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Research on Efficient Development Technology of Chang7 Shale Reservoir of Ordos Basin

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Abstract: In view of the ordos basin Chang7 shale oil "pressure-stuffy-mining" shown in the process of "horizontal length is uneven, the drilling time after large volume fracturing, and drainage system strength is different", by the analysis of indoor experiments, numerical simulation and mine production data, comprehensive study regional geological characteristics and investment cost, optimize the length of the volume fracturing in ordos basin Chang7 shale oil reservoir efficient development technology policy. studies have shown: (1) Based on the relationship between geological characteristics of the study area and horizontal section length and production and single well investment, the reasonable horizontal section length in this area should be controlled at about 1500m; (2) The seepage process is mainly oil and water displacement in small pores for oil displacement, and the formation pressure time is 30-45 days; (3) Horizontal well return strength is large, and the oil time is relatively fast, but with the increase of the return strength, the horizontal well sand is serious, and the artificial crack diversion capacity is reduced; (4) Establishes the single well based reservoir classification structure of shale oil, based on the change characteristics of flow filling ratio in the return stage. The research results will effectively guide the development and production of shale oil reservoir in the combined area of Ordos Basin.

Keywords: Ordos Basin, Shale Oil, Volume Fracturing, Efficient Development Technology, Reasonable Production System

1. Introduction

Chang7 shale oil in Ordos Basin is a typical continental shale oil, with reserves of up to 4 billion tons, which is a realistic replacement resource for the second high-quality development of the oil field [1-4]. Through more than a decade of key breakthrough experiments, Changqing Oilfield has realized the effective scale development of shale oil, and took the lead in building a million-ton CNPC shale oil development demonstration area. However, compared with tight oil and shale oil in North America, Chang7 shale oil has low pressure coefficient and insufficient natural energy [5-6], As a result, in the development of natural energy, the yield decline is fast (the first year decline rate exceeds 30%), and the low recovery rate is low (5~8%), and it is difficult to achieve economic, reasonable and effective development. Therefore, it is very important to explore the efficient development technology of shale oil reservoir and optimize the relevant technical policies for the economic and reasonable development of Chang7 shale oil reservoir.

At present, the shale reservoir in Ordos Basin mainly adopts the development method of "pressure-stuffy-mining". The production dynamic characteristics under this development method can be divided into four stages: stuffy well after volume fracturing, liquid drainage, initial and later stable production. Under this development method, Chang7 shale reservoir can achieve large-scale and effective development. However, there are still obvious deficiencies in the relevant technology policies under this development method, mainly manifested in the following three aspects: First, the length of the horizontal section is uneven, and the relationship between section length and yield is not clear; second, the length of stuffy well time after large-scale volume fracturing is different, and the relationship between stuffy well time and water content, yield and pressure is not clear. Third, the understanding of the return system after volume fracturing is not clear. The too fast return rate destroys the balance between the wellbore pressure and the hydraulic crack pressure, resulting to the large amount of reflux, crushing and embedding of proppant into the stratum, affecting the diversion ability of the artificial seam network formed by volume fracturing.

In view of the deficiencies existing in the above development technology policy, this paper combines the indoor physical seepage experiments, numerical simulation and mine production data on in-depth research and analysis, combining the geological characteristics and investment cost, optimize the area of the horizontal section long, volume fracturing well time and discharge strength of fracturing fluid a set of technical policies for the efficient development of Chang7 shale reservoir in Ordos Basin effectively guide the field practice.

2. Optimization of the Horizontal Segment Length

Horizontal well technology is increasingly widely used in the development of shale reservoirs, and the length of horizontal well horizontal section is one of the key factors affecting the yield and recovery of horizontal Wells. It is of great significance to determine the reasonable horizontal section length of horizontal well to realize the efficient and economic scale development of shale reservoir. Therefore, the length of the horizontal section is optimized by integrating the reservoir geological characteristics and the relationship between the yield and the investment of a single well. First of all, the Ordos basin is deep and wide, the sediment filling rate is slow, and the development of argillous sedimentary rocks can be subdivided into Chang7_1, Chang7_2 and Chang7_3 from top to bottom. Through fine characterization of the single sand body of Chang7 shale reservoir in combined area (Figure 1), we find that the sand body width of Chang7_1 sections is between 900-1520m, average 1210m; sand body thickness is 8.5-12m, average 10.2m; the width ratio of sand body is 106:1-126:1, average 119:1. The width of sand body of Chang7_2 sections is between 690-1300m, average 1150m; sand body thickness is 6.7-10.2m, average 9.2m; the width ratio of sand body is 102:1-127:1, average 125:1. The average width of the sand body in this area is 1200m, but the length of the horizontal well section in this area is mainly distributed at about 2000m, indicating that about 800m in the area is located on the non-sand body, which is an invalid horizontal section. Secondly, according to the relationship between the length of the horizontal section of Chang7 horizontal Wells in the combined water area (Figure 2) and the initial yield and the cumulative oil production of the first horizontal well (Figure 3), it is found that with the increase of the horizontal well length, the single well production did not improve significantly, and there is no obvious correlation between the increase of the horizontal well length and the increase of the single well production, For example, level initial oil production at the segment length of 1500m is basically close to the horizontal segment production length at 2000m, This is also different from the previous understanding that the longer the horizontal segment, the higher the capacity of horizontal Wells. In addition, by analyzing the relationship between the horizontal section length of different horizontal Wells and the single well investment, we found that when the horizontal section length is greater than 1500m, the investment in the single well increased significantly (Figure 4), from 9.19 million to 10.65 million.

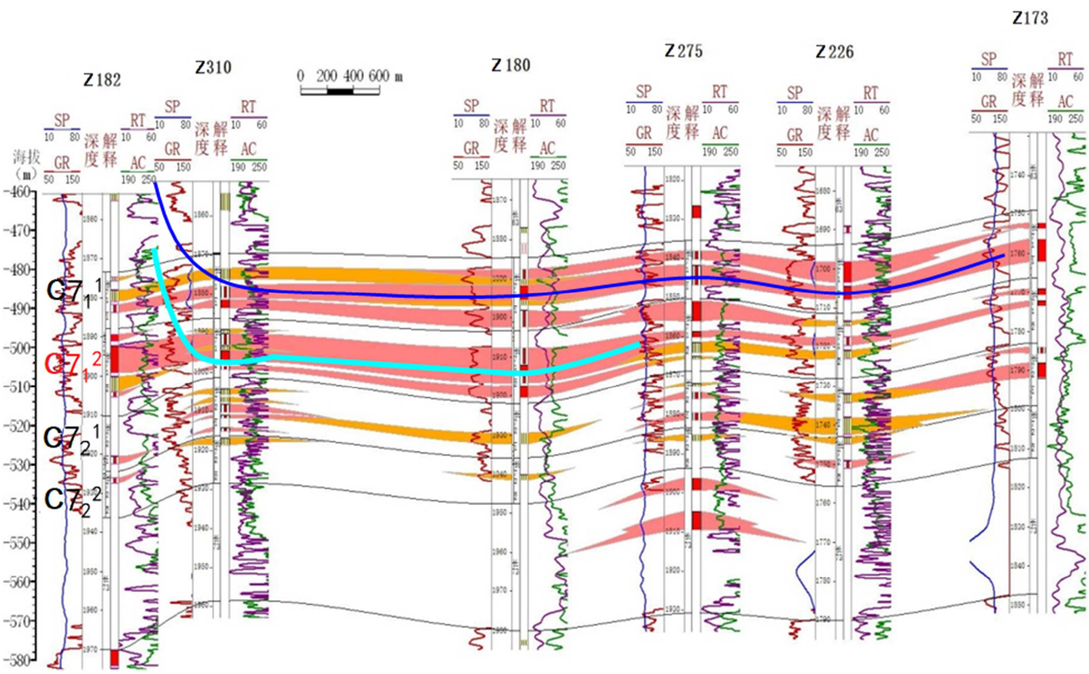

Figure 1. *Reservoir profile of Heshuizhuang 182-Zhuang 173.*

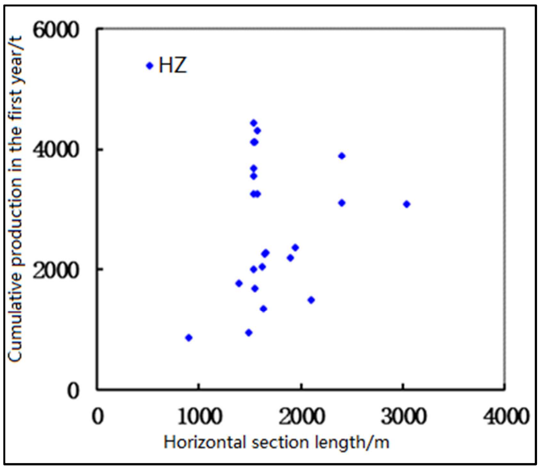

Figure 2. *Length of horizontal well of length 7 and initial yield.*

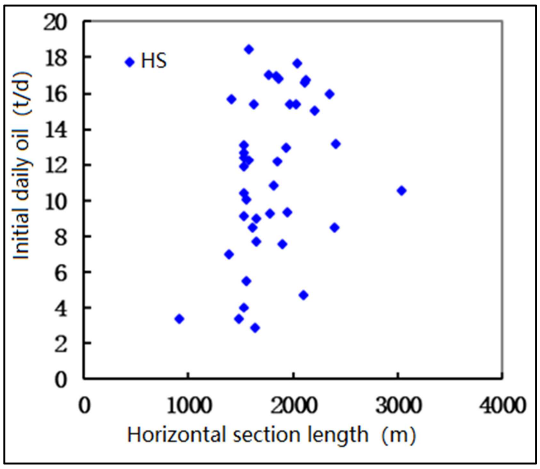

Figure 3. *Length of horizontal well and oil production in the first year.*

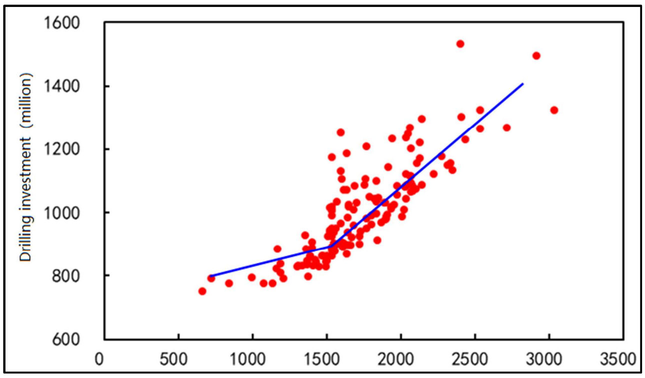

Figure 4. *Longdong Demonstration Area Long 7 Shale Oil 2018-Current horizontal well drilling investment chart.*

According to the above analysis, the 2000m horizontal section length designed in the combined water area not only increases the investment cost of a single well, but also does not reach the ideal yield. The reasonable horizontal section length in this area should be combined with the geological characteristics of the gas reservoir and the drilling cost, mainly with 1500m length.

3. Mill Time Optimization

At present, the production management system of "stuffy well, in production" is adopted in the research area after horizontal well pressure. When the fracturing fluid in the hydraulic crack will seep into the reservoir matrix and replace the oil and gas. The length of stuffy well time determines the effect of oil and gas displacement and crude oil recovery. Therefore, the infiltration time is optimized through indoor infiltration experiment, numerical simulation and mine practice.

3.1. Core Infiltration Experiment

Three representative rock samples from the study area were selected to monitor the displacement process of oil and water in the pore throat space using NMR technology.

3.1.1. Nuclear Magnetic Resonance Principle

Nuclear magnetic resonance (NMR) uses a hydrogen nucleus (proton 1H) The magnetism and its interaction with the external magnetic field, the technique of measuring the amplitude and relaxation rate of the hydrogen MR relaxation signal in the pore fluid of the formation core [7-11]. Generally, the NMR transverse relaxation time T2 has a one-to-one linear relationship with the rock pore radius r, expressed as follows as [12-14]:

$$\frac{1}{T_2} = \rho\left(\frac{S}{V}\right) = \frac{C}{r} \tag{1}$$

Specifically, ρ is the surface relaxation rate, μm/ms; S is the pore surface area occupied by the fluid, μm2; V is the pore volume occupied by the fluid, μm^3; C is the conversion coefficient, μm/ms. For a certain rock sample, the conversion coefficient C is certain, so the point with large rotation time corresponds to a large pore, and the point with short rotation time corresponds to small pores; the larger the rotation time, the larger the pore.

3.1.2. Experimental Rock Samples and Experimental Fluid

The experimental core was a plunger sample of 2.54cm in diameter and 4cm in length. In order to distinguish the NMR signals of oil and water, the $CaCl_2$ solution with the same mineralization degree (25000ppm) as the formation water and fluorine oil with viscosity of 1.02MPa s at room temperature and density of 1.044 g/cm^3.

3.1.3. Experimental Steps

(i) The samples were vacuumized and pressurized for saturation. After vacuming the core to 133Pa and pressurized the saturated $CaCl_2$ solution at 20MPa, the saturated sample quality was measured and the sample effective pore volume and effective porosity were calculated.

(ii) The establishes the bound water saturation of the water. Connect the experimental device and check the sealing and connectivity of the device, put the core into the core clamp, and use the simulated oil to replace the saturated water core to establish the bound water saturation. Then, the rock sample is aged at the formation temperature for 15 days to measure the NMR T2 spectrum curve after aging the rock sample.

(iii) Put the rock samples containing bound water into a self-suction bottle and record the time and the amount of oil absorption with $CaCl_2$ solution. The record is encrypted at the initial stage of the experiment, and the recording time can be gradually extended in the later stage. When the infiltration volume is stable for 24h, the infiltration volume ends.

(iv) Removed the sample from the suction vial and put it into the NMR instrument to determine the T2 spectrum curve of the rock sample again.

3.1.4. Experimental Results

Since the experimental oil is a fluorine oil without a signal, the experimental T2 spectrum curve only represents the water belief signal, and the change of the T2 spectrum curve reflects the change of the oil phase in the experimental core. Figure 6 shows the NMR T2 spectrum curve and the relationship curve between permeability efficiency, permeability speed and permeability time.

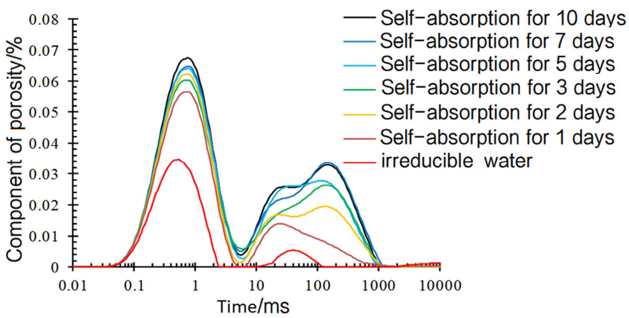

Figure 5*. NMR curve during infiltration of rock consolidation 2 2-1.*

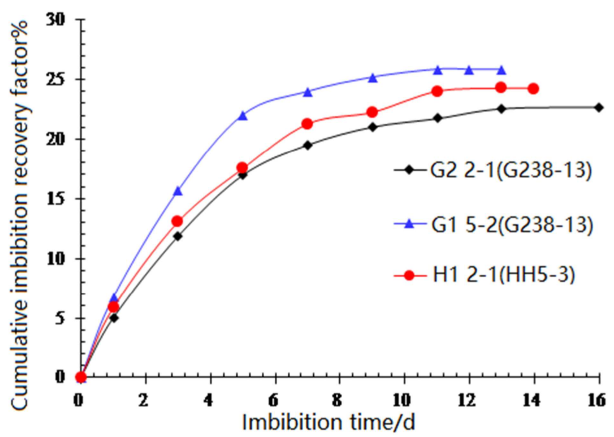

Figure 6*. Change curve of rock sample permeability recovery rate with permeability time.*

As can be seen from the figure, in the bound water state, the rock-like T2 spectrum shows unimodal characteristics, and it is mainly distributed in the relaxation time between 0.1 and 1 ms. With the increase of infiltration time, the area of the T2 spectrum curve gradually increased, and the early stage is mainly reflected in the runaway time is less than 10ms, with the increase of infiltration time, the part is more obvious than 10ms. This indicates that the early stage of the infiltration process is mainly the oil and water replacement in small pores, Moreover, because the wetting property of rock samples is neutral-weakly hydrophilic, and the hair tube force is the power of the permeability and displacement, so the early permeability rate is large, and the permeability and recovery rate increases rapidly. As the infiltration time increases, the seepage in the small hole peaks, and the seepage absorption production volume mainly comes from the contribution of the larger pores. After the infiltration rate reaches 10d, the permeability speed and recovery rate remain basically unchanged, and the reasonable stuffy well time in this study area should be 10d.

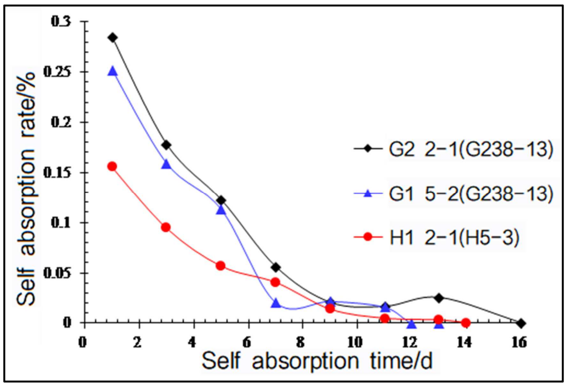

Figure 7*. Change curve of rock sample seepage speed with seepage time Figure 6 Static infiltration experiment results of rock samples.*

3.2. Numerical Simulation

Based on the experimental results, we further combined the geological characteristics of the research area and the well position distribution of the developed well, and simulated the relationship curve between saturation distribution, seepage distance, pressure gradient and seepage time in the "stuffy well" stage after volume fracturing.

Figure7 shows that the saturation field is rearranged during the "stuffy well" process. It can be seen from the figure that the crude oil in the matrix far away from the volume fracturing transformation area during the "stuffy well" process is basically not used passively, and its seepage mainly occurs in the artificial seam network formed in the volume fracturing transformation area. Figure 8 shows the curve of the seepage displacement distance and the pressure gradient with the time of the bored well, As can be seen from the figure, with the extension of the stuffy well time, the intrusion distance of the fracturing fluid changes gently, the formation pressure is gradually gentle, and the infiltration and displacement effect is weakened. When infiltration reached to 40 days, the pressure gradient weakened to 0, and the infiltration distance approached the peak, which indicates that the reasonable stuffy well time was 40 days after pressure in the study area, after which the infiltration effect was weak.

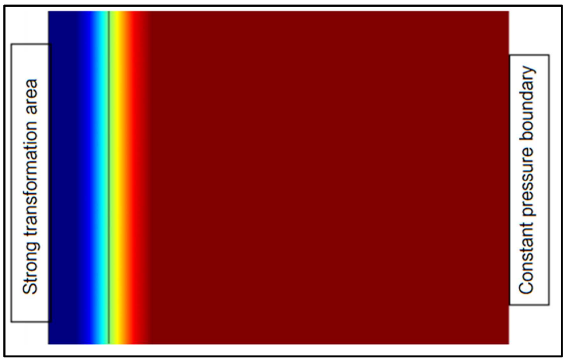

***Figure 8.** Schematic diagram of the saturation field rearrangement in the bored well stage.*

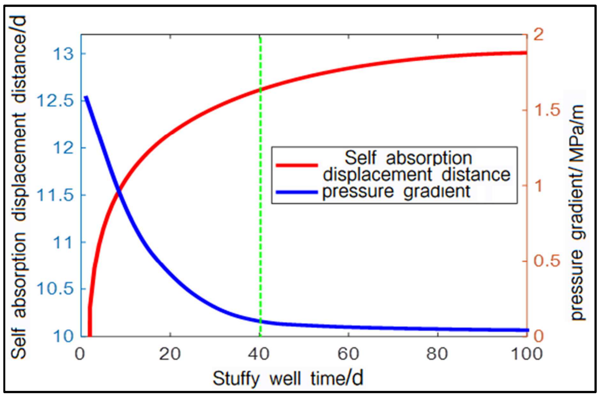

***Figure 9.** Change rule of seepage and displacement distance with the time of bored well Mine data analysis.*

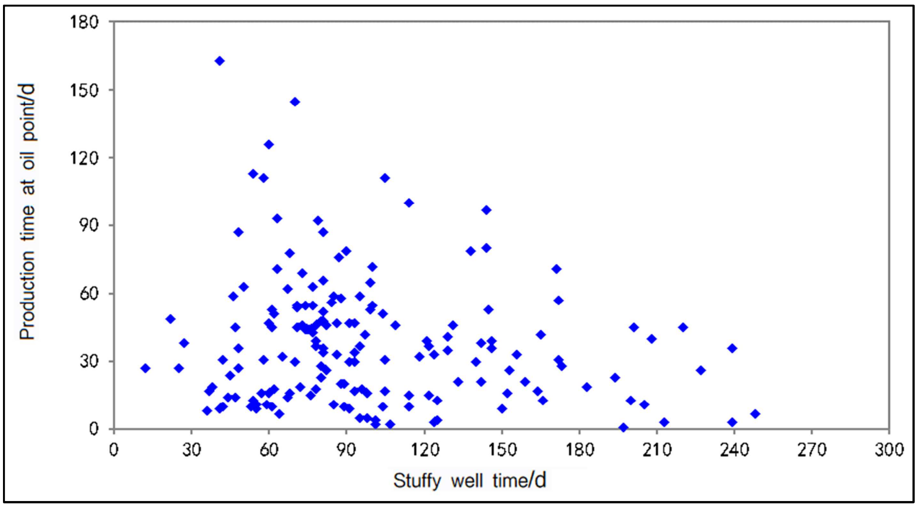

***Figure 10.** Horizontal well boring time and see oil time diagram.*

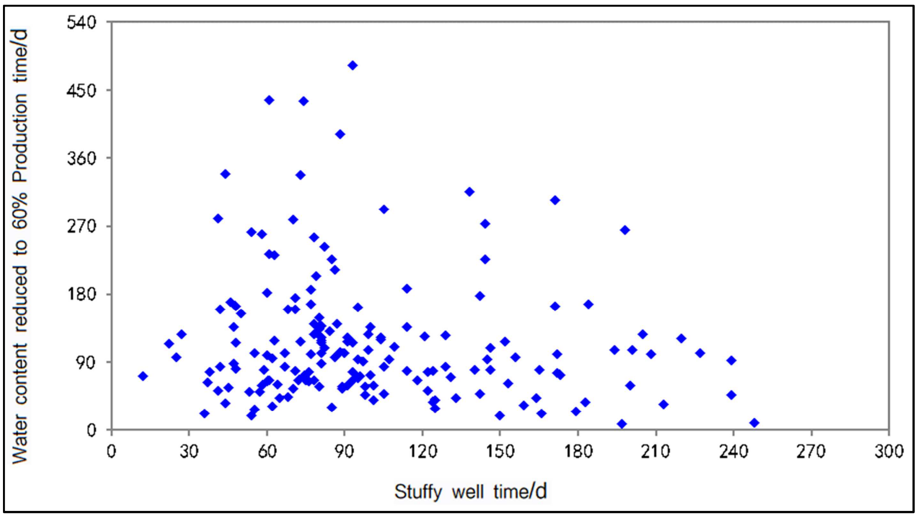

***Figure 11.** Well well time and time to 60%.*

3.3. Analysis of Mine Data

Numerical simulation and indoor experiments can obtain a reasonable stuffy well time in the study area, but these times are very good enough to guide the field practice. On the basis of numerical simulation, the relationship between different boring well time and oil seeing time and production time under low water content is further calculated (Figures 10-11). As can be seen from the figure, with the extension of the horizontal well boring time, the oil time and the decrease of water content to 60% production time are relatively short, which shows that the longer the boring well time will be conducive to the decrease of water content. However, the boring well time is too long, which makes the strength and impact range of the later well production large, which is not conducive to the improvement of production. Therefore, a reasonable stuffy well time should not be too long. In addition, we further counted the pressure drop curve of the well head in a production well in the study area (Figure 12). As can be seen from the figure, the pressure drops rapidly in the first 10 days of the "stuffy well" stage after volume fracturing, and the pressure drop rate reaches 0.6MPa /d, which is in the pressure expansion stage of the fracturing fluid; With the stuffy well time increasing, the pressure drop gradually slows down and the pressure drop rate decreases to 0.1MPa /d, in the process of oil-water replacement, and after the seepage time exceeds 35 days, the wellhead pressure is basically unchanged and the seepage displacement effect weakens, which shows that the reasonable stuffy well time in the study area should be controlled at 35 days, which is basically consistent with the simulation results. Therefore, combined with indoor experimental research, numerical simulation and mine practice, the reasonable stuffy well time in the study area should be controlled at 30-45 days.

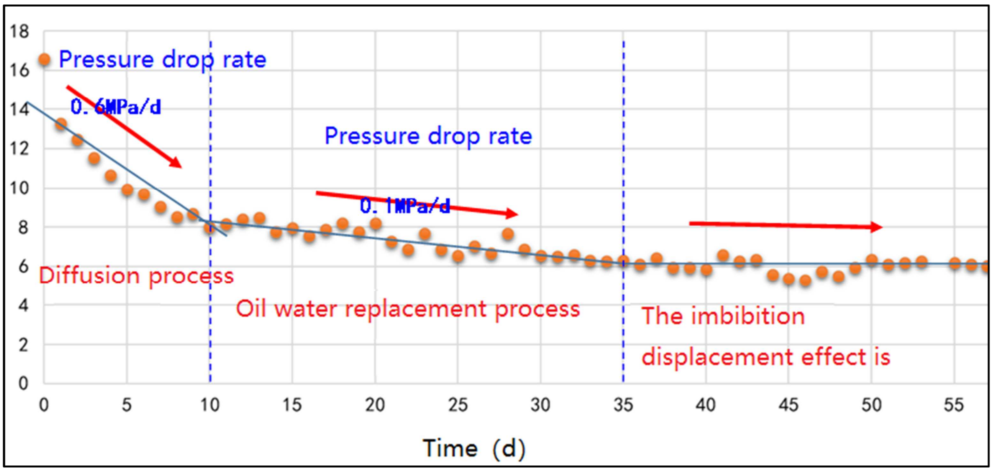

Figure 12. *wellhead pressure drop curve during stuffy well pressure of a production well in the study area.*

4. Rearrangement Strength

The size of the return rate significantly affects the diversion ability of the artificial seam net formed after volume fracturing, and it is important to determine the reasonable return working system to improve the recovery rate of shale reservoirs. Therefore, through the analysis of the mine field, the influence of the return rate on the fracture diversion ability is clarified, and the reasonable return strength of each well is set according to the flow satiety change characteristics of different types of wells in the study area. Production data can be distributed through the statistical study area, When using large horizontal well return strength, the oil time of horizontal well is relatively fast, but with the increase of the return strength, he horizontal well sand phenomenon is very serious, such as the process of no control blowout (corresponding to the high return rate), the horizontal well sand up to 28.2m^3, 57.83% compared with the control discharge sand (Figure 13).

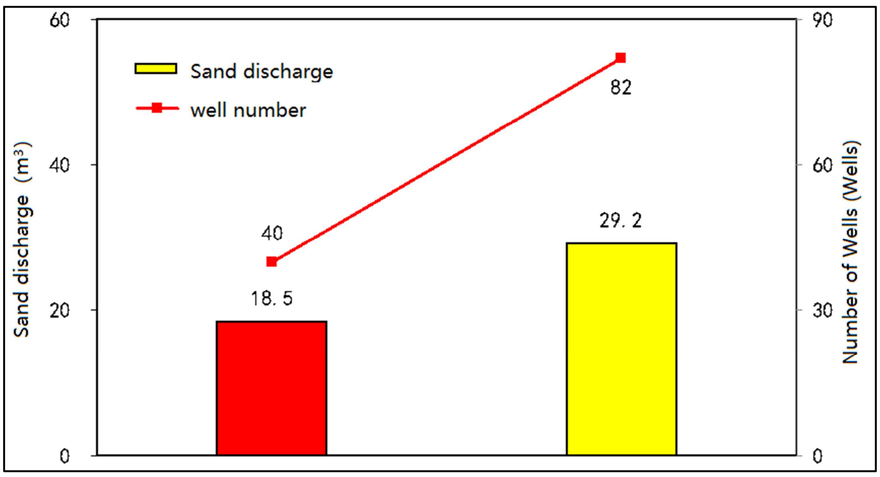

Figure 13. *Bar chart of quantity control and sand discharge.*

Therefore, the too fast return rate of the horizontal well, it is easy to destroy the pressure balance between the wellbore pressure and the hydraulic cracks, resulting in a large number of proppant reflux, crushing and embedded in the formation, the formation of sand discharge phenomenon is very serious.

At the same time, this also seriously destroys the diversion ability of the artificial seam net formed during volume fracturing. Through indoor experiments, it is found that the maximum damage of the sand outlet to the joint network diversion capacity can reach more than 30%, and the damage is irreversible. Therefore, the return rate is not easily too high for the area.

To this end, this paper establishes shale oil based on a single well According to the change characteristics of flow filling ratio in return stage (Figure 14), the flow filling ratio is 1.5, reasonable strength of 2.8-3.2m^3/d 1.0 m, 1.4~1.6, between 2.5~3.0 m^3 /d m, 1.2 to 1.5, and reasonable discharge strength of 1.8~2.3 m^3/dm.

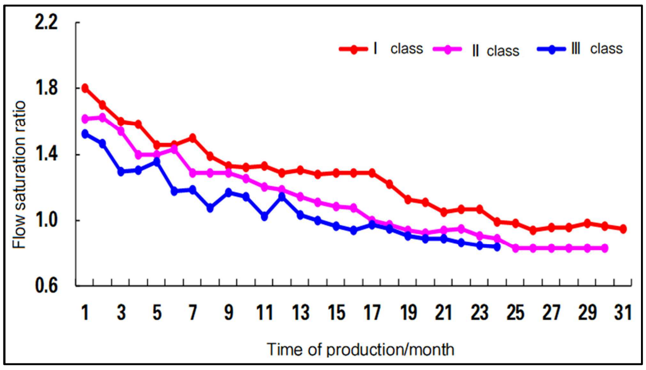

Figure 14. *Classification flow satiety ratio curve of the horizontal well.*

5. Conclusion

(1) The reasonable horizontal section length in this area should be combined with the geological characteristics of the gas reservoir and the drilling cost, with the main length of 1500m, and differentiated well layout.
(2) Static infiltration experiment shows that the infiltration process is mainly the oil and water replacement in small pores, and the water enters the small pores to replace the oil into large pores. After a certain time, the permeability speed and recovery are reduced.
(3) Data simulation and mine data show that with the extension of the stuffy well time, the fracturing fluid intrusion distance changes gently, the formation pressure is gradually gentle, the seepage replacement effect is weakened, and the reasonable stuffy well time after the optimization pressure is 30-45 days, and then the seepage effect is weak.
(4) The maximum damage of the diversion capacity of the sand outlet network can reach more than 30%, and the damage is irreversible.
(5) By establishing the reservoir division, type and stage framework of shale oil based on a single well, combined with the change characteristics of the flow and filling ratio in the return stage, the return system of different types of horizontal well can be defined.
(6) Flow fill ratio of Class I horizontal well is equal to 1.5, reasonable strength is 2.8~3.2 m^3/d·100m; flow fill ratio of Class II horizontal well is 1.4~1.6, reasonable strength is 2.5~3.0 m^3/d·m; flow fill ratio of Class III Wells is 1.2~1.5, reasonable discharge strength is 1.8~2.3 m^3/d·mm.
(7) The research results presented in this paper will effectively guide the efficient development and production of shale oil reservoir in Heshui area of Ordos Basin.

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