Prediction of Porosity and Fluid Saturation from Full Stack Seismic Data Using Seismic Inversion and Neural Network Analysis*

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Abstract

Prediction of rock physical parameters such as porosity and hydrocarbon saturation is essential for exploration and development of hydrocarbon reservoirs. These parameters affect the signature of the seismic data significantly. Studying this signature is essential for seismic reservoir characterization which, in turn, opens up new opportunities in places where the qualitative interpretation is the most commonly applied techniques. This article describes the successful utilization of probabilistic neural network analysis in predicting the effective porosity and hydrocarbon saturation over the reservoir zone. The Upper Abu Roash G sandstone reservoir is of Cenomanian age in Wadi El-Rayan Field, Western Desert, Egypt. It is composed of three subunits; Estuary channel, Estuary funnel bar, and Estuary mouth bar.

Seven wells were used and full stack 3D seismic data was inverted to P-impedance. The effective porosity and water saturation logs have been converted from depth to time and sampled at the same sample rate as the seismic data. Then, the neural network analysis method was applied using full stack seismic data as an internal attribute while P-impedance and RMS Velocity cubes as external attributes in order to generate 3D porosity and Water saturation volumes over the reservoir zone. The Correlation coefficients, for the blind well, between the predicted and measured porosities and water saturation following that the probabilistic neural network show correlation of 0.95 and 0.97 respectively. A high effective porosity and hydrocarbon

saturation values are located to the west of the main producing field and were interpreted to be a possible reservoir. The results suggest that the combination of post-stack seismic inversion and PNN can be applied effectively to estimate reservoir properties.

Selected References

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* presenter

Objectives

- Overcome the limitation of the 3D data in the study area and maximize its benefits.
- Go further beyond the seismic reflector to estimate the effective porosity; hence, the quality of the reservoir.
- Predict Fluid saturation of the reservoir.
- Provide a guidance and participatein reservoir characterization to identify reservoir properties and contribute to facies modelling.

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2. Methodology
   a) Seismic Inversion
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3. Results
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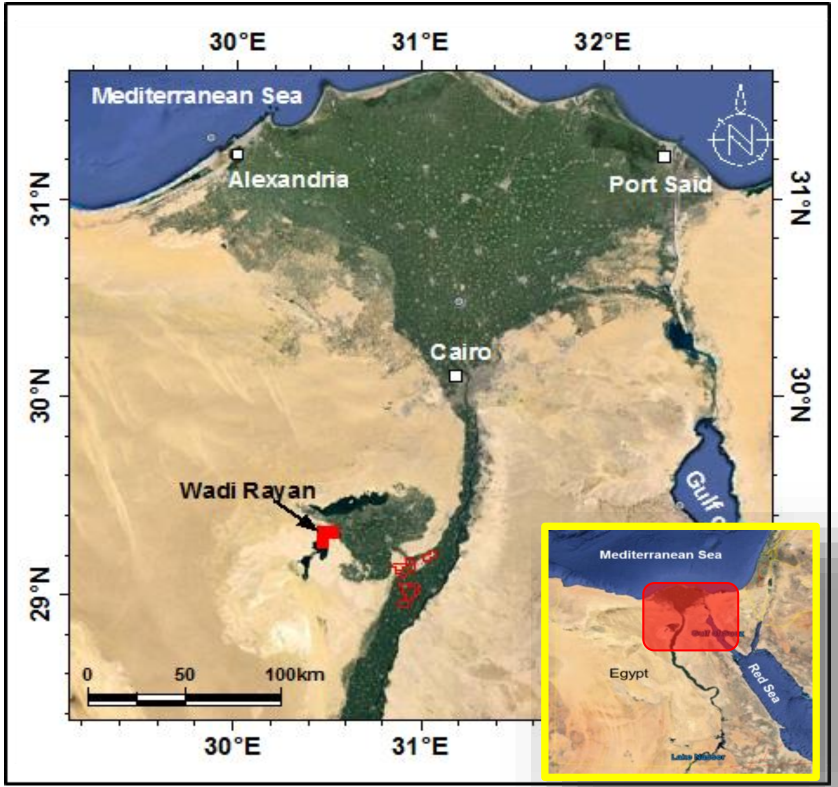
Area of Study

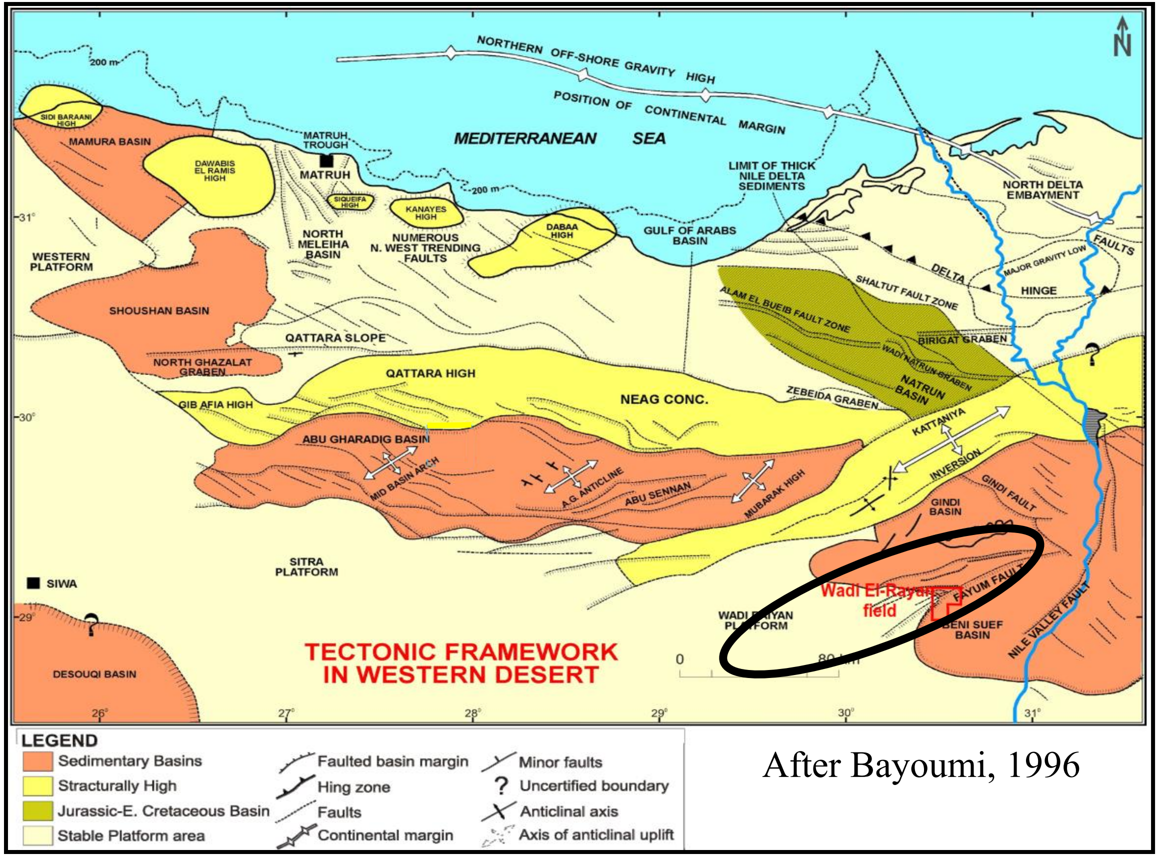
- Western Desert.
- 115 Km Southwest Cairo.
- ≈ 50 Km^2.
- Elevation: -11 to +64 meters (sea level).
- Discovered in 1996
- Reservoir: ARG-5 (Late Cenomanian)
- 26 API



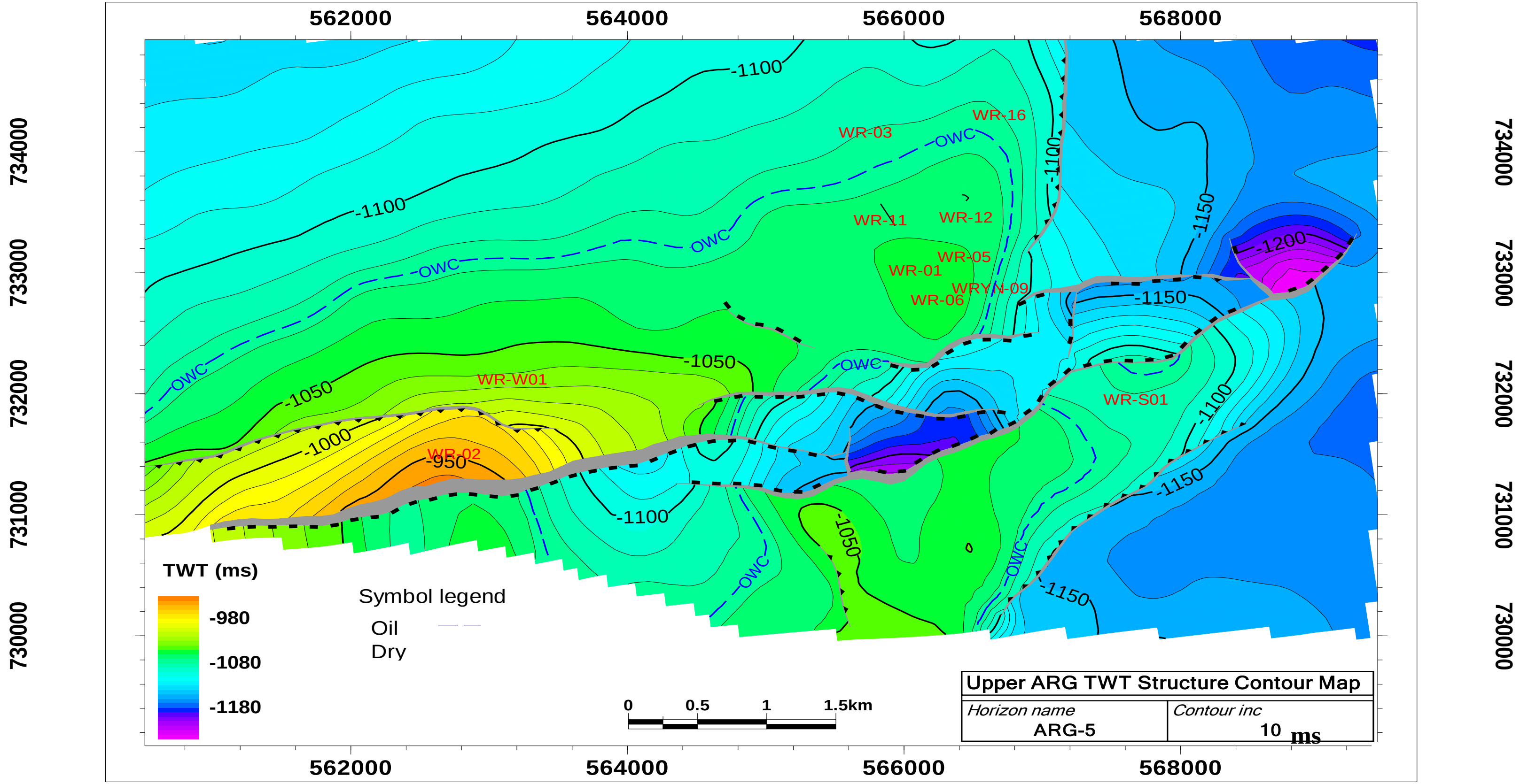
Index map showing the location of the Wadi Rayan Field in the Western Desert, Egypt.

Tectonic Framework

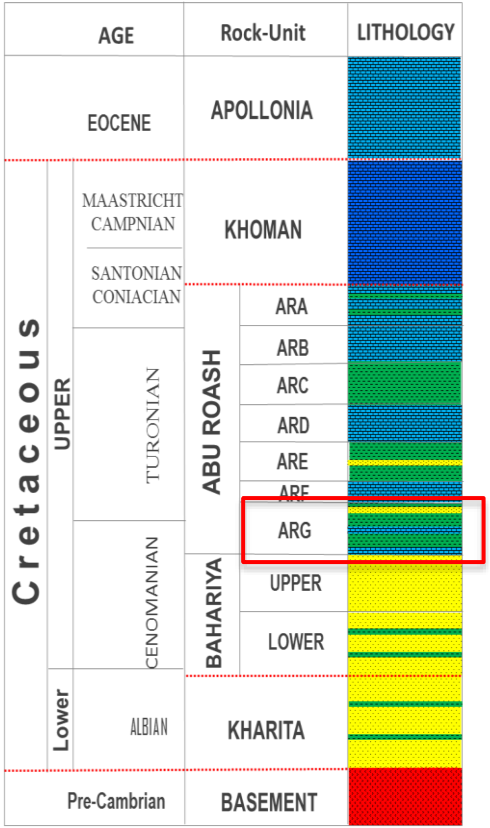
- It is located in a platform area between two major sedimentary basins which are Eocene age Gindi basin to the North and Albian age Beni Suef basin to the South East.



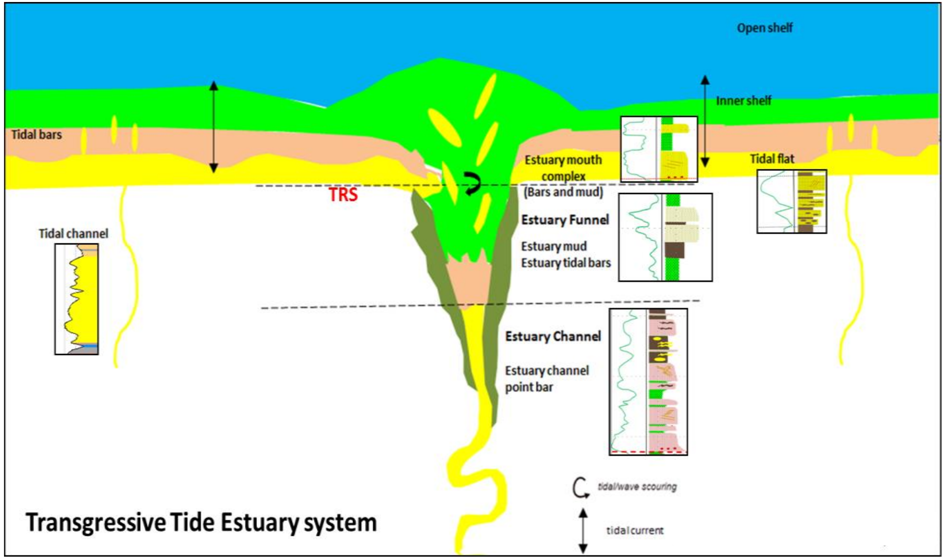
After Bayoumi, 1996



TWT structure contour Map for upper ARG



Wadi El-Rayan Stratigraphic column



Wadi El-Rayan simplified model.

Hasan, 2016

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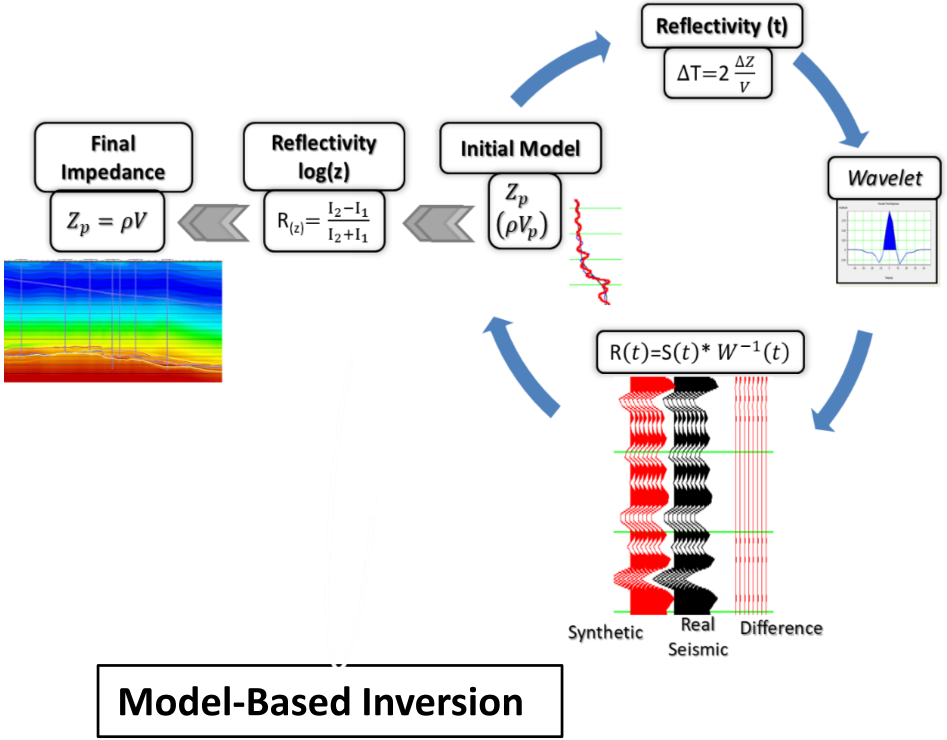
2. Methodology

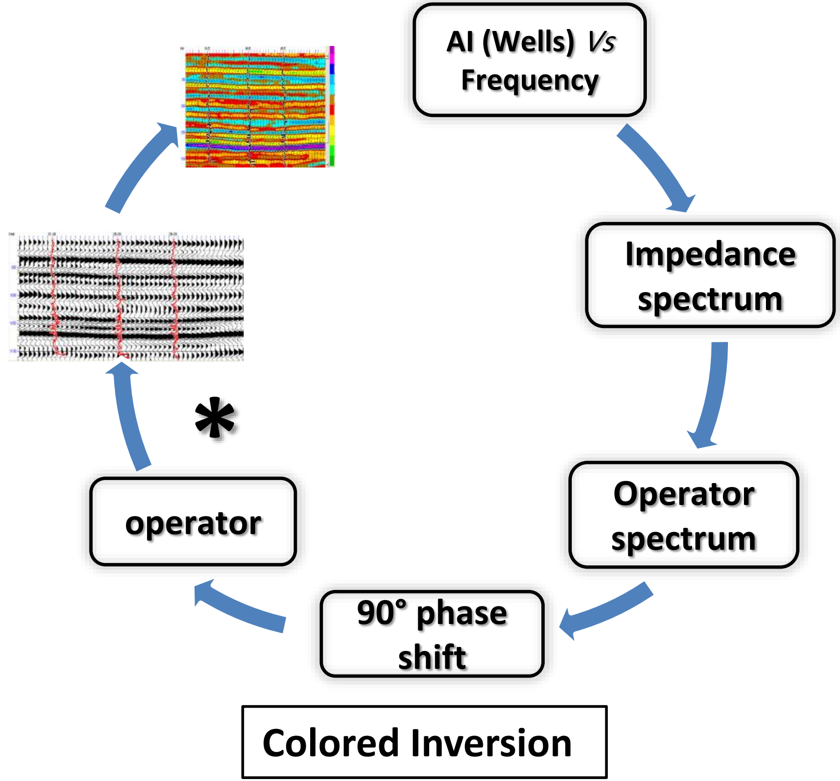
a) Seismic Inversion

Why we used seismic inversion in the study area?

- AI is closely related to lithology, porosity, pore fill, and other factors.
- Inversion increases the resolution of conventional seismic data and in many cases puts the study of reservoir parameters at a higher level (Veekan and Silva, 2004).

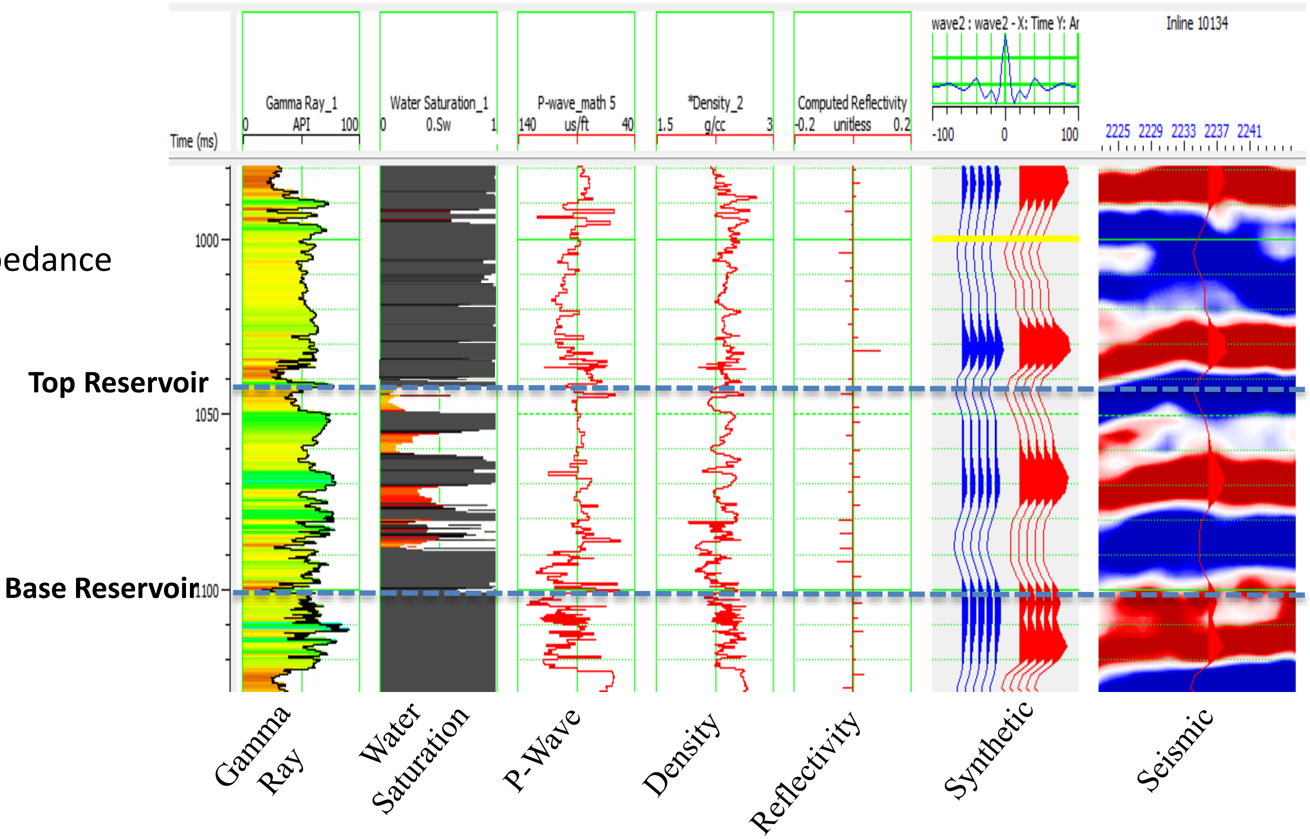
Inversion Workflows





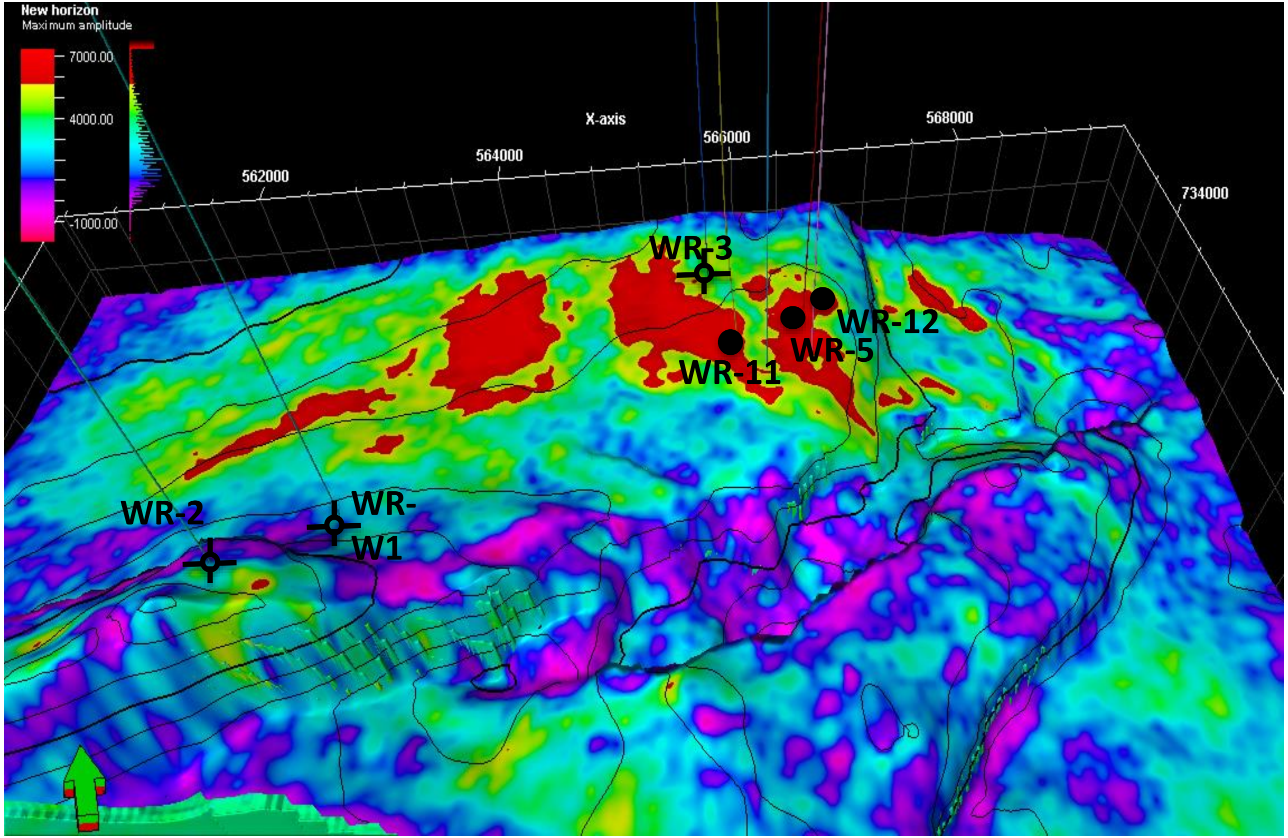
WR-1

- Thickness up to 100 ft.
- Average porosity 20-24%
- The increase in acoustic impedance denoted by a peak.



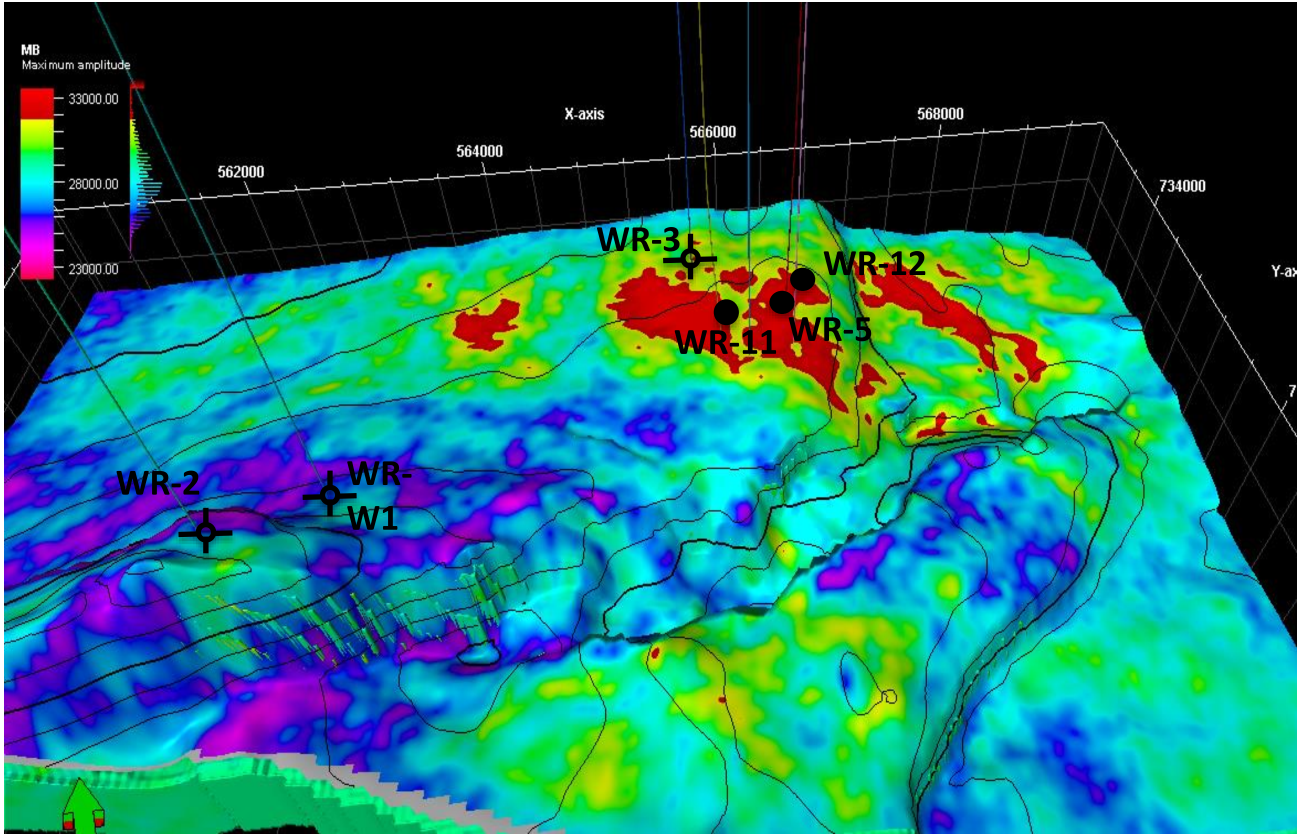
Inversion Results

- Relative P-Impedance slice (Maximum amplitude) on ARG-5 +30 ms window, overlaid by TWT contours.



Inversion Results

P-Impedance slice (Maximum amplitude) on ARG-5 +30 ms window, overlaid by TWT contours



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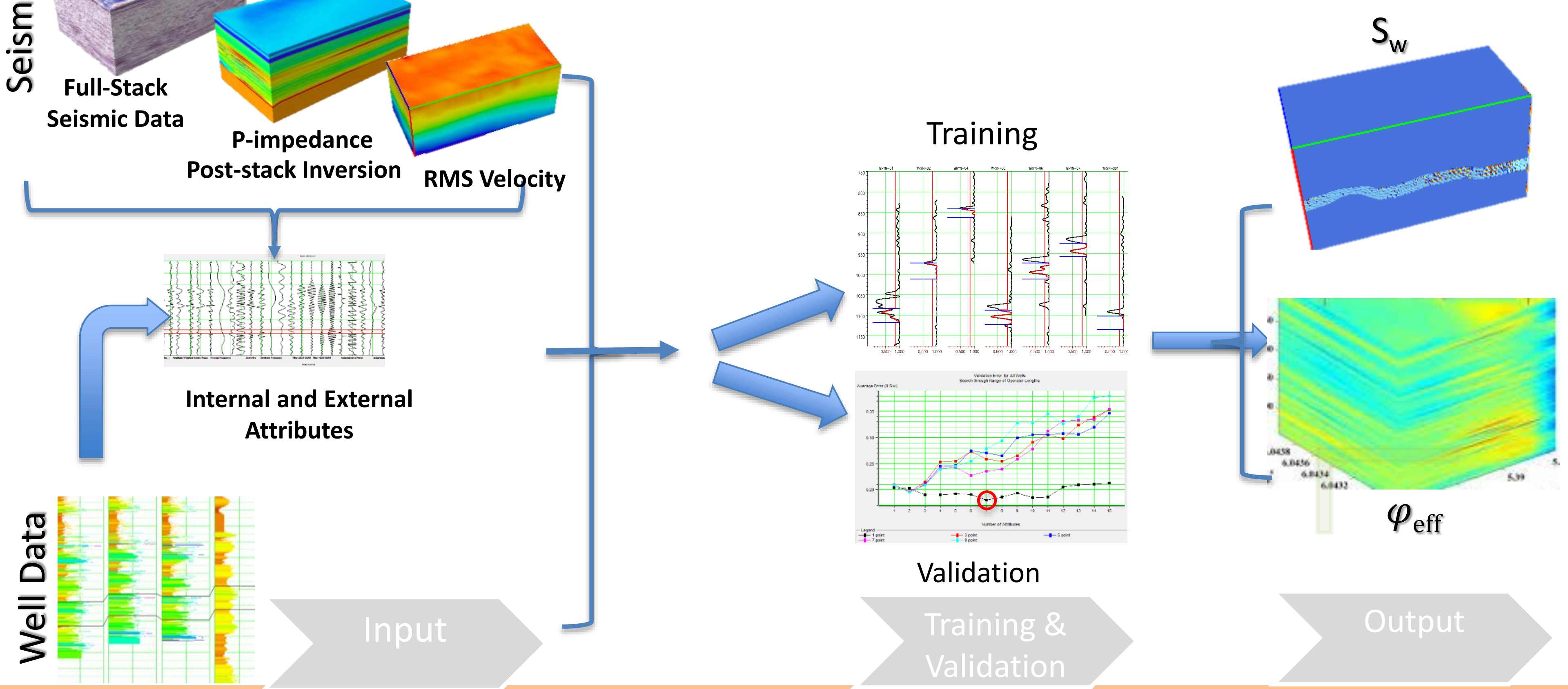
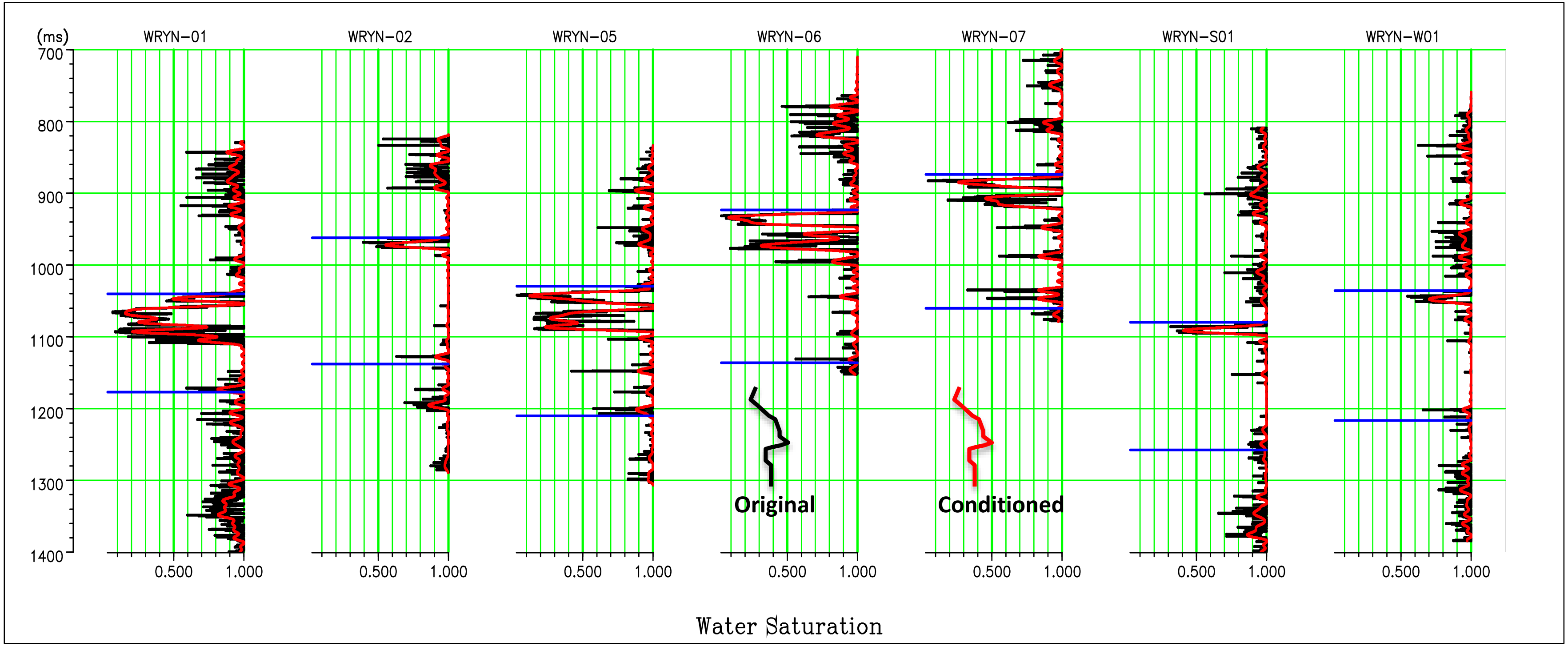
PNN Workflow

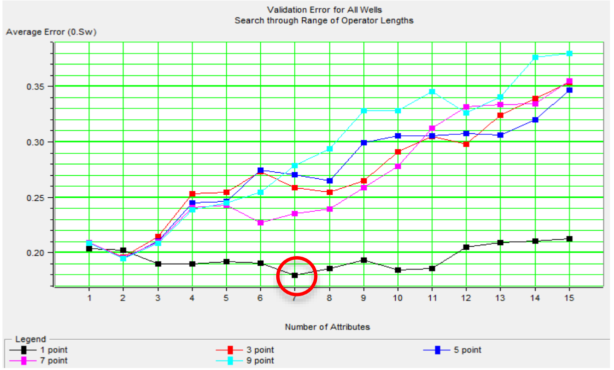


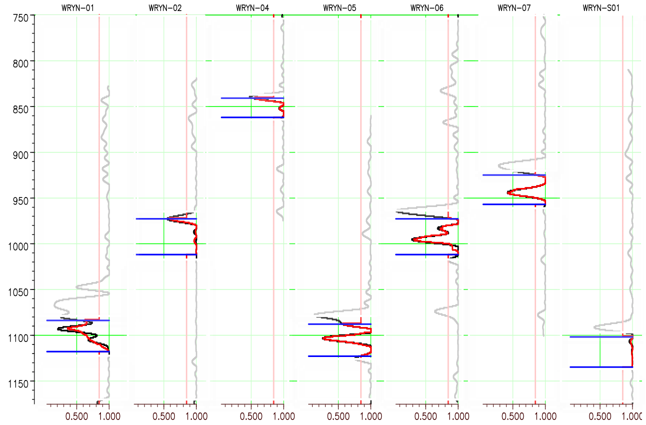
Well log Data Conditioning

- Resampled @ 4ms



PNN Training and validation (water saturation)

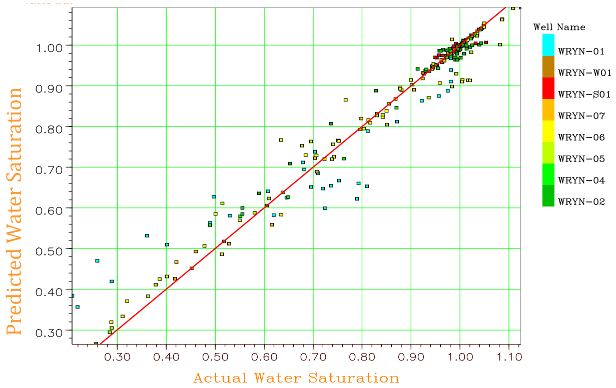




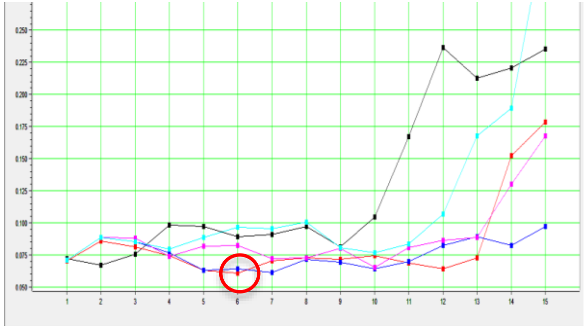
Training Correlation Coefficient: 0.97

	Target	Final Attribute	Training Error	Validation Error
1	Water Saturation	Y-Coordinate	0.193840	0.203828
2	Water Saturation	Derivative	0.187483	0.202296
3	Water Saturation	Colored inversion	0.177482	0.189594
4	Water Saturation	Filter 35/40-45/50	0.173655	0.189729
5	Water Saturation	Amplitude Weighted Frequency	0.170982	0.191694
6	Water Saturation	Integrate	0.166184	0.190562
7	Water Saturation	Dominant Frequency	0.161441	0.179242
8	Water Saturation	Quadrature Trace	0.159458	0.185626
9	Water Saturation	Filter 25/30-35/40	0.155191	0.192957
10	Water Saturation	Time	0.152968	0.184593
11	Water Saturation	Derivative Instantaneous Amplitude	0.150503	0.185834
12	Water Saturation	Filter 45/50-55/60	0.148507	0.205141
13	Water Saturation	Cosine Instantaneous Phase	0.147787	0.209000
14	Water Saturation	Instantaneous Phase	0.147460	0.210642
15	Water Saturation	Amplitude Weighted Phase	0.146993	0.212315

The lowest error at:
7 attributes with
1-point operator

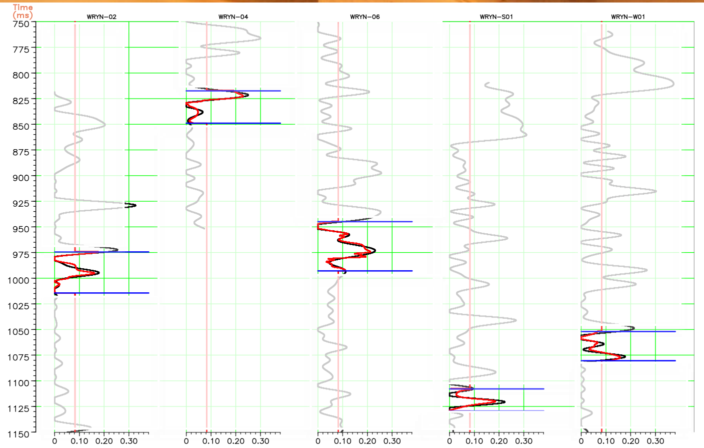


PNN Training and validation (porosity)

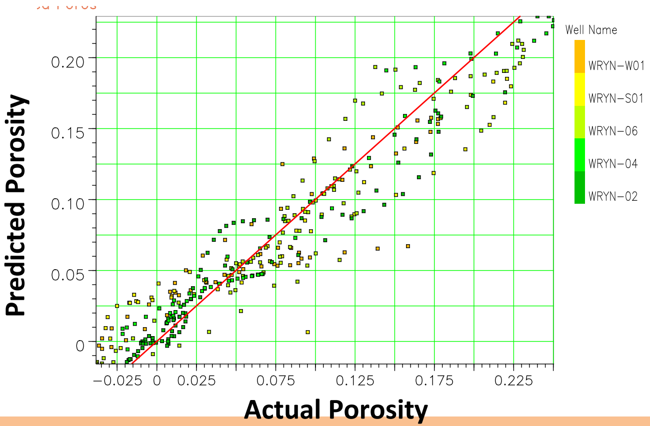


	Target	Final Attribute	Training Error	Validation Error
1	Porosity	Filter 15/20-25/30	0.065853	0.070531
2	Porosity	Derivative Instantaneous Amplitude	0.060192	0.085481
3	Porosity	Cosine Instantaneous Phase	0.055913	0.081313
4	Porosity	Filter 25/30-35/40	0.049203	0.074320
[illegible]	Porosity	Second Derivative	[illegible]	[illegible]
6	Porosity	Instantaneous Frequency	0.043183	0.060608
7	Porosity	Filter 55/60-65/70	0.041792	0.070293
8	Porosity	Instantaneous Phase	0.040600	0.072739
9	Porosity	(Colored Inversion)**2	0.039414	0.071748
10	Porosity	Filter 35/40-45/50	0.037266	0.074435
11	Porosity	Filter 5/10-15/20	0.034699	0.068634
12	Porosity	Second Derivative Instantaneous Amplitude	0.034032	0.064022
13	Porosity	1 / (Velocity)	0.033278	0.072541
14	Porosity	Integrated Absolute Amplitude	0.032959	0.152342
15	Porosity	Dominant Frequency	0.032623	0.178689

The lowest error at:
6 attributes with
3-point operator



Training correlation Coefficient: 0.95



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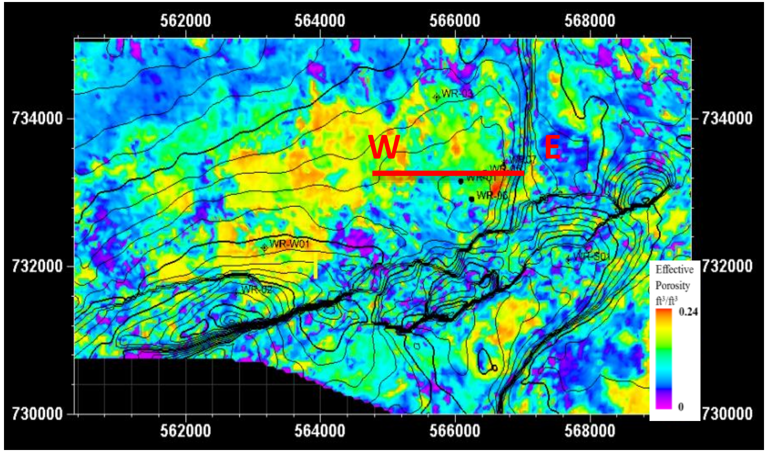
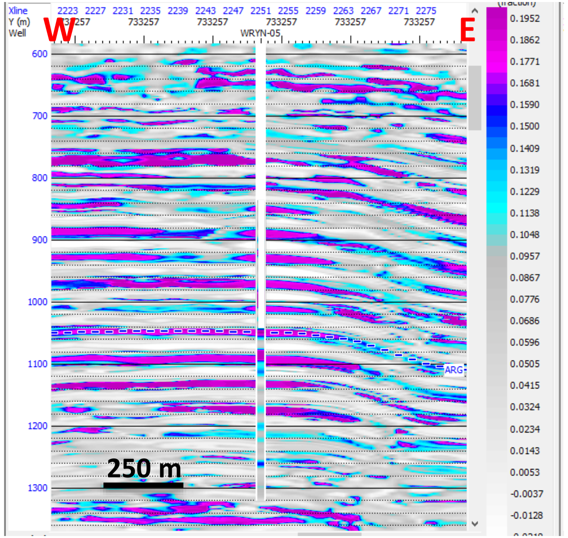
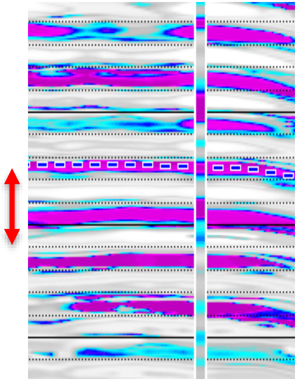
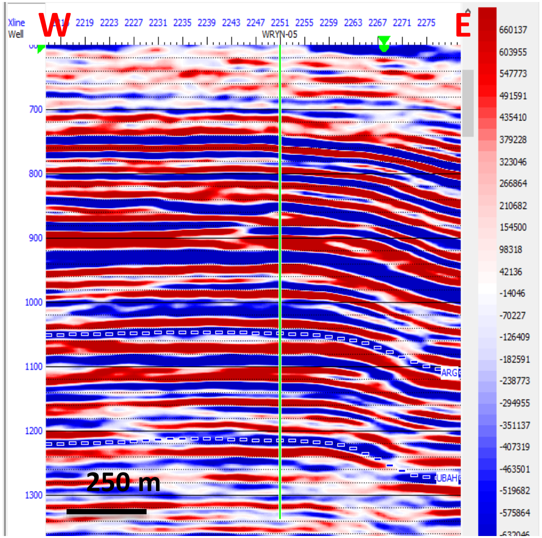
PNN Results- WR-5 well location





Reservoir Zone





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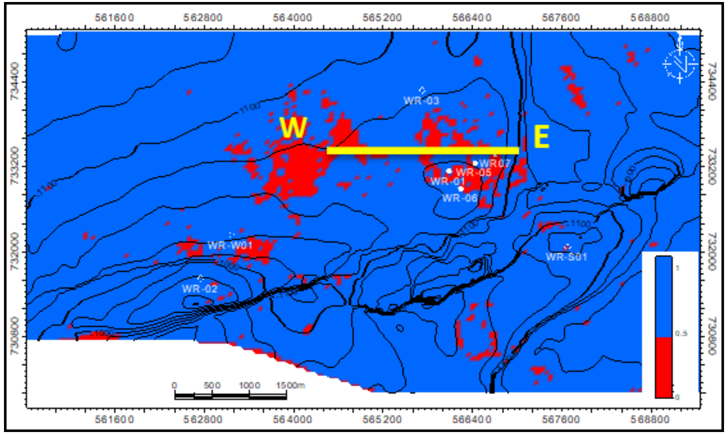
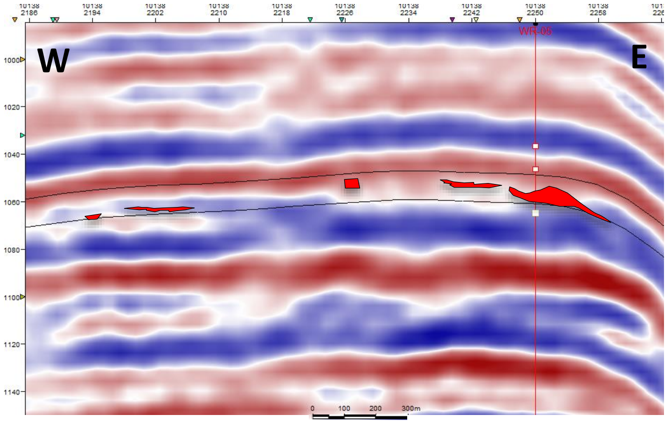
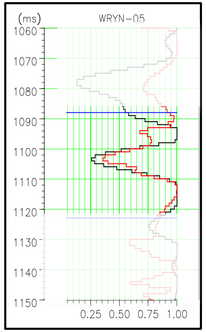
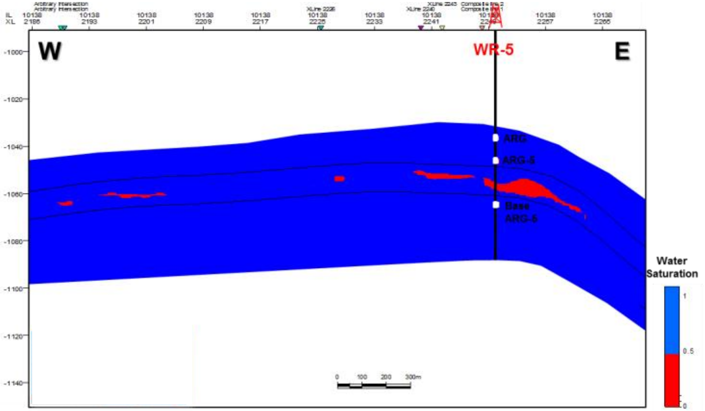


WR-5





Water Saturation



Conclusion

1. The main challenge was to overcome the obstacles and limitation of the seismic data in the study area and extract additional geological information about the subsurface.
2. In clastic reservoirs, where there is heterogeneity, by integrating Seismic Inversion with PNN we could produce 3D porosity and water saturation Volumes.
3. Based on the results of seismic inversion and neural Network analysis, an anomaly has been delineated to the west of the main field which could contain a potential hydrocarbon.

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QPC

EGPC

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