CSCanada
Advances in Petroleum Exploration and Development
Vol. 6, No. 1, 2013, pp. 27-31
DOI:10.3968/j.aped.1925543820130601.1639

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
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Reason Analysis on the Variation of Reservoir Thickness Interpretation of Different Logging Series in Sanan Development Zone

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Received 12 August 2013; accepted 14 September 2013

Abstract
In the oilfield development process, for the geological problems, the new logging apparatus has been developed and the logging series are constantly changing. Comparing the thickness interpretation of different logging series, this paper has analyzed the variation reasons of the thickness and the effect factors of thickness interpretation such as well logging series, mud properties, formation pressure, formation fluid properties and well spacing density. This provides a more reliable parameter for calculating oil geological reserves accurately and improving reservoir evaluation.

Key words: Logging series; Reservoir; Thickness division; Effective thickness

Liu, J. Y., Yang, Y., Feng, W., & Gan, S. L. (2013). Reason Analysis on the Variation of Reservoir Thickness Interpretation of Different Logging Series in Sanan Development Zone. *Advances in Petroleum Exploration and Development*, *6*(1), 27-31. Available from: http://www.cscanada.net/index.php/aped/article/view/j.aped.1925543820130601.1639
DOI: http://dx.doi.org/10.3968/j.aped.1925543820130601.1639

INTRODUCTION
Either in the exploration stage or in the development stage, the reservoir thickness interpretation and division has always been one of the main tasks for oil geologists and is an extremely important basic work. For the geological problems in the process of oilfield development, however, with the deepening of oilfield development work, the new logging apparatus has been developed and put into application in oilfield production. The logging series applied to the Daqing Oilfield production have varied from 1960s lateral logging, 1970s simplified lateral logging, the well logging for water flooded layer in the 1980s to the current new logging series[1,2]. In view of constant change of logging series, we must both in theory and practice ascertain the variation rules and influent factors of logging interpretation and thickness division to improve the new drilling thickness interpretation coincidence rate, which is of great theoretical significance and application value for further oil exploitation, the development effect improvement of oilfield water injection and scheme formulation of tertiary oil recovery[3-5].

1. THE COMPARISON OF ELECTRIC LOGGING THICKNESS INTERPRETED BY DIFFERENT LOGGING SERIES
So far, the logging series of Daqing Oilfield have basically gone through five stages, as follows: lateral logging and simplified lateral logging (abbreviated old logging series) as well as the well logging for water flooded layer, 8900 logging series and high resolution logging in open hole (abbreviated new logging series).

To observe all kinds of sandstone thickness variations, the East Nan 2 Block of Sanan Development Zone of Daqing Oilfield was used as the research object. Based on reservoir group as a unit, sandstone thickness of Class Ⅰ, Class Ⅱ and effective thickness of sandstone divided by different logging series, were respectively counted. In the East Nan 2 Block, there are 97 wells, including basic well pattern applying old logging series, primary and secondary infill well patterns applying the well logging for water flooded layer, tertiary infill well pattern applying new logging series.

1.1 The Variation of Sandstone Thickness of ClassⅡ Interpreted by Different Logging Series

In the East Nan 2 Block, the reservoir sandstone thickness of ClassⅡ interpreted by logging series for water flooded layer is higher than that of the old logging series. The reservoir sandstone thickness of ClassⅡ interpreted by the new logging series is lower than that of the old logging series except GⅣ (Table 1).

Table 1
The Variation of Untabulated Thickness of the East Nan 2 Block Interpreted by Different Logging Series

Reservoir group	The old logging series (m) (basic well pattern)	Logging series for water flooded layer (m) (primary and secondary infill wells)	New logging series (m) (tertiary infill wells)
SⅠ	7	9.7	6.3
SⅡ	30.8	42.3	28.4
SⅢ	13.2	24.0	15.3
PⅠ	28.5	41.6	22
PⅡ	14.6	26.9	15.9
GⅠ	16.2	24.3	18.7
GⅡ	21.8	22.6	21
GⅢ		30.0	25.2
GⅣ		5.1	8.2

1.2 The Variation of Sandstone Thickness of ClassⅠ Interpreted by Different Logging Series

In the East Nan 2 Block, the reservoir sandstone thickness of ClassⅠ interpreted by logging series for water flooded layer is higher than that of the old logging series. The reservoir sandstone thickness of ClassⅠ interpreted by the new logging series is lower than that of the old logging series except GⅣ (Table 2).

Table 2
The Variation of Sandstone Thickness of the East Nan 2 Block Interpreted by Different Logging Series

Reservoir group	The old logging series (m) (basic well pattern)	Water flooded layer logging series (m) (primary and secondary infill wells)	New logging series (m) (tertiary infill wells)
SⅠ	4.4	7.8	4.8
SⅡ	20.4	37.0	23.9
SⅢ	7.0	20.1	11.7
PⅠ	24.5	40.2	23.7
PⅡ	7.8	23.5	11.3
GⅠ	6.1	19.4	9
GⅡ	9.2	16.5	10.3
GⅢ		22.8	10.6
GⅣ		3.0	3.5

1.3 The Variation of Sandstone Effective Thickness Interpreted by Different Logging Series

In the East Nan 2 Block, the reservoir sandstone effective thickness interpreted by water flooded layer logging series is higher than that of the old logging series. The reservoir sandstone effective thickness interpreted by the new logging series is lower than that of the old logging series except GⅣ (Table 2).

Table 3
The Variation of Sandstone Effective Thickness of the East Nan 2 Block Interpreted by Different Logging Series

Reservoir group	The old logging series (m) (basic well pattern)	Water flooded layer logging series (m) (primary and secondary infill wells)	New logging series (m) (tertiary infill wells)
SⅠ	2.7	3.9	2.1
SⅡ	13.3	21.6	14.2
SⅢ	5.1	10.3	5.9
PⅠ	18.6	30.6	17.2
PⅡ	4.4	11.8	5.9
GⅠ	3.7	8.3	5.7
GⅡ	6.8	8.2	6.6
GⅢ		9.9	5.8
GⅣ		0.7	1.6

2. REASON ANALYSIS ON THE VARIATION OF THICKNESS DIVIDED BY DIFFERENT LOGGING SERIES

2.1 The Influence of Logging Curve Anomaly

The logging series of basic well pattern mainly include lateral logging and simplified lateral logging series, whose curves have poor quality and can't reflect many thin-poor layers, especially untabulated reservoir . With the deepening of oilfield development, well logging technology has been constantly improved and enhanced. Compared with lateral logging series, the well logging for water flooded layer used during the period of primary and secondary infill well pattern is greatly improved and has a more sensitive reflection on thin-poor layers and untabulated reservoir, so the thickness of reservoir interpretation is generally larger.

It seems that new logging series put into production in recent years is not enough to adapt to thin-poor layers and can't reflect untabulated reservoir of Class Ⅱ poorly developed in the cores, which is main reason why untabulated reservoir thickness interpreted by new logging series reduce. Specific features:

(1) 0.25 m apparent resistivity of standard layer Sa-0_2 has decreased in amplitude and its baseline also offsets

(2) Apparent resistivity curves of microelectrode has gradually decreased in base value and amplitude year by year, and even there is no amplitude in some permeable layers, which have great effect on thin-poor layers identification.

(3) SP curves in some permeable layer have no amplitude or amplitude positive anomaly, and its baseline also offsets.

(4) Compared with the well logging for water flooded layer, SP and 2.5 m apparent resistivity curves have poorer resolution and can not reflect many thin-poor layers.

(5) Compared with compensated interval transit time curves of old logging series, high-resolution interval transit time of new logging series has a more sensitive to thin-poor layers and deducts more ratios of high resistivity layer in thickness interpretation. Therefore, the effective thickness of the thick layer becomes less.

2.2 Influence of Mud Property on the Reservoir Thickness Interpretation

Drilling mud properties such as mud density, resistivity changes will directly affect the quality of well drilling and logging.

2.2.1 Influence of Mud Density Changes on the Reservoir Thickness Interpretation

The contrast logging tests of different mud density were done in Nan 8-4-736 well. The mud density measured four times was adjusted to 1.55, 1.65, 1.75 and 1.85. By the results of four measurements, combined with analysis and comparison of different mud density, the influence of mud density on each curve is as follows:

From the amplitude value comparison of four SP curves (Spontaneous Potential), mud with different density has great effect on amplitude values of SP curves (Table 4). As the mud density increases, the amplitude value of SP curves significantly becomes large. Such situation is reflected obviously in the thin layers. SP curve with density of 1.55 g/cm^3 has the minimum amplitude value. The amplitude difference of SP curve measured value between density of 1.55 g/cm^3 and 1.65 g/cm^3 is much larger than that of 1.65 g/cm^3 and 1.75 g/cm^3. The amplitude of SP curve between density of 1.75 g/cm^3 and 1.85 g/cm^3 has little difference.

Table 4
Difference Values of SP Curve with Different Mud Density

	Layers	Difference ratio between 1.65 and 1.55 %	Difference ratio between 1.75 and 1.65 %	Difference ratio between 1.85 and 1.75 %
Average value of thick layers	13	59	-15	0
Average value of thin layers	24	78	-9	3
Sums	37	69	-12	2

According to the results of electric logging thickness interpreted by different mud density logging in Nan 8-4-736 well, it can be seen: as the mud density increases, the corresponding untabulated thickness of electric logging interpretation also increases. Difference ratio of untabulated thickness from 1.65 g/cm^3 to 1.75 g/cm^3 is about 10% and from 1.75 g/cm^3 to 1.85 g/cm^3 is about 6%. The effective thickness of 1.75 g/cm^3 and 1.85 g/cm^3 has no difference, but is more than 1.65 g/cm^3 with an increase of approximately 13% (Table 5).

Table 5
Results of Electric Logging Thickness Interpreted by Different Mud Density Logging in Nan 8-4-736 Well

Mud density	1.65 g/cm^3	1.75 g/cm^3	1.85 g/cm^3
Untabulated thickness	75.4	83.5	89
Sandstone thickness	39.4	38.9	40.6
Effective thickness	20.7	23.6	23.4

From the results of four measurements, there are some differences between the microelectrode amplitude value and amplitude difference. If we deduct the difference of microelectrode curve caused by repeated measurement and hole diameter changes through the pigging, mud density will have some, but not very great influence on the microelectrode curve. However, mud density has great effect on the microelectrode amplitude difference. Reflected from microelectrode curve, the amplitude difference of micro-normal and micro-inverse logging curves becomes small, even none.

Seen from the curves of four measurements, the values of MSFL (Microspherical Focused Log), high-resolution deep and shallow lateral curves and sonic log curve have no significant differences , so different mud density has not too much effect on the above curves.

2.2.2 Influence of Mud Resistivity Changes on the Thickness Interpretation

The larger mud resistivity is, the higher microelectrode value is and the more obviously it changes. The mud resistivity size has little effect on amplitude difference of the microelectrode.

The contrast logging tests of different mud resistivity were done in Nan 8-D4-736 well. Measured mud resistivity was respectively 3.6, 3.9, and 4.4.

According to the results of electric logging thickness interpreted by different mud resistivity in Nan 8-D4-736 well, it can be seen: there is basically no change in the effective thickness and the untabulated thickness between mud resistivity 3.9 Ω·m and 4.41 Ω·m has little difference, but is more than 3.6 Ω·m with approximately 20% (Table 6).

Table 6
Results of Electric Logging Thickness Interpreted by Different Mud Resistivity in Nan 8-D4-736 Well

Mud resistivity	3.6 Ω·m	3.9 Ω·m	4.4 Ω·m
Untabulated thickness	77.6	95.6	96.4
Sandstone thickness	43	47.3	52.4
Effective thickness	25.1	25.4	25.2

2.3 Influence of Formation Pressure Changes on the Reservoir Thickness Interpretation

After years of water injection development in Daqing Oilfield, multi-pressure systems were formed in reservoir formation. On the longitudinal direction, high pressure, undervoltage and normal pressure layers coexist. SP curve of normal pressure layers is negative anomaly and abnormal amplitude decreases with the increase of the clay content. Under the condition of near-balanced drilling, SP curve in high pressure layers has little negative anomaly, tending to no negative anomaly and even positive anomaly and can present mudstone characteristics. Statistics of Gaotaizi formation pressure changes of Nan 2 Block over the years shows that: in recent years, formation pressure in this block is high and the average reservoir pressure has been close to or above average original formation pressure. Because of high formation pressure and low mud density while drilling, SP curve is straight and microelectrode amplitude and amplitude difference is small, which reflect the poor reservoir properties and affect the thickness interpretation.

2.4 Influence of Formation Fluid Properties on Logging Thickness Interpretation

At present, the reservoir formation water is non-original formation water whose salinity significantly decreased obviously. The current formation water salinity is lower than the original formation water salinity which is 7000-8000 mg/L, causing negative anomaly of SP decreased. Interpretation of the current electrical standards also needs to use the bottom half of SP curve to control and divide effective thickness as well as the bottom third of SP curve to control and divide untabulated thickness, thus the reduction of formation water salinity can affect the results of electric logging interpretation thickness.

CONCLUSIONS

(1) The reasons why the thickness interpreted by new logging series according to the old standard becomes less is the changes of drilling conditions and logging curves as well as the impact of the original electrical standards and the oil occurrence description in core.

(2) Mud density has a great influence on the amplitude difference of SP curve and has a certain influence on micro-electrode curve, but has little effect on other curves.

(3) Mud resistivity has a great influence on the amplitude values of micro-electrode and MSFL curves and has a certain influence on amplitude difference of SP curve, but has little effect on other curves.

(4) Formation pressure and formation fluid properties also have some impact on the logging interpretation thickness.

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