Application of Well-Logging Curves preprocessing in Reservoir Prediction

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Abstract. In most cases, in the well-logging process, due to the interference of environment, geology and other factors, the original logging data is often mixed with various uncertain information, and the geological indicator is not obvious. For these reasons, the well-logging curve used for reservoir prediction are often reprocessed to eliminate the influence of non-geological factors on it, so as to guarantee the rationality and accuracy of the prediction results. This paper takes Gaotaizi reservoir in Q130 block located in Songliao basin as an example, aiming to strengthen the geological matching between well-logging curve and sand body through optimized processing such as well-logging curve standardization, normalization and curve reconstruction, so as to improve the accuracy of thin interbed reservoir prediction and provide a strong technical guarantee for the rolling development of this bl.

1. Introduction
Q145 block belongs to Qian'an oil field of Songliao basin. Its main productive oil sands are of thin thickness and scattered distribution, belonging to typical thin interbedded sand and shale reservoirs. Because of the strong reservoir heterogeneity, AC in high-speed mudstone and sandstone distribution area overlap is serious, cannot fully reflect the changing rule of sandstone and mudstone, so the conventional wave impedance inversion technique, using AC for inversion, in the application effect too bad to accurately describe the spatial distribution of sand body, seriously affected the main block rolling extension of reservoir development. According to the preliminary analysis, an important reason for the poor reservoir prediction effect is that the development Wells in the study area have large drilling time span, long spacing, diverse drilling teams and inconsistent logging interpretation standards. Therefore, the optimization and perfection of basic data will help improve the accuracy of reservoir prediction in this area.

2. Log processing
In the log data collected in this study, the curves that are sensitive to oil reactions mainly include AC, GR and RLLD, and the curve processing mainly includes standardization of AC and RLLD curves and normalization of GR curves.
2.1. Curve normalization

Curve between the purpose of standardization is to eliminate well and well due to factors such as instruments, drilling fluid, the construction time curve of the system error, making them in all the curve of the well accord with the actual geological characteristics to achieve the best overall characteristics, to participate in the basis of logging curve reconstruction and inversion processing data to provide a unified benchmark (Figure 1).

![Figure 1. AC standardization before and after comparison.](image)

2.2. Curve normalization

For sand-shale formations, the gamma value measured in the well can reflect the relative content of mud in different small layers. However, for multiple Wells, the natural gamma value measured at the same level sometimes varies greatly, which makes it difficult to establish a uniform reservoir parameter interpretation model. Therefore, the natural gamma curve should be normalized.

The normalization of the curve makes the dimensions and amplitude of each well curve consistent. On the basis of curve standardization, normalization processing is required (except acoustic wave curve), that is, the curve value range of all Wells is limited to [0, 1] to ensure the consistency of their contribution to reconstruction (Figure 2). In this study, the relative value method of the correlation curve was adopted, and the SP and GR curves were processed respectively by the normalization calculation formula, so that each well had a uniform scale on the plane, which provided a unified standard for the next step of curve reconstruction.

![Figure 2. Effect comparison before and after curve normalization.](image)
3. Curve reconstruction

The acoustic time difference curve can be directly involved in inversion when it can well reflect the regional lithologic change and the real situation of the stratum. In this case, curve reconstruction becomes a technical means to help solve the above problems.

The reconstruction of reservoir characteristic curve is based on rock physics, and the optimal selection and reconstruction of one or several logging curves can well distinguish lithology between multiple Wells, which can not only reflect the reservoir characteristics, but also improve the well seismic matching relationship, thus improving the quality of synthetic records.

According to the statistics, the natural potential and gamma curve in the study area have the best response to sandy and mudstone, which can be well divided into sandstone and mudstone (figure 2). These two curves can be reconstructed into a new curve with the dimension of acoustic curve, which can then be used to carry out wave impedance inversion and improve the prediction of longitudinal resolution.

3.1. Curve reconstruction method based on SP

SP curves can reflect the quality of the reservoir after pretreatment and standardization. The reservoir characteristic curve reconstructed by SP curve is mainly used in reservoir prediction for the purpose of evaluating reservoir thickness and quality. The time difference of acoustic wave is inversely proportional to SP curve. The model of reconstructing reservoir characteristic curve by using natural potential is as follows:

\[ \Delta t' = a - b SP' \]  

In the formula, \( \Delta t' \) is the reconstructed AC, which has the same dimension and order of magnitude with acoustic time difference. \( SP' \) is the response of natural gamma logging after pretreatment and standardization. \( a \& b \) Is the regional experience coefficient.

3.2. Curve reconstruction method based on GR

The GR curve reflects lithology or reservoir permeability through formation radioactivity. After pretreatment and standardization, it can reflect reservoir quality under certain conditions. The reservoir characteristic curve reconstructed by GR curve is mainly used in reservoir prediction for the purpose of evaluating reservoir thickness. The time difference of acoustic wave is inversely proportional to GR curve. The model of reconstructing reservoir characteristic curve by using GR curve is:

\[ \Delta t' = c - d GR' \]  

In the formula, \( \Delta t' \) is the reconstructed AC, which has the same dimension and order of magnitude with acoustic time difference. \( GR' \) is the response of natural gamma logging after pretreatment and standardization. \( c \& d \) Is the regional experience coefficient.

3.3. Processing

① As the contribution of different curves to reservoir characteristics is different, different weighting coefficients are set for different curves \( K_j \), \((0 < K_j < 1, j \) stands for different curves).

② The corresponding curves are calculated by weighting coefficient \( K \): \( \frac{K_j}{(C_{ur1'} - C_{ur1})} \)

③ The weighted value of one of the curves is used as the weighting coefficient, and the acoustic value is weighted, \( 1 - K_j(C_{ur1'} - C_{ur1}) \) \( C_{ur1} \) is Acoustic.

④ The weighted acoustic value was taken as the base value, and the third step was repeated, and the weighted value of the second curve was used to reconstruct the acoustic matrix.

⑤ Repeat steps ③ and repeat steps ④ so that all the curves involved in the reconstruction are weighted to sound wave.

At this point, the curve weighting process ends. In the reconstruction process, since the curve involved in reconstruction has numerical fluctuation and plays a regulating role on the acoustic curve, the AC of the mudstone section increases in a large direction, while the AC of the sandstone section
decreases in a small direction. Therefore, for the target layer, the time-depth relationship is basically consistent, with only a small difference in local position.

3.4. Result of the Curve reconstruction

Compared with the original acoustic wave curve, the shape of the amplitude spectrum of the reconstructed acoustic wave curve is basically unchanged, and the amplitude of low, medium and high frequency components within the frequency range are correspondingly improved, so that the reservoir features are completely highlighted (Figure 3).

![Figure 3](before the reconstruction) (after the reconstruction)

**Figure 3.** The response of reconstructed log to sandstone and mudstone.

The reconstructed pseudo-sound wave curve does not separate the original sound wave curve in frequency, so the original frequency component is retained. At the same time, the frequency of different curves is added into the pseudo-acoustic curve through data fusion technology. Therefore, the pseudo-acoustic curve not only retains the original frequency component but also adds more abundant frequency information, which plays a good role in highlighting the reservoir characteristics, suppressing non-reservoir information and enhancing the difference between sandstone and mudstone (Figure 4).

![Figure 4](logging_curve_before_after)

**Figure 4.** Logging curve reconstruction before and after comparison.
4. Reservoir prediction effect

After the log data are processed by the above methods, the sparse pulse wave impedance inversion is conducted again, and it can be seen in the inversion profile that: ① On the whole, the inversion effect is good and the resolution is high. ② The horizontal distribution feature of the reservoir is obvious, the change of thin thickness and the sharp out feature are clearly visible, especially the vertical and horizontal distribution feature of the main sand body is clear, and the inter-well sand body relationship is clear, which can realize the horizontal tracking of thicker single sand body or a group of thinner single sand body. ③ In the relatively dense eastern well pattern region of the study area, the inversion profile can clearly reflect the changes of each single sand body between Wells, so the connectivity of each single sand body between Wells can be analyzed, providing a basis for the stratified system mining or the adjustment of injection-production relationship in the development process.

According to the research results, combined with the actual production situation, in 6 Wells deployed in the study area, through has prediction before drilling drilling results and actual drilling data comparison, we think that both on the structural height and quantitative characterization, sand body has made significant achievement, better depict the vertical structure characteristics of the sand body in the study area and the lateral distribution of sand body (Figure 5).

![Figure 5. Reservoir sand body inversion prediction effect.](image)

The results of planar inversion prediction show that the sand body in the eastern block is mainly distributed in the western and eastern locations, where the thickness of the sand body in the areas of dry well 153-14, dry well 153-13 and dry well 153-47 is the largest and shows a strip distribution, with thickness range of 7.5-9 meters. The maximum thickness of sand body in the western block is mainly concentrated in the middle part, which shows a decreasing trend to the west. Within 2Km2 around the dry 11-2 well area, the thickness of sand body is more than 8 meters, and the maximum thickness is up to 9.5 meters. The sand body is less developed near well dry 15-1755.
5. Conclusion

Under certain conditions, the logging data used for reservoir prediction must be processed twice to ensure the rationality and accuracy of the results. In Qian’an area, the curves suitable for curve reconstruction mainly include DT, SP, and GR, which can objectively reflect the quality of the reservoir. The post-treatment curve has good effect in wave impedance inversion profile, with high vertical resolution, which can more clearly describe the spread pattern of sand bodies in the reservoir. In the area of dense well pattern, it can clearly reflect the variation of each single sand body between wells, so as to guide water injection development.

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