Research on prediction method of fractured reservoir

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Abstract. In oil and gas exploration engineering, it is very difficult to identify and evaluate fractured reservoirs. Not only do we need to have scientific and reasonable methods, but we must also grasp relevant data and information through field investigations. Only in this way can we comprehensively predict cracks. In this paper, the characteristics of fractured reservoirs in China are briefly discussed, and some effective methods for predicting fractured reservoirs are given in combination with scientific evaluation methods for the reference of the frontline personnel.

1. Introduction

With the continuous advancement of China's industrialization process, China's demand for oil and gas resources is also increasing at this stage. While driving the development of China's oil and gas exploration projects, it has also made some conventional oil and gas reservoirs less and less, and the difficulty of mining has also become greater and greater. The emergence of this situation also makes China's future oil and gas exploration projects inevitably develop in the direction of unconventional oil and gas reservoirs and deep reservoirs. Among these unconventional oil and gas reservoirs, the exploration and development of fractured reservoir oil and gas is an important part of it. In the mid-1970s of the last century, CHMuury understood the structural cross-section as a “beam” with curved surface properties and used geometric methods to derive the curvature value and fracture porosity of the section and constructed a quantitative crack.

2. Definition and characteristics of fractured reservoirs

2.1. Definition of fractured reservoir

The so-called fractured oil and gas reservoirs refer to the oil and gas reservoirs located in the fractures of the reservoir and percolation channels. Under normal circumstances, the reservoir has good impermeability, and there are also some reservoirs with poor permeability, high density, and hard and brittle rocks, such as common dense limestone, marl and mudstone and many more. The causes of these fractures are more complex and diverse, but the main feature of their structure is that they have larger fractures, so they also attribute fractured oil and gas reservoirs to structural oil and gas reservoirs. If the structural map of the oil and gas reservoir shows an anticline, it can also be called a fractured anticline oil and gas reservoir.

2.2. Characteristics of fractured oil and gas reservoirs

Due to the characteristics of the fractured reservoir, the original pore size and density distribution are uneven, and the overall permeability is also quite poor, but the permeability near the fracture development zone is quite good. Due to the uneven distribution of the development of storage and infiltration space, even at various locations in the same reservoir, there are obvious differences in its performance. The complex lithology of the reservoir, as well as the unbalanced physical properties and
the variable distribution of the reservoir space, have become the main characteristics of fractured oil and gas reservoirs.

3. Fracture reservoir classification
According to the different types of causes, the cracks can be split into artificially induced cracks and natural cracks. Among them, natural fractures split into fractures (fractures formed by tectonic action or tectonic movement, which can be further decomposed into associated fractures and induced fractures according to the structural order) and non-structural fractures (from diagenesis, dry fracture, weathering, recrystallization and pressure Cracks formed by dissolution).

Fractured reservoirs refer to reservoirs with fractures as the main storage space and seepage channels, and some are also dispersed in the reservoirs, and the isolation and additional connection function of fractured reservoirs are classified in various ways. Reservoir lithology divides fractured reservoirs into a variety of reservoir types, namely carbonate fractured reservoirs, sand and mudstone fractured reservoirs and other rock fractured reservoirs.

Some people also divide fractured reservoirs into other types: one is tight rock, such as the Lower Permian (Yangxinian) in the Sichuan Basin, whose rock fracture degree is less than 1% and permeability is less than 0.1 milidarcy. Its structural fractures developed and formed effective reservoirs and permeable spaces; the second category are paleo-weathered crust dissolution pores and cave reservoirs, with extremely low permeability, generally less than 0.01 milidarcies, but matched with later structural fractures, Formation of fracture-hole (cave) reservoirs, such as the Sinian and Ordovician reservoirs in the Sichuan Basin, the Upper Triassic Xujiahe Formation sandstone (offset 5% ~ 6%), their conversion permeability is very low, generally around 0.01 milidarcy, only when structural fractures develop Only in regions can fractures be formed—preliminary reservoirs and industrial gas reservoirs.

In terms of external factors, the formation fracture system, structural deformation, scale curvature, structural position and other factors related to formation stress are relatively affected. The closer the distance to the fault, the more likely the structural cracks will develop; the more severe the structural deformation, the smaller the dimensional curvature. Small, such as the location of the folds in the stratum, the structural fractures also become more and more homogeneous in terms of the reservoir's own rock characteristics and mechanical characteristics, reservoir thickness, rock composition, particles, structure and other factors. The smaller the reservoir thickness, the easier it is to form fractures; the rock particle fractures, the easier to develop microfractures. Lithology controls the mechanical properties of rocks. Reservoirs with different lithologies have different degrees of fracture development. In addition, dissolution has an effect on the initial distribution of cracks.

4. Conventional evaluation methods
In the process of crack identification, it is necessary to combine the specific terrain of the area and conduct in-depth research and analysis before we can formulate corresponding solutions. For the research and observation of the core, understanding the logging response and the dynamic characteristics of oil and water wells is extremely effective for in-depth understanding and identification of fractures, whether in terms of technical operability or accuracy, as well as safety and practicality All aspects have good effects.

4.1. Core observation
Use the visible filler in the collected core or cuttings composition to confirm whether there are cracks in the rock layer below. The cracks in the rock are usually generated due to changes in underground stress and expand outwards, so after analyzing the collected cores, the size of the crack spacing, as well as the length, width and cut through of the crack can be roughly calculated At the same time, it can also calculate the inclination of the fracture and the specific location and permeability, and the content of these data is extremely important for the analysis and research of the fracture [1].
4.2. Logging response characteristics

It is an important evaluation method for logging identification of fractured oil and gas reservoirs through the collected logging data to identify the fractures in the rocks and confirm the scale of the oil and gas reservoirs in the fractures. It is worth noting that while using different logging methods, fractured oil and gas reservoirs also have different manifestations. The fracture logging methods commonly used at this stage include the following: (1) Formation dip logging. (2) Long source distance sonic logging [2]. (3) Bilateral logging. (4) Azimuth electric negative rate imaging. (5) Downhole sonic television imaging logging and other methods.

4.2.1. Formation dip angle logging

Formation dip logging is one of the most efficient and direct methods for judging reservoir fractures. The formation dip angle logging technology can accurately calculate the parameters related to the interval where the fracture is developed, as well as the density and extension direction of the fracture. Due to the complex conditions in the rock formation, mud often penetrates into the fractures, and this situation will cause abnormal performance of high conductivity, so the micro-resistivity curve with high resolution can be obtained by the dip angle logging equipment. Completely record and analyze these curves, so that you can accurately find the location of the fracture in the well wall area, and at the same time calculate the occurrence of the reservoir in the fracture.

4.2.2. Long source distance acoustic logging

The principle of long source distance sonic logging is to use the long source distance of the equipment, combined with the high compensation effect at the wellbore, so that the changes of longitudinal and transverse waves can be accurately judged [3]. Through advanced equipment, the time difference in the longitudinal wave transmission process, as well as the changes, amplitude and time curves generated by the full wave waveform can be completely and accurately recorded. In addition, the full wave can also be output by changing the density of itself, and the effect reflected by the cracks on the variable density map is that the color of the band is lightened, the overall contrast effect is weakened, and the band will be There are interruptions and distortions, accompanied by interfering strips such as step shapes. Compared with other methods, the cost of long source distance sonic logging technology is relatively low, and the effect is quite good.

4.2.3. Double lateral logging

The characteristics of dual lateral logging can accurately identify limestone and sandstone mud cracks. After passing the field test, the equipment is used to record the response characteristics of the fracture at various angles through a double-sided logging curve, and then the characteristics of the curve are studied to calculate the relevant parameters that characterize the fracture: the fracture opening and extension length, the fracture on both sides The relationship between the positive and negative difference of the logging curve. The curve form of the characteristic of the high-angle crack curve is: the resistivity formed by the high-angle crack will be weakened on the dense high-resistance background, and the
The curve will tend to be balanced, with a positive difference between the deep and shallow sides. The form of the low-angle crack curve is: the resistivity formed by the low-angle crack is weakened in the dense high-resistance background, and the curve is sharp, and the lateral difference between deep and shallow is negative.

4.2.4. **Micro-resistivity imaging logging**

Imaging logging is a parameter fed back through the detection of resistivity distributed along the circumference of the well, and the physical properties of the rock such as the amplitude of sound waves in the field, and then the overall information of the borehole wall is displayed using digital images. It can use the high-definition imaging equipment to produce high-definition imaging maps to accurately identify and analyze the cracks and holes in the rock, and understand the overall structure of the internal cracks and important data content such as stress analysis [4]. If there are cracks, karst caves or other geological phenomena in the stratum, the resistivity detected by the device will change accordingly, and then after the special treatment of this change, the electrical signal can be converted into white. Color pictures in yellow, brown and black. If there is a large amount of mud, filtrate, or other ore bodies in the cracks in the rock layer, the color image converted from the collected data information will show a black sine wave; if the cracks in the rock layer are filled with some When high-density, high-resistance mineral bodies (such as calcite), the color image displayed by the information collected by the device is a black line. Because the imaging color map can intuitively and visually understand the downhole situation and the surrounding strata along the well in a detailed and comprehensive manner, the ability and accuracy of identifying cracks in the rock formation is the highest, but this way The cost of use is also relatively high.

5. **Protection measures for fractured oil and gas reservoirs**

Through the study of the damage mechanism of oil and gas reservoirs, the purpose is to form corresponding protective measures to effectively protect oil and gas reservoirs, so as to achieve the purpose of timely discovery of oil and gas reservoirs. In view of the above-mentioned damage mechanism of oil and gas reservoirs, there are currently two main protection measures for oil and gas reservoirs: physical methods and chemical methods.

5.1. **Physical methods**

The physical method is the shielding temporary plugging method for protecting oil and gas reservoirs, which belongs to the category of particle accumulation and ideal filling theory. Its focus is based on the known pore size and distribution characteristics of oil and gas reservoirs. By adding temporary plugging agents of suitable particle size to drilling fluids, a dense mud cake is quickly formed in the very shallow parts of the oil and gas reservoir well wall, so that the oil and gas reservoir permeability It drops sharply to a very small value to prevent the drilling fluid's solid and liquid phases from further intruding into the oil and gas reservoir, while forming dense mud cakes, and to ensure easy removal before the oil well is put into production. Its basic method is to select different particle size distributions according to the pore distribution characteristics of oil and gas reservoirs to form a dense mud cake. The methods to be followed mainly include $1/3 \sim 2/3$ bridge principle, geometric fractal theory, D90 theory and broad spectrum temporary blocking principle.

For fractured oil and gas reservoirs, through the "9th Five-Year" technical breakthrough, it is believed that the fibrous temporary plugging agent is added to the formulation of drilling and completion fluids in porous oil and gas reservoirs. The particles cross-link with each other to form a flocculent, which is easier to deposit on the fracture surface than spherical particles of the same size; after the flocculent particles are deposited on the fracture surface, it is not point contact, but multi-point contact, even surface Contact, has high stability, can form a stable bridge; the strength of the flocculation is low, it is easy to deform under the pressure difference, it can fill any shape of crack, cooperate with rigid particles, deformable particles, can be at the entrance of the crack Form an effective plug.
1/3 \sim 2/3 bridging principle: The theory believes that when the particle size of the bridging is matched by 2/3 of the average pore diameter of the pore, its bridging at the pore throat of the formation is the most stable, and no particle transport will occur. Migration phenomenon, and when the particle size of the bridging particles matches 1/3 of the average pore diameter of the pore throat, the formation of the bridge plug is essentially the accumulation of particles at the pore throat, and there is still a significant particle migration phenomenon. And under a certain positive pressure difference, a certain amount of bridging particles and filling particles in the drilling fluid system that match the formation pore throat form a shield ring (inner mud cake) on the reservoir well wall, so as to achieve temporary blocking of the shield effect. A certain amount of bridging particles and filling particles in the drilling fluid system usually requires that the concentration of the solid particles of the bridge plug should not be less than 3%, and the concentration of filling particles (including deformable particles) should not be less than 2%.

For fractured reservoirs, the "1/3 to 2/3 particle size bridging theory" is used, and the principle of selecting various temporary plugging agents is: the average diameter of the rigid temporary plugging agent should be 2/3 of the average opening of the reservoir fractures. The average particle diameter of filled temporary plugging agent and deformable temporary plugging agent should be 1/3 of the average opening of reservoir fractures.

Geometric fractal theory: reservoir pore size distribution and temporary plugging agent particle distribution have fractal characteristics in the range of self-similarity. Reservoir pore distribution fractal dimension and temporary plugging agent particle size distribution fractal dimension represent the complexity of sandstone pore space and particle size distribution, and can better reflect the true distribution of pore and particle size. Therefore, according to the fractal dimension of sandstone pore distribution in oil and gas reservoirs, temporary plugging agents with the same or similar particle distribution fractal dimension can be selected as the preferred temporary plugging agent for this oil and gas reservoir. The average particle diameter of shaped particle temporary plugging agent.

5.2. Chemical methods
It is important to protect the oil and gas reservoirs from the drilling fluid itself. Commonly used drilling fluids for protecting oil and gas reservoirs include formate drilling fluid completion fluid, silicate drilling fluid completion fluid, polyalcohol drilling fluid completion fluid, synthetic-based drilling fluid completion fluid and underbalanced drilling fluid completion fluid.

Formate drilling fluid completion fluid: This is because the formate drilling fluid completion fluid is composed of soluble formate system without bentonite, low inert solid content, strong ability to inhibit collapse, and low drilling fluid can be used. The completion fluid density solves the problem of the stability of the borehole wall. The formate divalent salt has no precipitation and has good compatibility with oil and gas reservoir fluids. Therefore, it is beneficial to discover oil and gas reservoirs and has good compatibility with oil and gas reservoir fluids. But its high cost restricts its further development.

5.3. Technology of isolation membrane drilling and completion fluid
Regardless of whether physical or chemical methods are used to protect oil and gas reservoirs, this is because the heterogeneity of formation rocks is very strong, and the physical properties of rocks obtained through localization cannot fully express the underground conditions.

Proposed the isolation membrane water-based drilling fluid completion fluid technology. This technology is to form an isolation membrane on the well wall by polymer adsorption or chemical reaction, that is, to form a protective layer on the periphery of the well wall to prevent drilling fluid from entering the formation. Effectively prevent formation hydration and expansion, block formation bedding cracks, to prevent the collapse of the well wall and protect the oil and gas layer.

This technology theoretically believes that by adding one or several film-forming agents to water-based drilling fluids, the drilling fluid system can form a higher-quality film on the surface of the shale and other formations. It prevents drilling fluid filtrate from entering the formation, thereby playing an excellent role in protecting the oil and gas layer and stabilizing the well wall [5].
This film-forming technology avoids the uncertainty of formation physical properties and avoids the damage of drilling fluid and completion fluid filtrate to the reservoir to the greatest extent. This isolation membrane can be chemically, physically or perforated during completion eliminated.

6. Conclusion
In summary, as a kind of complex oil and gas reservoir, fractured oil and gas reservoirs must go deep into the field during the exploration process, do corresponding data analysis, understand and master the distribution law of fracture development zones, and also use Multi-method, multi-angle way for comprehensive prediction. If you just follow the one-way approach, it will only make the predicted results more limited. Taking geological structure research as an important core, quantitative analysis of reservoir fracture porosity and permeability is introduced, and finally the response results of various logging data curves are used to give important data references for reservoir fracture prediction results.

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