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Research Article

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Ultra-Low Permeability Reservoirs Ways of Well Pattern Optimization Research

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ABSTRACT

In order to further improve the development effect of H block purpose layer, this paper utilized reservoir numerical simulation technology, using the orthogonal design method to form of well pattern, well pattern parameters, the azimuth and length of horizontal well. Optimization results show that the recovery degree as index, select the following ways as the best reservoir development effect: the five point well pattern forms; horizontal well length of 900-1000 m, well spacing of 200-350m, well array distance of 300-350m; horizontal section perpendicular to the fracture; horizontal section length of horizontal injection wells of 500m. The research results can guide the economic and efficient development blocks in ultra-low permeability reservoirs.

KEYWORDS: ***Super-low permeability reservoir; Well pattern way; Optimization design***

Introduction

Fuyu oil reservoir in H block development is stable. The average thickness of sandstone is 6.4m. Average effective thickness is 4.8m. Porosity is 10.9%. Permeability is $0.63\times10^{-3}\mu m^2$. Reservoir types is lithological reservoir with "three low" characteristics. It is low-porosity, low-permeability, low-oil saturation. Nearly east-west microfracture of reservoir development and the stress field of hydraulic fracture is in the same direction.

From the domestic and foreign research results, horizontal wells have three obvious advantages over the vertical well. They are big rock exposed area, lateral connectivity of dispersion reservoir and variational oil drain geometric features. So horizontal well is an important technical means for exploitation of ultra-low permeability reservoir. But the ultra-low permeability oil reservoirs using horizontal well development still faces many problems at present. For example, well pattern choice, horizontal length, fracturing section number and so on. This paper to the question of the development used reservoir numerical simulation. And Eclipse numeral simulation software has been applied to well pattern parameter optimization.

1. Build Model

This paper studied H block. Sandstone thickness is 3~8m. Porosity is 10.9%. Permeability is $0.63\times10^{-3}\mu m^2$. 3D geological model is established using Petrel software, as shown in figure 1. Area block dimension is 10m×10m, with 0.5m for a grid

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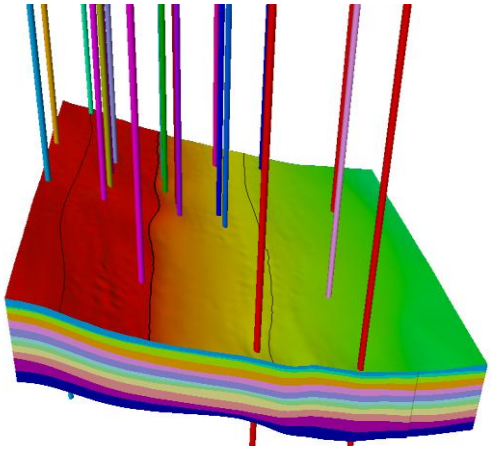
vertically. Other layers are 1m as a grid. Grid numbers are 579×579×65=21790665. Areas are 14.79km^2. The number of horizontal well is 17. The number of vertical well is 20. Location map as shown in figure 2.

Fig.1 Geological Model figure



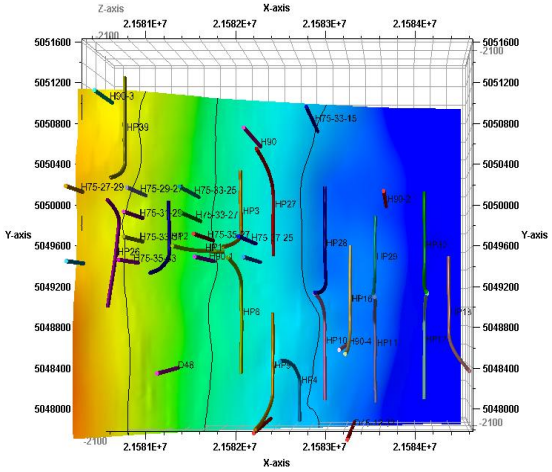


Fig.2 The Location Map

The reserves and production history matching have been studied. The Petrel geological model has been leaded into Eclipse numerical simulation software. The total number of model grid is 219×218×1= 47742. Grid spacing is 15m×15m×4.8m（X×Y×Z）. Model area is 10.74km^2. Model geological reserves is 179.5×10^{4}t. Reserves abundance is 16.71×10^{4}t/km^2. Fluid PVT data are as shown in the table below.

Table 1 The conceptual model fluid PVT parameters

viscosity of crude (cp)	1.79	Oil volume factor(m3/m3	1.2578
oil density (kg/m3)	736.7	Formation water	1.0
Oil compressibili	9.464561E-5	Formation water	2.96076E-5
Rock compressibili	8.783587E-5		

This paper designs the horizontal-vertical mixing well pattern and horizontal well pattern. Species number is 22. In the five point well pattern, there are four pattern forms of horizontal injection-horizontal production well pattern (WP1、WP2、WP3、WP4). There are two pattern forms of vertical injection- horizontal production well pattern （WP5、WP6）. In the seven point well pattern, there are six pattern forms of horizontal injection-horizontal production well pattern （WP7、WP8、WP9、WP11、WP12、WP13）. There are two pattern forms of vertical injection-horizontal production well pattern（WP10、WP14）. In the anti-nine point well pattern, there are six pattern forms of horizontal injection-horizontal production well pattern （WP15、WP16、WP17、WP18、WP19、WP20）. There are two pattern forms of vertical injection- horizontal production well pattern （WP21、WP22）. According to the horizontal orientation optimization theory and numerical simulation results, when horizontal Wells as production Wells perpendicular to the direction of fracture the development effect is best. Then WP4、WP6、WP11、WP12、WP13、WP14、WP18、WP19、WP20、WP22 are excluded. The rest of 12 well patterns conduct numerical simulation, prediction of 10 years, the results are as follows.

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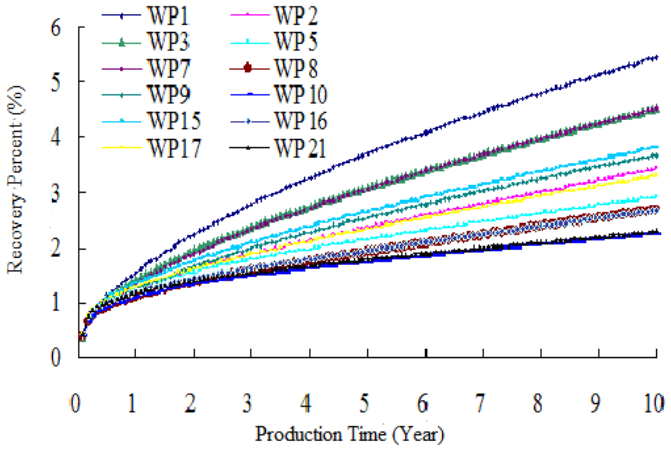

Fig.3 The recovery degree under different well pattern form change curve

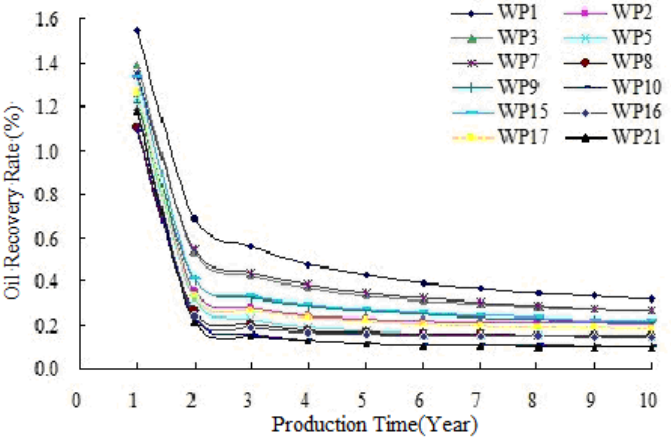

Fig.4 The oil recovery rate under different well pattern form change curve

The results show that, The WP5, WP2, WP10 and WP21 feed flow insufficiently badly. The WP2, WP5, WP8, WP10, WP16 and WP21 have been injected water development for 10 years for water breakthrough. Horizontal injection well array with a certain angle for the WP3、WP9、WP17. Therefore, the 13 kinds of pattern are not suitable for the optimum well pattern. What is more, the five point well pattern can enhance energy supplement, and enhance oil recovery. The WP1 is the optimal well pattern.

3. Well pattern parameter optimization

The orthogonal design method optimized horizontal well pattern parameters. Horizontal section length, well spacing and well array distance have been selected to evaluate each factor with five levels. Orthogonal design table is shown in the following table

Table .2 Block pattern parameter optimization orthogonal design table

Consideration	Horizontal section length/m	well spacing/m	well array distance/m
Test1	300	200	200
Test 2	300	250	250
Test 3	300	300	300
Test 4	300	350	350
Test 5	300	400	400
Test 6	500	200	250
Test 7	500	250	300
Test 8	500	300	350
Test 9	500	350	400
Test 10	500	400	200
Test 11	700	200	300

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Test 12	700	250	350
Test 13	700	300	400
Test14	700	350	200
Test 15	700	400	250
Test 16	900	200	350
Test 17	900	250	400
Test 18	900	300	200
Test 19	900	350	250
Test 20	900	400	300
Test 21	1000	200	400
Test 22	1000	250	200
Test 23	1000	300	250
Test 24	1000	350	300
Test 25	1000	400	350

In order to prevent the water breakthrough, considering the half of fracture length in the block is 150m, so the well array distance must be greater than 300m. So the experimental program which row spacing is less than 300m should be excluded. According to the above five point well pattern optimization, production well flowing bottom hole pressure has been set 8MPa. Water injection well flowing bottom hole pressure is 28MPa. Considering the horizontal well bore internal friction losses, Simulation to predict time is 10 years. The results have been shown in the figure below.

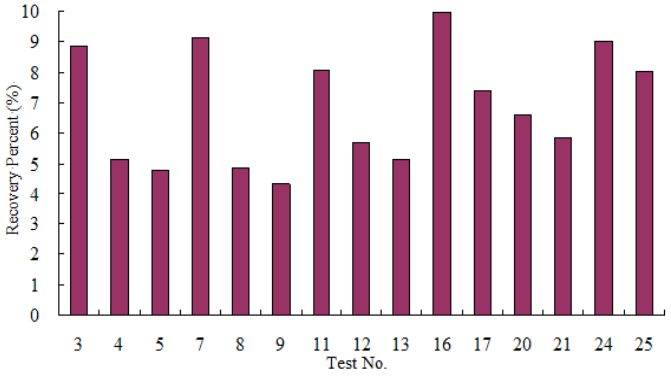

Fig.5 The histogram of recovery degree under different solution

The results show that, recovery percent of test 16 is highest. So the best horizontal section length is 900-1000m. The best well spacing is 200-350m. And the best well array distance is 300-350m.

4. Horizontal well orientation and length optimization

On the basis of well pattern form and well pattern parameters optimization, five-spot pattern has been chosen. Well spacing and well array distance is 300m both. There are three schemes. Horizontal well orientation has been parallel to fracture direction, perpendicular to fracture direction. And the angle between the horizontal well orientation and the fracture direction is 45°. Simulation prediction time is 10 years. Considering horizontal injection Wells length of 200m, 300m and 500m, 600m and 700m and 800m, using numerical simulation technology optimized reasonable horizontal section length of horizontal injection Wells.

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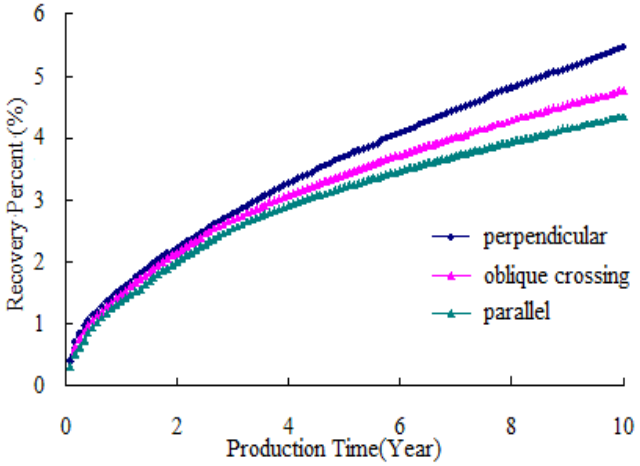

Fig.6 Under the different azimuth pattern deployment recovery degree of the contrast figure

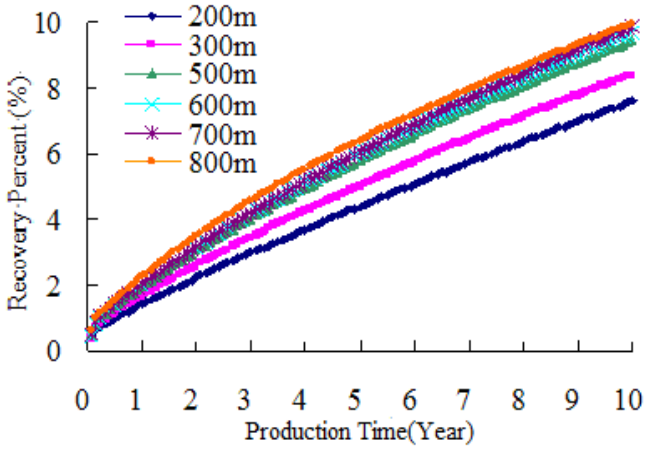

Fig.7 The curves of different length of horizontal injection recovery degree

The results show that, when the horizontal well orientation is perpendicular to fracture direction, recovery percent is the highest. Taken together, when the horizontal well orientation is perpendicular to fracture direction, development effects are the best.

From Fig.7, when the horizontal section length is more than 500m, increasing range of recovery percent is small. So the optimal horizontal section length of horizontal injection wells is 500m.

Conclusions

1. In order to make better application of horizontal well drilling technology in low permeability reservoirs, comprehensive optimization analysis of well pattern is needed correctly. Application of reservoir numerical simulation method to optimize the key parameters of horizontal well pattern, ultra-low permeability reservoir has achieved good development effect.

2. When the horizontal well direction is perpendicular to the fracture direction, it is beneficial to achieve the best horizontal well fracturing effect, and the development effect is best.

3. Well pattern optimization results showed that, pattern shape is five points well with horizontal injection wells and horizontal production wells. Horizontal length is 900-1000m. Injector producer distance is 200-350m. Well array distance is 300-350m.

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