A Multilayer Perceptron Neural Network to Estimate Total Organic Carbon (TOC) Content Using Well Logs in Raniganj Sub-Basin, India

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Abstract

The Total Organic Carbon (TOC) content of source rock is arguably the most essential parameter to assess the development potential of an unconventional reservoir. Traditionally, TOC is estimated using laboratory methods such as Rock-Eval pyrolysis, elemental analysis, etc. However, since the presence of organic carbon has an effect on the response of well logging tools, TOC may be estimated using wireline logs, which provides a continuous depth profile of TOC.

In this study, the aim is to evaluate the TOC content depth profile for shale in the Barren Measure Formation of the Raniganj sub-basin. The existing methods of TOC estimation from wells logs have limited application and accuracy in predicting TOC content, especially for the Barren Measure shale which has a high variation of TOC with depth in the broad range of 2 - 8 wt. % as shown in Fig 1. ΔlogR Method is a popularly used technique that estimates TOC using resistivity and porosity logs, but it has limiting assumptions and also requires prior information on the thermal maturity of the source rock. A popular Artificial Neural Network (ANN) based model to determine TOC in Barnett and Devonian shale formations was given by Mahmoud in 2017. However, the ANN architecture proposed by Mahmoud, as well as the ΔlogR Method are not adequate in predicting TOC with satisfactory accuracy for the Barren Measure Shale.

Hence, we developed a new model using Multilayer Perceptron (MLP)-ANN for predicting TOC content from the caliper, gamma, resistivity, and bulk density logs. The MLP-ANN has 4 layers and has been optimized using the Adam optimizer. The loss function used is mean squared error. The model is created using TOC values from Rock-Eval pyrolysis of 111 core samples from 3 wells in the Raniganj sub-basin, of which 10 data points are reserved for testing the model. It is compiled using the Keras API with a TensorFlow backend. The hyper-parameters of the algorithm are fine-tuned to obtain the best model for improved prediction of TOC.

Based on Pearson correlation coefficient 'r', root mean square error (RMSE), and mean absolute error (MAE) (as tabulated in Table 1.), the developed ANN model outperformed the existing methods in predicting the

TOC content for Barren Measure Shale. The estimated TOC-depth curves may further be used in the model-based inversion scheme of 3D seismic data to obtain a TOC model for the Raniganj sub-basin.

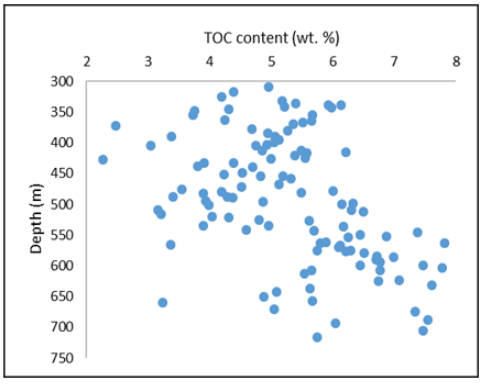

Fig. 1: The high variation of TOC content (2 - 8 wt. %) for the Barren Measure Shale in the 3 wells of Raniganj sub-basin.

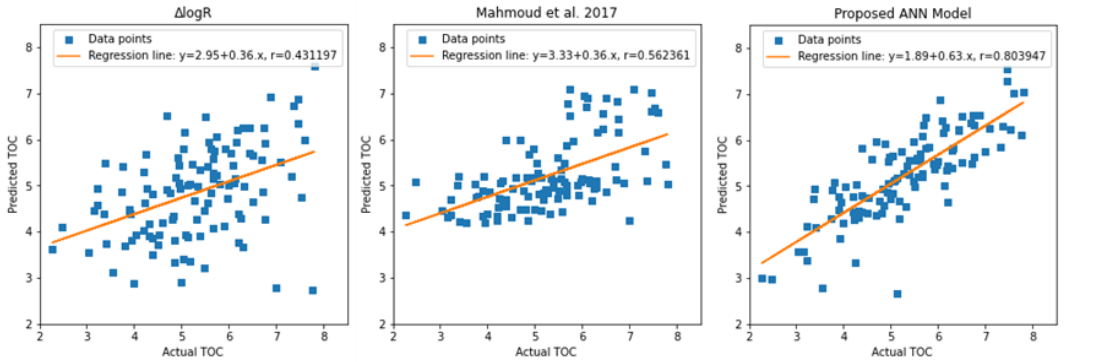

Fig. 2: Actual TOC vs. predicted TOC for the (a) Δ log R Method, (b) Mahmoud et al., 2017 Method and (c) the Proposed MLP ANN.

Table 1: Performance of Δ log R Method, Mahmoud et al., 2017 Method and the Proposed MLP ANN in predicting TOC.

	Pearson coefficient 'r'	RMSE	MAE
ΔlogR	0.431197384	1.268783	0.951987
Mahmoud et al., 2017	0.56236103	1.001474	0.792857
Proposed MLP ANN	0.803947231	0.718554	0.554562

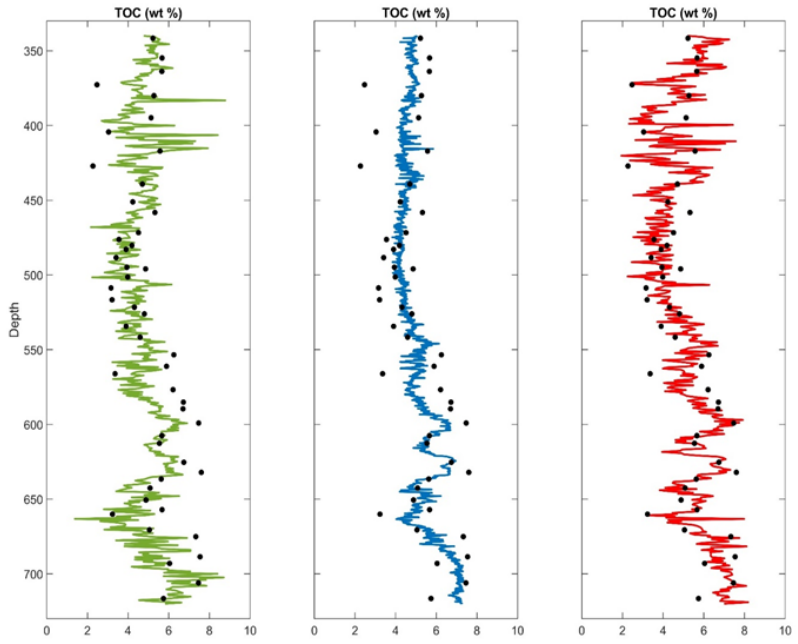

Fig. 3: A comparison of the predicted TOC-depth curves with the actual core-derived TOC for one of the wells, using the (a) Δ log R Method, (b) Mahmoud et al., 2017 Method and (c) the Proposed MLP ANN