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Extended Abstract

High-resolution estimation of acoustic slowness and pore pressure in Binaloud oil field using NMR data in neural network training

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Abstract

In this study, the application of data obtained from NMR logs and the estimation of pore pressure using these data, along with the training of a multilayer perceptron neural network, were comprehensively investigated. NMR data, as a powerful tool for evaluating reservoir rock properties, possess the ability to extract key parameters such as pore size distribution, porosity, permeability, free fluid volume, and irreducible volume. These parameters directly influence pore pressure and play a significant role in determining the hydrodynamic behavior and performance of the reservoir. The primary objective of this study was to develop a precise and high-resolution method for estimating pore pressure using NMR data and a multilayer perceptron neural network algorithm. By utilizing quantities derived from NMR tools and a machine learning model, we were able to estimate compressional slowness with remarkable quality and accuracy and reliably calculate the pore pressure across the target interval. This high estimation accuracy enables improved reservoir engineering forecasts and optimal decision-making in hydrocarbon resource management. The results demonstrate that integrating accurate NMR data with modern deep learning technologies, particularly multilayer perceptron neural networks, can serve as an efficient and reliable approach for pore pressure estimation. This method not only enhances data resolution but also reduces the costs and time required to obtain accurate pressure data. Ultimately, this approach can lead to the optimization of reservoir engineering processes, improved efficiency, and reduced risks associated with hydrocarbon reservoir exploitation.

1. Introduction

Accurate estimation of pore pressure is a key parameter in evaluating the mechanical properties of formations, designing drilling operations, and enhancing safety in oil and gas reservoirs. This parameter plays an important role in predicting reservoir behavior, identifying fracture zones, and optimizing enhanced recovery processes. One of the main challenges is obtaining high-resolution depth data for precise pore pressure estimation, which can be addressed using compressional slowness data and advanced methods such as neural networks. The objective of this research is to develop an accurate and reliable method for estimating pore pressure by employing multilayer perceptron neural networks and low-resolution data. The results of this study can help reduce logging costs, improve the accuracy of pressure estimation, and enable better drilling operation designs. In the future, expanding this method by incorporating more geophysical data and 3D modeling can provide more accurate predictions at new drilling sites.

2. Methodology

This study was conducted with the aim of developing a precise, cost-effective, and high-resolution method for estimating pore pressure in oil and gas reservoirs. The main motivation behind the research was to reduce dependency on costly and spatially limited MDT log data by replacing them with more commonly available logs of lower cost, using advanced machine learning approaches. In the first stage, a comprehensive set of petrophysical data from a studied well was collected. In this dataset, compressional slowness was considered as the target variable, and the following NMR log features were selected as input variables: porosity, permeability, longitudinal-to-transverse relaxation time ratio (T1/T2), logarithmic mean of transverse relaxation time (T2 log mean), porosity of NMR bins one to eight, the Clipper log (imaginary NMR component), free fluid saturation, and bound fluid saturation. All features and the target variable had the same resolution as the full set data, equal to 0.1 meters. To estimate compressional slowness, a Multilayer Perceptron (MLP) neural network with four hidden layers and ReLU activation functions was employed. The dataset was split into 90% for training and 10% for testing. The model was trained using the backpropagation algorithm along with the Adam optimizer. Initially, the model was trained on the full-depth range of the full set logs. It successfully reconstructed compressional slowness with a correlation coefficient of 94% and a Root Mean Square Error (RMSE) of 0.03 compared to the actual values. The model was then extended to the full depth range of the NMR data, comprising 18,908 points, and compressional slowness was again estimated with a correlation coefficient of 94% and an RMSE of 0.03.Subsequently, 16 pore pressure points from MDT log data were used to optimally determine the exponent n in Eaton’s empirical equation, using the least squares method[1-3]:

$$P_P=P_L-(P_L-P_H)\left(\frac{\Delta T_n}{\Delta T}\right)^n \quad (1)$$

Finally, pore pressure across the entire depth interval was calculated by inserting the predicted slowness values and the estimated exponent into Eaton’s equation. The final accuracy was evaluated by comparing the calculated pore pressures with actual MDT measurements. Ultimately, high-resolution pore pressure estimation at a vertical resolution of 0.005 meters—equal to that of the NMR data was successfully achieved.

3. Results and Conclusions

This study explored the use of NMR log data and multilayer perceptron neural networks to estimate pore pressure with high accuracy and resolution. NMR-derived parameters such as porosity, permeability, and fluid volumes directly affect pore pressure and reservoir behavior. By combining these data with machine learning, the model successfully estimated compressional slowness and pore pressure. The results show that integrating NMR data with deep learning provides a reliable, cost-effective method for pressure estimation, aiding reservoir management and enabling accurate pressure prediction at new well locations.

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