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Key Technology for Leak Prevention of Igneous Rocks in a Certain Oilfield in Bo Zhong

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Abstract: ***A certain oilfield in Bozhong has experienced multiple volcanic eruptions, with developed fractures in igneous rocks and frequent drilling leaks; In the early stage, 7 out of 8 exploration wells experienced 23 leaks, resulting in losses of over 24 million yuan. In response to the high risk of leaks in the igneous rock development area of this block, based on the concept of geological engineering integration, an innovative key technology for preventing leaks in igneous rocks in a certain oilfield in Bozhong was proposed, with "pre drilling prevention, monitoring while drilling, and rapid plugging" as the core. Through 30 on-site construction operations, a new operational approach was provided for the problem of leaks in igneous rock formations, effectively reducing drilling risks and costs.***

Keywords: Bohai Oilfield, Igneous rock, Leak prevention, On site construction.

1. Introduction

The main components of igneous rocks in Bohai Oilfield include granite, andesite, and basalt. Igneous rocks have strong heterogeneity, discontinuous distribution, and complex lithology. Among them, basalt is rich in pore morphology after magma eruption and condensation, and forms a porous structure through weathering and dissolution. The rock has strong rigidity and is prone to multi-scale fracture development and expansion under tectonic movement, which is the main reason for leakage; Secondary voids such as dissolution pores and structural fractures may experience leakage, while igneous rocks are formed by the condensation of magma after eruption, and there may be cracks between them that can lead to wellbore leakage [1-3].

The geological conditions of a certain oilfield in Bozhong are complex, with large sections of igneous rocks developed in the Dongying and Shahejie formations of the main reservoir sections. The lithology is complex, and it has been invaded by volcanic rocks multiple times. The development of unconformity fractures has led to frequent occurrences of complex situations such as microcracks and leaks in igneous rocks. During the early drilling process of exploration and development wells in a certain oilfield in Bozhong, more than 70% of the wells experienced leakage that affected normal drilling [4-5].

层位	1井区											5井区			6井区										2井区	
	A10	A14	A20	A5	A6	A8	A4	A13	A3	A1	A2	A18	A19	A22	A26	A27	A28	A31	A36	B3	B6	B8	B9	A32	B10	B25
平原组																										
明上段																										
明下段																										
馆陶组																								29		
东一段															36											
东二上段			4.5			17		48						60	30			30		16						25
东二下段				8				12		90.6			80		10		30			18					21	
东三段	60				8						60				28	30	12		60		40	40	52			
沙一段		99										40														
沙二段							9		30																	
沙三段										30		40														

Figure 1: Leakage rate statistics of a certain oilfield in Bozhong

In response to the challenges of poor drillability and high risk of wellbore leakage in the igneous rock development area of a certain block in Bozhong. The main focus is on how to finely characterize igneous rocks, identify formation fractures, define drilling risks for different types of igneous rocks, and predict how to avoid drilling high-risk igneous rocks when risks are uncontrollable; How to solve the problem of precise calculation of ECD while drilling; How to conduct research on three major aspects, including efficient leak sealing.

Based on the concept of integrated geological engineering, multiple seismic attributes are applied to accurately identify cracks according to their seismic response characteristics. Based on the strength of variance anomalies, the degree of crack opening is predicted, and an innovative key technology for preventing leaks in igneous rocks in a certain oilfield in Bozhong is proposed, with "pre drilling prevention, monitoring while drilling, and rapid plugging" as the core.

This technology is based on the principles of "avoidance, prevention, blockage, and caution", forming four key technologies: (1) fine prediction technology for igneous rocks. (2) Igneous rock drilling avoidance technology. (3) Precise control technology of ECD while drilling. (4) Efficient plugging technology while drilling

2. Main Key Technologies

2.1 Fine Prediction Technology for Igneous Rocks

Using logging data, for the first time, the Dongying Formation of the igneous rock development segment was divided into igneous rock cycles; Based on the division of cycles and seismic data, construct a regional framework for igneous rock cycles; Based on seismic reflection characteristics, combined with ancient landforms and volcanic channel distribution, finely depict the planar distribution characteristics of overflow facies igneous rocks; And using VSP data and adjacent well comparison method, for the first time, the depth of the formation and overflow facies igneous rock were predicted in real-time in sections on site.

2.2 Fire Rock Drilling Avoidance Technology

Based on accurate prediction data of formation depth and overflow phase igneous rock development intervals, while meeting the requirements of the reservoir, drilling avoidance is carried out by optimizing the directional well trajectory and fine-tuning the target points. The principles are as follows: 1) Directly avoid overflow phase igneous rock development intervals under the allowable trajectory conditions; 2) For overflow facies igneous rocks that cannot be avoided from drilling, select a layer with a smaller thickness to pass through; 3) For volcanic channel facies igneous rocks, due to their extremely poor drillability and high risk of leakage, the principle of drilling around is adopted to resolutely avoid such igneous rocks According to the development of igneous rocks at the bottom of the Lower East Second Member, adjust the trajectory in advance to ensure the drilling thickness of high-quality sandstone reservoirs in the Lower East Third Member and below.

2.3 Precise Control Technology of ECD While Drilling

1) Accurate acquisition of steady-state annular effective liquid column equivalent

$$ECD = f\{A, B, C, D\}$$

Among them, ECD is the equivalent drilling fluid density in the annulus at a certain depth inside the wellbore, g/cm^3;
A is the influencing factor of drilling fluid performance,
B is the influencing factor of drilling cuttings characteristics in the wellbore,
C is the influencing factor of drilling parameters,
D is the influencing factor of wellbore and formation physical properties.

Utilize bottom hole assembly to connect or circulate parameters midway, finely adjust and correct bottom hole assembly pressure loss, confirm drilling fluid rheological properties with the well site at any time, and optimize hydraulic models in a timely manner. The three-point method is used to fit the pressure consumption of power drilling tools. For drilling tools such as screw motors and MWD, there is a non-linear relationship between pressure loss and displacement. For the actual pressure loss changes of each set of tools, a small medium large three-point fitting method is used to draw the pressure loss envelope, and then interpolation is used to solve the pressure loss accuracy of the drilling tool at different displacements. Standardization of analytical methods. By quantitatively analyzing the sensitivity of factors such as rock fragment size, rock fragment density, hydraulic model, and wellbore roughness that affect hydraulic parameters, a standardized recommendation method is proposed for predicting hydraulic parameters in the lower wellbore section. Mud performance can refer to the mud performance of the corresponding wellbore section in the neighboring well Wellview. After modifying the mud performance, hydraulic parameter prediction can be made for the lower wellbore section.

The steady-state model calibration method is shown in the following figure.

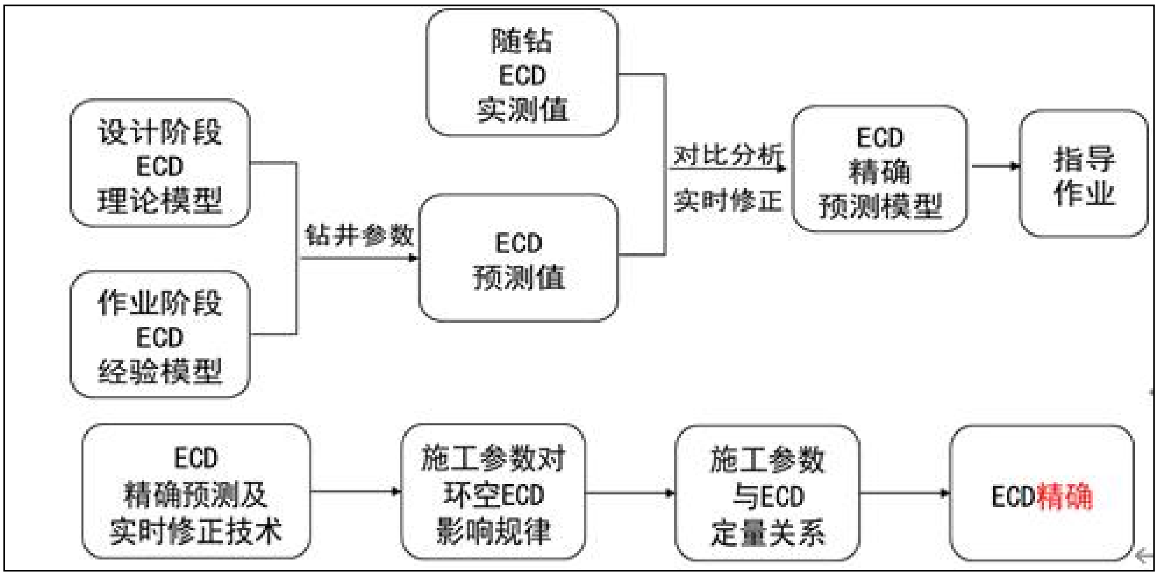

Figure 2: Calibration method for steady-state annular effective liquid column equivalent

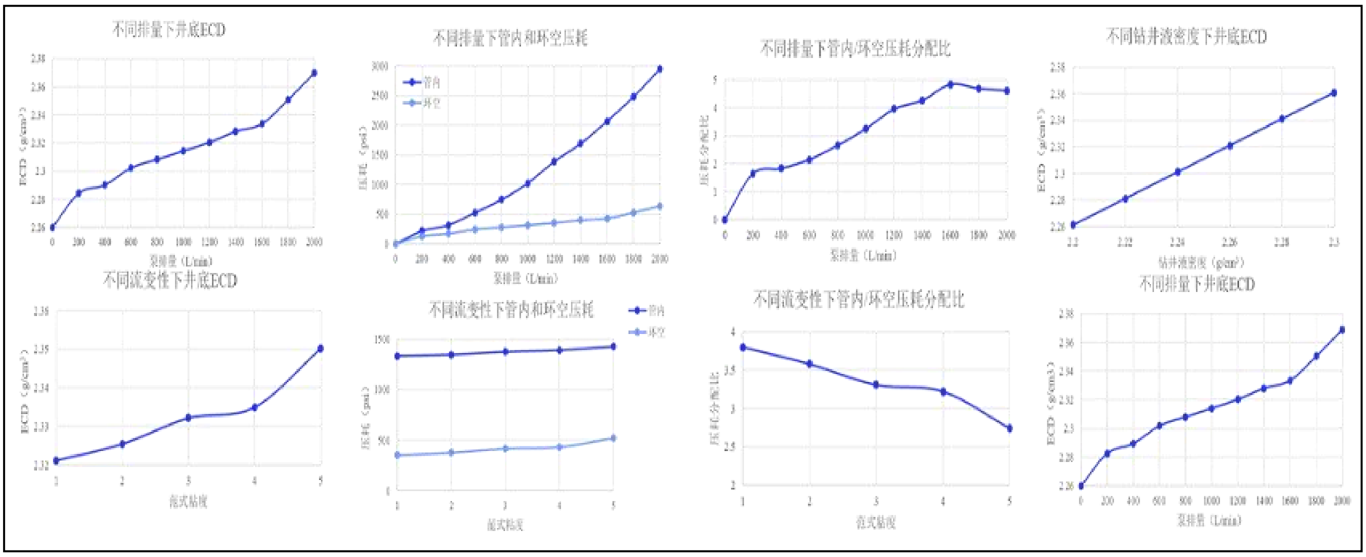

Figure 3: Sensitivity analysis of ECD parameters in a certain well

2) Accurate acquisition of effective liquid column equivalent in non steady state annulus

$$Swab\ or\ Surge = f\{A, B\}$$

Among them, Swab is the equivalent of pumping pressure, and Surge is the equivalent of excitation pressure;
A is the predetermined parameter factor while drilling,
B is the adjustable parameter factor while drilling.

The non steady state model calibration method is shown in the following figure.

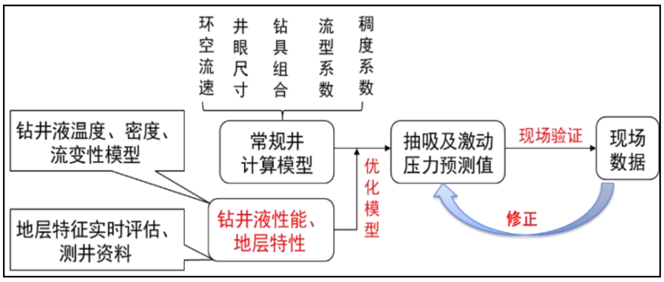

Figure 4: Non steady state annular effective liquid column equivalent correction method

2.4 High Efficiency Plugging Technology While Drilling

The drilling plugging tool mainly consists of an outer cylinder, a fixed sleeve, a pressure cap, a ball seat, a guide pin, a reversing sleeve, a disc spring, a core shaft, a floating piston, and a blocking ring, as shown in Figure 5. Among them, the ball seat includes an upper ball seat, a middle ball seat, and a lower ball seat. The upper and lower ball seats have a "memory function" and can be used repeatedly.

During the drilling process, the plugging tool is connected between the drill rods and inserted while drilling. Generally speaking, its bypass hole is in a closed state. When there is a wellbore leak during the drilling process, immediately stop drilling, throw the switch ball and replace it with a small displacement to seal it in the upper ball seat. Increase the displacement to a certain extent, compress the disc spring, move the core shaft downwards, and the guide pin causes the reversing sleeve to change direction. Continue to increase the displacement, and the switch ball disengages from the ball seat. At this time, the bypass hole is opened (as shown in Figure 5); Then throw the isolation ball, which is seated on the lower ball seat, and pump the sealing material into the wellhead to flow out from the bypass hole, thus achieving the sealing operation; After the well leakage operation is completed, the switch ball is put back into operation and the displacement is increased to a certain extent. Both the switch ball and the isolation ball are detached from the ball seat. Under the restoring force of the disc spring, the core shaft moves upward and the bypass hole is closed.

When a wellbore leak occurs again and needs to be plugged again, the above operation should be repeated. Therefore, one drilling can achieve multiple plugging operations, and the number of times it is opened or closed depends on the capacity of the ball catcher under the tool. At the same time, this tool can effectively protect precision tools such as bottom screw drill, rotary guide, MWD, etc. of the drilling tool assembly, and can flush the opening of the blowout preventer. Up to now, while drilling plugging tools have been widely used in wells with leakage risks in Bohai Oilfield, and have become standard equipment for plugging drilling tools in Bohai Oilfield.

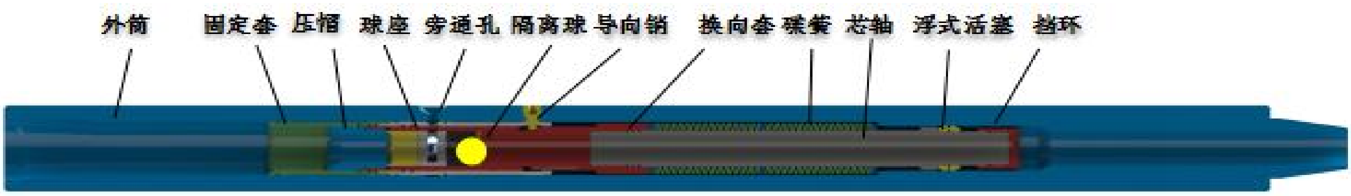

Figure 5: Schematic diagram of the structure of the plugging tool while drilling

3. On Site Application Situation

The fine identification and drilling avoidance technology of igneous rocks has been successfully applied in the drilling of more than 30 wells in a certain oilfield development project in Bozhong. The success rate of predicting the overflow phase igneous rocks has reached 80%, and the prediction error of geological layers and overflow phase igneous rock depth is controlled within 20m. Under the guidance of the prediction results, by optimizing the bit, adjusting the trajectory in advance and optimizing the appropriate drilling parameters, the drilling avoidance or less drilling of igneous rock and the drilling avoidance of igneous rock section with high hardness were realized. The average penetration rate of igneous rock section in an oilfield in Bozhong increased by about 10%, and the drilling avoidance of igneous rock was nearly 1000 meters, effectively improving the drilling efficiency. ECD fine control technology is applied to 63 ports in BZ34-9, including 40 ports on platform A and 23 ports on platform B; The drilling and plugging tool has been successfully applied 35 times in a certain oilfield in Bozhong, providing a new operational approach for the problem of wellbore leakage in igneous rock formations, effectively reducing drilling operation risks and costs. The use effect has been recognized by the party A, and has also brought considerable economic benefits to the company.

4. Economic and Social Benefits and Promotion Prospects

(1) Fine prediction and drilling avoidance techniques for igneous rocks. This technology has been successfully applied in the drilling of more than 30 wells in the Bozhong 34-9 oilfield development project, avoiding drilling in igneous rocks for nearly a kilometer, saving about 18 days of construction time, and saving nearly 20 million yuan in costs. This technology provides a feasible exploration model for fine characterization of igneous rocks and drilling avoidance techniques for the development of China National Offshore Oil Corporation and other igneous rock underlying oil fields at home and abroad. (2) Precise control technology of ECD while drilling. The successful application of 63 wells in the BZ34-9 oilfield development project in Bozhong has directly created a direct economic benefit of 15.12 million yuan for the company. (3) Efficient plugging technology while drilling. This technology has been successfully applied 35 times in the development well project of BZ34-9 oilfield in Bohai. Currently, it has created a direct economic benefit of 11.26 million yuan for the company and provided a new approach for treating well leakage in Bohai oilfield; Meanwhile, the tool has applied for one national invention and published one article.

The Bozhong 34-9 oilfield is the first domestically developed igneous rock oilfield on the sea, and its successful development will drive the development of more than 10 igneous rock development areas in the Bohai Sea; Therefore, the four key technologies formed by this project (fine prediction technology for igneous rocks, drilling avoidance technology for igneous rocks, precise control technology for ECD while drilling, and efficient plugging technology while drilling) will create considerable economic benefits for the company, achieving a shift from the previous "single personnel mode" to a "personnel + process + tool mode".

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