Technical analysis of improving sand body penetration rate in horizontal well

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Abstract: Because the measurement data of horizontal well lags behind the actual position of bit, accurate geological guidance is the key to improve the rate of sand body drilling. Taking the thin and poor reservoir sand body at the edge of a development zone as an example, this paper introduces the horizontal well geosteering technology in detail, five techniques have been developed, including marker layer selection, seismic software aided guidance, target identification, lwd data analysis and rate of penetration control. The technique has achieved high sand body penetration rate in 7 horizontal wells. This technology provides a favorable guarantee for the effective development of thin and poor reservoirs in horizontal wells.

1. Introduction
Due to the shortage of measurement while drilling (lwd) technology and instrument, the data measured while drilling in horizontal well lags behind the actual position of bit, among which the gamma log lags 8-9m, the deep and shallow resistivity log lags 10-11m, and the deviation and azimuth log lags 16-17m. The real-time deviation data can only be used to predict and analyze the actual position of the bit, and the position of the sand bed can be judged in advance according to the logging, logging and drilling information, and the suitable deviation angle of the bit can be predicted in advance according to the structural trend, to direct the drilling of horizontal wells.

2. Selection of Marker Layer.
Limited by the dogleg degree in drilling technology, the angle adjustment of each drill pipe in the deflecting section of horizontal well is controlled within 70. In order to enter the destination layer at an optimal angle, a marker layer needs to be established above the destination layer. The Marker Layer is a rock layer or a group of rock layers with obvious characteristics that can be used as a marker of stratigraphic correlation. The marked strata should be characterized by obvious fossil and lithological features, stable horizon, wide distribution and easy identification. It is necessary to set 1-2 marker zones at the top of the target zone and make clear the electrical characteristics, drilling characteristics or logging characteristics of the marker zones because the logging data and logging data of the horizontal well lag behind the actual position of the bit, the vertical depth of the marked formation should be in the range of 10 ~ 20m, which is favorable for adjusting drilling trajectory and determining the structural change of the target formation relatively accurately[1].

T 7 layer(Fig. 1) in the east of Area A is about 13 meters away from the target layer. Because the water body is relatively shallow when it is deposited and the rock layer contains calcium, the induced value on LWD while drilling is obviously increased and the gamma value is not obviously decreased. In drilling, it is shown that the penetration rate is decreased and the pump may be blocked, and in mud logging, it is shown that acid drips from cuttings are bubbling[2].
3. Seismic interpretation software for auxiliary guidance.
Seismic interpretation software can bypass the barriers of time-depth conversion, track horizontal wells in time domain by taking advantage of the more accurate advantage of earthquakes in time domain, and make full use of high resolution seismic plane, modified while drilling model and horizontal well trajectory, guiding horizontal well tracking to improve drilling success rate.

Seismic interpretation software plays an important role in horizontal well tracking, especially in the following two cases: one is the undrilled area which lacks well data, the other is the thin and poor target zone, and it can also be used in horizontal well auxiliary design.

4. The response characteristics of logging while drilling (lwd) and mud logging are analyzed to guide horizontal well.
Because the detection depth of resistivity logging tool is greater than that of natural gamma-ray logging tool, it is possible that the resistivity curve is thicker than the natural gamma-ray curve at the top and bottom of the reservoir in the high-angle section of the horizontal well. When comparing the logging-while-drilling (lwd) curves in the horizontal section with those in the adjacent vertical wells, special attention should be paid to whether the detection depth of the logging tool in the horizontal well exceeds the reservoir interface, when the detection depth exceeds the distance between the well axis and the reservoir interface, the resistivity inversion often occurs due to the influence of the surrounding rock.

5. Identification of entry target in horizontal well.

5.1. The formation has been drilled and compared with the reference log.
Before the horizontal well is drilled to the designed target point, it is necessary to stratify the drilled formation on the logging-while-drilling (lwd) curve converted to vertical depth, and with the reference well for stratigraphic correlation (especially the Marker Layer) and logging curve shape and numerical correlation, so as to determine the current bit location, and whether to reach the design target, at the same time, the response of WOB and bit rate is observed, and the synthetic judgment is made according to the seismic interpretation profile and the spatial distribution of sedimentary micro-facies relative oil-bearing sand body.

5.2. Comparison of the thickness of the upper sand and mudstone in the inclined section before drilling to the target point with the thickness of the corresponding section in the reference well.
In the formation with a certain dip angle, the vertical depth of sand and mudstone layers shown by the
logging-while-drilling curves in the deviated section of the horizontal well is different from that shown by the logging curves in the vertical well, the magnitude of this difference depends on the dip angle of the formation and the dip angle of the horizontal well.

5.3. Logging-while-drilling (lwd) curve characteristics of horizontal well when drilling to target point
When the horizontal well is drilled to the target point, the penetration rate increases, the natural gamma logging value decreases and the resistivity logging value increases obviously. Before the logging-while-drilling (lwd) tool reaches the target point, the resistivity increases with the depth of exploration, which indicates that the oil layer will be drilled into the target point.

5.4. Correction of designed horizontal well trajectory
When the depth error between the designed target and the actual target is too large, the structural model must be revised again, and the coordinates and depth of the control points of the 2nd, 3rd, 4th,.., and with the drilling directional personnel timely communication, re-calculation, design drilling trajectory[3].

6. Control the penetration rate and keep the track running smoothly[5]
When the track of horizontal well penetrates into the target zone, the penetration rate increases obviously, and it is necessary to control the penetration rate properly. The penetration rate is too fast, which not only easily causes engineering accidents such as choking and sticking, but also affects the accuracy of logging data, the most important thing is that the drill pipe can easily drill out very thin target layer and can not keep running smoothly, which causes unnecessary loss (drilling rate), and also affects the later casing running and perforation effect. Because of different lithology during drilling, self-increasing or self-descending phenomena often occur in borehole deviation, especially in the case of thin target formation, and it is very difficult to control trajectory[4].

7. Application effects.
During the drilling process of thin and poor formation at the edge of Area A, the average sand body penetration rate of 7 horizontal wells reached 91.7% by using the technology of tracking adjustment while drilling. (table 1), at a high level.

| Well name | Well type | Design situation | Actual drilling |
|-----------|-----------|------------------|-----------------|
|           |           | Destination layer | Length of horizontal segment | Horizontal segment length (m) | Formation Length (m) | Penetration rate% |
| well1     | oil well  | PI11a            | 412.04          | 363.08               | 363.08               | 100               |
| Well2     | oil well  | PI11a            | 449.88          | 406.6                | 406.6                | 100               |
| Well3     | oil well  | PI11a            | 472.37          | 473.0                | 305.2                | 64.5              |
| Well4     | water well| PI11a            | 423.88          | 399.32               | 399.32               | 100               |
| Well5     | water well| PI11a            | 428.23          | 393.8                | 352.8                | 89.6              |
| Well6     | oil well  | PI11a            | 399.84          | 389.6                | 389.6                | 100.0             |
| Well7     | water well| PI11a            | 355.65          | 346.0                | 323.8                | 93.6              |
| Total     |           |                  | 2771.4          | 2540.4               | 91.7                |

8. Conclusion.
1. Choosing reasonable marker bed can provide enough space for horizontal well drilling adjustment.
2. Integrated application of seismic, logging, logging, drilling and other information, combined with geological understanding, can effectively adjust while drilling horizontal well.
3. The research results can be extended to the low permeability reservoirs in the outer front facies, and it has guiding significance for the horizontal wells in different reservoir conditions and
development stages.

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