



Comprehensive Evaluation on the Developing Effect of Horizontal Well Pattern in Tight Oil Reservoir by Using Well Logging Data

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Abstract: The complexity of tight oil sandstone in terms of formation conditions, microscopic pore throat conditions, seepage mechanism, etc. makes the most prominent contradiction in the oilfield development process is the main oil reservoir has high water injection pressure, water injection is difficult, and it is difficult to establish an effective driving between oil and water wells. The horizontal well drive oil volume is large and the starting pressure is low, which is beneficial to reduce the water injection pressure of the main oil layers. At the beginning of this century, the horizontal well water injection technology has gradually matured, making the horizontal well pattern net injection development model of tight oil and gas reservoirs widely used in China. The development of tight sandstone horizontal wells is inseparable from the fine characterization of reservoir heterogeneity (Ling et al., 2008; Zhang et al., 2015).

The discontinuous distribution of poorly permeable interlayers in tight sandstones makes reservoir heterogeneity more serious, meanwhile because of the division of the interlayer, the whole sand body is divided into several parts that are independent of each other, which changes the remaining oil enrichment mode of the traditional rhythm sand body, and the lateral distribution of the barrier also has a large impact on the distribution of remaining oil (Feng et al., 2013). The horizontal well runs through a sand body, and the sand body has a certain heterogeneity, and the inner interlayer will have a certain sealing effect on the injected water. Figure 1 shows the relative positional relationship between the perforation section of the horizontal well and the interlayer and the vertical well in the sand body running through the horizontal well. Case A means that the horizontal well perforation section happens to cut through the interlayer, and Case B means that there is a sandwich between the horizontal well perforation section and the production well; Case C means that there is no interlayer between the horizontal well and the production well. The injected water enters the formation under a certain pressure, according to the seepage theory, the situation A will be difficult to inject water, and in case B, the injected water will be normal, but the production well will not be effective. Case C is an ideal injection-production relationship.

The average sandstone thickness of the sandstone Y17 layer in the horizontal well is about 6.6m in the target area. The lithology

is mainly fine sandstone, siltstone, silty shale and argillaceous sandstone, and the shalystone is well developed, so the reservoir is a typical heterogeneous tight sandstone body, where, the permeability difference of the formation reached 20.1, the coefficient of variation of permeability reached 1.05, the penetration coefficient of penetration reached 2.63, and the homogenization coefficient was only 0.38. A large number of developed shalystone layers make the reservoir porosity and permeability very low, so it acts as an ultra-low permeability reservoir. The rock formation includes three interlayers, the first is the shaly interlayer whose lithology is mudstone and silty mudstone, and whose oiliness is oil patch, oil trace or oil-free. The pore and permeability is usually several tens of times or even hundreds of times lower than the sand stone layers. The second is the calcium interlayer, which formed by the carbonate cemented dense layer under certain conditions. The calcium interlayers are generally located at the bottom or top of the river sand body, and a small amount is located inside the river sand body, almost with no permeability.

The third is the property interlayer, whose lithology is argillaceous siltstone with oil immersion, oil patch or oil-free. Its permeability is about 10 times lower than reservoir (Zhang et al., 2008). The logging curve can be used to effectively identify the interlayer (Ma et al., 2008). Fig. 2 shows a typical curve of three types of interlayers drilled in a well with coring information in the target area as an example. Natural gamma (GR), High resolution acoustic time difference (AC), Medium induction (ILM), Microresistivity (MSFL or RMN) can be used to find interlayers. It can be calculated from the figure that the total thickness of the sand body is 25m (2032–2057m), and the total thickness of the nine interlayers is 12.2m, the ratio is about

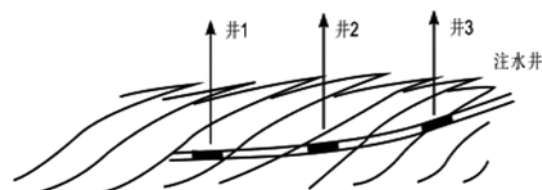


Fig. 1. Schematic diagram of the relative position relationship between the perforation section of the horizontal well and the interlayer and the vertical wells

(In the figure, well 1, well 2, well 3 are production well; horizontal well is injecting well, and black section in horizontal well is perforating section)

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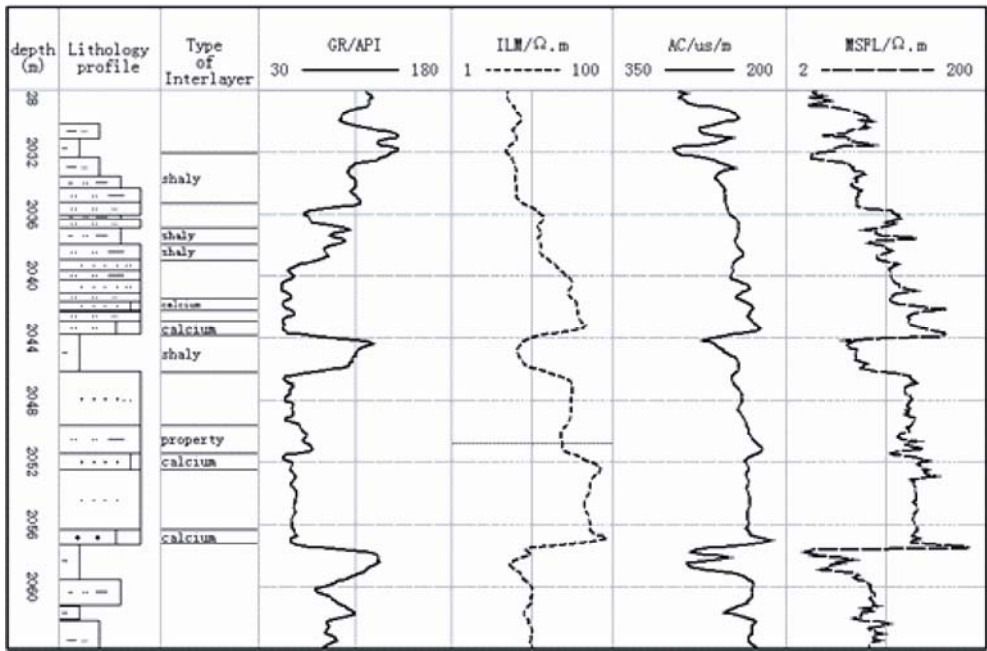


Fig. 2. Characteristics of typical interlayer logging curves

Table 1 The number and ratio of interlayers' thickness of shu3#-ping27 and its production wells

Well	Ratio of interlayers' thickness	Well	Ratio of interlayers' thickness	perforation section	Ratio of interlayers' thickness
Y3#-J278	0.78	Y3#-F28	0.45	A	0.42
Y3#-JS26	0.54	Y3#-J271	0.35	B	0.11
Y3#-JS267	0.57	Y3#-27	0.85	C	0.20
Y3#-J267	0.51	Y3#-J261	0.51	D	0.15

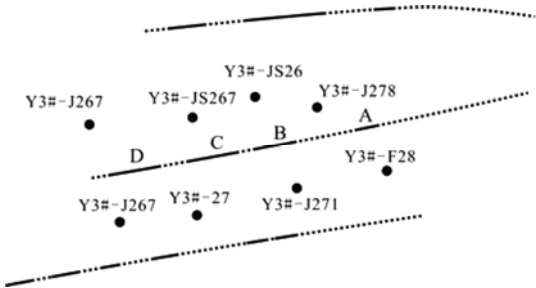


Fig. 3. Schematic diagram of horizontal well tree 3#-ping27 and its surrounding vertical wells

0.431.

- Let's define the variables as following.
- dgr—the value of the interlayer GR value relative to the pure sandstone and pure mudstone of the interval;
 - dilm—The ratio of the interlayer ilm value to the ILM value of the layer of pure sandstone;
 - dac—The ratio of the interlayer AC value to the layered pure sandstone AC value;
 - dmr—The ratio of the interlayer MSFL value to the interval pure sandstone MSFL value;
- Through the comparison of the intersection plots, the criterion is obtained:
- Calcium interlayer: $AC \leq 228 \text{ us/m}$ and $dgr < 0.125$ or $dmr > 2$ ($dilm > 1.13$)
 - Shaly interlayer: $dgr > 0.5$ and $AC > 240 \text{ us/m}$
 - Property interlayer: $dmr < 0.85$ ($dilm < 0.55$) and $0.5 > dgr > 0.22$

and $AC > 228$

According to the above criteria (1)-(3), we can identify the interlayers both horizontal well perforation sections and the surrounding production wells, where horizontal wells use logging while drilling, judging by dgr, AC, dac, and dilm values. We can ignore the error caused by the slope of the rock because the horizontal well penetrated the middle area of the sand body. And the interlayers of production wells can be identified by using dgr, AC, dac, and dmr values. The total thickness of interlayers in each well can be calculated, and its ratios to the thickness of the whole sand body are shown in Table 1. Fig. 3 is a schematic diagram of the distribution of horizontal well Y 3#-ping27 and its surrounding vertical wells.

Fig. 4 shows the production of the initial production of 8 production wells for 20 months. It can be seen that Y3#-J271 has the best consequent; followed by Y3#-J267, Y36-J261, Y356-JS267, Y356-JS26. There are two wells that are basically unaffected, namely Y3#-J278, Y3#-27. Combined with Table 1, it can be easily analyzed that the ratio of interlayers' thickness of section A reaches 0.52, and the ratio of interlayer thickness of Y3#-J278 reaches 0.78, indicating that the channel between the two is poor, similar to Fig.1 where case A and B exist simultaneously. And Y36-F28 is better, similar to case A in Fig. 1. To Y3#-27 well, the interlayer thickness ratio is very high, reaching 0.85, and the section C is also higher, reaching 0.20, similar to Case B in Fig.1. For the most effective Y3#-J271, the interlayer thickness ratio is very low, about 0.35, and the interlayer thickness ratio of the B section is only 0.11.

Therefore, the interlayer has a great influence on the effective

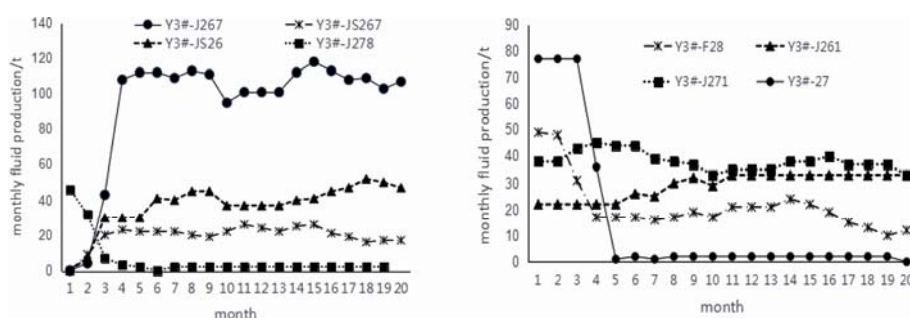


Fig. 4. The production of the initial production of 8 production wells for 20 months

exploitation of horizontal wells. In this paper, the horizontal LWD and vertical well logging data are used to establish the identification method of the interlayers in the sand body, and the three kinds of interlayers controlling modes of the driving water are established. By using the actual production data through a set of horizontal well networks we can obtain some conclusions. The effect of the three controlling modes indicates that the water injection affection of the horizontal well can be well evaluated by using the fine thickness and distribution of the interlayers. However, as can be seen from Figure 3, the horizontal well pattern involves three horizontal wells. If the perforation sections of the three wells can be correlated with the log evaluation, better results will be obtained. Unfortunately, the other two horizontal wells did not implement the measurement of the LWD projects.

Key words: tight oil reservoir, horizontal combined well pattern, interlayer, controlling effect, well logging data

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