Energy and Environment Research; Vol. 5, No. 2; 2015
ISSN 1927-0569 E-ISSN 1927-0577
Published by Canadian Center of Science and Education

Research on Self-potential Baseline Drift Processing in Wangji Oilfield

Shengqun Dai[1,2], Ke Zhang[1,2], Shangfeng Zhang[1,2], Hong Fang[3] & Bingbing Ma[4]

[1] Geoscience School of Yangtze University, Wuhan Hubei, China

[2] Key Laboratory of Exploration Technologies for Oil and Gas Resources, Ministry of Education, Yangtze University, Wuhan Hubei, China

[3] Shuguang Oil Production Plant, Liaohe Oil Field, Panjin Liaoning, China

[4] Second Oil Production Plant, Henan Oil Field, Nanyang Henan, China

Correspondence: Hong Fang, Shuguang Oil Production Plant, Liaohe Oil Field, Panjin Liaoning, China. postal code: 124010. Tel: 0086-150-4276-2880. E-mail: fhenglish@163.com

Received: July 31, 2015 Accepted: September 11, 2015 Online Published: October10, 2015

doi:10.5539/eer.v5n2p30 URL: http://dx.doi.org/10.5539/eer.v5n2p30

This research is sponsored by National Natural Science Foundation Program of China: High-quality Reservoir Developmental Mechanism under the Background of Volcanic Activities in the case of Baizhong in Hailaer Basin, NO. 41302095.

Abstract

The positive amplitude anomalies and base line drifts of self-potential (SP) curves make it difficult to recognize the amplitude anomalies and impossible to carry on the standardized calibration. In this way, it becomes extremely hard to read the amplitude anomalies of self-potential curves, increasing the difficulty in lithology recognition and stratigraphic correlation. What's more, it is impossible to apply the computer technology to do the batch processing. Aimed at the practical problems, taking advantages of the collected digital logging data, positive self-potential anomaly recognition and transformation models have been established, converting the positive anomalies in the sandstone intervals into negative ones, solving the problem of two types of amplitude anomalies in the same scale range. Self-potential base line drift processing moves the biased base line to the null line step by step, adopting the method of piecewise fitting differential migration. With satisfying results, the conformation, amplitude and jugged degree are accordant with the primary curve, forming the technique of self-potential curve processing, laying foundation for logging translation and geological research.

Keywords: self-potential; positive amplitude anomaly transformation; baseline drift; standardized calibration

1. Introduction

Self-potential (SP) curve is important for distinguishing permeable reservoirs from impermeable ones in sand-mudstone sections. The magnitude of SP amplitude anomaly reflects reservoir permeability. In most cases, the larger the amplitude anomaly is, the better the reservoir permeability is. Although that is not absolutely correct, it meets the requirements of lithology, and permeable and impermeable strata division. Therefore, self-potential curves are widely applied in scientific practices (Wang, 2003; Wang, 2008; Xie, 1992; Liao, 2013).

Due to differences of well logging series and the trend of formation water salinity rising with depth, the application of SP to recognize sandstone and mudstone encounters difficulty: the measured SP values varies so much that it is impossible to show every well's curves clearly in one coordinate; with positive and negative anomaly of SP shown in a certain range, large errors can be produced easily for amplitude anomaly recognition; it is difficult to obtain SP amplitude anomaly values because there are base line drifts in SP curves, and even large drifts for some wells.

So far, it has been recognized that SP base line drifts, and lots of scholars use SP base line drifts to interpret flooded layers, but there are few reports about the method to deal with SP base line drifts. As for the widely-used well logging interpretation module of Discovery, the process of SP baseline is carried on well by well and interval by interval with low efficiency; although the basics of SP positive amplitude anomaly have been demonstrated in detail in well logging essays, most SP amplitude anomaly for targeted interval sandstone are negative, therefore, positive ones are usually ignored and there are no references for processing positive SP amplitude anomaly; owing to SP base line drifts and the existence of positive and negative amplitude anomaly, SP curve calibration cannot be standardized. With all these problems to be solved in processing SP curves, well logging interpretation or geological research cannot be dealt with in batch.

2. Electromotive Force and Its Varying Pattern

As it is well known, negative charges on the surface of mudstone have the ability to adsorb positive ones from the mud, forming a thin set of electric potential on the surface of mudstone, thus making up mudstone base line. This thin set of electric potential depends on the magnitude of formation water salinity. The salinity of shallow formations is low with less cations to be adsorbed and a certain amount of anions left on the surface of mudstone, and the value of electromotive force is negative; with the buried depth and formation water salinity rising, the amount of cations adsorbed by mudstone increases, and the value of electromotive force gradually become positive. The increasing of electromotive force of mudstone results in mudstone base line drifts (Wang, 2003; Tan, 2012).

Electromotive force of sandstone intervals includes diffusion electromagnetic force, diffusion-adsorption electromagnetic force and electro-filtration electromagnetic force, with the latter two forces as minor ones, the directions of which are opposite, offsetting each other; electromotive force of sandstone intervals mainly comes from diffusion electromagnetic force, and there are positive electromotive forces when the formation water salinity is larger than mud filtrate salinity, and negative electromotive forces when smaller.

Drilling mud is mostly dominated by freshwater. And generally formation water salinity increases with the depth. With drilled depth rising, ions of high-salinity formation water will move into the mud, resulting in the following phenomenon: with shallow formation water salinity less than mud filtrate salinity, positive electromotive force is formed in sandstone intervals and SP will produce positive amplitude anomaly; with formation water salinity equal to mud filtrate salinity in the middle formations, no electromotive forces are produced and so is SP amplitude anomaly; with formation water salinity higher than mud filtrate salinity in deep layers, SP will produce negative amplitude anomaly.

3. Processing of SP Curves

3.1 Calculation of Mudstone Baseline

One of the key steps in processing SP curves is to determine the location of mudstone baseline. Mudstone intervals are characterized by high natural gamma and low resistance with most borehole diameters enlarged. According to the characteristics of natural gamma and resistance curves, mudstone baseline can be located with the aid of CAL curves and average values of baseline SP can be worked out; the second key step in the process of SP curves is to determine proper interval length, which should be small enough to decrease the error brought by baseline drift; while there is amplitude anomaly in sandstone SP, it is necessary to increase interval length to make sure that the interval length can include a well section with amplitude anomaly so that the two SP values can be calculated above and below the amplitude anomaly, laying foundation for baseline drift and positive SP amplitude anomaly transformation (Chen, 2012; Xu 2009).

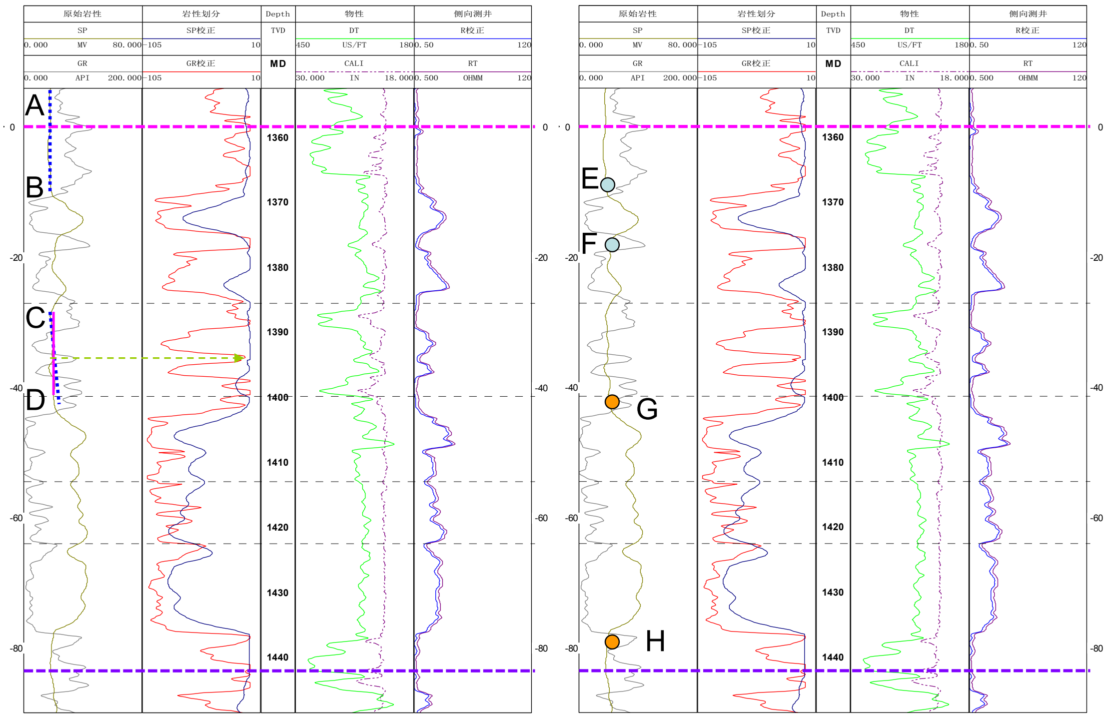

Figure 1. SP baseline drift and positive amplitude anomaly transformation of Well Bi 275

As it is shown in Figure 1 that in AB section natural gamma is high, resistance is low and borehole diameter is enlarged to some degree. What's more, mudstone baseline is typically perpendicular, which can be directly moved to zero line horizontally; in CD section mudstone baseline is oblique with an angle between it and the vertical direction, which will be translated after calculating its average SP values so that mudstone baselines can be moved to null line. From Point E to Point F, there are positive SP amplitude anomalies, but the sandstone interval is so thin that the length of subsections cannot be too long for calculating mudstone baseline in case that the migration effects turn bad due to large-slope baseline. From Point G to Point H, because there are large-scale positive SP amplitude anomalies it is necessary to extend the length of subsections for calculating mudstone baseline to get accurate locations of the upper and lower mudstone baseline related to amplitude anomalies, to carry on baseline drift reasonably and convert positive amplitude anomalies into negative ones.

Above all, the length of subsections for calculating SP mudstone baseline is a variable, determined by lithology and the scale of amplitude anomalies. No satisfying processing results can be obtained with subsections too short or too long.

3.2 Expression for SP Mudstone Baseline

In order to characterize mudstone baseline, the direction from the surface to the deep layer is the direction of x axis and the y axis is SP amplitude anomaly. The average SP value of mudstone baseline is 0.

When mudstone baseline doesn't drift, the expression of mudstone baseline is as following:

$$Y=0 \tag{1}$$

When mudstone baseline drifts, the expression of mudstone baseline is like this:

$$y = a \cdot D + b \tag{2}$$

a and b as coefficients; D as measured depth, m.

Because there are differences among the magnitudes of mudstone baseline drift for different measured sections, and slopes and intercepts vary with measured intervals, it is necessary to adjust the origin of the coordinate system to mudstone baseline varying pattern by segmentation calculating method for mudstone baseline.

3.3 Expression of SP Amplitude Anomaly

The directions of SP amplitude anomalies can be derived from the average SP values of segmentation mudstone baseline. When SP values are obviously larger than mudstone baseline, there are positive amplitude anomalies in

SP curves. On the contrary, there are negative ones.

When there appears SP amplitude anomalies, curves cannot be represented by the mudstone linear expression characterized by clear error increase between matched linear expression and discrete measure values. A quadratic curve is taken to characterize SP curves. The following is the function.

$$y = e * D^2 + f * D + g \tag{3}$$

e, f and g as coefficients; D as measured depth, m.

The second-order differential of the quadratic curve is as following.

$$y=2*e \tag{4}$$

It can be seen that SP amplitude anomalies are positive when e is above 0 and negative when e is below 0.

3.4 Processing of Positive SP Amplitude Anomaly

The direction of amplitude anomaly has no effect on reservoir permeability determination, but in a certain scale range, positive and negative amplitude anomalies of the curves are limited, which will further affect reservoir permeability determination. Therefore, it is necessary to transform positive amplitude anomalies into negative ones.

While converting positive SP amplitude anomalies into negative ones, the upper and lower mudstone baseline locations of positive SP amplitude anomalies must be determined, like Points E and F from Figure 1. After calculating average SP value z of these two points, the positive SP amplitude anomalies are converted into negative by utilizing the following function:

$$y_1 = z - 2 \cdot y \tag{5}$$

Z as mudstone baseline SP, mv; y as measured value of positive SP amplitude anomaly, mv.

3.5 SP Baseline Drift Processing

The purpose of SP baseline drift processing is to locate SP baseline to the zero line from shallow formations to deep ones, with amplitude anomalies varying when baselines drift; the basic thinking of drift processing is piecewise fitting and differential migration; the result of drift processing is that the depth of SP amplitude anomaly is consistent with that of the preprocessing curve and the magnitude of amplitude anomaly is constant. After baseline drifting processing, zigzag curves appear at the endpoints of each migrating intervals, which can be eliminated by curve smoothing processing.

3.6 Standardization of SP Curves

Because accuracy of different instruments varies, there are great differences among SP measured values of each well. It is necessary to carry out standardization processing to form a calibration system. For curves with SP amplitude anomaly and baseline drift processed, it is easy to get the maximum and minimum values of the curves. Then calibrate curves with different accuracies into the standardized range from negative 100 to 0. The equation is as following.

$$SP^* = 100 * \frac{SP(i) - SP_{\min}}{SP_{\max} - SP_{\min}} - 100 \tag{6}$$

SP* as SP after standardization processing, %; SP(i) as SP value of a certain well after baseline drifting, mv; SP_{max} as the maximum SP value of a certain well after baseline drifting, mv; SP_{min} as the minimum SP value of a certain well after baseline drifting, mv.

4. Application Case

For well logging data of Wangji oilfield, SP amplitude anomalies of some wells are positive. For instance, for the interval from 1450 to 1500m of Bi 218 well (Fig.2), natural gamma, caliper, electric resistance, AC and other well logging data indicate sand-mudstone, but the SP curve of sandstone section has positive amplitude anomaly while the SP curve of a deep section has negative anomaly. Thus, convert the positive one to negative. The existence of these two amplitude anomalies affects the normal representation of the curve amplitude anomalies. Sandstone SP amplitude anomalies will be converted into negative ones by utilizing the method introduced in this paper, laying foundation for the subsequent SP curve processing.

It is common for baselines to drift in SP well logging and SP baseline drift seriously in some wells of Wangji oilfield. Taking Wang 47 well as an example, the primary measured values of SP are 0 to 17.83mv, with 13.7mv at the depth of 1085m and 16.8mv at 1235m. About 20% of the baseline drifts in a 150-meter interval. The primary measured values of SP of Wang 50 well are from 0 to 20.18mv, with 8.5mv at 1085 and 16.4mv at 1295m. Nearly 100% of the baseline drifts in a 210-meter interval (Fig.3). After baselines drift, all the baselines are migrated to the zero line from shallow to deep formations.

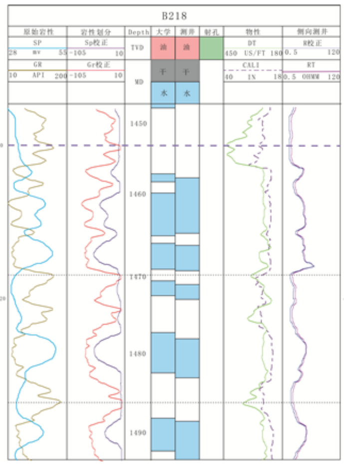

Figure 2. Bi 218 well positive SP amplitude anomaly processing

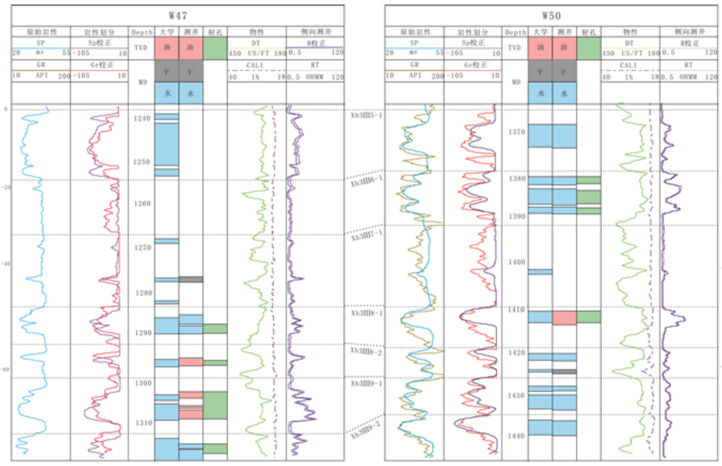

Fig.3 Wang 47-Wang 50 SP baseline drift processing

SP measured values vary a lot, causing SP logging curve not able to display in a coordinate system, for example, the measured SP values are 0-68.17mv for Bi 218 and 0-20.18mv for Wang 47 and Wang 50. After standardization processing, SP curve calibration range is limited to -100 to 0. No matter how great the primary measured values vary, SP curves can be clearly displayed in a coordinate system; when obtaining the magnitude fo SP amplitude anomaly, the magnitude of absolute values will make no difference; sandstone and mudstone recognition can be processed in batch by SP and other curves, which has greatly improved the efficiency.

5. Conclusions and Understanding

(1) SP positive amplitude anomaly recognition and conversion models are established to convert positive anomalies of SP curves of a sandstone section to negative ones, solving the problem of showing two amplitude anomalies in the same calibration range.

(2) The processing of SP baseline drift deals with the difficulty in calibrating SP curves, making it easy to determine the magnitude of SP anomalies, laying foundation for computer technology to withdraw SP amplitude anomaly data in a batch.

(3) It is easy to upload standardized SP curves to well logging interpretation software and geologic mapping software, providing convenience for reservoir recognition and stratigraphic correlation, thus increasing the work efficiency to the utmost.

(4) The research results have been programmed into a software, forming a series technology of SP positive amplitude anomaly and baseline drift processing and standardized calibration processing.

References

Chen, N. N., Yang, S. C., & Huang, J. Y. (2010). Study on Log Interpretation for Water Flooded Layer of the Complex Fault Block Oil Reservoir in the Second Member of Shahejie Formation of Shengtuo Oilfield. *Journal of Earth Sciences and Environment: 32*(4), 355-62. *http://dx.chinadoi.cn/10.3969%2fj.issn.1672-6561.2010.04.005*

Chen, Y. H., Li, X. Y., & Chuai, X. Y. (2012). Log Curve Variation Characteristics and Evaluation of Different Development Phases in Beibei Block of Lamadian Oilfield. *Well Logging Technology, 36*(1), 94-100. *http://dx.chinadoi.cn/10.3969%2fj.issn.1004-1338.2012.01.020*

Hou, L. H. (2001). Influencing Factors of Baseline Shift Amplitude of Spontaneous Potential. *Journal of the University of Petroleum, China, 25*(1), 93-95. http://dx.chinadoi.cn/10.3321%2fj.issn%3a1000-5870.2001.01.023

Huang, D. W., & Liu, J. X. (2006). Analysis of the Offshore Oil or Gas Reservoirs' Spontaneous Potential Characteristic and Its Origins. *Well Logging Technology, 30*(2), 164-167.

http://dx.chinadoi.cn/10.3969%2fj.issn.1004-1338.2006.02.020

Liao, D. L., Yang, M. Q., & Du, J. J. (2013). The Analysis of Influencing Factors and Reconstruct Response Equation of Spontaneous Potential. *Science Technology and Engineering, 3*(15), 4356-4359. http://dx.chinadoi.cn/10.3969%2fj.issn.1671-1815.2013.15.040

Tan, F. Q., Xu, Ch. F., & Gang, L., et al. (2012). On Water-flooded Pattern for Conglomerate Reservoir of the Third Block in Karamay Oilfield. *Well Logging Technology: 36(2):202-206. http://dx.chinadoi.cn/10.3969%2fj.issn.1004-1338.2012.02.019*

Wang, B., Fan, X. M., & Chen, Q. Y., et al. (2008). Modeling Effect of Invaded Zone on SP Log with Finite Difference Method. *Well Logging Technology, 32*(2), 164-168. http://dx.chinadoi.cn/10.3969%2fj.issn.1004-1338.2008.02.016

Wang, J. H., Pan, Zh. P., & Deng, M. Sh., et al. (2003). Relationship between Spontaneous Potential (SP) and Apparent Effective Thickness (AET) of Reservoirs. *Petroleum Exploration and Development, 30*(5), 65-67. http://dx.chinadoi.cn/10.3321%2fj.issn%3a1000-0747.2003.05.019

Wang, W. H., Jiang, Z. X., & Cao, Y. Ch. (2003). Application of Logging Curves in Identifying Northern Ramp Sequence Boundary of Chenjiazhuang Uplift.*Journal of Jianghan Petroleum Institute, 3*(25), 62-64. http://dx.chinadoi.cn/10.3969%2fj.issn.1000-9752.

Xie, J. l. (1992). The Analysis of Relationship between SP and Formation. *Well Logging Technology: 16*(4), 249-258.

Xu, F., Chen, J. Y., Zhang, J. L., et al. (2009). Application of Spontaneous Potential Logging in Recognition of Blind Zone. *Oil Drilling and Production Technology, 31*(1), 53-56. http://dx.chinadoi.cn/10.3969%2fj.issn.1000-7393.2009.z1.011