PS Horizontal Stresses Prediction Using Sonic Transition Time Based on Convolutional Neural Network

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Abstract

Recently, geomechanical investigations have held a crucial position in subsurface studies, not the least of which is understanding horizontal stresses (HS) consisting of minimum and maximum (Sh_{min} & SH_{max}, respectively). This is because they are vital in establishing oilfield-development planning such as carbon capture and storage (CCS) and enhanced oil recovery (EOR). In order to calculate these parameters, a myriad of direct and indirect methods has been provided. Since they may need to take a lot of time and money, or employing them in some situations is impossible or difficult, such as weak formations, this study strives to estimate Sh_{min} and SH_{max} using a state of the art technology in data science fast and accurately. The study area is in a carbonate formation with a thickness of about 300 m. For this purpose, a set of seismic information, including Compressional (DTC) and Shear (DTS) waves transit-time obtained from a well-logging operation, was utilized. In the next step, the correlation between input and target parameters was evaluated by the coefficient of determination (R^2). Statistical analysis shows that R^2 between the SH_{max} and Sh_{min} with DTC and DTS are approximately 0.85 and 0.81, respectively. Then, a deep learning method called Convolutional Neural Network (CNN) was employed to predict the HS. Finally, the obtained results were evaluated at different statistical benchmarks. According to the results, CNN could predict Sh_{min} with r=0.93 and R^2=0.86, and the root mean square error (RMSE) is 4.6. CNN was similarly performed to calculated SH_{max} with r=0.92, R^2=0.85, and RMSE = 3.73. Other statistical analyses of results illustrated that seismic velocities could be considered a reliable anchor to predict HS.

Keywords: Horizontal Stresses, Deep Learning, Convolutional Neural Network, Seismic Velocities, Statistical Analysis, Well-logging Data

Reference

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In-Situ Stresses

In reservoir geomechanics, investigating stresses is one of the fundamental tasks. Different studies have introduced stresses as in-situ stresses in the two-main group, including vertical stress (SV) and horizontal stresses (HS) consisting of Shmin and Shmax.

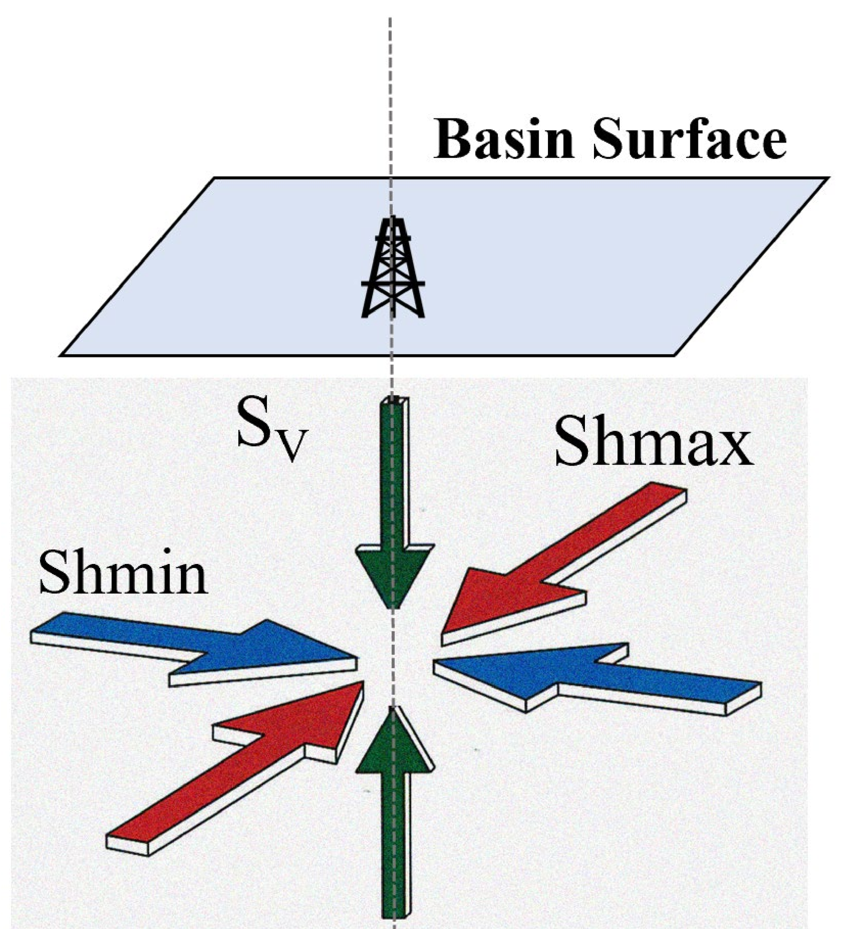

Figure 1. An example of horizontal and vertical stress in a well.

The Used data & Methodology

This study strives to estimate Shmin and Shmax using new technology in data science fast and accurately called Convolutional Neural Networks (CNN) by two seismic data:

- Delta – T Compressional (DTC) (µs/m)
- Delta – T Shear (DTS) (µs/m)

The study area is a carbonate formation with a thickness of about 300 m.

CNN

The convolutional neural network is a deep learning algorithm resulting from advancement in multilayer perceptron, which tackles the overfitting problem by regularizing the connection between neurons. This method consists of three different layers; the convolutional layer works like the input layer in the traditional neural network, and the majority of calculations occur in this layer which can be followed by other convolutional layer or pooling layer, which works on reducing the dimensionality of the input parameters and followed by a Fully connected layer that is considered as the output layer.

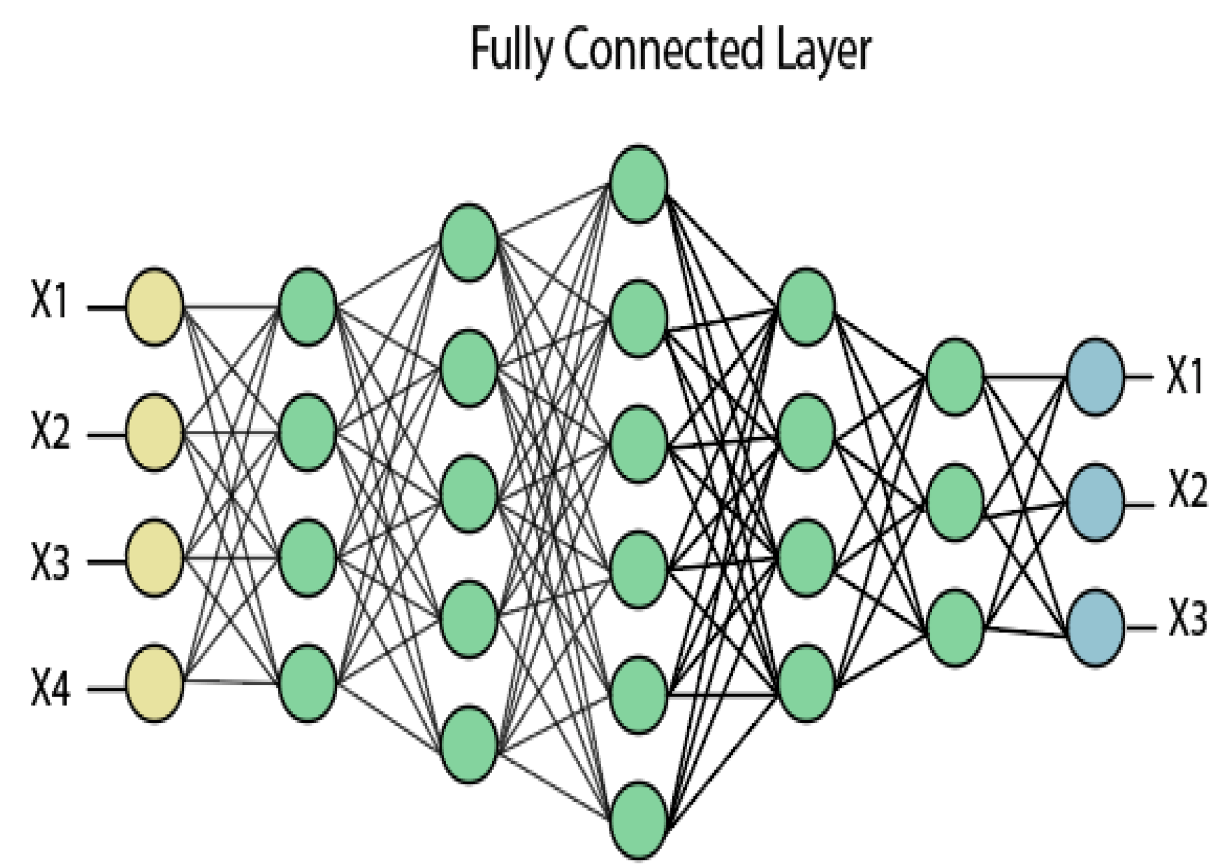

Figure 2. A schematic diagram of a fully connected layer.

Results

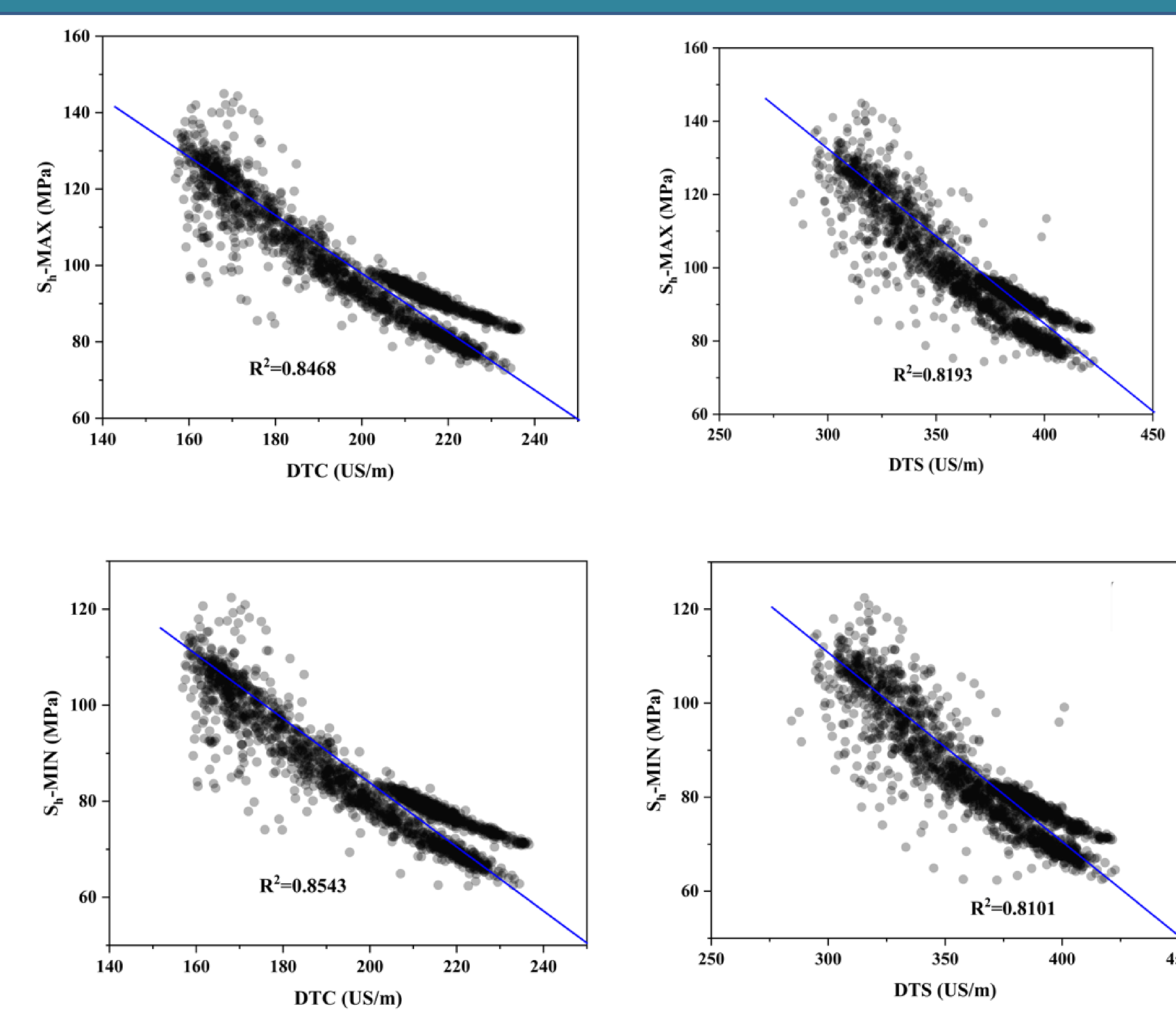

Figure 3. Correlation between Shmin & Shmax with DTC & DTS.

Table 1. The coefficient of determination (R^2) between horizontal stresses and transition times (DTC & DTS).

HS (MPa) / DT	DTC (us/m)	DTS (us/m)
Shmax	0.8468	0.8193
Shmin	0.8543	0.8101

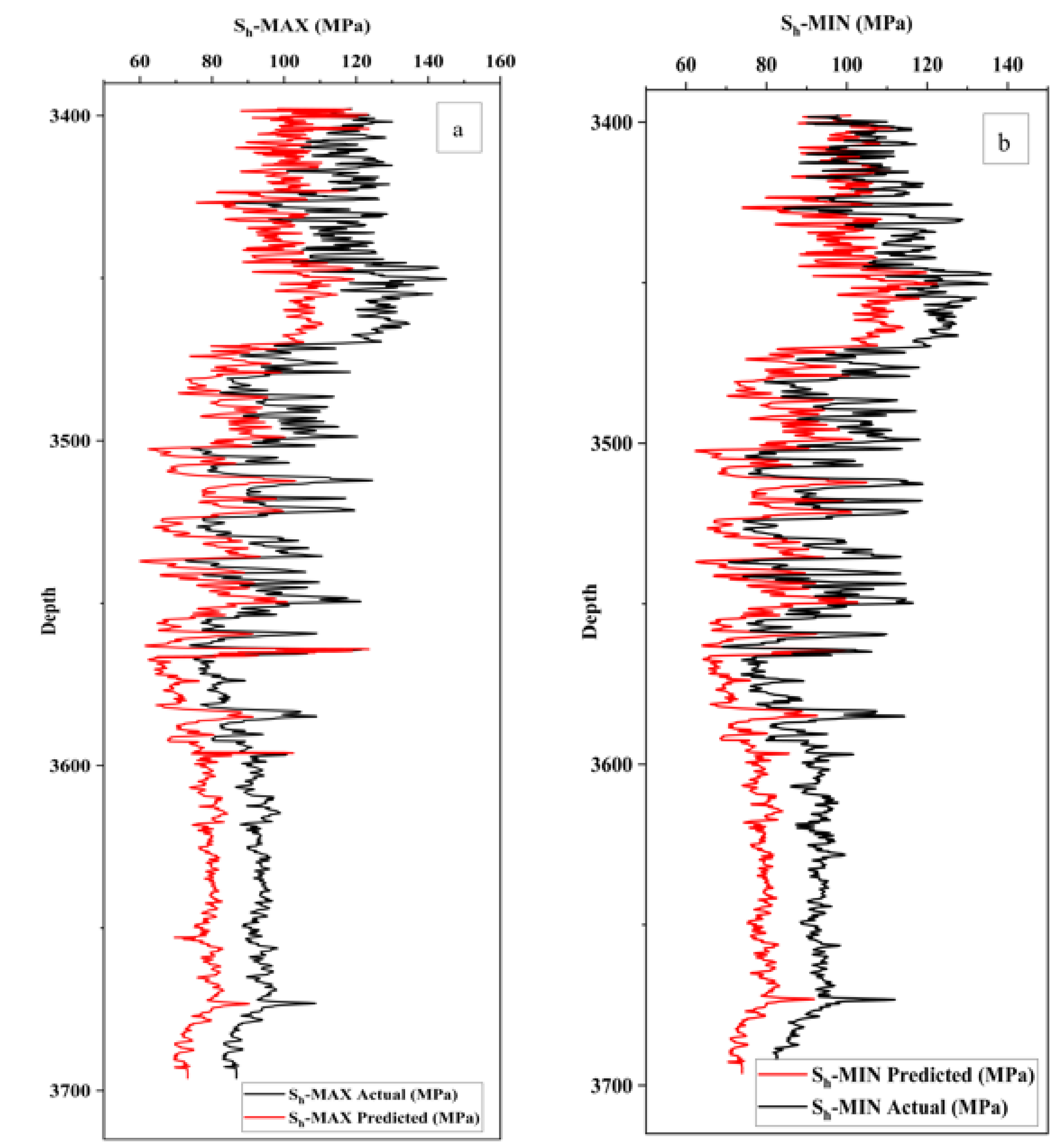

Figure 4. Estimation (red) and original (black) of HS by CNN.

Table 2. Train, Test, and All results for CNN method to predict Shmin.

Bench mark	r	R^2
Train	0.93	0.86
Test	0.93	0.86
All	0.92	0.86

Table 3. Train, Test, and All results for CNN method to predict Shmax.

Bench mark	r	R^2
Train	0.93	0.87
Test	0.92	0.85
All	0.93	0.87

Conclusions

In this study, a CNN model was recruited to predict horizontal stresses through well-logging data. The CNN model predicted the trend of both Shmax and Shmin with high accuracy, 0.93 and 0.92, respectively.

-The coefficient of determination for the regression was measured 0.87 and 0.86 for Shmax and Shmin, respectively.