Application of a new method of reservoir interface prediction in geological steering of horizontal Wells

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Abstract. New method in this paper, we study the reservoir interface prediction in the application of horizontal well geological guidance function, the article in the process of study, theoretical analysis of the horizontal well geosteering and reservoir prediction interface, new methods and combining the theory and practice, studies the reservoir prediction interface new method in the application of horizontal well geosteering.

Key words: Reservoir interface; New prediction methods; Horizontal well; geosteering.

1. Introduction

Geological steering of horizontal Wells is of great significance to the exploitation of oilfield resources. In the traditional geological steering research of horizontal Wells, the prediction method of reservoir interface is not accurate enough, and the calculation of formation dip Angle is not accurate, which leads to the deviation in the "landing" stage of horizontal Wells, and affects the subsequent oilfield exploitation. Therefore, based on technical data and practical cases, this paper proposes a new reservoir interface prediction method, which can improve the calculation accuracy of formation dip Angle, and then realize accurate reservoir calculation, laying a good foundation for the subsequent horizontal well "landing" stage.

2. Geosteering analysis of horizontal Wells

Horizontal Wells refer to oil Wells with horizontal distribution of boreholes in the reservoir. Under normal circumstances, Wells with large parallel hole extension distance and well deviation of about 85° are regarded as horizontal Wells. The biggest characteristic of horizontal well is that the empirical trajectory of horizontal well is in parallel with the distribution of the whole reservoir. In order to ensure the efficient production of oil reservoir, the geological data of oil reservoir area should be known in real time and the trajectory of the well should be adjusted. The work of obtaining geological data, adjusting boreholes, and surveying experience is also known as geosteering.

Through the theoretical analysis, it can be found that the geological steering of horizontal Wells is the key to the exploitation of horizontal Wells. Whether the geological steering of horizontal Wells is reasonable or not and the efficiency of horizontal Wells directly determines the oilfield exploitation efficiency of horizontal Wells.

3. A new method for reservoir interface prediction

Reservoir interface prediction method is an important work in horizontal well steering, the core of which is the acquisition and calculation of formation dip Angle. In the process of horizontal well work, reservoir can be predicted by seismic data. However, in general, the vertical resolution of seismic data is affected by certain factors, and there is a certain gap between it and the actual value of reservoir. In horizontal well exploitation, the distribution of horizontal well borehole and the whole reservoir is almost one, so the error of reservoir prediction will affect the later exploitation work. In addition, after the horizontal well "lands", the deviation Angle of the whole horizontal well is about 85°, even if the reservoir prediction error of 1m, it will also cause great rigidity to the horizontal well, resulting in the problem of reservoir drilling rate decline. Judging from the practical application effect of the current reservoir interface prediction method, although the reservoir interface prediction method has a certain effect. However, the calculation error of dip Angle in the whole method is large, which will directly affect the whole reservoir prediction. Therefore, this paper analyzes the calculation and optimization of formation dip Angle and proposes a new method for reservoir interface prediction [1].

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3.1 Multiple methods are applied to obtain dip Angle

The dip Angle is the key factor affecting the prediction of the whole reservoir interface. Therefore, in the whole process of reservoir interface prediction and analysis, accurate acquisition of formation dip Angle is required. At present, the methods to obtain formation dip Angle mainly include imaging logging calculation of formation dip Angle, offset well logging calculation and analysis method, and formation thickness variation calculation method. The three dip calculation methods have different application ranges, so in the actual application process, it is necessary to apply different logging techniques according to the known situation of reservoir interface, so as to ensure reasonable logging application and directly improve the application effect of technology. The following is an analysis of the three dip calculation methods:

1.1.1 The dip Angle is calculated from the variation of formation thickness. The formation thickness is the main factor affecting the dip Angle, and the change of the thickness will inevitably change the dip Angle. Therefore, it is necessary to clarify various construction techniques in the whole process of analysis of formation thickness change to ensure more reasonable measurement application and improve the comprehensive application effect of thickness measurement. The stratum may have different states such as horizontal and dip in dip measurement. Therefore, the dip Angle of the whole formation is different. In the dip calculation model, the horizontal well traverses the formation including the upper and lower vertices. In the calculation process, the upper vertex is named as the top layer entry point, and the lower vertex is the bottom boundary layer. As shown in Figure 1, the position of each point can be considered as a plane, where the relationship between dip Angle and overall formation thickness becomes more obvious. In Figure 1, the dip Angle of the stratum is A, the thickness of the stratum is H, the distance between the upper entry point and the exit point is H2, and the bottom thickness, the horizontal distance between the two points and the included Angle have constructed a triangle. Therefore, in the calculation of formation dip Angle, the inverse trigonometric function can be used to calculate:

a=arctan（H2 ／S2 ）

In the formula, the vertical distance of H2 formation.

In the publicity, S2 represents the horizontal distance between the entry point and the exit point.

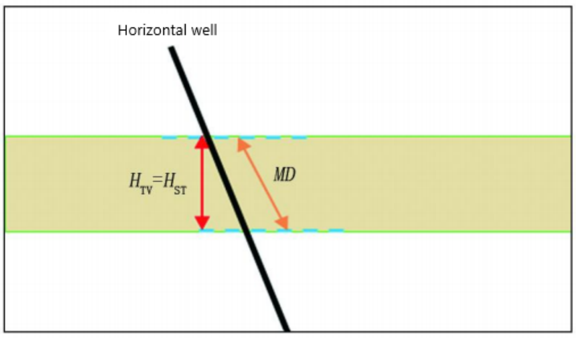

Fig. 1 Calculation of dip Angle in horizontal formation

Note: in the figure, Htv is the apparent thickness of formation, Hst is the true thickness of formation, and MD is the parallel track footage (straight-line distance between two points).

However, in practice, it can be found that the thickness of the whole reservoir may not be completely horizontal, but also may appear inclined state. Under the condition of inclined stratum, there will be a certain gap between the visual thickness of stratum plane and the actual thickness of stratum. As shown in Figure 2, there is a certain gap between the visual thickness of Htv and the real thickness Hst after the occurrence of stratum inclination, resulting in different inclination conditions. At this time, the calculation of stratum inclination Angle will also change, and a= Arctan (H2 / S2) is still used for calculation. However, in the formula, H2 represents the formation thickness - the distance from the entry point to the exit point.

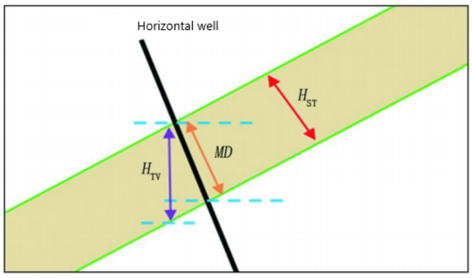

Fig. 2 Calculation of dip Angle under dip condition

Using stratum thickness to calculate, its application is simple, simple and direct, and can effectively control the error. However, if the stratum is thin, it is difficult to determine the apparent thickness and the specific thickness of the stratum, and the accuracy of the determination will be greatly reduced, which directly affects the determination effect.

1.1.2 Imaging logging calculates formation dip. Imaging logging is one of the widely used techniques in geosteering. When it is used in the calculation of formation dip Angle, the calculation principle is relatively simple. It is mainly used for logging with the azimuth of ground well. By picking up the distance between the two measurement points and wellbore dimensions, the dip Angle can be measured accurately and effectively using geometric formulas. For example, in a density imaging log, there will be an Angle between the wellbore diameter and the density imaging detection range. See Figure 3. In the figure, L represents the interval between Wells and A represents the diameter of induction area at the lower end of density imaging, and the two form A boundary, where Angle B represents the included Angle between horizontal well and formation, and the inverse trigonal function can be constructed between the three lines, whose specific calculation formula is β = Arctan [(L + 2R)/A]. At this time, at the well inclination Angle O, the formation inclination A is β+ θ -90 °. In the formula, R represents the primary radius of density imaging. Density imaging is used to predict and analyze reservoir interface, and the measurement accuracy is good. However, considering the high cost of imaging logging, imaging detection technology is seldom used in geosteering.

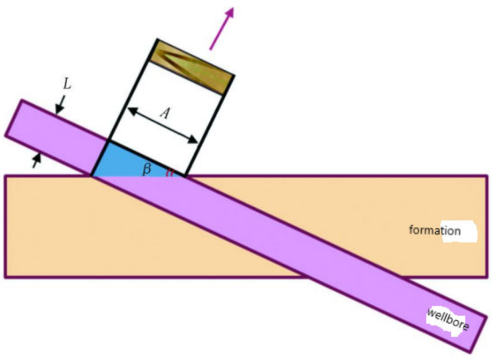

Fig. 3 Angle between density imaging logging and formation

1.1.3 Use offset Wells to calculate dip angles. The offset well calculation method is also one of the common calculation methods, which is mainly applied to the data related to the marker layer of the disabled offset well. For example, offset well zoning, thickness stability, lithologic characteristics, etc., after obtaining relevant information, the formation dip Angle can be calculated based on altitude and horizontal distance. In the actual calculation process, it is necessary to understand the main trend of the formation along the well, which mainly includes downdip mode along the well track and updip mode along the well track. In different modes, the formation dip Angle is different. FIG. 4 and FIG. 5 show different dips in different modes. The dip Angle of the formation is mainly affected by the horizontal distance between offset Wells and the vertical height difference. Therefore, the following formula is constructed: $\alpha = \arctan (H1 / S2)$. In the whole formula, the distance between the horizontal well S1 traversing the zone and the offset well, and H1 represents the vertical elevation difference between the two Wells.

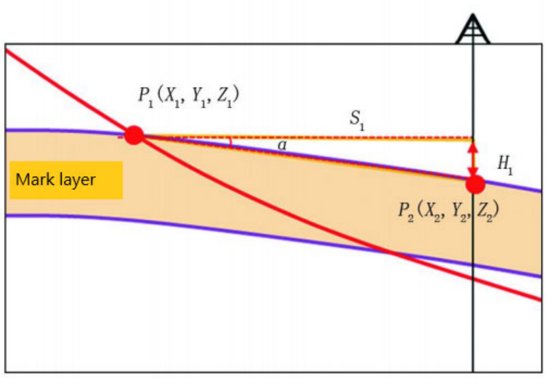

Fig. 4. Formation dip pattern along well trajectory

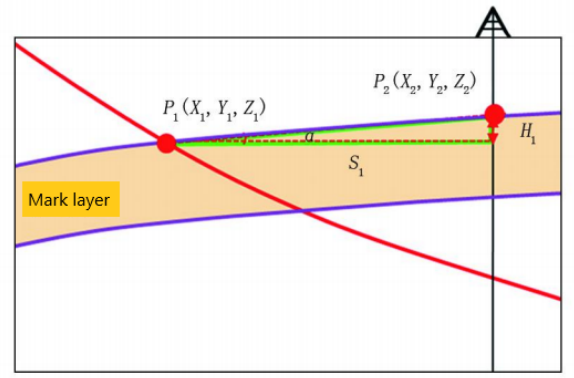

Fig. 5 Updip pattern of the formation along the well trajectory

Offset logging is a comprehensive computing technique that can be used to quickly estimate dip angles for different conditions. In the process of application of this calculation technology, it is necessary to measure the distance between Wells, but in fact, the error of the distance between Wells is relatively large, which will seriously affect the logging problems and is not conducive to the development of various logging work.

3.2 Solution of boundary distance equation

After the calculation of dip Angle, the boundary distance equation needs to be built, and the boundary distance equation can be used to continue the prediction of reservoir interface. Similarly, boundary formation prediction also includes down-hole dip and up-hole dip modes. In the whole process of boundary distance calculation, the formation is mainly calculated comprehensively along the down-hole dip mode of well trajectory to ensure the good implementation of calculation and improve the application effect of well calculation. The calculation of boundary distance is also very important. The position point of horizontal well bit, the entry point and exit point of marker layer and the thickness between target layers are the main factors affecting the boundary distance. Therefore, a variety of data application values can be mixed to construct trigonometric functions, and the boundary distance can be reverse-computed by using trigonometric functions. The actual analysis of boundary distance calculation is as follows, and the distance study of boundary distance formula is as follows:

1.2.1 In the downward dip state of the ground layer, $L1 = (Z3 - Z2) - S3 \tan\alpha$

In the formula, Z3 represents the bit position point.

In the formula, S3 represents the horizontal distance between the bit and the exit point.

1.2.2 When the ground layer is tilted upwards, $L1 = (Z3 - Z2) + S3 \tan\alpha$

In the formula, Z3 represents the bit position point.

In the formula, S3 represents the horizontal distance between the bit and the exit point. See Figure 6/7.

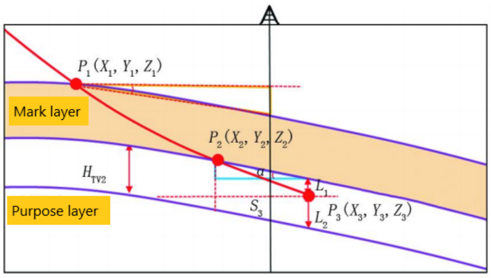

Fig. 6 Formation dip pattern along well trajectory

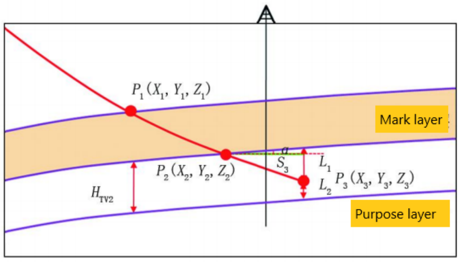

Fig. 7 Formation upwelling pattern

3.3 Application of integrated geosteering process

Integrated geosteering processes are also used in the new forecasting method. In the implementation of geological steering of horizontal Wells, it is difficult to adjust the work in the later stage if there is initial deviation. So, in the prediction of the new method is proposed in the integration process of geosteering, main is to establish a geosteering pretreatment scheme, after the deviation problem, can according to the integration of geosteering process to finish the work, the following is a new method of prediction of geosteering technology process, geosteering technology process analysis:
1.3.1 Complete data collection. Data collection is the premise of geological traverse. In the whole process of geological data collection, geological data, reservoir data, geophysical data and marker layer data in horizontal well area should be collected.
1.3.2 Geological design analysis shall be completed, and geological design analysis shall be required after data collection to ensure the good development of various geological designs and improve the subsequent geological guidance management. In the whole stage of geological design, it is required to analyze the original structural formation dip Angle, calculate the formation dip Angle by adjacent Wells, calculate the formation dip Angle by itself and pick up the formation dip Angle by imaging, mainly through the analysis and calculation of the formation dip Angle to determine the basic situation of the reservoir [2].
1.3.3 Optimizing the well trajectory and analyzing the reservoir boundary distance according to formation dip Angle, formation correlation and formation thickness plays a very important role in the application of formation dip Angle and can improve the application effect of formation.
1.3.4 Finally, analyze and understand the actual situation of the geological reservoir to confirm whether the reservoir meets relevant standards and ensure the good development of subsequent oil Wells [3].

4. The main role of the new method of reservoir interface prediction in geological steering of horizontal Wells

The new prediction method of horizontal well reservoir interface is introduced above, including integrated geosteering process, formation dip Angle calculation combination and boundary distance calculation and analysis. In the specific research, in order to verify the application of the new prediction method proposed in this paper, the logging of an oilfield as an example, summed up the specific application of 13 oil Wells in the oilfield geological guidance.
3.1 The field consists of 13 horizontal Wells with a 100% hit rate and 90% penetration rate and a drilling cycle time of 24 hours.
3.2 In the process of drilling, in order to verify the new method of reservoir interface prediction, a new type of reservoir interface prediction software is constructed by combining information technology. The prediction software is used for comprehensive drilling prediction to ensure the good implementation of various prediction work [4].
3.3 In this well, a new method of reservoir interface prediction was used to understand dip and other conditions. Through calculation and analysis, it is found that ZJ09, ZJ08 and ZJ10 are 22.3m, 5.8m and 6.5m respectively from landing. The prediction showed that the entire interval was drilled in 12.25 minutes. The dip angles were 89°, 89.5° and 0° in different cases throughout the drilling operation. The logging was a fine fluorescent sandstone, and the drilling was successfully completed. The plane position of the drilling target was less than 20m away from the design position, which was shown by relevant technical statistics to ensure the completion of the whole calculation and application, and played a good role in the application of logging calculation [5].

5. Conclusion

This paper summarizes the application of the new method of reservoir interface prediction in horizontal well geosteering based on theory and practice. It is hoped that the research of this paper can be helpful to the application of horizontal well formation drilling method and promote the good implementation of formation drilling.

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