Applied Mathematics and Nonlinear Sciences

<https://www.sciendo.com>

Research on the normalisation method of logging curves: taking XJ Oilfield as an example

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Submission Info

Communicated by Juan Luis García Guirao

Received November 27th 2020

Accepted January 31st 2021

Available online April 8th 2021

Abstract

During the long-term exploration and development of the oilfield, it is difficult to ensure that all well logging curves are measured by the same type of instrument, the same calibration standard and the same operation mode. For different wells, there must be systematic errors caused by these reasons. Therefore, in addition to environmental correction, it is necessary to standardise logging curves. In XJ oilfield, three logging companies use wireline logging and logging while drilling to complete logging, in multi-well logging interpretation. To eliminate the systematic errors of different measuring tools, to maximise the geological information reflected by logging curves, and to make logging interpretation follow the same standard as much as possible, it is necessary to standardise the logging curve in the whole oilfield. This article takes the standardisation of well 106 in XJ oilfield as an example, the standardisation of different methods was compared, the method of combining frequency histogram and mean variance is better.

Keywords: logging curve, normalisation, XJ oilfield, frequency histogram, mean variance robot

1 Introduction

The practice of long-term oilfield development has proved that even if the logging curves are corrected by environmental impact correction and depth editing, there are still measurement system errors that do not reflect formation changes among different logging companies, different measuring instruments and different wells. In the multi-well logging interpretation, to eliminate the systematic error of different measuring tools, to make the logging curve reflect the geological information to the maximum extent and to make the logging interpretation

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follow the same standard as much as possible, it is necessary to standardise the logging curve in the whole oilfield.

The essence of standardisation is to select the same group of formations with the same geophysical characteristics and the same logging response characteristics as the standard layers in an oil field or a region. When the oilfield standard distribution mode of various logging data is established by key wells or standard layers, the correlation analysis technology can be used to comprehensively analyse the logging data of each well and to correct the systematic measurement error of the instrument so as to eliminate the influence of non-geological factors on the well logging and make the logging response more in line with the geological reality.

In XJ oilfield, three companies, Schlumberger, Halliburton and Baker Hughes, completed logging work in two ways: wireline logging and logging while drilling. Different companies use different calibration methods for instruments and different measurement methods. In the multi-well logging interpretation, to eliminate the systematic errors of different measuring tools, make the logging curves reflect the geological information to the maximum extent, and make the logging interpretation follow the same standard as much as possible, it is necessary to standardise [1] the logging curves in the whole oilfield. The standardisation of logging data is a meticulous and important basic work, and its quality will have an important impact on the future multi-well logging interpretation and the comprehensive geological research results of the oil field. If the correction is not reasonable, it will affect the geological interpretation and geological application of the logging data.

There are many methods of standardisation, and the most common methods used are frequency histogram method, trend surface analysis method and mean variance method. Each method has its unique advantages and limitations. In the specific application process, using a certain method alone cannot achieve the desired effect and requires multiple methods to be used in conjunction.

2 Selection of standard wells and standard layers

2.1 Selection of standard wells

To ensure the rationality and accuracy of the standardised results, the selection of standard wells needs to meet certain conditions. In the process of actual work, the following conditions were mainly considered:

- (1) It is located in the high structural position of the whole block, which can completely reflect the information of the block.
- (2) The logging time is relatively new, and the curve quality is reliable.
- (3) Most wells are measured by the same logging company, and the standard is relatively uniform.
- (4) The well curve quality is good, and the distinction between sandstone section and mudstone section is obvious.
- (5) There are many layers drilled.

According to the above-mentioned standards, well A29 was selected as the standard well in this standardisation process, and the standard well was measured by Schlumberger company in 2010. Ninety percent of the wells in the study area belong to the Schlumberger measurement while drilling method, and there are many layers encountered, and A29 is a core well with abundant coring data, which can facilitate the interpretation. From the well location map of the entire block (Figure 1), it can be seen that well A29 is located at the structural height, which can reflect the geological characteristics of the region.

From the analysis of the logging curve in Figure 2, the performance of well A29 in sandstone and mudstone is obviously different. The neutron and density of the sandstone intersect. The curve quality is good, and it is suitable for standard well.

2.2 Selection of standard layers

In the process of standardisation, the selection of standard layers is particularly important. Generally, 1–2 strata with stable sedimentation, moderate thickness and small change, wide distribution range, obvious lithol-

Fig. 1 Well location map of the study area.

Fig. 2 Logging curve of well 29.

Fig. 3 Profile of well connection of marker bed in the study area.

Fig. 4 GR distribution histogram of standard well in upper mudstone layer of H000.

ogy and logging response characteristics and easy to identify are selected as standard layers, which are near the main production layer as far as possible. Through the comparative analysis of well curves in the whole area, combined with the regional geology and the distribution of oil-bearing well sections, the H000 overlying mudstone layer is selected as the main marker layer, and the H0_a overlying large mudstone lower stable mudstone section is selected as the auxiliary marker layer. The selected mudstone marker bed has large and stable sedimentary thickness, obvious logging response characteristics and is located near the oil-bearing section, which is a good logging data normalisation marker bed in this area.

The GR distribution histogram of the standard well in the upper mudstone layer of h000 is shown in Figure 3, and the GR distribution of the standard well in the standard layer is stable around 142.

After determining the standard well and the standard layer, all wells in this area need to be standardised. Because they are affected by the formation conditions, not all wells can meet the standard layer [2]. Therefore, for wells that do not reach this layer, we need to select an auxiliary layer to correct. The method of correction is the same as that of a standard layer.

3 Methods of standardized treatment

There are many standardisation methods. In addition to the trend surface method, standard wells and standard layers must be selected. The selection of standard wells and standard layers must follow certain guidelines.

According to the characteristics of the logging data of XJ oilfield [3], according to the quality characteristics of different types of logging data, the cable logging data and the logging while drilling data are first standardised

separately, and then the standard is unified. The frequency is used in processing. The combination of the histogram method and the mean variance method has completed the overall standardisation task of the oil field and achieved ideal results.

3.1 Principles of standardisation method

3.1.1 Frequency histogram method

The frequency histogram method can intuitively reflect the frequency distribution of the curve between each well and the standard layer of the standard well and facilitate comparison between them. The frequency histogram divides the standard layer of each well into several sections according to the logging value and counts each. Draw the frequency histogram of the logging frequency of the logging value of each well in the standard layer and compare it with the standard well. This method considers that the standard layer is stable, and the peak value and frequency distribution of frequency histogram in the standard layer remain unchanged. Each well is calibrated to a uniform range according to the standard well. The correction amount of each well is determined by histogram [4]. Two points need to be avoided in the application of frequency histogram method: (1) No suitable standard layer can be found in the whole area. (2) The standard layer is thin, and there are a few data points in the standard layer. When drawing the frequency histogram, the data is scattered and there is no obvious rule.

3.1.2 Trend surface analysis

Trend surface analysis [5] is a commonly used method for standardisation. In the oilfield, the geological parameters are not stable in the formation but have certain change rules. These geological parameters combined with the logging response reflecting the formation characteristics show regular changes in spatial distribution, showing a certain natural trend, which can be fitted as a curved surface, called trend surface.

The trend surface divides a concrete or abstract surface of spatial distribution into two parts [6]. The first part changes slowly, and the other part changes quickly. The slow-changing part is the component that reflects the change law of the entire study area, which is called the trend component. The fast-changing part reflects the local change law, which is called the residual component. In the analysis of the trend surface, the most commonly used methods are polynomials and Fourier series. The mathematical surface that we obtain through multivariate analysis technology will only be affected by regional values to eliminate the influence of regional outliers or interference values and complete the standardisation of logging curves.

In the formation, the logging response value that can reflect the characteristics of the formation usually has a certain relationship with its spatial distribution and conforms to the corresponding law. The trend surface we make is to simulate the natural trend value of the formation [7], and the principle of fitting is to make the trend value that is closer to the true value of the formation. The following formulas are usually used to express the trend value and the remaining value:

$$z(x, y) = \hat{z}(x, y) + e \quad (1)$$

Among them, $\hat{z}(x, y)$ and e in the formula are the trend value and the residual value, respectively. Substituting the known data, using regression analysis to find the regression equation $f(x, y)$, satisfying:

$$Q = \sum_{i=1}^n [z_i - f(x_i, y_i)] \quad (2)$$

Take the minimum value and get the regression surface:

$$\hat{z} = f(x_i, y_i) \quad (3)$$

Therefore, the trend value is $\hat{z} = f(x_i, y_i)$ residual value $z_i - \hat{z}$. The logging value can be corrected according to the trend value and residual value.

3.1.3 Mean variance method

The mean variance method is also called the normal distribution method [8]. After we select the standard wells of the standard wells, we obtain the logging data $a_1, a_2, a_3, \dots, a_n$. After obtaining this set of data, their expectation can be calculated as Ea , and the variance is $S^2(a)$. After we complete the standard layer data of the standard well, we need to calibrate this layer of other wells and take the data of other wells as $b_1, b_2, b_3, \dots, b_n$, this set of data needs to be corrected. The corrected data have a linear relationship with the previous data. Assuming that the corrected data are $c_1, c_2, c_3, \dots, c_n$, this set of data meets the data before correction

$$cn = kb + d \quad (4)$$

After correction, the expectation and variance of CN and an are equal

$$E(a) = E(c), s^2(a) = s^2(c) \quad (5)$$

$$Ea = kEb + ds^2(a) = k^2s^2(b) \quad (6)$$

$$k = [s^2(a)/s^2(b)]^{1/2} \quad (7)$$

$$d = E(a) - [s^2(a)/s^2(b)]^{1/2}Eb \quad (8)$$

The correction equation can be found

$$c = [s^2(a)/s^2(b)]^{1/2}b + Ea - [s^2(a)/s^2(b)]^{1/2}Eb \quad (9)$$

3.2 Application examples of standardisation

3.2.1 Quality inspection of logging data

The quality of the logging curve is a prerequisite to ensure the reliability of logging interpretation results. In the process of logging data processing, the computer takes out the logging data of each sampling point according to the depth point by point for quantitative calculation, so there are very strict requirements on the quality of the logging curve. The pre-processing of logging data in logging project mainly includes [9]: logging quality inspection, logging curve environment correction, curve depth matching, GR curve splicing, data repair of expanding section, resistivity inversion, normalisation processing, and so on. After logging quality inspection, depth matching, GR curve splicing, borehole expansion repair, resistivity inversion and other preprocessing research work, the system error of various curves is reduced, the reliability of curve use is improved, and standardisation can be guaranteed. The accuracy of the results.

3.2.2 Logging data standardisation

In normal applications, using a method for normalisation often fails to achieve the expected results. As shown in Figure 5, the frequency histogram method or the mean variance method alone cannot be consistent with the standard well. Several methods are needed to work together to make the correction accurate. In the process of standardisation of the XJ oilfield, the entire region has stable stratum deposition and no trend surface correction is required. Due to the difference in logging companies and measurement methods, the abnormalities in the logging environment after correction have been combined. The frequency histogram method and the mean variance method are used for correction. Combining the two methods has achieved good results.

Before correction, it is necessary to determine the correction method for each well [10–14]. The curve shape of some wells is similar to that of standard wells, which can be corrected directly by frequency histogram method. For some curves with a large difference in distribution frequency and different shapes of curves, it is necessary to use frequency histogram together with mean variance method. In this project, multiplication factor and addition factor are used to characterise them Correction amount.

Fig. 5 Frequency histogram of GR curve of well a.

Fig. 6 Frequency histogram of GR curve of standard well.

For the XJ oilfield, most wells in the same area have similarity in the shape of the curve, conform to the same law and perform stable in the standard layer. Therefore, most wells can be processed by the frequency histogram method, and a few wells require A curve corrected by the mean-variance method after the mean-variance processing. The shape of the curve can be made to conform to the laws of geology. Figure 7 shows the changes in the shape of the curve before and after normalisation by the mean square error method.

After the correction of the mean variance of the curve, the correction amount of all curves [11] is statistically analysed, as shown in Table 1. If only frequency histogram method is needed to correct, then only the additive factor correction amount is needed. If the mean variance method is used for correction, the addition factor and multiplication factor exist.

After the correction amount is counted, the wells in the XJ block can be standardised. According to the method mentioned above, the contrast map before and after GR before and after standardisation can be obtained.

From the normalised GR curve, it can be seen that the frequency histogram method and the mean variance method can be used in combination to obtain a better standardisation effect than using one method alone, which is suitable for multi-well standardisation research.

3.2.3 Application of standardised curve

In the actual processing process, the gamma, density and neutron curves were all standardised, and the standardised curves were used for logging interpretation, and the shale content and porosity logging interpretation of the whole area were counted. According to the statistics of the whole well section of shale interpretation, the shale content of sandstone section is about 5% (Figure 10), with good consistency; according to the statistics of porosity of sandstone reservoir HB layer, the porosity is between 24 and 29% (Figure 11), and the porosity consistency of the sandstone section is better.

Fig. 7 GR frequency histogram before and after normalisation by mean square error method.

Fig. 8 Distribution of GR curve of standard layer before normalisation.

Fig. 9 GR curve distribution of standard layer after normalization.

Fig. 10 Statistical chart of consistency of shale interpretation in the study area.

Fig. 11 Consistency analysis of porosity interpretation in the study area.

Table 1 Properties of raw materials

Well name	GR				
	System median	Single well median	Offset		Logging company
			Additive factor	Multiplication factor	
A1	142	139.2	2.8	1	Halliburton
A2	142	137	5	1	Halliburton
A3	142	149	-7	1.12	
A4	142	147	-5	1	Schlumberger
A5	142	133	9	1.1	Schlumberger
A6	142	136	6	1	Schlumberger
A7	142	134	8	1.134	Baker Hughes
A8	142	139	3	1	Schlumberger
A9	142	141	1	1	Schlumberger
A10	142	128	14	0.98	Baker Hughes
A11	142	133	9	1	Baker Hughes
A12	142	144	-2	1	Schlumberger

The interpretation result is shown in Figure 12. From the well diagram, there is no obvious lithological change in the formation. The HB layer at the high part still has a pure oil layer of 3 m thick, and the thickest part of the H1B layer has about 10 m oil layer. It is recommended to continue to pay attention. The newly obtained interpretation result is compared with the actual production data, which is more in line with the actual production situation. After the logging curve is standardised, the accuracy of the logging interpretation is improved.

4 Conclusion

- (1) The standardisation of logging curves is the basis of logging interpretation. The standardisation of logging curves can reduce the impact of logging interpretation results due to different logging standards in different periods or by different logging companies and eliminate the above reasons. The system error caused by it improves the accuracy of logging interpretation.
- (2) Reasonable selection of standard wells and standard layers is a prerequisite for standardisation work, which is of great significance to the accuracy of standardisation results.
- (3) There are many kinds of standardisation methods, mainly including frequency histogram method, trend surface analysis method and mean variance method. Through practical application, it is found that single method cannot achieve ideal results, and it is usually necessary to combine several methods with the actual situation of

Fig. 12 Comparison of logging interpretation results after standardization.

the oilfield.

(4) According to the actual situation of the XJ oilfield, this article uses the frequency histogram method and the mean variance method together to achieve good results and lay the foundation for the fine logging interpretation later.

Acknowledgements: This work was supported by Key Project of Science and Technology Research Program of Hubei Provincial Department of Education, grant number D20191302, and Open Fund of State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation (Chengdu University of Technology, PLC20190501).

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