Neural Network Analysis versus Pre-Stack Seismic Inversion for Reservoir Characterization, Scarab Field, Offshore Nile Delta, Egypt*

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Abstract

The simultaneous pre-stack inversion is a very powerful method used to delineating the gas bearing reservoirs in clastic systems. It was successfully used in reservoir characterization. However, this method has its limitations regarding the requirement of reliable set of wavelet, suitably wire-line logged wells and sufficiently dense initial model. Therefore, the need arises for using another method that can provide similar (or even better) results and does not require that much data. A methodology that utilizes neural network analysis was developed to stand against the pre-stack inversion.

The simultaneous pre-stack inversion was applied over the Scarab Field, part of the West Delta Deep Marine concession, offshore Egypt, with the aim of exploring the potential of this method for quantitative interpretation. The Scarab Field is a submarine channel-based gas reservoir that extends laterally over 20 sq km. Six wells were analyzed in a rock physics study prior to the inversion process. Three angle gathers (near: 0-15°; mid: 15-30°; far: 30-45°) were inverted for P-wave impedance (Zp), S-wave impedance (Zs) and Vp/Vs using the pre-stack inversion method. The neural network analysis was performed using the full stack seismic data along with the well log data in the training stage, cross-validate the results and produced P-wave impedance (Zp), S-wave impedance Zs, and Vp/Vs volumes. The P-impedance and Vp/Vs volumes were used to predict water saturation (Sw) values using neural network analysis. Direct comparisons were made between neural network results and the pre-stack inversion results at a blind well location to measure the quality of each method. The results achieved in this research suggest that the application of the proposed neural network methodology leads to quite good predictions.

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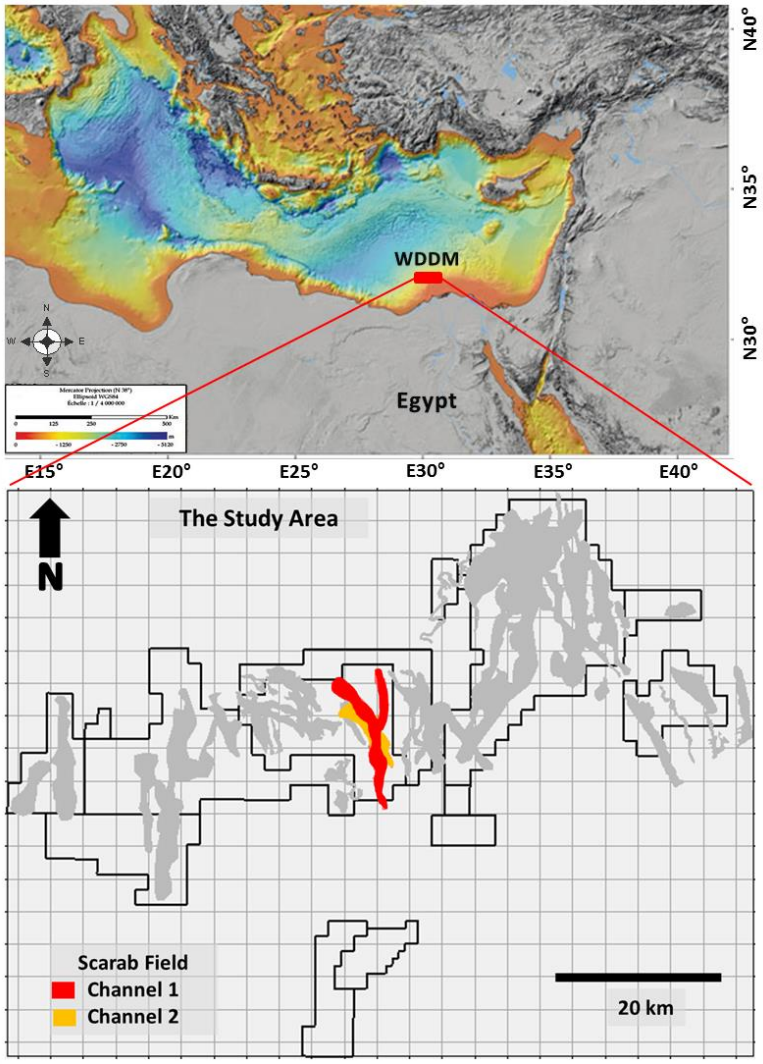
Outline

- Introduction
- Pre-stack Inversion
- Neural Network
- Reservoir Characterization
- Conclusions

Area of Study

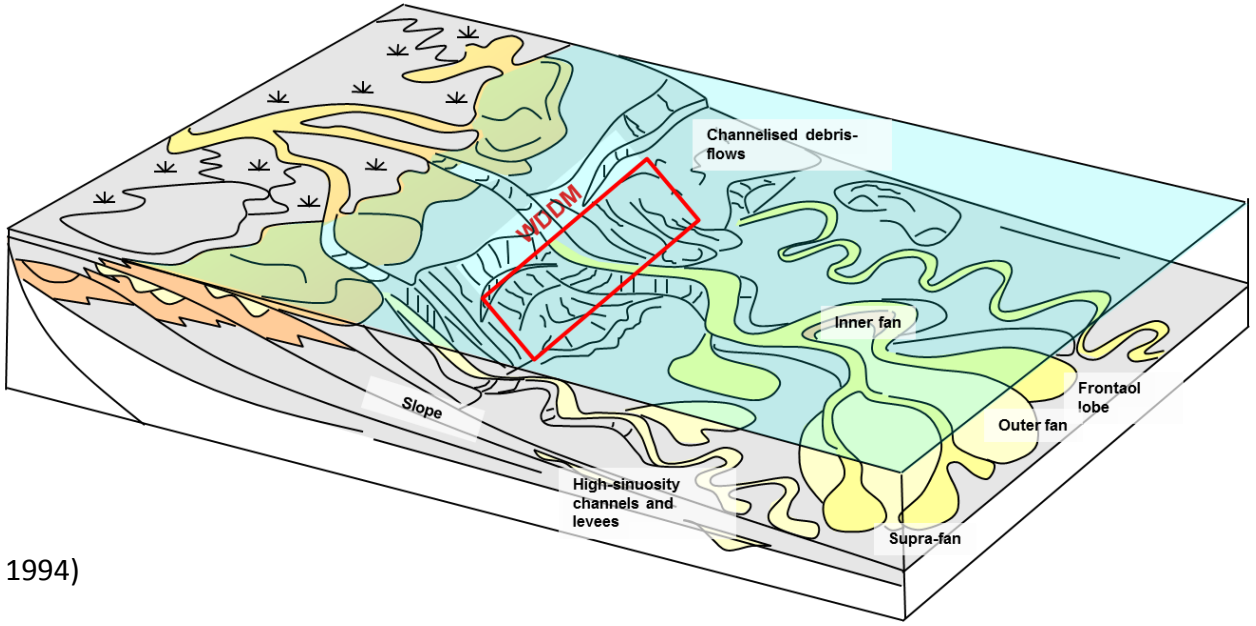
- Egypt
- Offshore Nile Delta
- West Delta Deep Marine (WDDM) concession covers 6150 km²
- The Scarab Field is a Pliocene gas field located 90km north of Alexandria in water depths of 250-850m.



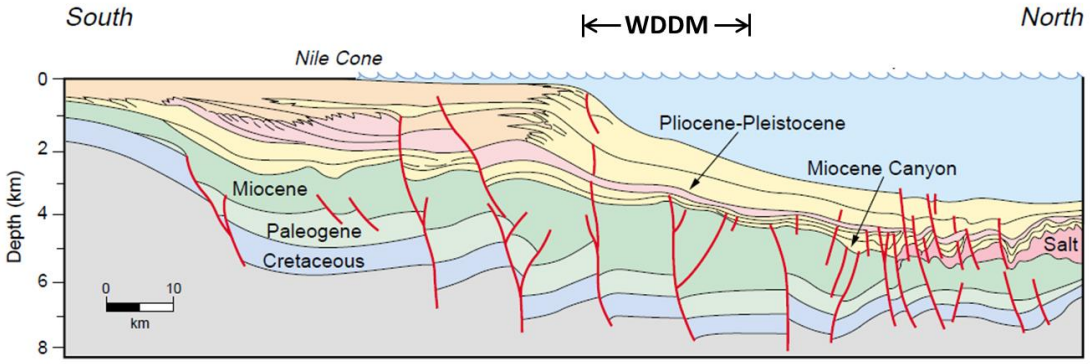
(After Mohamed et al., 2014)

Geological Model

WDDM Simplified Model

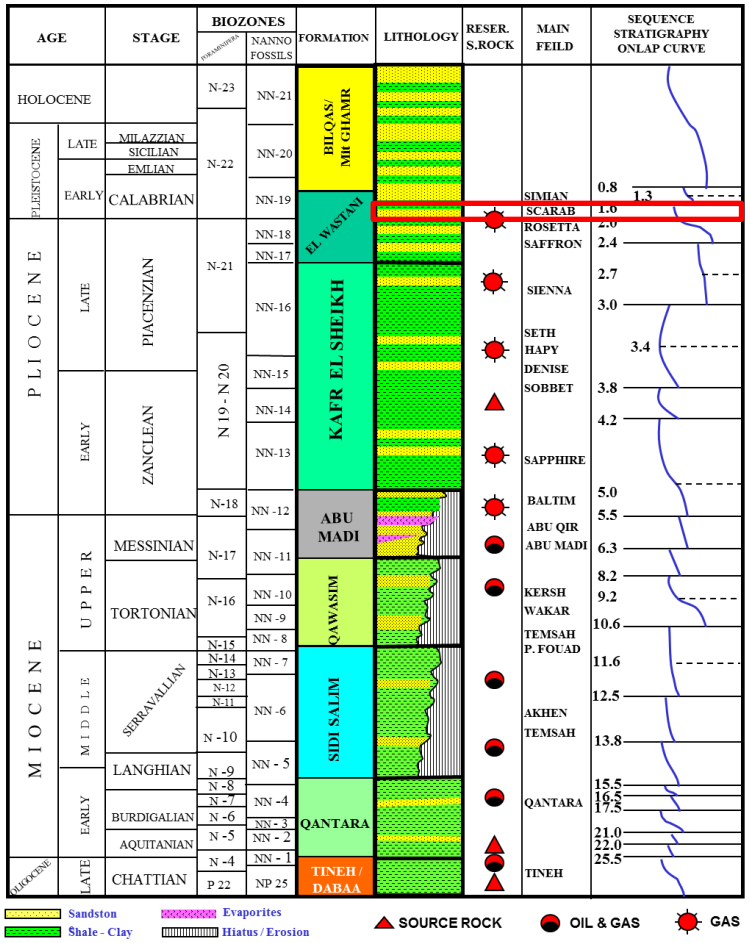


(modified from Reading and Richards, 1994)

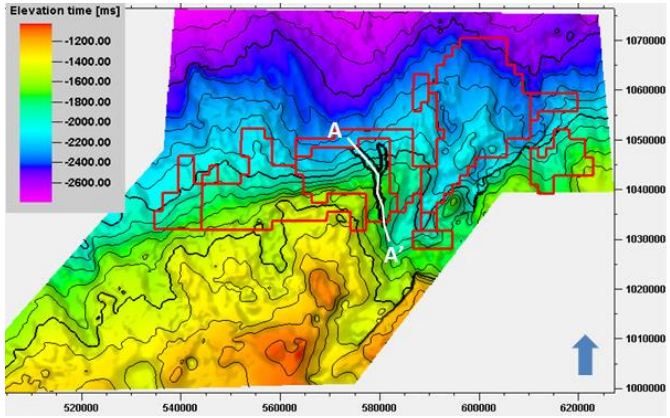


(modified from Abdel Aal et al., 2006)

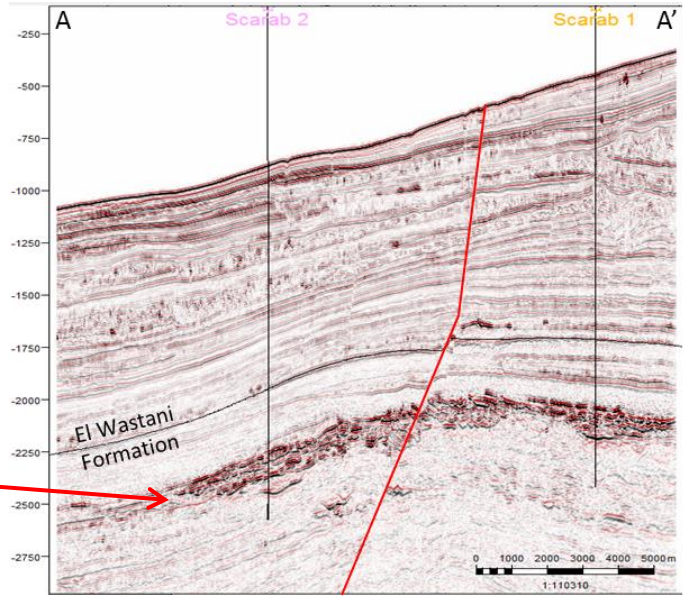
Stratigraphic Column



Nile Delta stratigraphic column and hydrocarbon system



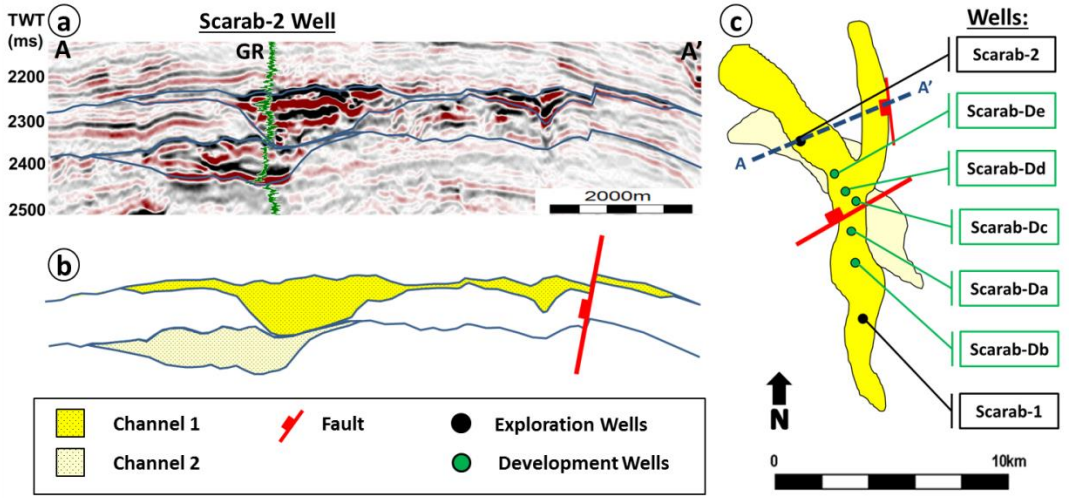
El Wastani formation TWT map



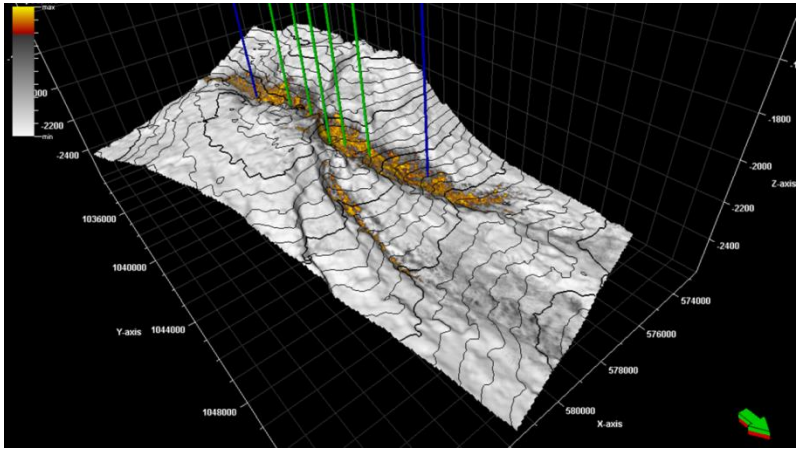
Scarab field: Late Pliocene, El Wastani formation

Field Characteristics

- Complex submarine channel system
- Two stacked channels: Channel 1 and Channel 2
- Channel 1 is 16km long and up to 7km wide at its widest point
- Seven wells: two exploration and five development wells



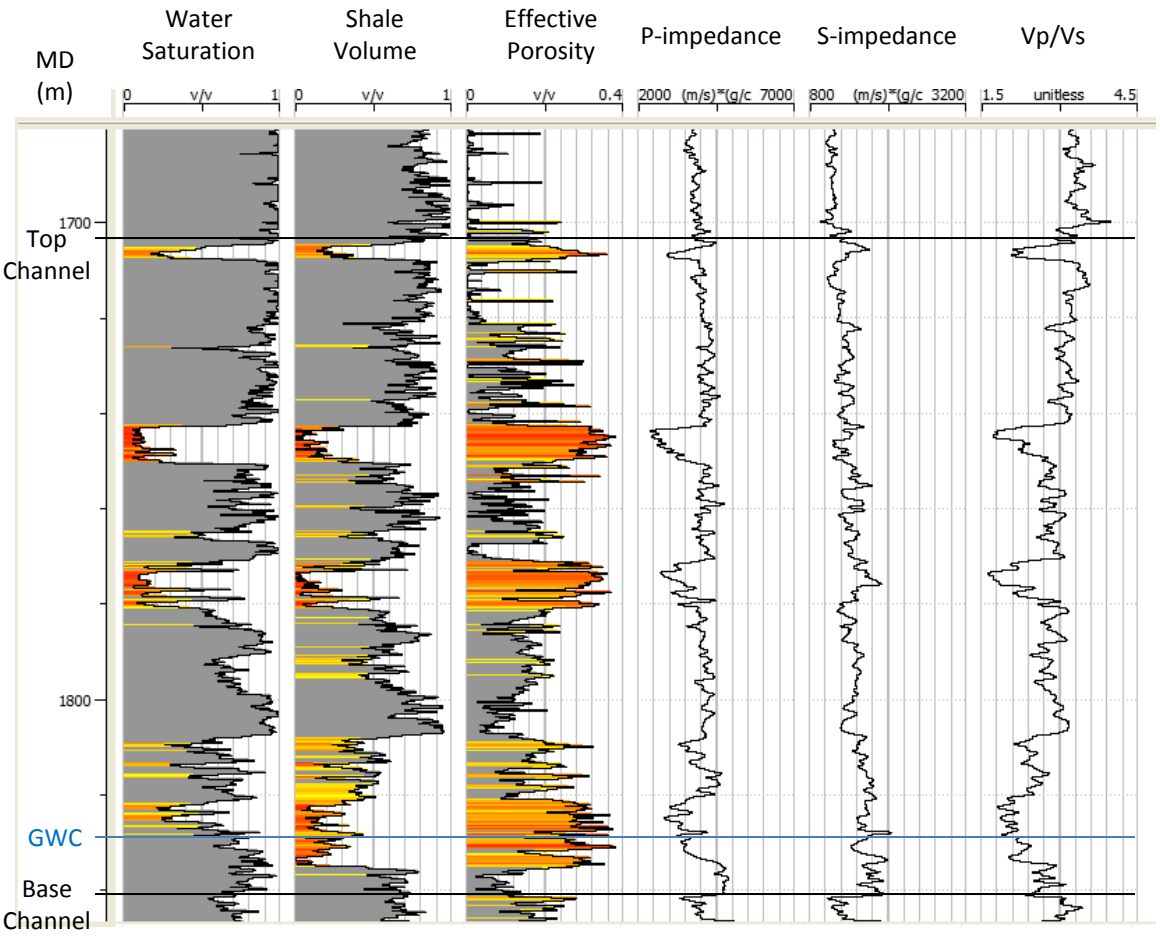
(After Mohamed et al., 2014)



Attribute slice over Channel 1 reservoir

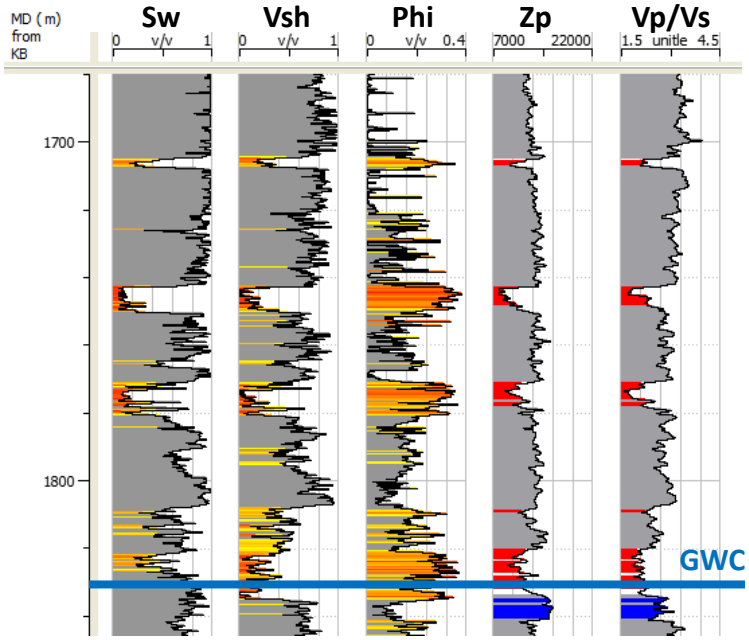
Reservoir Features

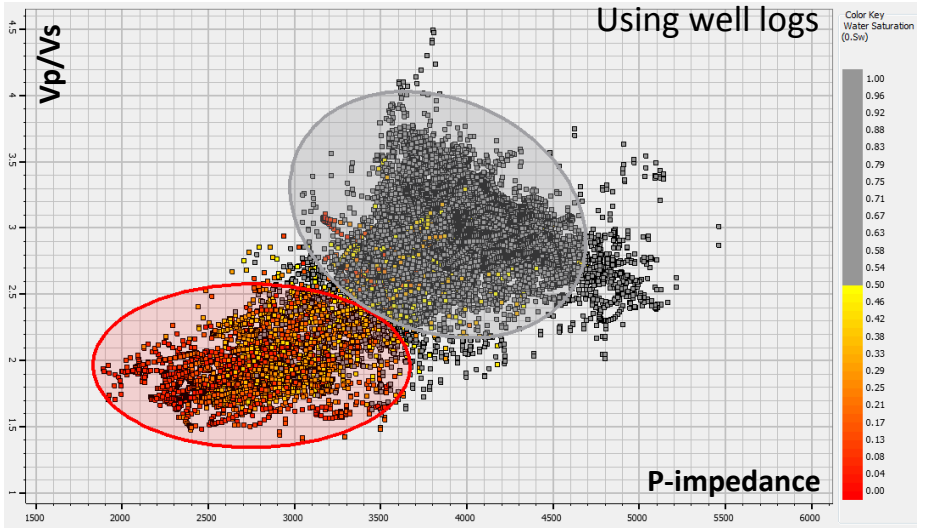
- Multiple stacked channels that are up to 170m in gross thickness, 50m of pay
- An average non-shale porosity of 28%
- An average water saturation of 28%

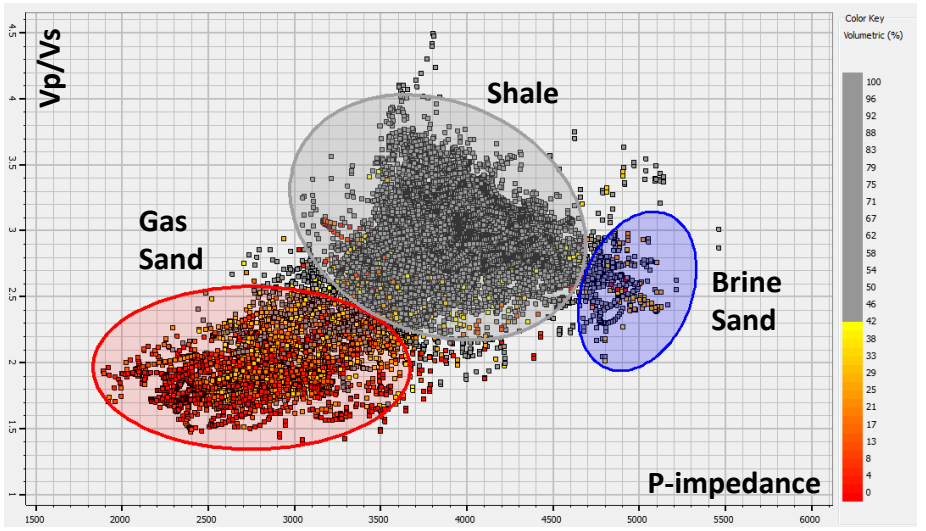


Pre-stack Inversion

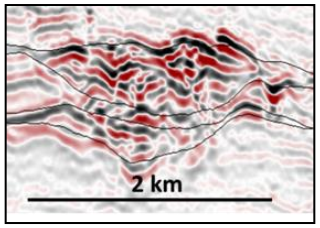
- Why we use the pre-stack inversion method?
  - ✓ Gain more information than was previously possible from full-stack seismic data alone
  - ✓ Inversion products can be used to distinguish the different lithologies; gas sand, brine sand and shale



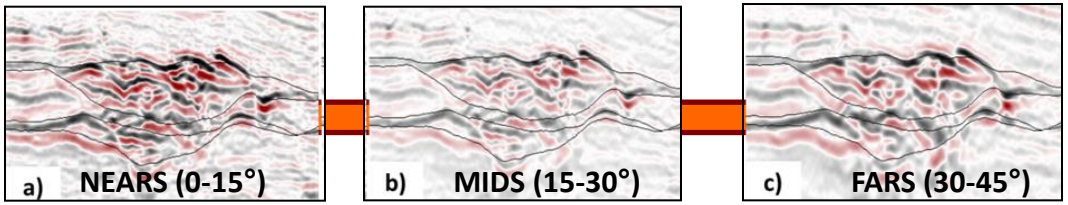




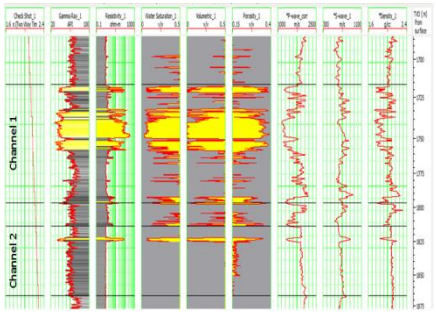
Inversion Workflow



3D Seismic

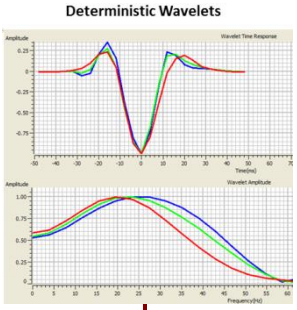


Angle Stacks



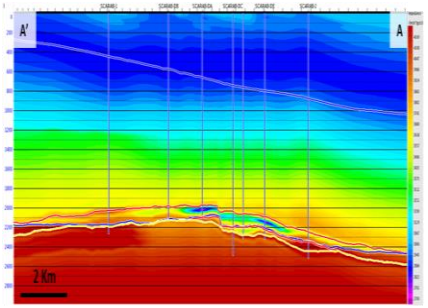
Well logs
(Zp, Zs & ρ)

+



Wavelets

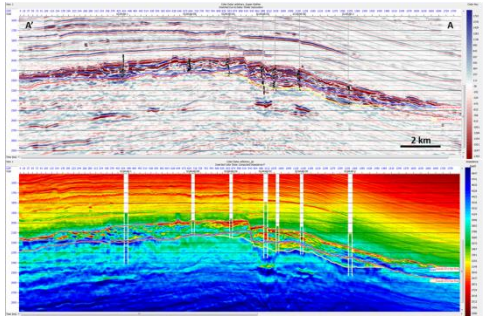
+



Initial Model

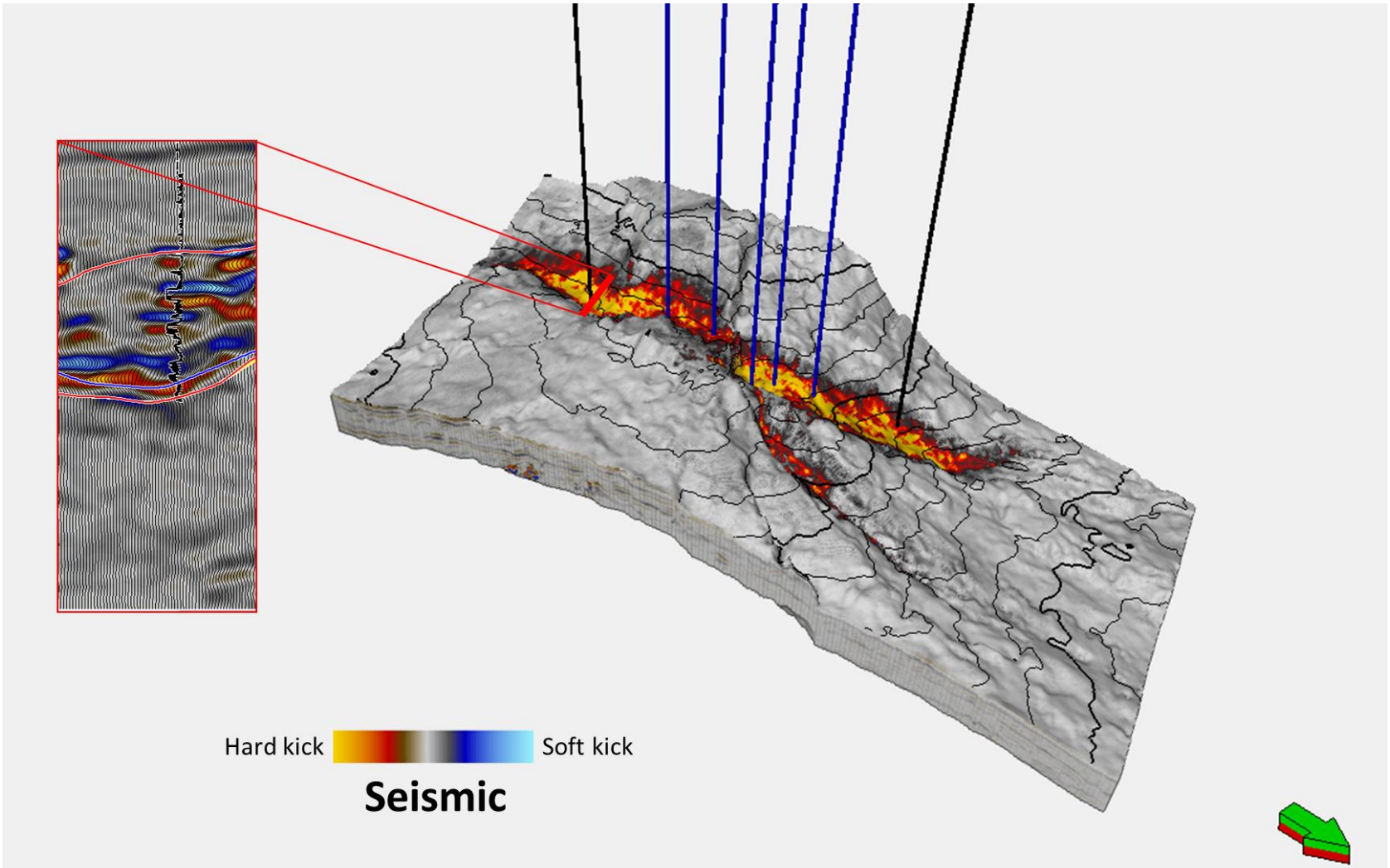
Seismic data

Inverted data

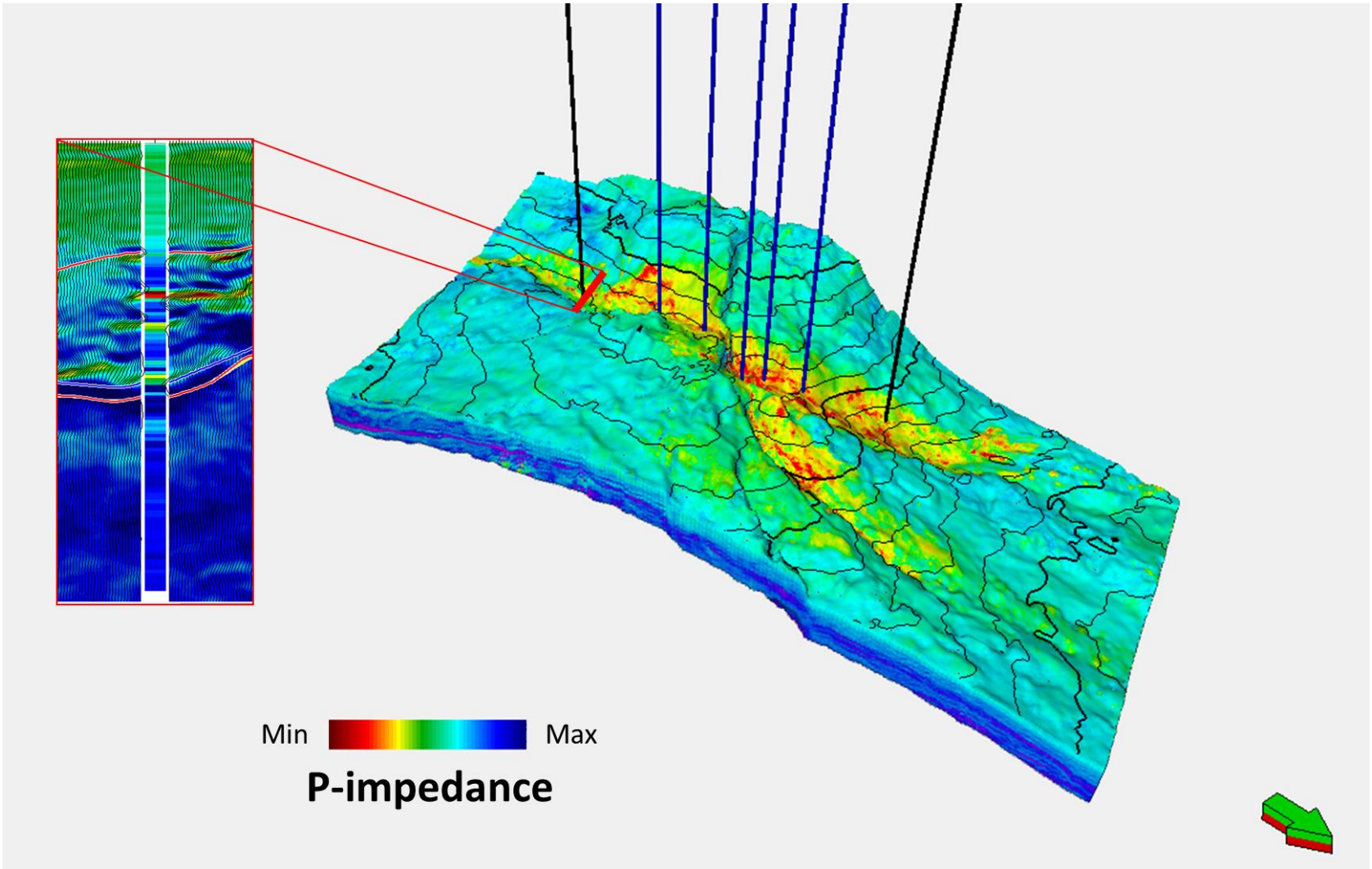


Inversion products:
Zp, Zs, & Vp/Vs

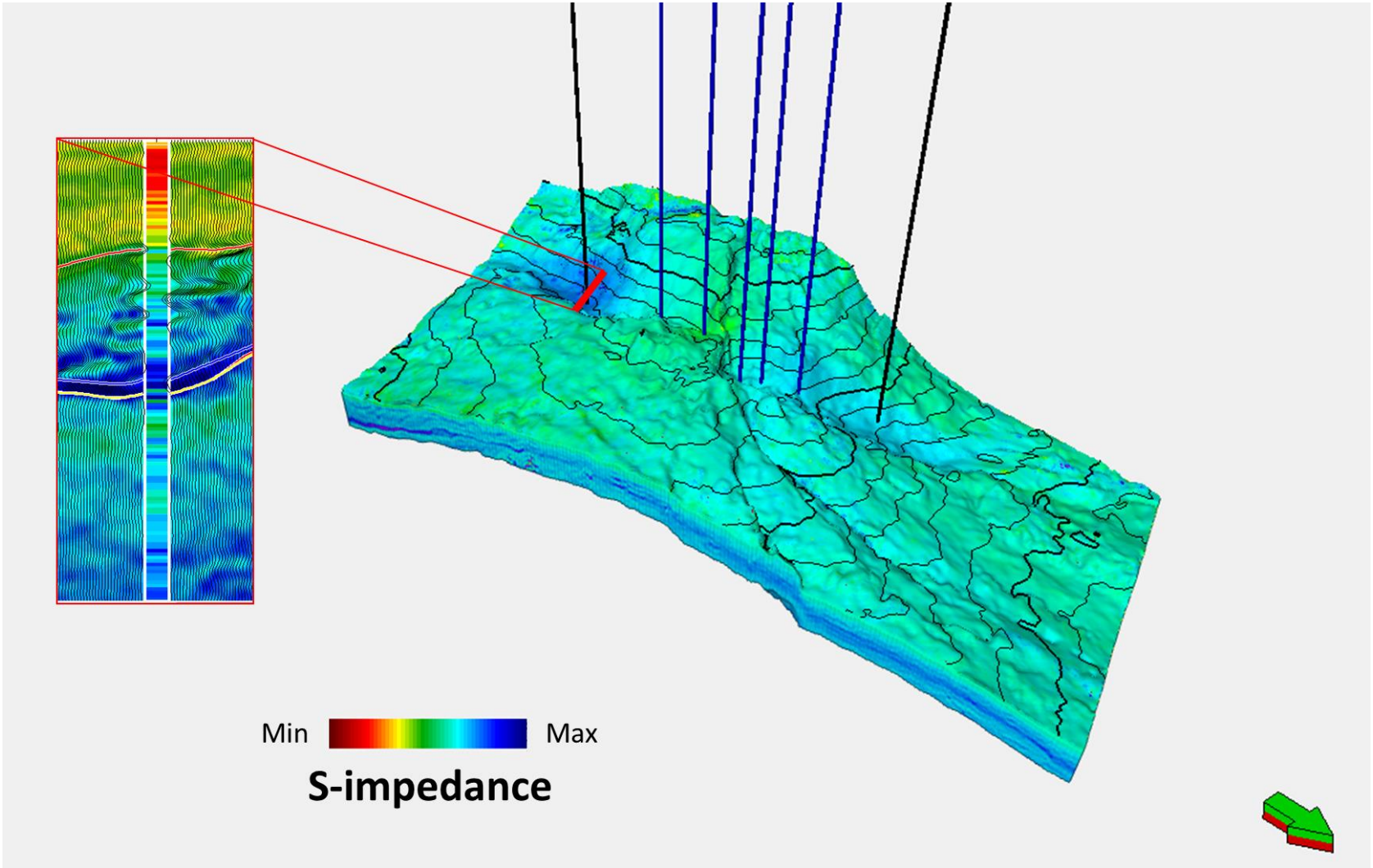
Inversion Results



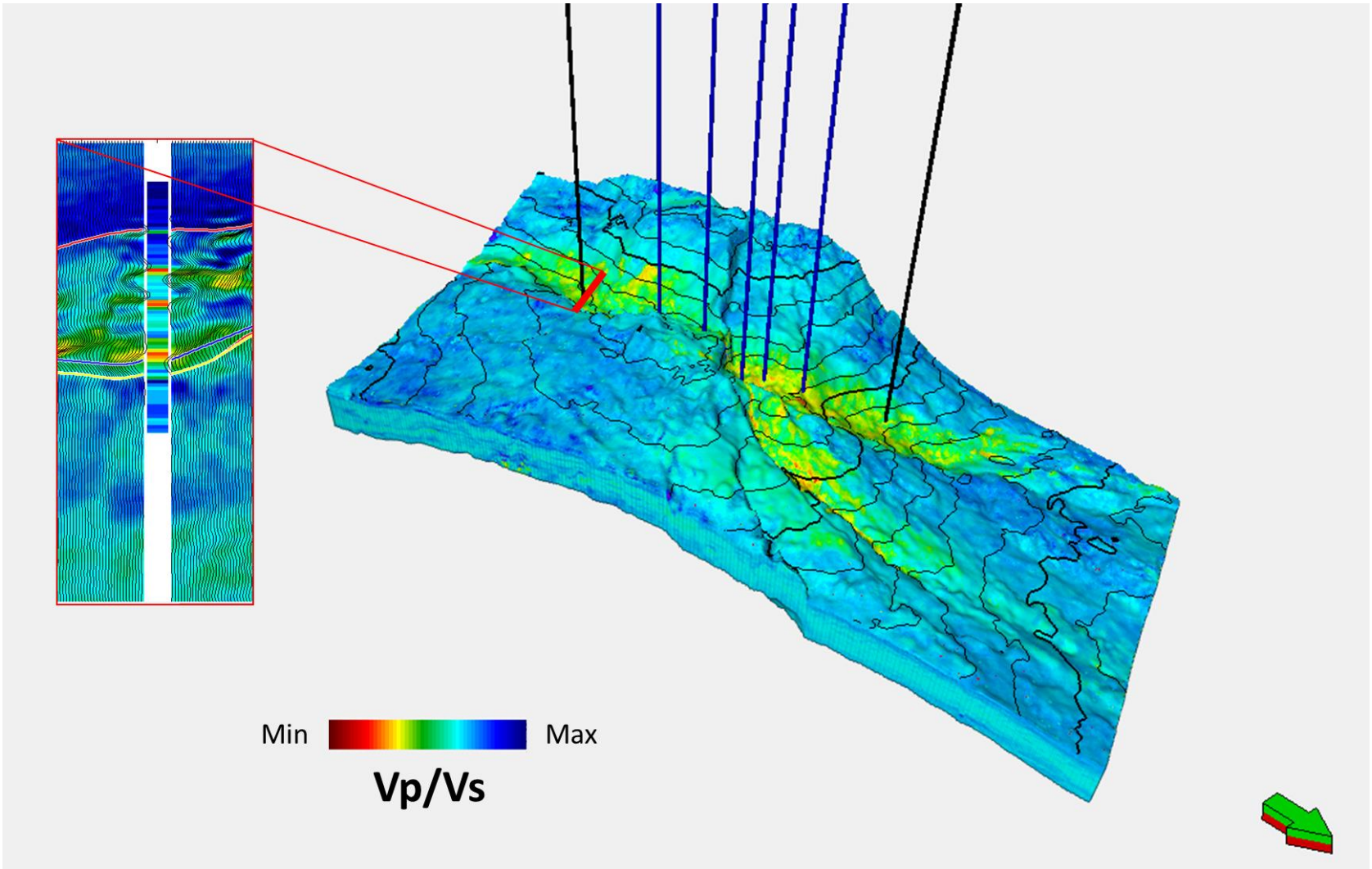
Inversion Results



Inversion Results



Inversion Results

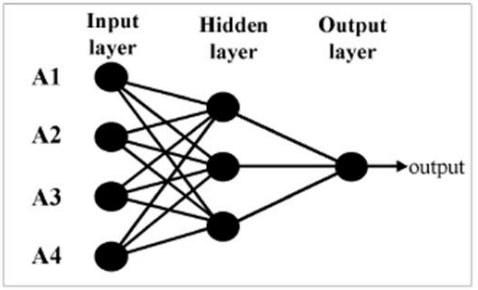


Neural Network Analysis

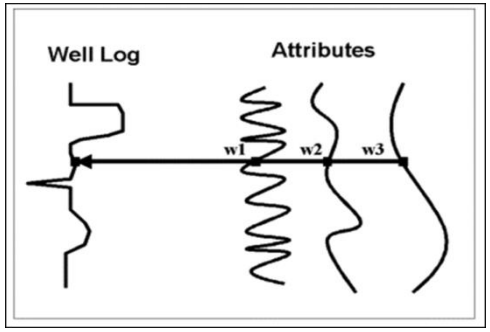
- Why we use the Neural Network method?

  - ✓ It can circumvent the general nonlinearity between seismic-log relationships and do not require a deterministic model algorithm.

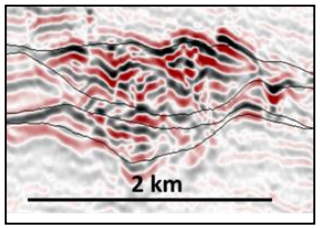
  - ✓ Using the neural-network procedure instead of pre-stack inversion mitigates some of the limitations of the inversion process. It can predict any log property, not only impedance logs.



The basic architecture of multi-layer feed-forward neural network (Hampson et al., 2001)



Neural-Network Workflow



3D Seismic

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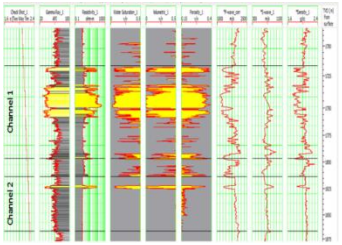
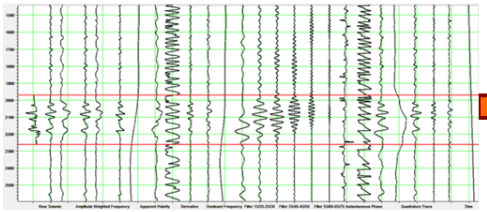
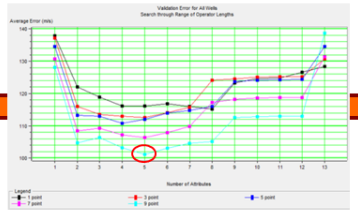


Well Logs
(Zp, Zs & Vp/Vs)

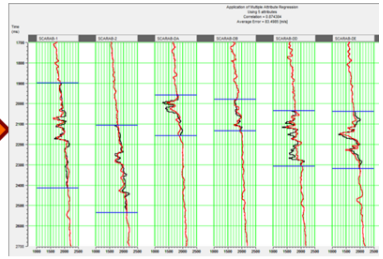
Train the Network



Target log versus seismic internal attributes

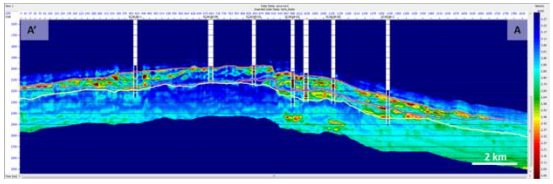


Validation error plot

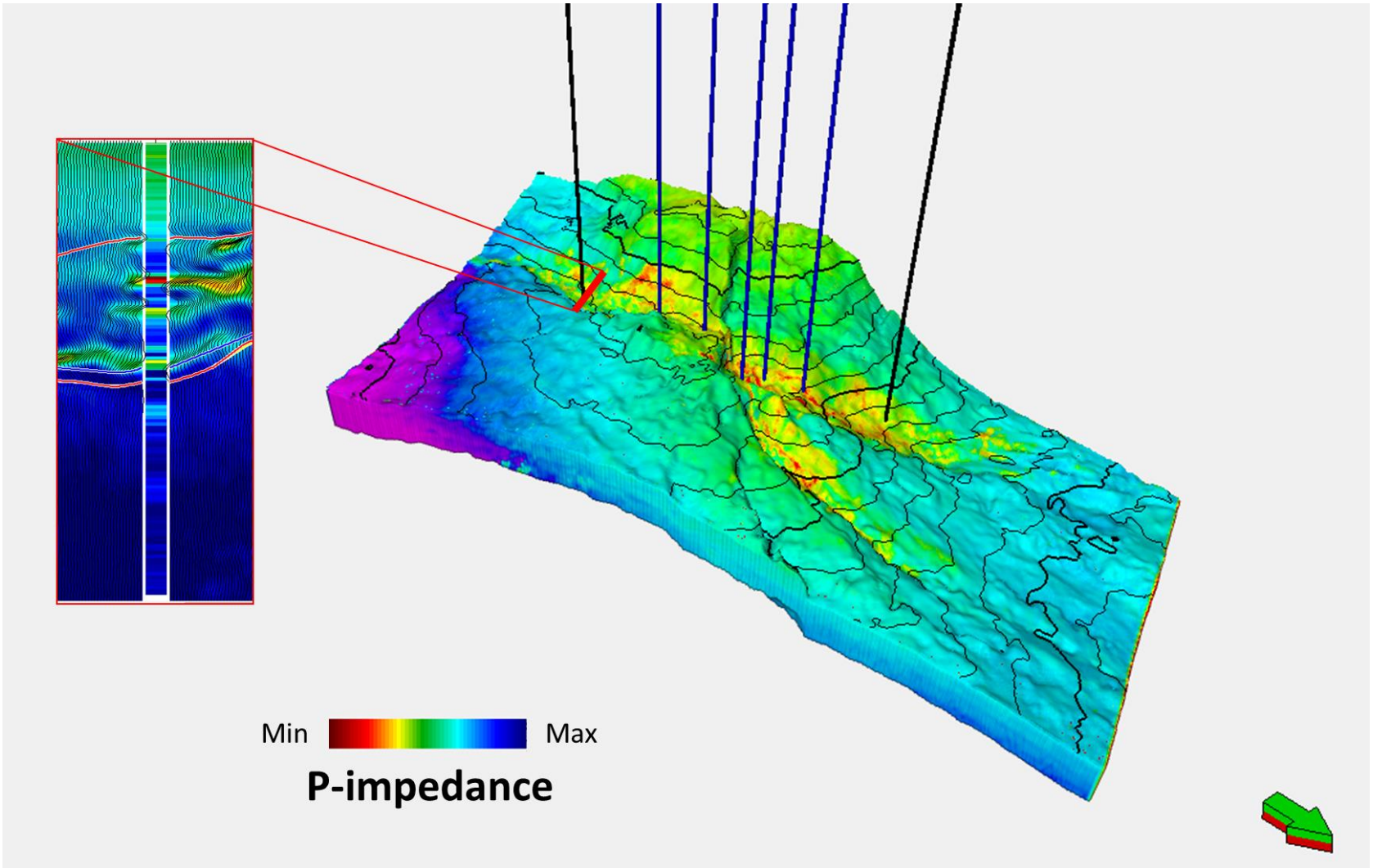


The training results of the neural network

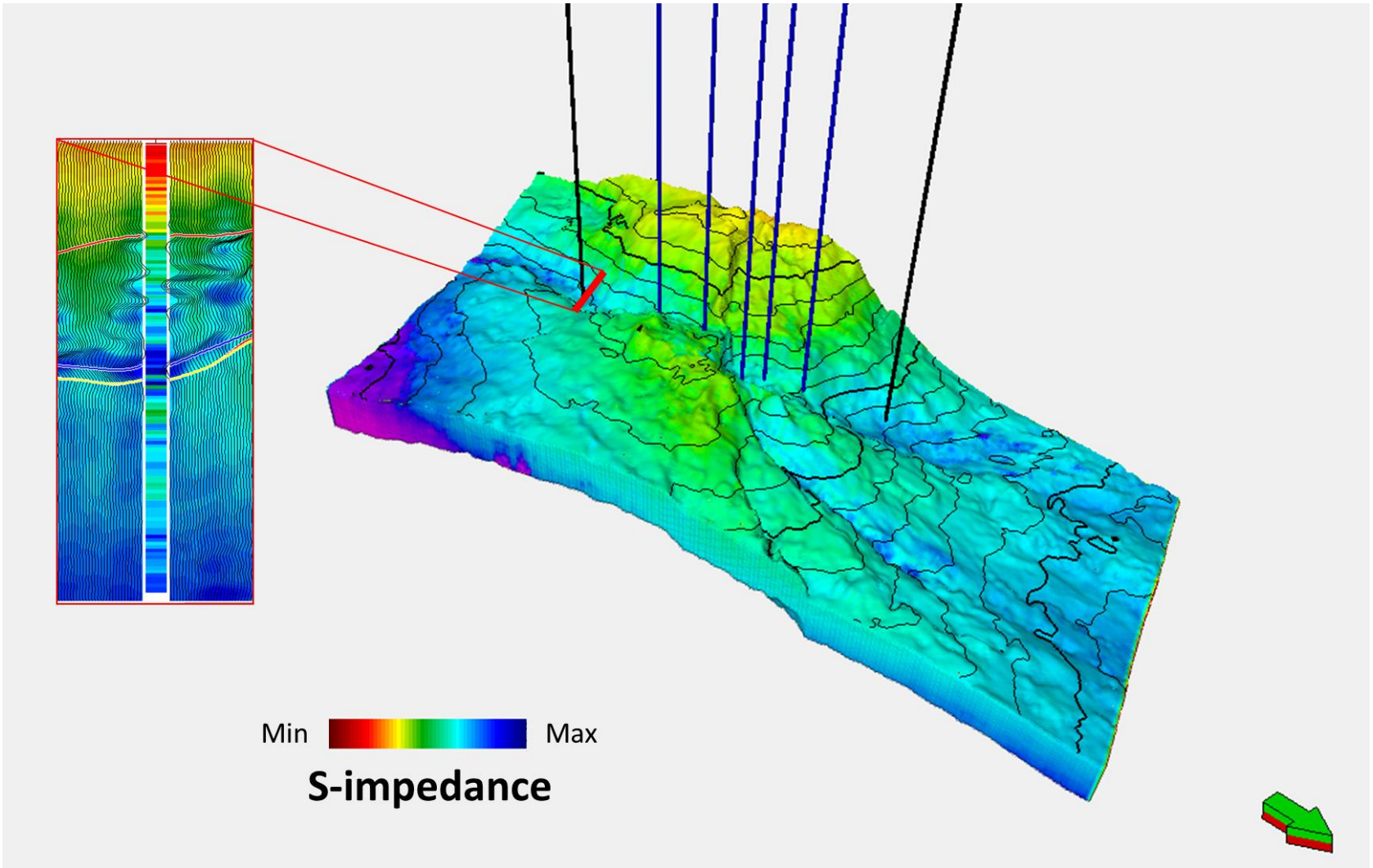
Zp, Zs, & Vp/Vs



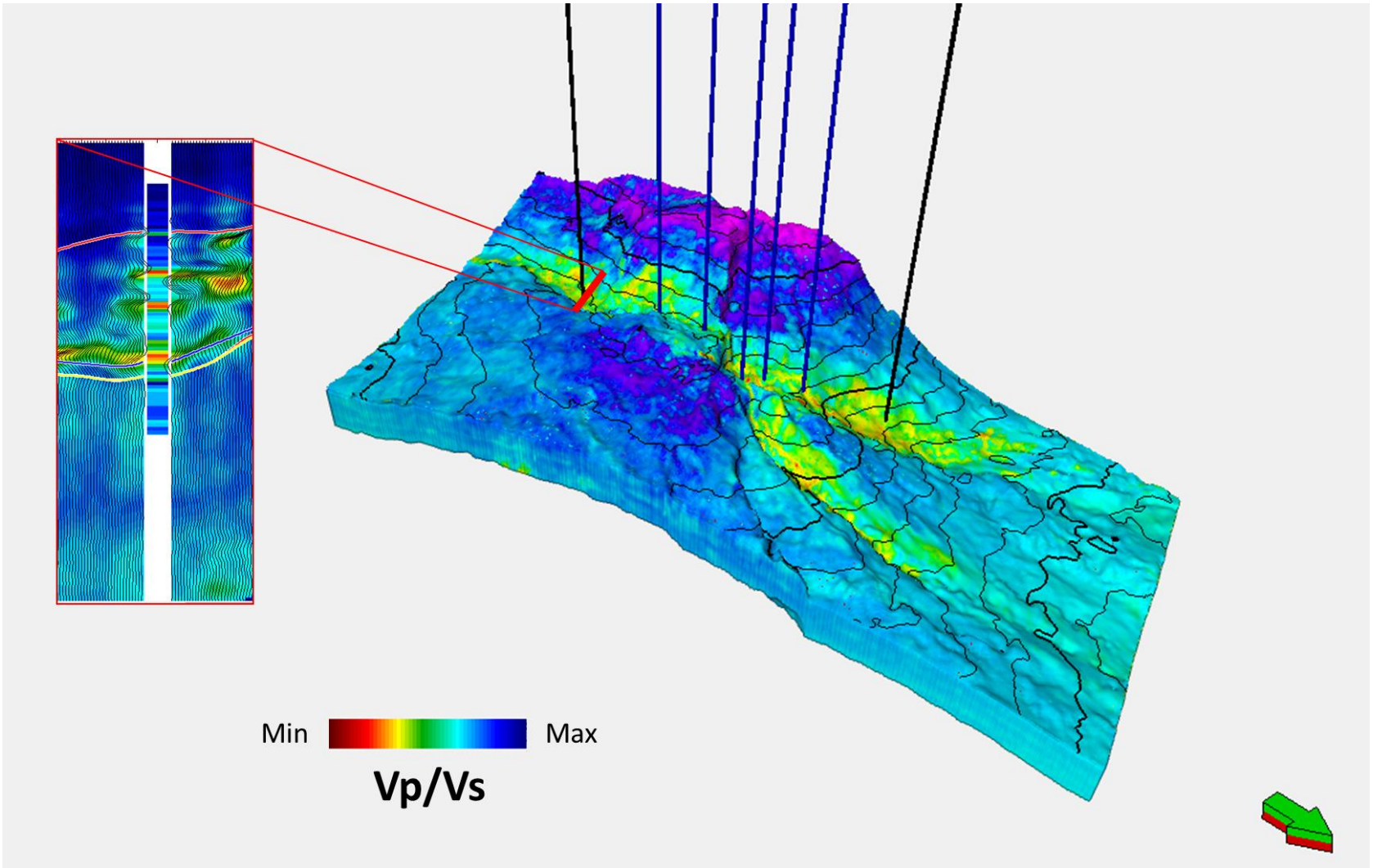
Neural-Network Results



Neural-Network Results



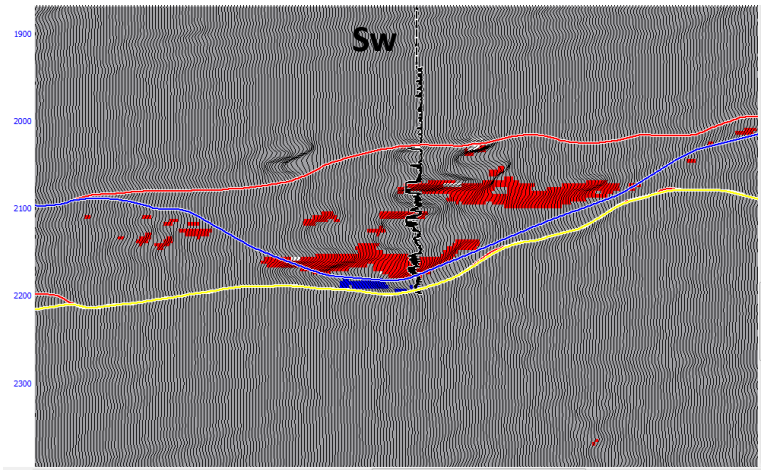
Neural-Network Results



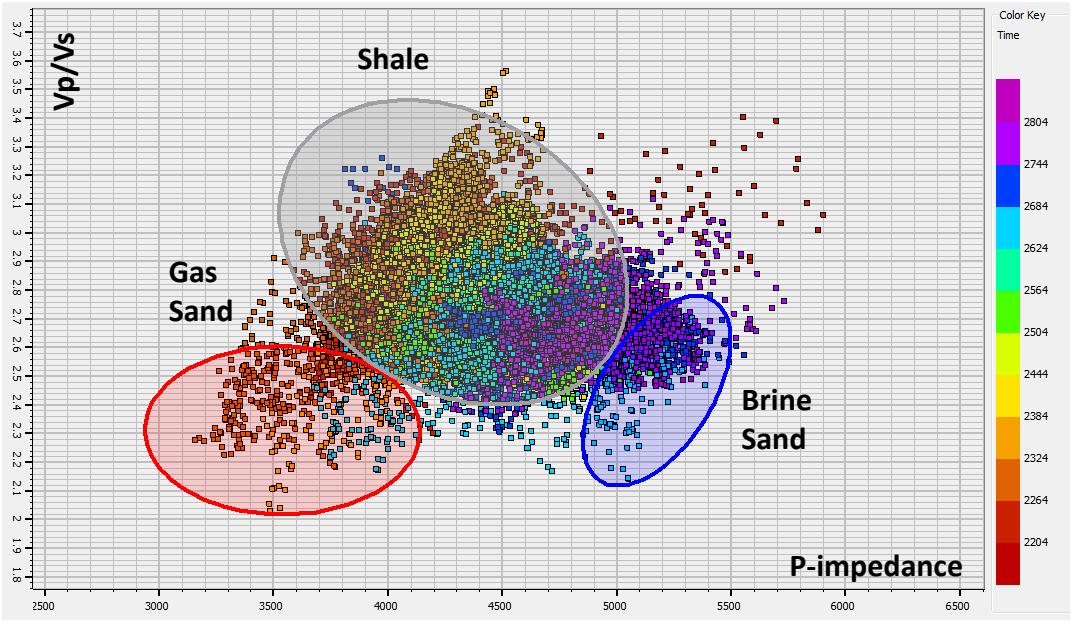
Reservoir Characterization

- Gas Sand Detection
  - We can cross-plot inverted P-impedance and Vp/Vs volumes to separates gas-bearing sands, brine sand and shale.
- Water Saturation Prediction
  - Using the neural network analysis:
  - The neural network method can be trained with calculated water-saturation logs at well locations against the seismic response, P-impedance and Vp/Vs.
  - We can take advantage of inferring nonlinear relationships between the given well logs, the seismic amplitude data, P-impedance and Vp/Vs volumes.

Reservoir Characterization

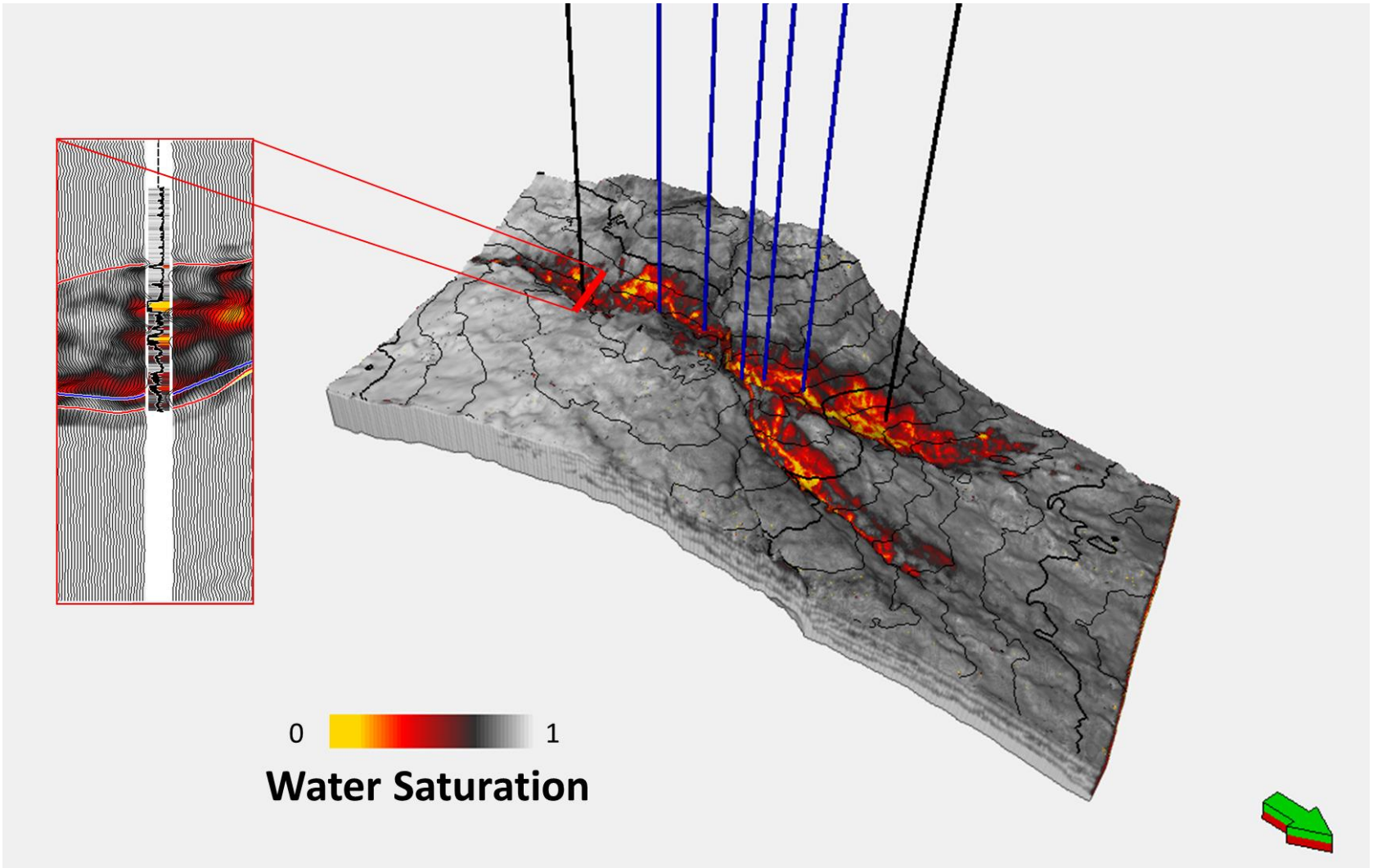


Lithology volume



P-impedance versus Vp/Vs crossplot using seismic inverted volumes

Reservoir Characterization



Conclusions

- The simultaneous pre-stack inversion is a very powerful tool to improve the seismic image and reservoir characterization especially with elastic parameters such as Vp/Vs ratio.

- The neural network analysis can provide comparable image to that obtained from pre-stack inversion and even better and a lot easier, we don't need any horizons or wavelet extractions. Conversely we can predict any log property not just the impedance logs, which effectively reduces the time and efforts.

- P-impedance and Vp/Vs inverted volumes can be used to separate different lithologies.

- The neural network analysis successfully predict Sw, this will in turn will have the ultimate effect of production enhancement and economic profitability.

Acknowledgement

- Dr. Hamed Z. El-Mowafy

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