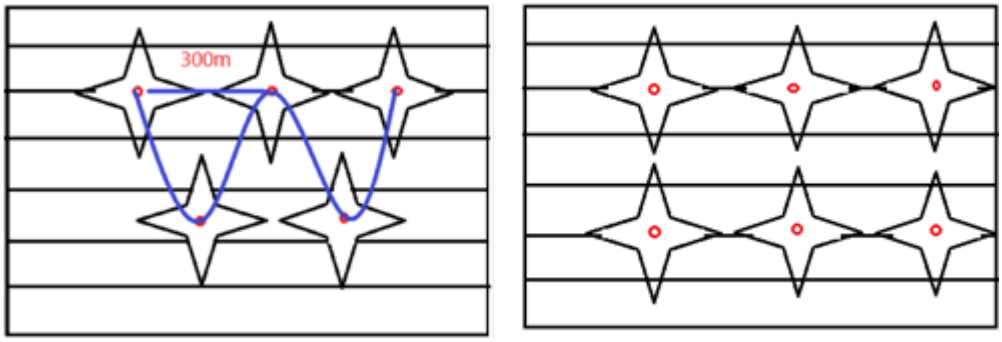

Figure 4: Schematic diagram of vertical well location deployment

5. Conclusion

1) Aiming at the development difficulties of deep shale gas, the three - dimensional development technology was innovatively simulated by numerical simulation.
2) For the deep shale gas in the south of Yongchuan, the well pattern and well spacing shall be reasonably deployed horizontally; Vertically, adopt a layout and staggered well network deployment method.
3) The theory and technology of "volume development" can provide theoretical basis and technical support for the overall utilization of unconventional oil and gas resources such as deep shale gas reserves, and has broad application prospects.

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