Integrated Workflow for the Reservoir Properties Prediction using the Ultra-Far Seismic Data, Mansoura Area, Onshore Nile Delta, Egypt*

Walaa Fathy[1] and Asghar Shams[1]

Search and Discovery Article #42325 (2019)**
Posted February 25, 2019

*Adapted from oral presentation given at the GEO 2018 13th Middle East Geosciences Conference and Exhibition, Manama, Bahrain, March 5-8, 2018
 DOI:10.1306/42325Fathy2019

[1]Heriot Watt University, Edinburgh, United Kingdom (wmf1@hw.ac.uk)

Abstract

The onshore Nile delta middle and late Miocene are dominated by siliciclastic sediments of variant reservoir quality; this allows researchers to introduce different techniques to predict reservoir properties, which aids in promoting areas with good reservoir quality. In this paper, we used AVO simultaneous inversion with ultra-far seismic data. The selection of ultra-far seismic data was to demonstrate the reliability of ultra-far data (reaching 45°) and to increase the accuracy of fluid delineation, with the additional benefit of the density cube resulted from this type of inversion. The ultra-far data was an output from the gathers conditioning processes, which was applied to the whole CDP gathers for the area of study. A proper rock physics analysis using well logs in the area of study showed good potential to link the elastic properties to the reservoir properties and suggests that the AVO simultaneous inversion can easily discriminate between different lithological units and fluid types. By applying the results in the unexplored areas within the area of study, this can help in di-risking delineated prospects. The AVO simultaneous inversion was applied for the different angle stacks (near, mid, far and ultra-far) seismic data using the statistically extracted wavelet from each corresponding partial angle stack. The reservoir properties prediction was done using multi attribute analysis, which helped in increasing the predictive power between well locations using the inverted ultra-far seismic data, furthermore, to ensure a good correlation with the well logs. The well logs petrophysical analysis helped significantly in building up a representative rock physics model within the area of study. The developed model was later used to differentiate between wet sand, shale and gas sands. The prediction results showed a robust conformity between the structure, amplitude, and the different reservoir properties such as porosity, and water saturation, additionally, the predicted results indicated excellent match with well

data in terms of the range of reservoir properties within the reservoir, as well as outside the reservoir. The inverted density volume generated from AVO simultaneous inversion of the ultra-far seismic data used in the discrimination between low gas saturation, and the commercial gas; furthermore, it can be used to delineate new drillable locations that have a possible good reservoir quality.

GEO 2018
13th Middle East Geosciences Conference and Exhibition

CONFERENCE: 5 – 8 March 2018
EXHIBITION: 6 – 8 March 2018
BAHRAIN INTERNATIONAL EXHIBITION & CONVENTION CENTRE

Integrated Workflow For The Reservoir Properties Prediction Using The Ultra-far Seismic Data, Mansoura Area, Onshore Nile Delta, Egypt

W. Fathy & A. Shams, Heriot Watt University

HERIOT WATT UNIVERSITY

EGPC

petroceltic

Content

Presenter's notes: The content of my presentation today is introduction (giving highlights to the location and the geology of the area of study). Generally, building up rock physics model can play an important role in linking the elastic properties to the reservoir properties, and in the study area, it helps in understanding the key factors that affect the seismic amplitude, and using the log data can get a lithology and fluid discrimination. The work flow used in the gathers conditioning and the impact of this conditioning on the quality of the gathers and how we can rely on the ultra-far data (45-47) degrees. AVA analysis what we have done to monitor the AVA response in the study area (and is it proven or not?). Then, we 1) build rock physics (*Presenter's notes continued on next slide*)

(*Presenter's notes continued from previous slide*)

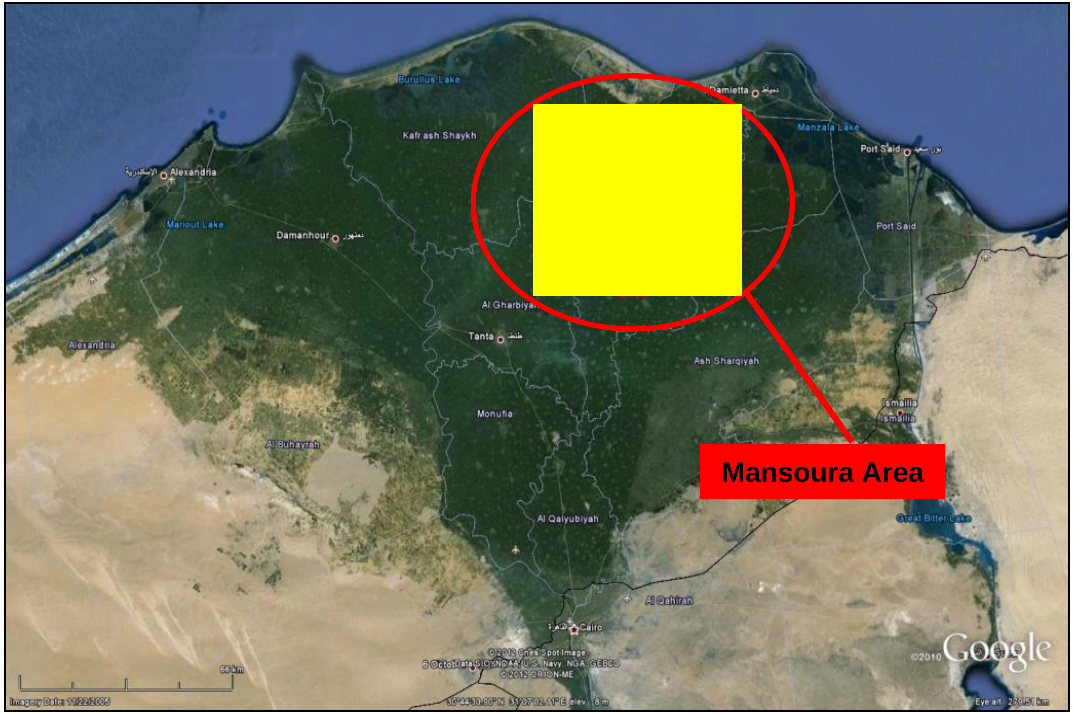
for the area of study showing the possibility of lithology and fluid discrimination using the log data, 2) perform the gathers conditioning, and 3) monitor the AVA response in the study area. We decided to apply AVO simultaneous inversion and we will see how it has validated the rock physics model, or in other words how the rock physics model constraints the seismic inversion. In addition to, how we get benefits from the ultra-far stacked data in terms of reservoir definition especially in the density and Vp/Vs cubes.

Introduction

- The Nile is the source of life for the Egyptians for all of recorded history.
- The Nile Delta is considered as the most significant gas province in Egypt.
- 200-300 TCF of undiscovered gas reserves in the Nile Delta prolific province, located in the Eastern Mediterranean region. (1-AAPG)

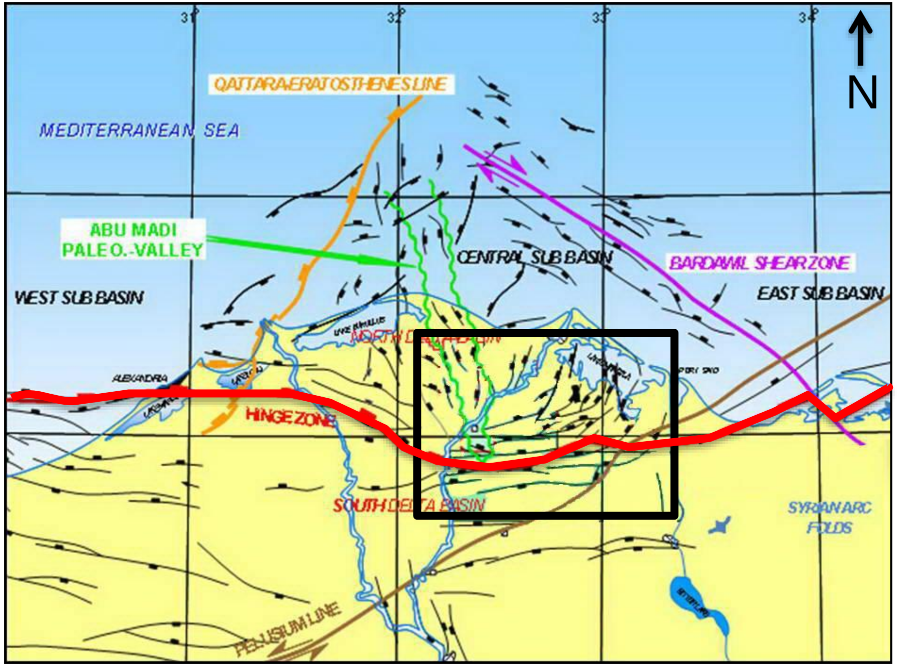
Introduction

- The area of study (Mansoura Area) is located in Northern Egypt 150 km NE of Cairo on the Eastern side of the onshore Nile Delta.

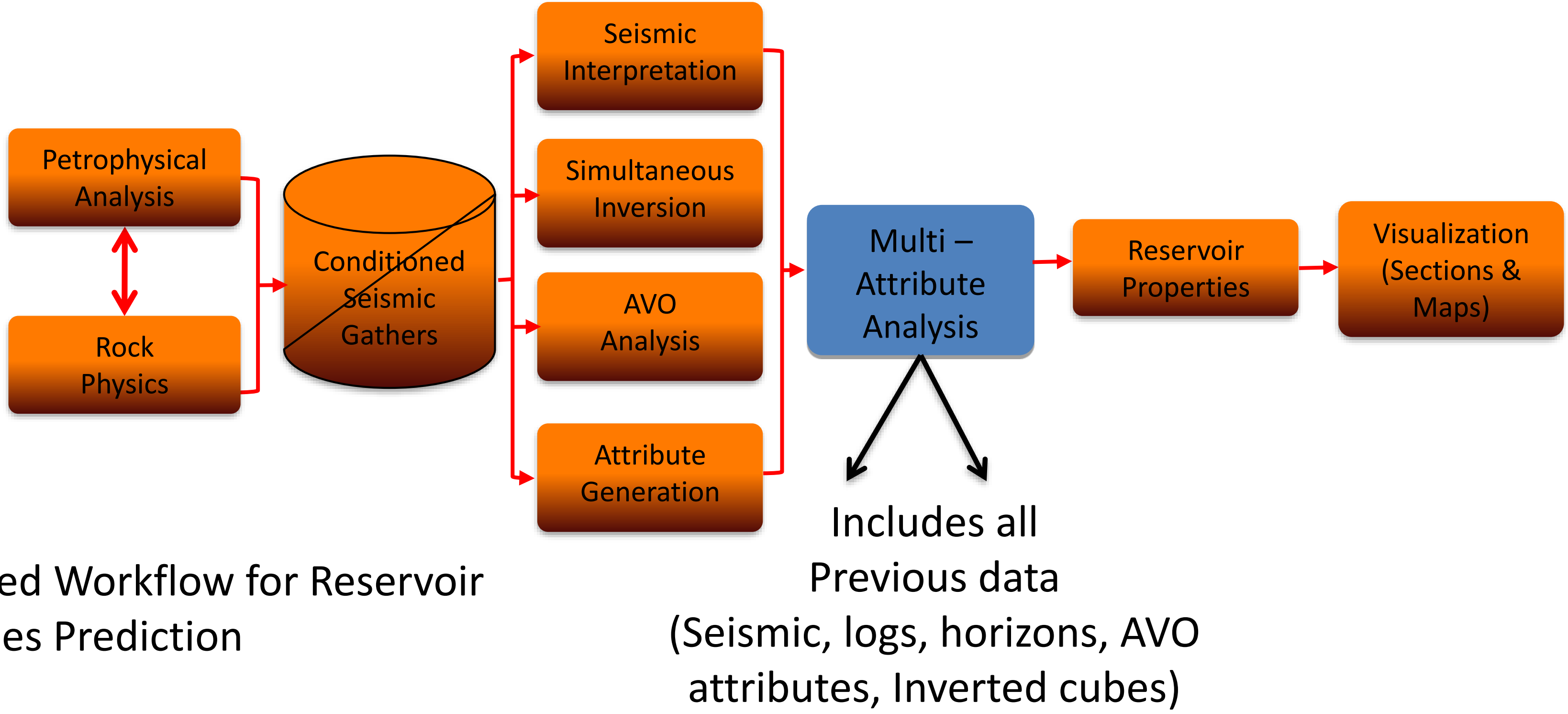


Introduction

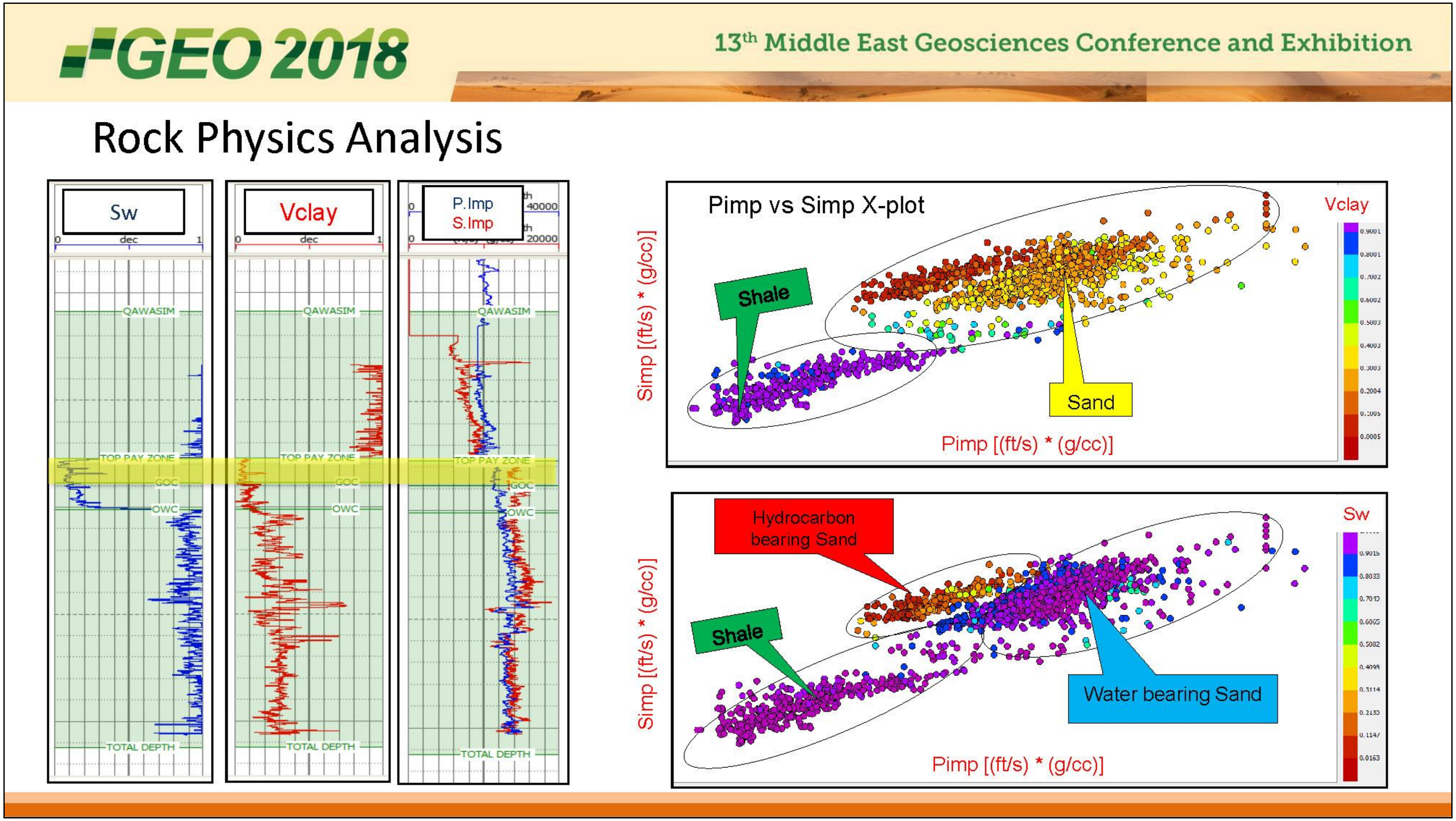
- Geologically, the area lies to the north and south of the Nile Delta hinge Zone and contains a thick sequence of Tertiary deltaic sediments from Oligocene to Recent age overlying older Mesozoic sequences.
- The operating company had acquired 3420 km^2 3D seismic data.



Introduction



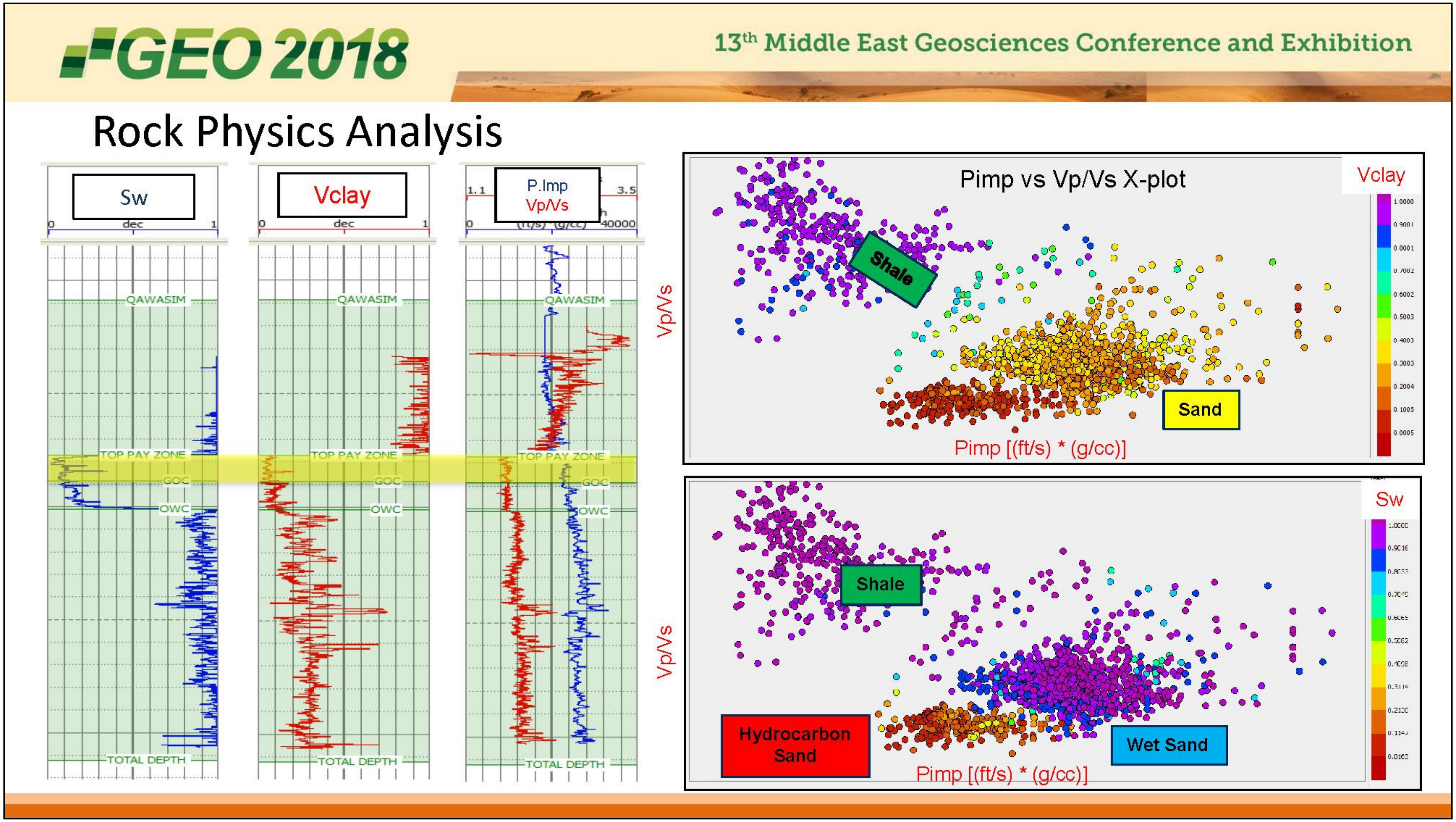
Integrated Workflow for Reservoir Properties Prediction



Presenter's notes: The logs used in this x-plot are Sw and Vcl which have been resulted from the petrophysical interpretation, p-imp and s-imp logs have calculated for the density and velocity logs recorded from the well. Here we have p-imp versus s-imp x-plot in which pimp plotted on the x-axis and s-imp plotted on the y-axis and the x-plot colored by the Vcl log ranging from 0 which is represented by the red color and 1 which is represented by the purple color. We can see a clear discrimination between the sand and shale. Sand is characterized by higher S and P-impedance than shale. (*Presenter's notes continued on next slide*)

(*Presenter's notes continued from previous slide*)

We used the same x-plot but colored this time with the Sw log in which the log ranging from 0 representing the red color and 1which is represented by the purple color. We can see also a clear discrimination between shale, water bearing sand and hydrocarbon bearing sand. Hydrocarbon bearing sand has P-impedance lower than that of water bearing sand and higher than that of shale.



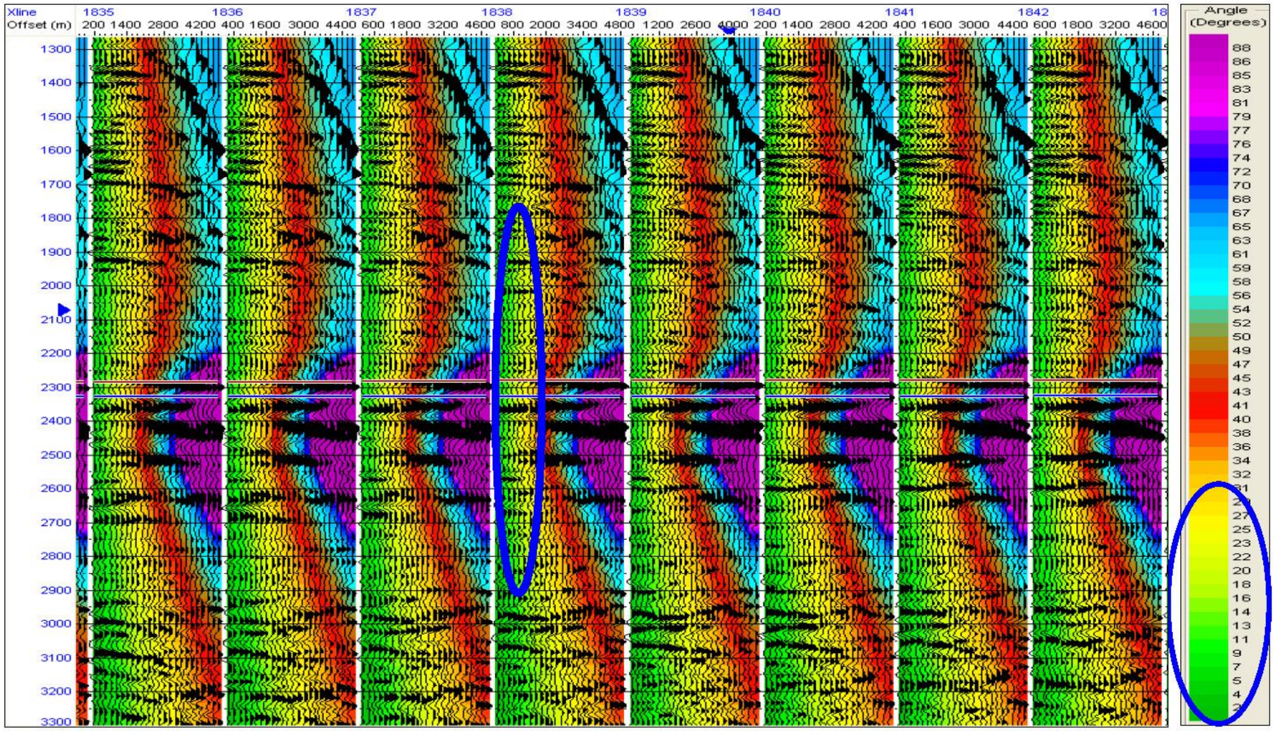
Presenter's notes: The logs used in this x-plot are Sw and Vcl which have been resulted from the petrophysical interpretation, p-imp and s-imp logs have calculated for the density and velocity logs recorded from the well. Here we have p-imp versus s-imp x-plot in which pimp plotted on the x-axis and s-imp plotted on the y-axis and the x-plot colored by the Vcl log ranging from 0 which is represented by the red color and 1 which is represented by the purple color. We can see a clear discrimination between the sand and shale. The shale is characterized by high Vp/Vs and low impedance, sand is characterized by higher impedance than shale and extremely lower Vp/Vs than shale. Gas sand is characterized by (*Presenter's notes continued on next slide*)

(*Presenter's notes continued from previous slide*)

very low Vp/Vs ratio and very low impedance, Wet sand characterized by high impedance and the Vp/Vs ratio is higher than gas sand and in the same time lower than that of shale. The shale is characterized by high Vp/Vs and low impedance.

Conditioning Gathers

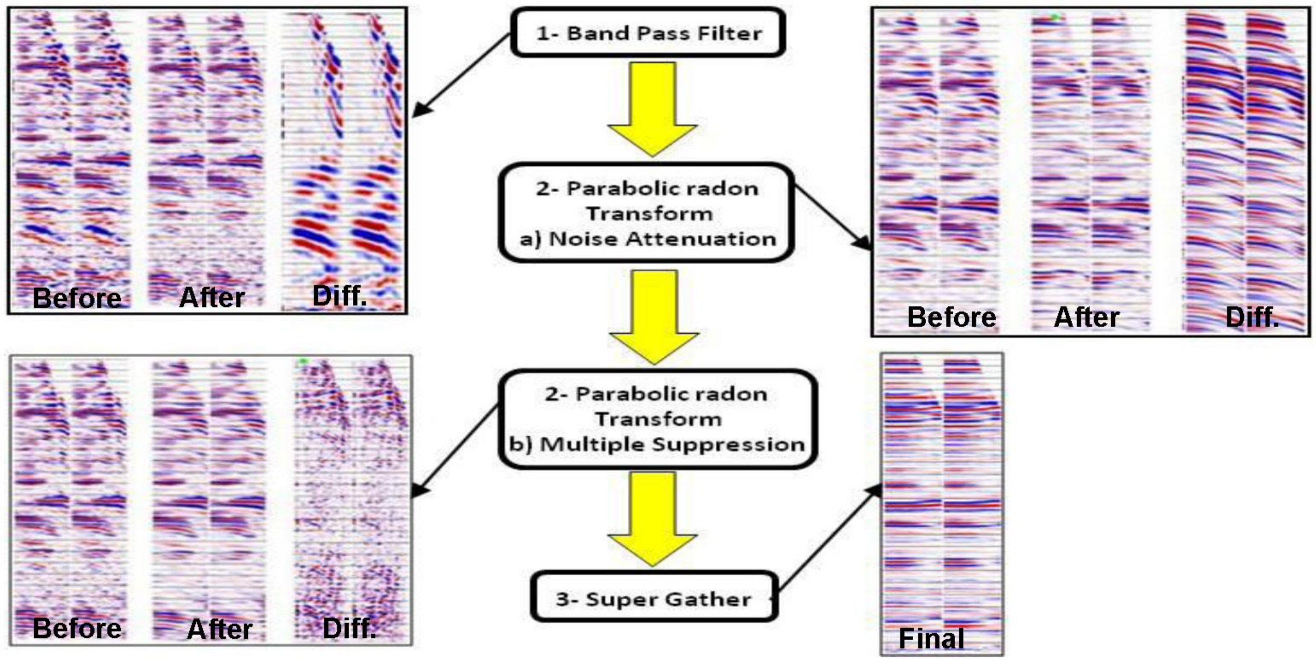
Offset traces Overlain by incident angles color annotations



Presenter's notes: Another benefit might be taken from the generation of angle gathers is to plot the offset overlain by the incident angles to get the maximum reliable angle range angles. The most reliable angle range is from 0 – 30 degrees.

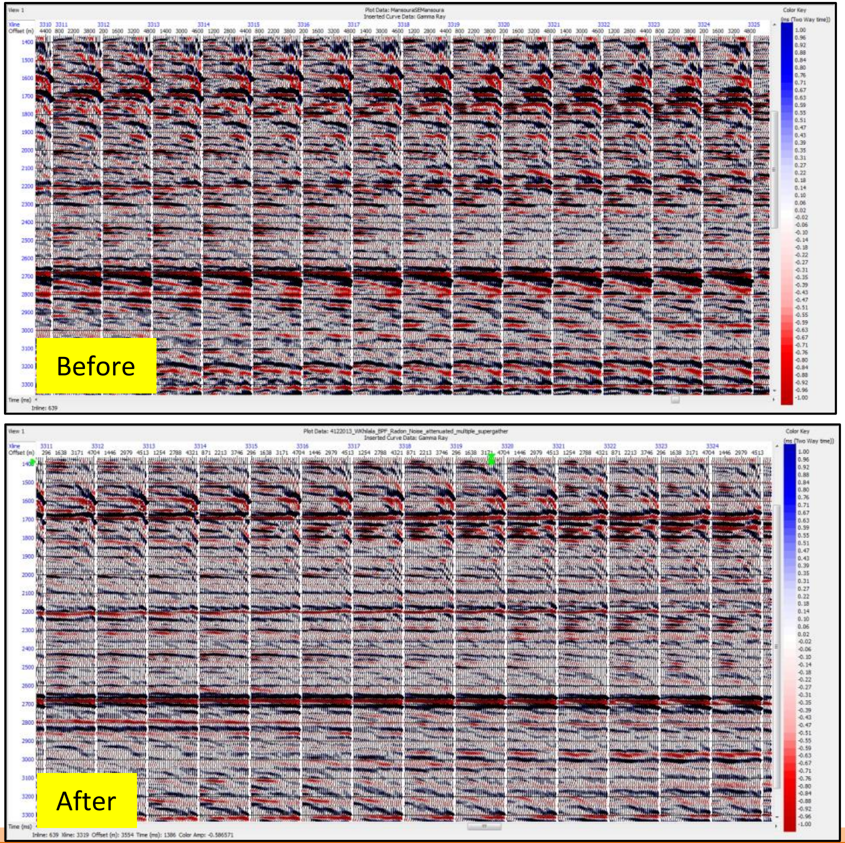
Conditioning Gathers

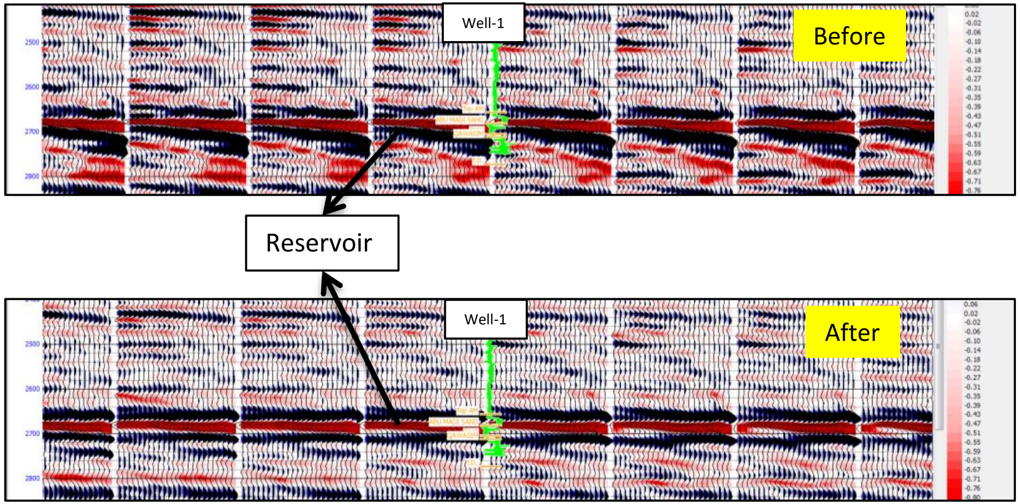
The applied conditioning work flow detailed as follows:
1- 1st Band-pass Filter,
2- Parabolic Radon Transform (Random Noise Attenuation)
3- Parabolic Radon Transform (De-Multiple)
4- Super Gather



Presenter's notes: By looking into the quality of the pre-stack seismic data, we realized that there is a potential to improve the S/N and proof the reliability of the ultra-far or high angles data. We have iterated a several workflows with different parameters to apply the gathers pre-conditioning and preparing the data for further sophisticated process can aids in better understanding for the reservoir characteristics. (Singleton,2009).

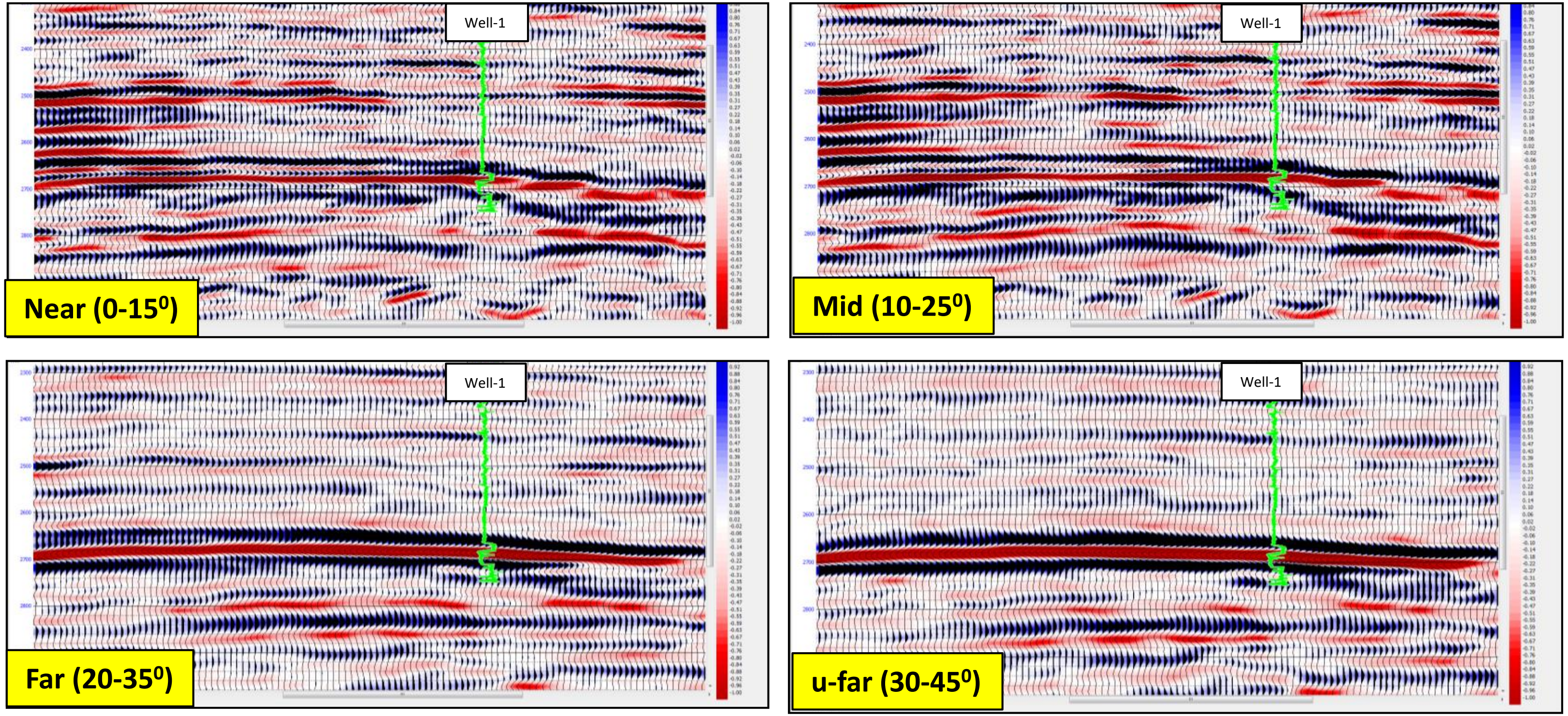
Conditioning Gathers



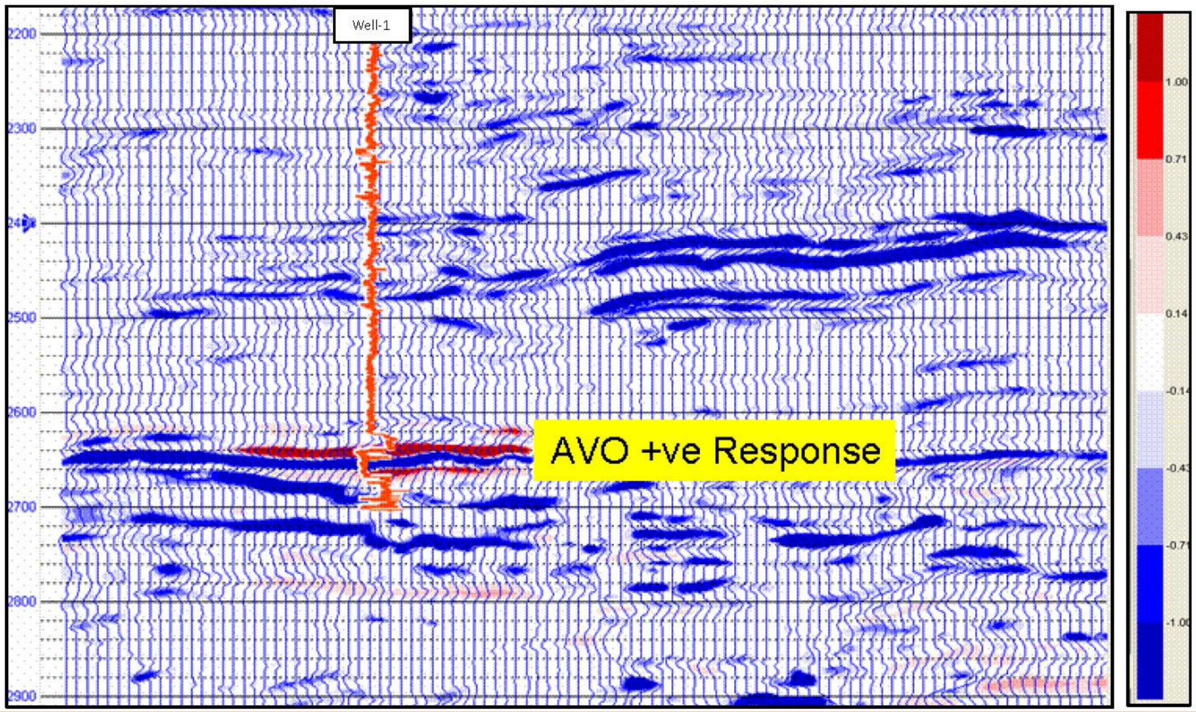


- The gathers becomes less noisy,
- Reflectors represent the reservoir, becomes more flat
- Good for the AVO analysis.

AVA Analysis



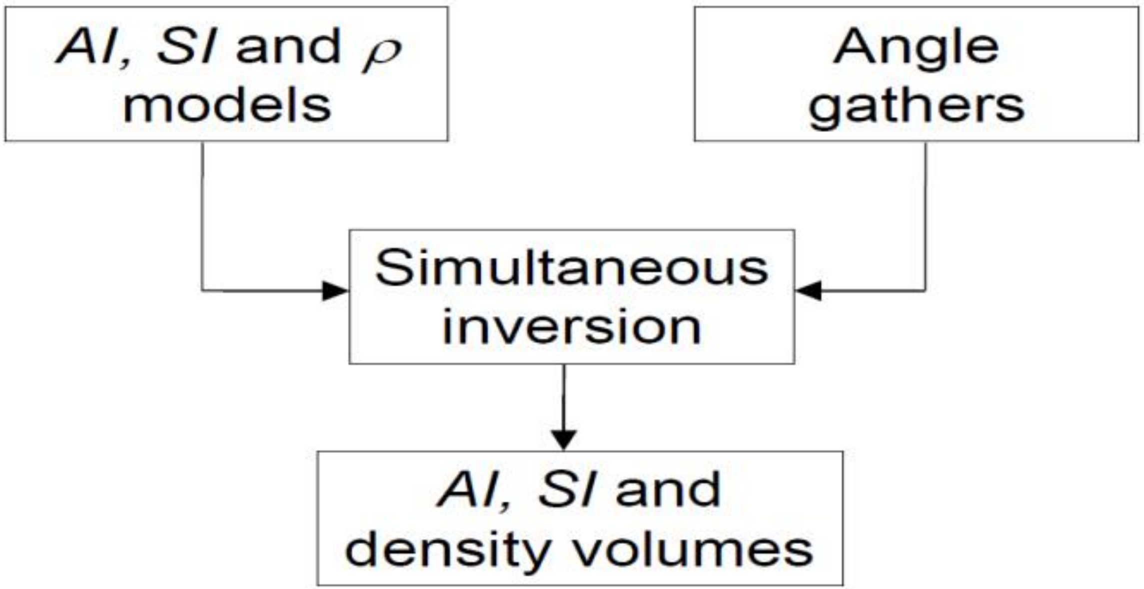
AVA Attributes; Product of Intercept and Gradient



Presenter's notes: The trace data shows the intercept, while the color display represents the product of the intercept and gradient that indicates the AVO anomaly. By calibration of this AVO anomaly with both the gamma ray log and top pay of gas well, we can notice the good match between the AVO anomaly associated with the reservoir level.

AVO Simultaneous Inversion

The AVO simultaneous inversion method used is based on P- wave and S-wave simultaneous inversion of partial angle stacks, in which seismic reflection amplitudes are correlated through a complex nonlinear relation with P-velocity, S-velocity, density and incident angle.

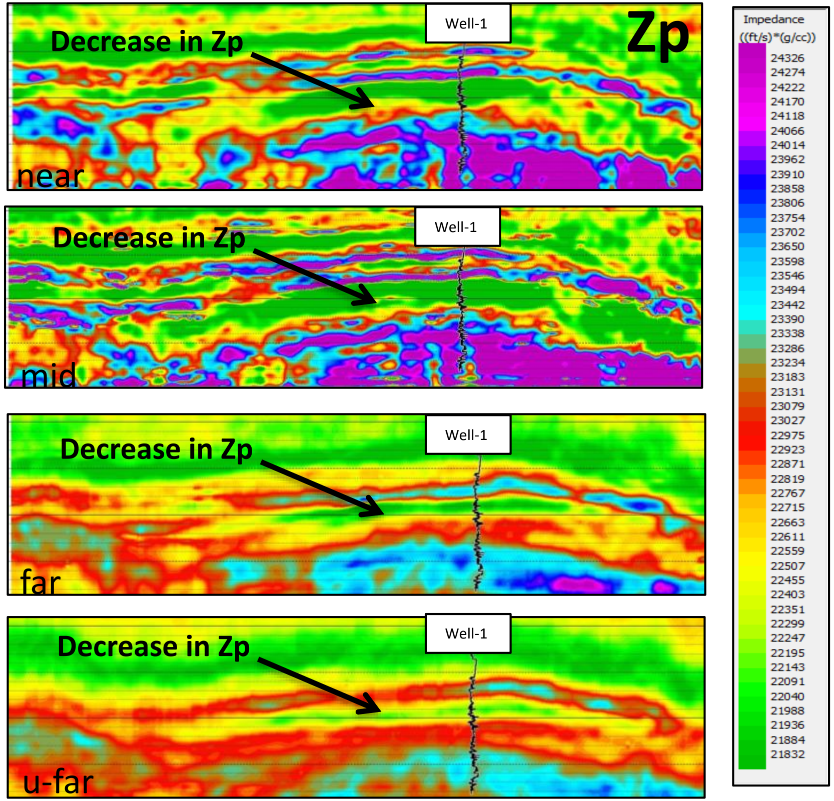


AVO Simultaneous Inversion

- The results of the inversion matching largely the rock physics model of the area in which,

- The P-wave inversion result shows a decrease in the acoustic impedance within the reservoir due to the presence of hydrocarbon.

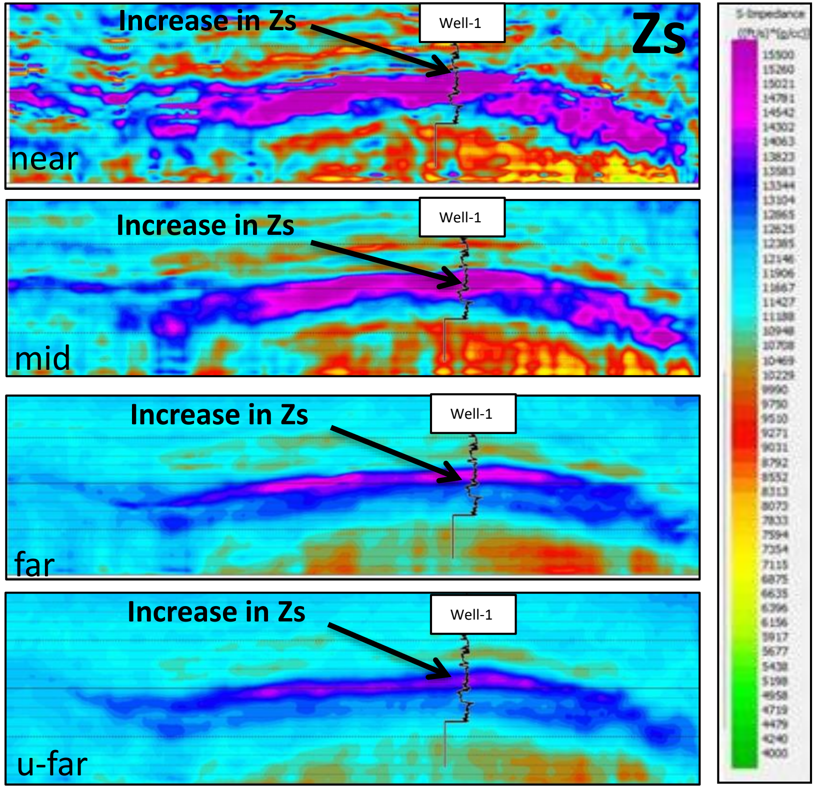
P-Impedance $AI = \rho V_P$



AVO Simultaneous Inversion

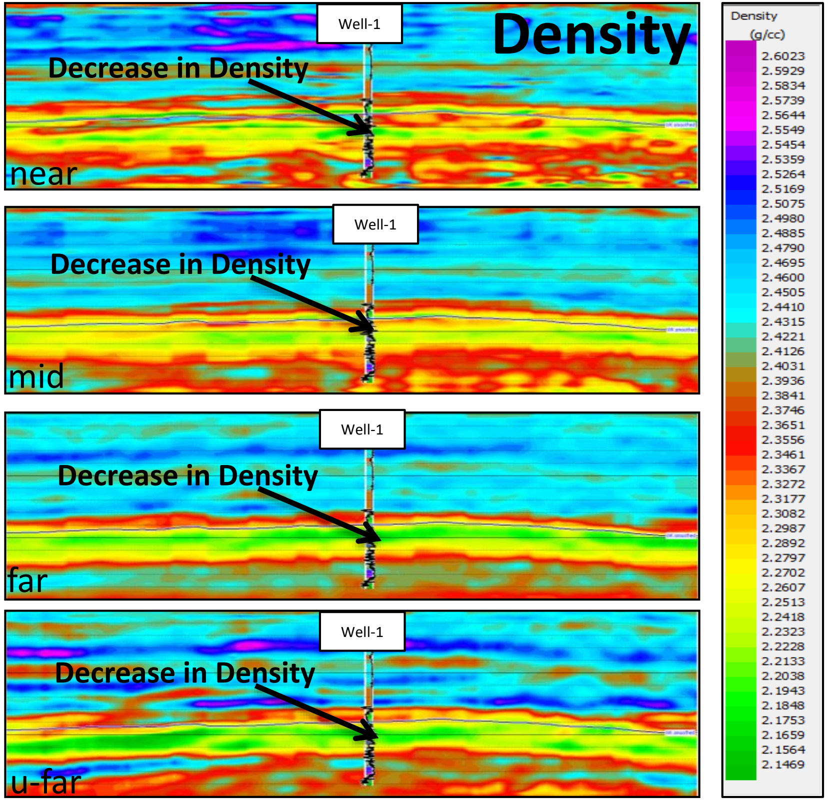
There is a increase in the shear impedance at the reservoir, perhaps due to increase in the bulk density

S-Impedance $SI = \rho V_s$



AVO Simultaneous Inversion

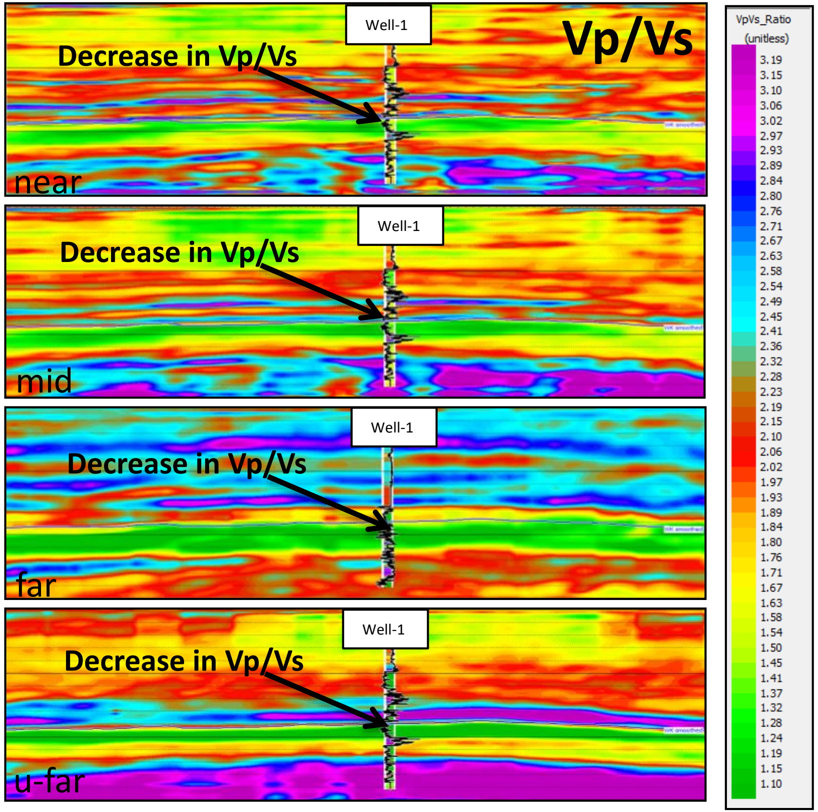
There is a sharp decrease in the density between the shale above the reservoir and the main sand body within the reservoir.



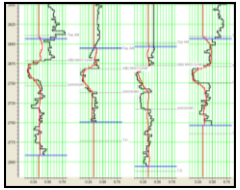
AVO Simultaneous Inversion

As the presence of hydrocarbon decreases the velocity and density, so Vp becomes smaller meanwhile, the shear velocity slightly affected with the hydrocarbon presence, that results in finding low Vp/Vs in the pay zone which is clear in our inversion results.

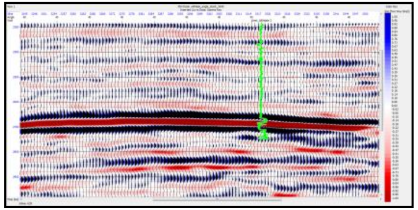
AI/SI = ρVp / ρVs = Vp/Vs



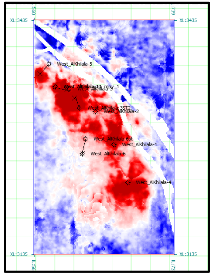
Input of Reservoir Properties Prediction



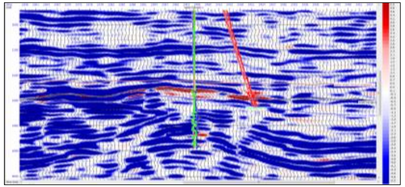
Logs to be Trained



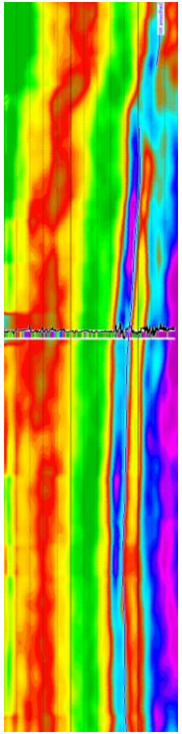
U-Far Seismic



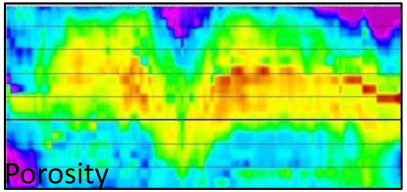
Horizons

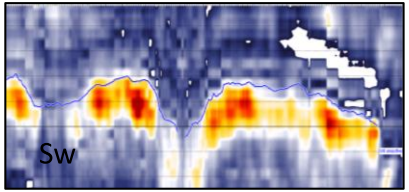


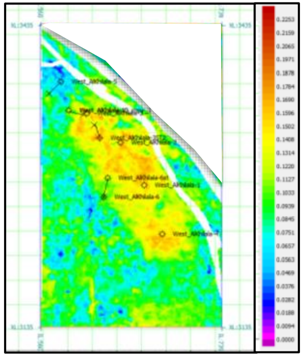
Attributes

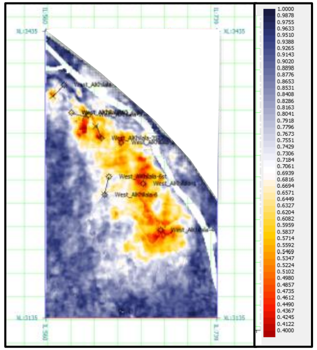


Inverted Cube





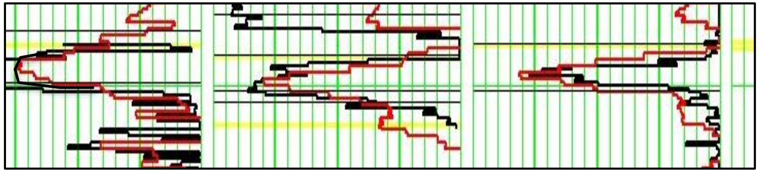




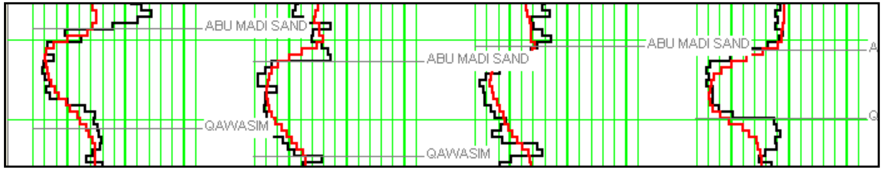
Resulting Prediction of Reservoir Properties

Reservoir Properties Prediction; Validation

Water Saturation



Porosity

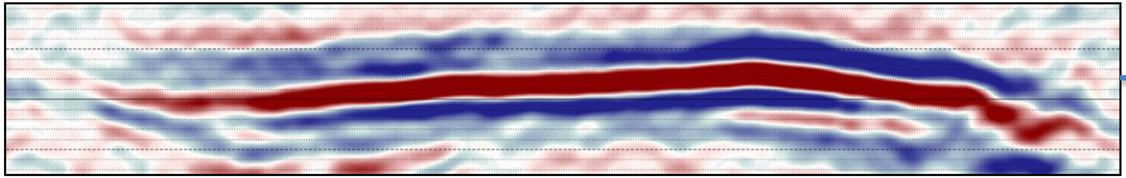


Modeled Logs

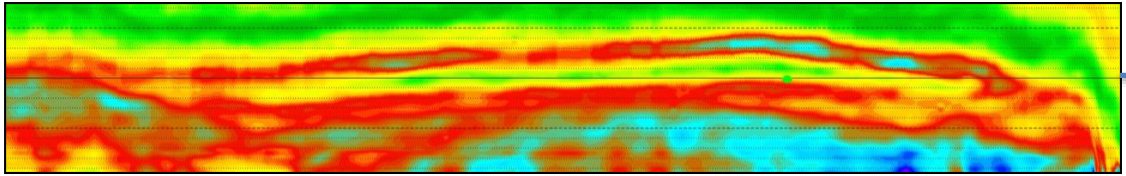
Original Logs

Reservoir Properties Prediction

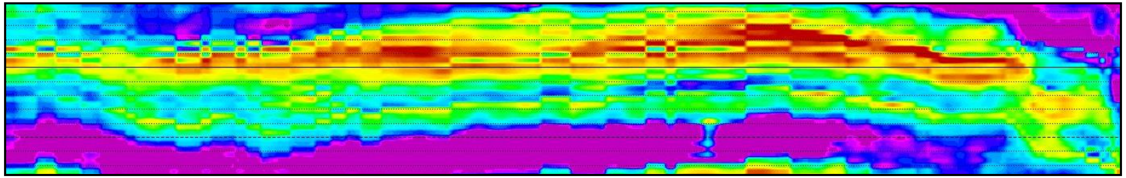
Seismic after Conditioning U-Far Stack



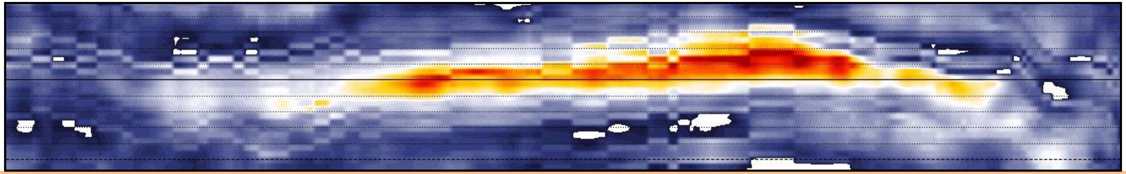
Zp Cube



Porosity Cube

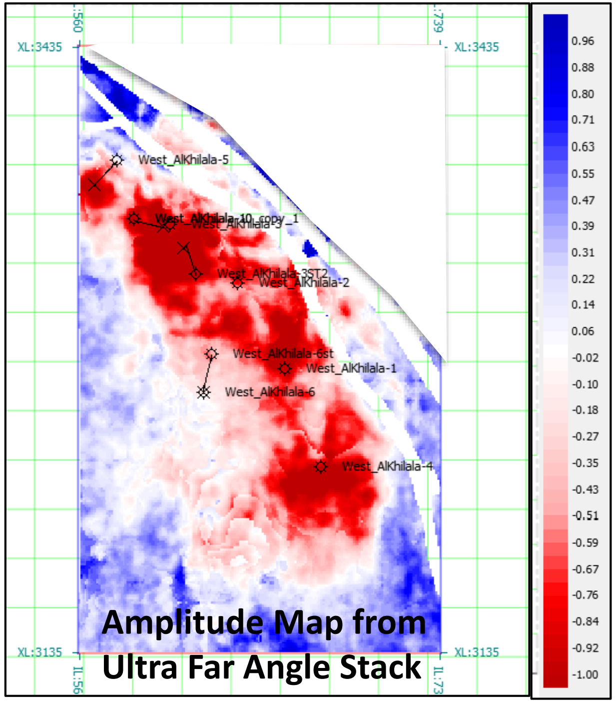


Water Saturation Cube

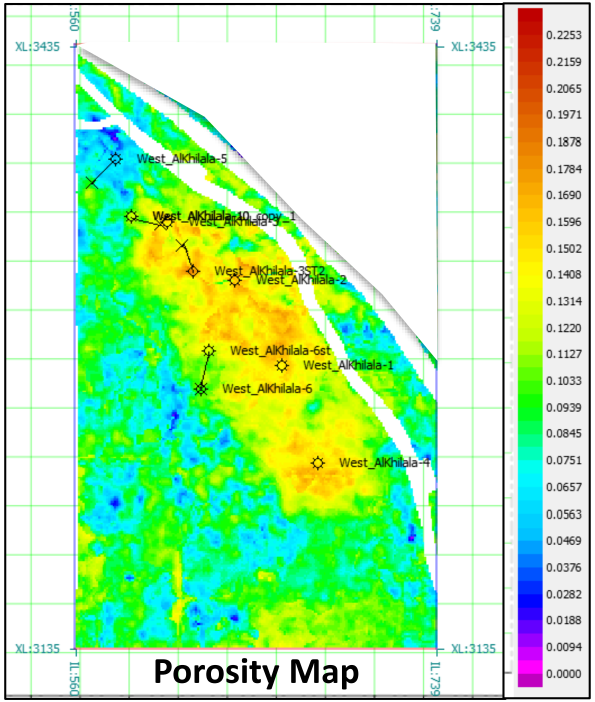


Main Input for inversion and reservoir properties prediction in addition to the trained logs

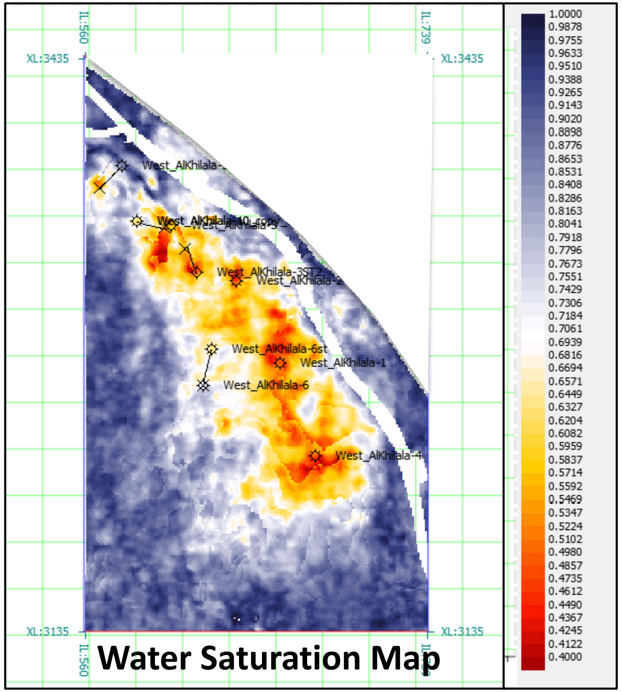
Reservoir Properties Prediction



Amplitude Map from Ultra Far Angle Stack



Porosity Map



Water Saturation Map

Conclusions

- ✓ Resulting from the gathers conditioning, the reliability of the ultra-far seismic data is useful for a detailed reservoir study in Mansoura area.
- ✓ By proving the reliability of the ultra-far data, now we can use the gathers up to 45^o instead of what used before (30^o).
- ✓ The petrophysical evaluation aids to build up a reliable rock physics model which constraints the seismic inversion.
- ✓ The cross-plot of (Zp) versus (Zs) represents a good tool in the onshore Nile Delta for both lithology and fluid discrimination.
- ✓ The inverted seismic data delineate the gas sand by decrease in (Zp) and the density were observed as well as a slight increase in (Zs).
- ✓ The gas sand detection with a good resolution is achieved by using the simultaneous inversion that benefitted from ultra-far.

Conclusions

- ✓ The more input data for the reservoir properties prediction, the more accurate results.
- ✓ The predicted porosity and water saturation cubes show excellent match with the original logs.
- ✓ The predicted reservoir properties used as input to the static model of the field, which consequently was used for field development plan.

Acknowledgements / Thank You / Questions

The authors would like to thank the Egyptian General Petroleum Corporation (EGPC) and Petroceltic International Companies (Plc) for their permit to publish this work.

The presenter would like to thank Dr. Asghar Shams in Heriot Watt university for his usual support.