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Research on reconstruction of transverse wave time difference curve based on neural network

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Abstract. Yilong-Pingchang Region is a transfer block of Daqing Oilfield, and is an important field for increasing reserve and production, and with development of shale in Lianggaoshan, Daanzhai and other strata, it is a key target for unconventional exploration and development. “Seven-character” evaluation and calculation of rock characteristic parameters are essential links in evaluation of shale oil and gas reservoir strata. Data on transverse wave time difference plays a very important significance in evaluation of unconventional reservoir strata, however, since the well-logging cost using array acoustic wave is relatively high, most of the old wells in the research area failed to have transverse wave time difference curve logging, thus causing a series of troubles for “seven-characteristic” evaluation, re-examination of old wells and fracturing transformation. In this paper, K.Mod module of Techlog software was used, to make optimal selection of the well-logging parameters sensitive to transverse wave time difference by extracting existing data on transverse wave time difference, and construct calculation method of transverse wave time difference based on neural network method, which has a relatively good effect upon verification, and plays a very important significance to evaluation of reservoir strata in the research area.

Keywords. Yilong-Pingchang, array acoustic wave, neural network, transverse wave time difference, curve reconstruction.

1. Introduction

Yilong-Pingchang block is a transfer block of Daqing Oilfield, and with Lianggaoshan Formation in Well Ping’an 1 has high production of industrial oil and gas, Lianggaoshan Formation has become an important stratum for exploration, with relatively great scale potential, thus being an important field of exploration, as well as a key stratum for oil and gas replacement. It is very necessary to carry out rock mechanics parameters for unconventional reservoir stratum, and the most direct method for obtaining rock mechanics parameters is rock mechanics test, however, due to the high cost of the test method and very limited rock-core data, such method has very limited scope of application. Transverse wave time difference is very important in well-logging evaluation of unconventional reservoir strata. However, some old wells and some new wells fail to have well-logging by array acoustic wave for cost reasons, therefore, it is very important to establish prediction model of transverse wave time difference. Well-logging data is the easiest to obtain, is relatively complete and can reflect the stratum property continuously, and using well-logging data to calculate rock mechanics parameters is a low-cost, practical and rapid evaluation method, and plays a great significance in evaluation of stratum. In this paper, K.Mod module of Techlog software was used to reconstruct transverse wave time difference curve based on neural network technology. During reconstruction of curve, the neural network model requires no prior establishment of well-logging response equation or provision of empirical formula, thus the reconstruction of curve is more accurate and rapid. Using neural network to reconstruct the transverse wave time difference curve, is to look for a non-linear mapping or fitting between the logged well-logging curve and the transverse wave time difference curve, and it mainly obtains a model by learning given training sample set, to reconstruct the transverse wave curve that is not logged. Upon practical modelling and verification, it is of a relatively good effect to reconstruct the transverse wave time difference curve using the neural network.

2. Analysis of principle and characteristics of neural network

Neural network is a cutting-edge inter-discipline that has developed rapidly in recent years, it is characterized by self-organization, self-learning, non-linear dynamic processing and so on, and has the capacity for associative reasoning and adaptive recognition. The neural network model’s learning function, self-adaption capacity, associative memory capacity and information processing method can be taken as a means for construction of curve. The network can realize high correlation between the network input factors and network output targets by training. The neural network consists of the input layer, hidden layer and output layer, where, all-connection method is adopted between the layers, while there is no mutual connection between units of the same layer. The basic thought of network algorithm is to constantly adjust and modify the link weight of network via back propagation of network output errors, thus minimizing the network error.

There are many methods for reconstruction of transverse wave time difference curve, and previously, longitudinal wave time difference wave and acoustic wave curve were mostly used to make fitting, so as to find out a fitting empirical formula to make reconstruction of curve. The in the following, the reconstruction method of curve based on neural network will be mainly introduced. Neural network method makes use of computer learning to simulate corresponding relation between transverse wave time difference of the wells having been logged array acoustic wave and various well-logging responses, to establish a relation model, and then applies such model to the wells having not been logged array acoustic wave to reconstruct the transverse wave time difference of such well section. By neural network algorithm, it takes acoustic wave, resistivity, gamma and other curves with relatively good quality as the input, and transverse wave

time difference curve with stable signal as the learning objective, to obtain reconstructed transverse wave time difference curve by constantly adjusting the learning times and the number of neurons. Existing transverse wave time difference wells were used to verify accuracy of the reconstructed.

Compared with traditional method, neural network method has overcome the shortcomings of traditional method such as complex operation, less influence factors taken into account and low reconstruction precision. This method is characterized by self-learning, self-organization and self-adaption, and can fully approximate any complex nonlinear relation. In practical use, the well section with regular well borehole shall be selected, and since there is a non-linear complex relation between well-logging response and various components of practical stratum, the neural network method uses the network model of error back propagation algorithm to perform learning of the relation between well-logging curves and prediction of well-logging curves.

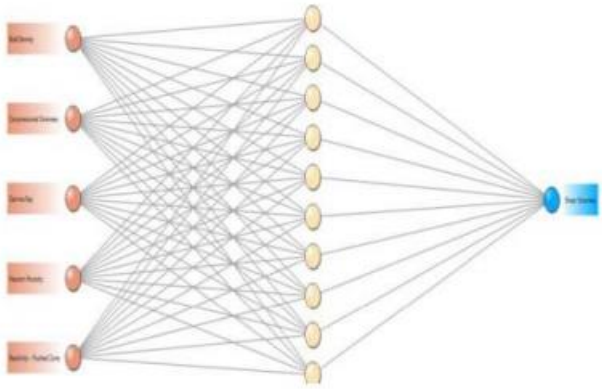

Figure 1. Structure of neural network

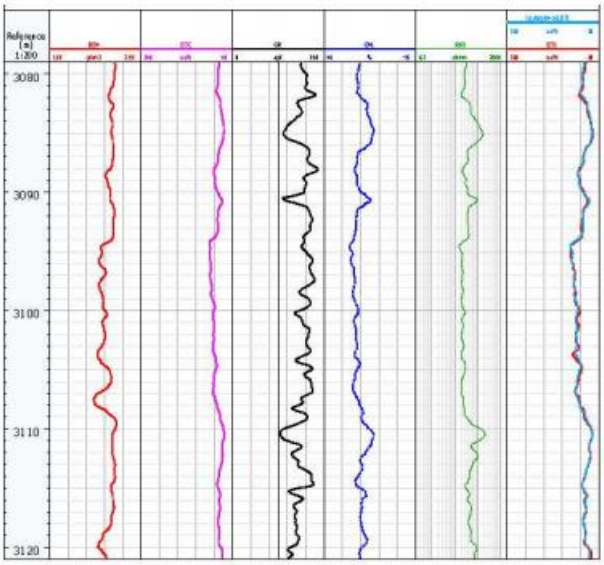

Figure 2. Comparison diagram between transverse wave time difference curve modeled by neural network and the logged transverse wave time difference curve of lg166 well

3. Determination of transverse wave time difference by neural network method

3.1. Standardization of well-logging curve

Due to different obtaining conditions of original well-logging curves, inconsistent scales, different under-well environments and other factors, there are certain system errors with well-logging responses of various wells to the same stratum and the same lithology character, which can have direct influence on calculation accuracy of the curve reconstruction, and bring some uncertainties to reconstruction. Therefore, to eliminate influence of these non-geological factors, and make the reconstruction result more accurate, it is necessary to standardize the well-logging data. In the research area, the lg166 well is of relatively regular borehole, and high well-logging quality, therefore, this well is selected as the key well. In Daanzhai section of stable distribution in the whole area, the middle and lower shell limestone is standard stratum, and mean translation method is used to standardize the input curve.

3.2. Selection of training samples

To obtain a relatively good curve reconstruction effect, curves in relatively strong correlation to the transverse wave

time difference must be found out in the research area. Representative data sets were selected without data redundancy, and biased weighting risks were prevented, without abnormal values. It was discovered by research that, total 5 curves including longitudinal time difference curve and natural gamma curve had a relatively good correlation with transverse wave time difference. In the research area, the wells whose longitudinal wave time difference, resistivity and natural gamma well-logging curve of the target strata have a relatively good correspondence to transverse wave time difference, and subject to small influence of the shaft are selected in priority, then well-logging data of these wells was intercepted as the training data, and non-linear algorithm of neural network was used to find out the relation among the well-logging curves of longitudinal wave time difference, resistivity and natural gamma and so on.

At the time of applying neural network, to improve calculation accuracy of the network, a hidden layer or neurons may be added for such purpose. In this paper, 3-layer network was adopted, i.e. the input layer, hidden layer and output layer.

The number of neurons of the input layer and output layer of the neural network can be determined in accordance with the problems ought to be solved and the data presentation mode. The principle for selection of the number of neurons in the hidden layer is as follows: on the premise of solving problems, there shall be 1-2 additional neurons to accelerate the rate of error decline. In this paper, 5 variables (density, longitudinal wave time difference, resistivity, natural gamma, compensated neutron) were selected as input of network, and 1 variable (transverse wave time difference) was selected as the output.

3.3. Realization of neural network module in Techlog software

Reconstruction of curve by neural network method makes use of computer learning to simulate corresponding relation between transverse wave time difference and well-logging responses, to establish a relation model, and then applies such model to the wells having not been logged transverse wave time difference to reconstruct the transverse wave time difference curve of such wells.

Figure 1 shows the structure of neural network, which uses the wells having been logged transverse wave time difference, to select the density, longitudinal wave time difference, natural gamma, neutron and flushed-zone resistivity curves with good well-logging quality and having relatively good correlation with transverse wave time difference as the input curves, and select the transverse wave time difference as the output curve, takes logging of transverse wave time difference of this stratum section as the learning objective, to obtain reconstructed transverse wave time difference curve by constantly adjusting the learning times and the number of neurons.

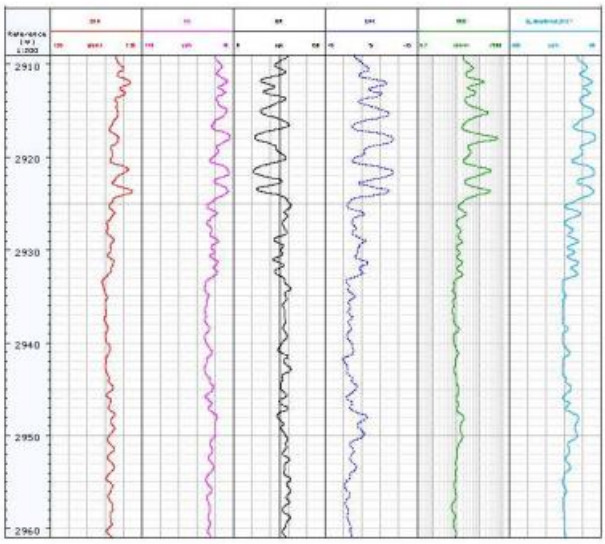

Figure 3. Well-logging result diagram of lg20 well using neural network to fit transverse wave time difference

3.4. Model verification and application examples

Figure 2 shows the comparison diagram between transverse wave time difference curve modeled by neural network and the logged transverse wave time difference curve of lg166 well, where, the transverse wave time difference curve obtained from calculation by neural network is basically coincident with the actually logged transverse wave time difference with a high goodness of fit and high model accuracy, showing that the model is reliable. The neural network prediction model was established first, and then applied to the wells having not been logged transverse wave, to realize reconstruction of transverse wave time difference curve.

4. Conclusion

For old wells having not been performed well-logging by array acoustic wave method, reconstruction of transverse

wave time difference curve is one of the methods for evaluation the reservoir strata. In this paper, neural network of K.Mod module in Techlog software was used to reconstruct transverse wave time difference curve, and it is characterized by quick operation, accurate computation, convenient operation and friendly interface. It can realize batch processing, and can be applied and promoted in other fields such as reconstruction of curves. This method is characterized by convenient operation and strong effectiveness.

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Biography

Yan Jicheng (1982-), senior engineer, graduated from Southwest Petroleum University in 2008, and is currently engaged in well-logging data processing and interpretation as well as research on reserve parameters.