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Estimation of P-Wave Velocity with Genetic Algorithm and Neural Network Approach Based on Wireline Logging Data

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Abstract

P-wave velocity is a very important parameter in exploration activities. P-wave velocity (V_p) can be determined from wireline logging data. Generally, the industry only does logging at certain depths which are considered to have prospects in order to save exploration costs. Missing wireline logging data will certainly be a serious problem because it requires complete and accurate data so that the chances of exploration success are high. A method is needed to estimate V_p using data other than sonic log. This research aims to estimate V_p based on available log data using Genetic Algorithm (GA) method and Neural Network (NN). The inversion process is carried out using the method in the Ikpiukuk1 well until the relationship of V_p is obtained with the gamma ray log, resistivity log and density log. The next process estimating V_p by blind test on the same well but the depth is different from inversion. The results showed that the Neural Network method was superior to the Genetic Algorithm method. In the three formations that are the object of research the Neural Network method is consistent because the estimation error is smaller than the Genetic Algorithm method.

Introduction

P-wave velocity information (V_p) is needed in exploration activities. One way to get V_p information is to process information from wireline logging data in the form of sonic logs. In some cases the available well data is incomplete because the industry is trying to reduce exploration costs [1]. Based on laboratory scale experiments it is known that V_p and rock parameters such as density, porosity, and clay content are interconnected [2]. With the relationship between V_p and physical parameters of rocks it is assumed that V_p is indirectly related to wireline logging data such as log density, gamma rays and resistivity [2]. In geophysics there is a process for extracting unknown rock parameter information from observational data. This process is called inversion or known as inverse modeling [3]. This study aims to estimate the price of V_p using two methods, Genetic Algorithm (GA), Neural Network (NN).

Methods

Genetic Algorithm is optimization based on natural selection and genetics that occur in nature, which is known as the process of evolution [4]. In the GA method the data in the form of numbers will be treated like living things undergoing an evolutionary process starting from natural selection, crossover and mutation. Neural Networks are basically inspired by the way humans think. Basically Neural Network is a computational algorithm that is based on the workings of the human brain [5]. In the human brain there are millions of neurons that are interconnected. The relationship between neurons in the human brain forms a kind of circuit, which is responsible for all human perceptions and behavior. Backpropagation Neural Network allows us to make predictions

Inversion in GA method uses the following mathematical model [6]:

$$V_p = \sum_{i=1}^n a_n \text{Log}_n^{b_n} \quad (1)$$

$$V_p = a_1 Z^{b_1} + a_2 GR^{b_2} + a_3 RHOB^{b_3} + a_4 ILD^{b_4} \quad (2)$$

Where V_p is the P wave velocity (m / s), Z is the depth (m), GR is the gamma ray log (API), $RHOB$ is the density log (gr / cc), ILD is the resistivity log (ohm.m), Log_n are the parameters or the type of logging to be used, a_n is the unknown parameter.

To calculate a match between V_p estimation and V_p observation used Mean Squared Error (MSE). Mathematically, MSE is stated as follows:

$$MSE = \frac{1}{n} \sum_{i=1}^n (V_{est(i)} - V_{obs(i)})^2 \quad (3)$$

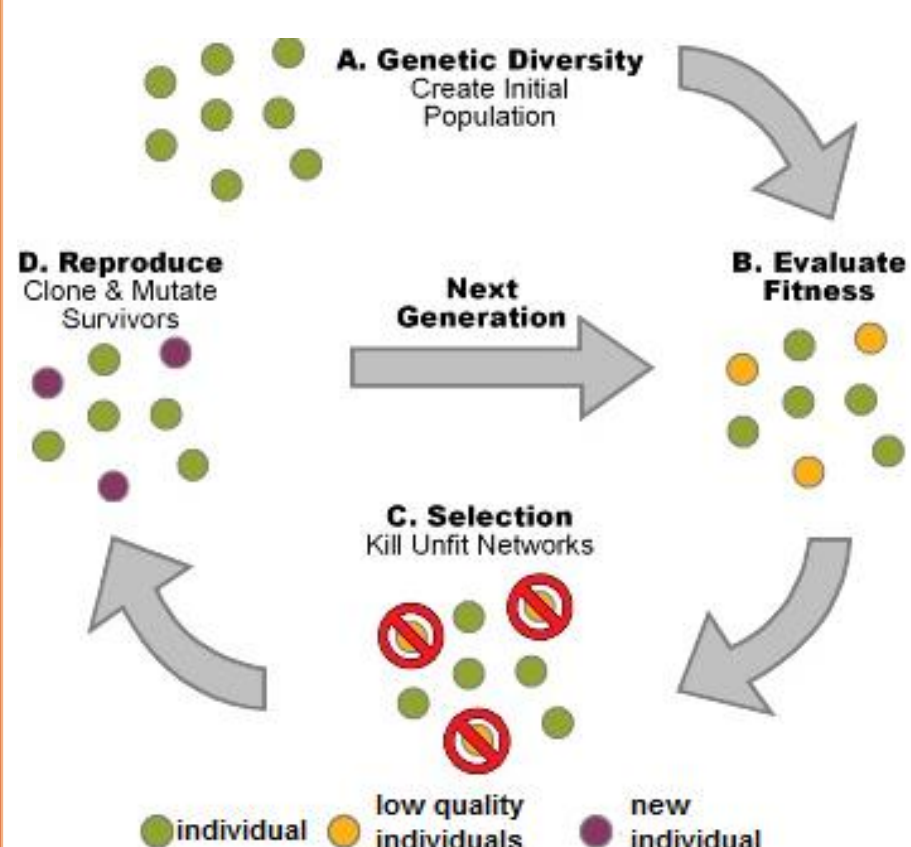


Figure 1. Genetic Algorithm [7]

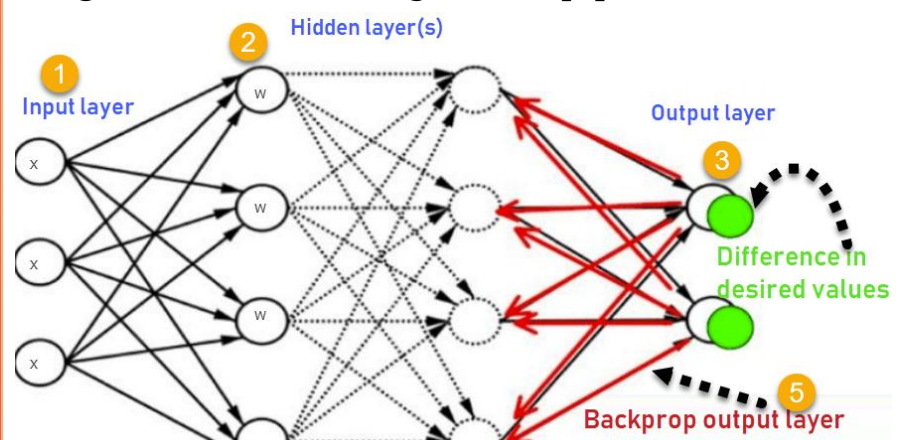


Figure 2. Backpropagation Neural Network [8]

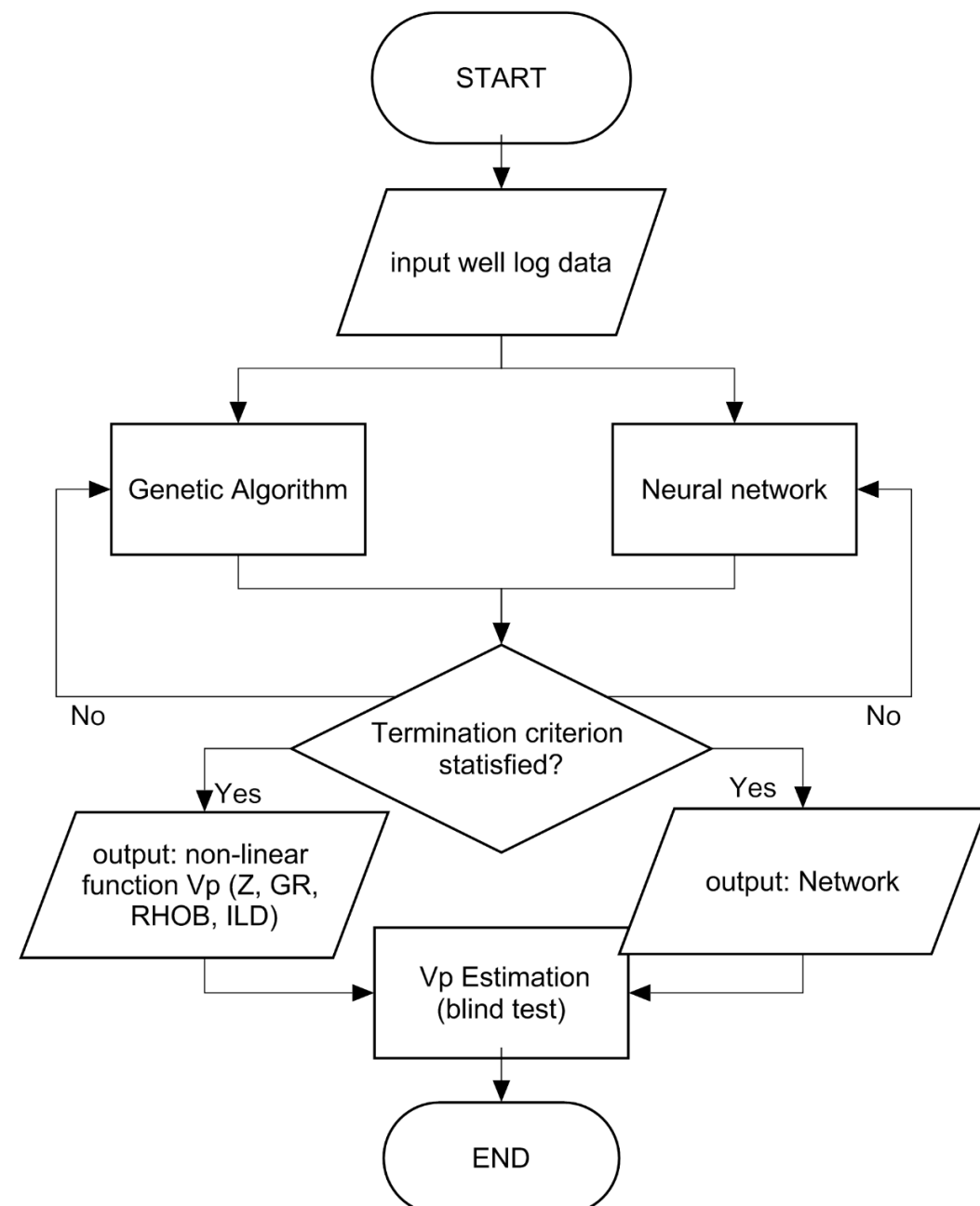


Figure 3. Workflow

Result and Discussion

In three different formations, the GA method inversion results show quite good results but NN method results are still better than GA because in Figure 4 it appears that the results of the blue line (NN) inversion are more fit than the green line (GA). In Figure 4 it can be seen that along the logging depth there is a mismatch between estimated V_p and observation V_p , however the NN method is better than GA because it looks closer to V_p observation. The results of the inversion and estimation of V_p by the GA method cannot yet out perform the NN method but the equation obtained from GA is easier to understand because it can explain the relationship between rock parameters directly with non-linear functions.

Table 1. Non-linear function from GA inversion

Formation	GA Output
Kingak	$V_p = 5.37Z^{0.79} + 5.53GR^{0.53} + 4.41RHOB^{5.98} + 4.75ILD^{1.90}$
Shublik	$V_p = 4.22Z^{0.83} + 0.20GR^{0.36} + 1.82RHOB^{6.85} + 7.80ILD^{0.76}$
Ivishak	$V_p = 2.37Z^{0.90} + 6.65GR^{0.60} + 5.75RHOB^{5.55} + 2.35ILD^{1.07}$

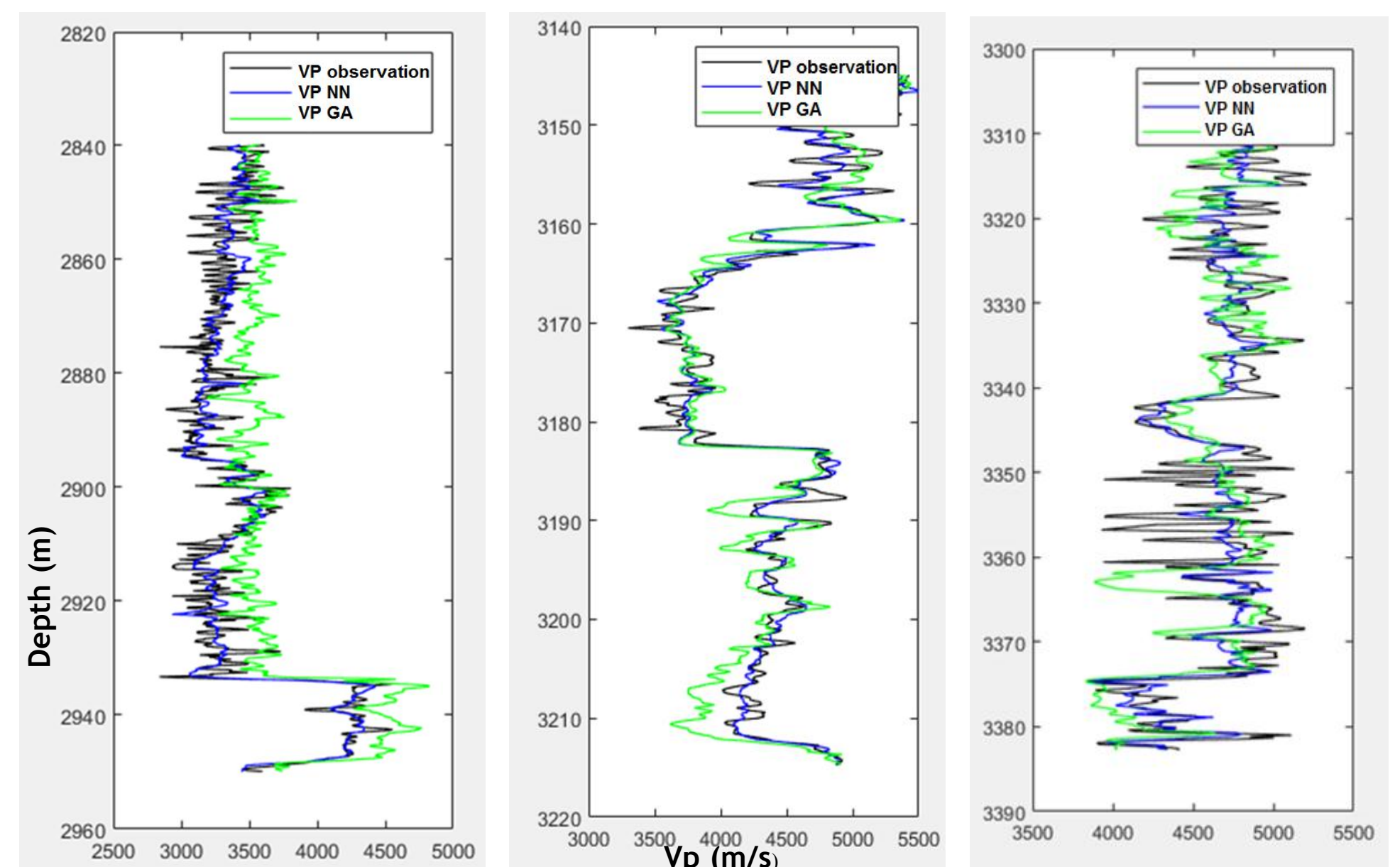


Figure 4. V_p estimation (from left to right) Kingak formation, Shublik formation, Ivishak formation

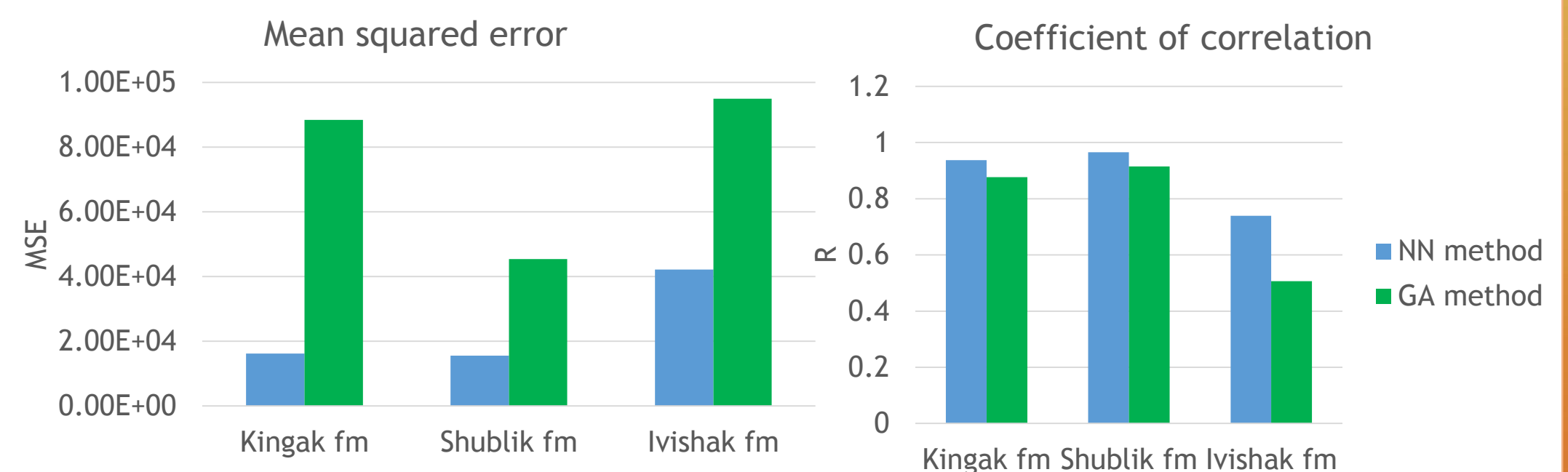


Figure 5. Mean squared error (lower is better), Coefficient of correlation (higher is better)

Conclusion

Based on the results of data processing and interpretation the following conclusions are obtained:

- The relation between V_p and well log data which is attached in Table 1 can be obtained using the GA method.
- Estimation of V_p in the Kingak formation, Shublik formation, Ivishak formation attached to Figure 4 can be obtained using the results inversion from GA and NN.
- Neural Network methods is superior to the Genetic Algorithm method because when tested on three different formations it has a smaller error value and a greater correlation coefficient.

References

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