PS Pre-Messinian Tight Reservoir Characterization — Western Nile Delta, Egypt*

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Abstract

The West Delta Deep Marine concession located approximately 100 km offshore of Alexandria, Egypt is of clastic nature with a variety of tectonic styles. Delineating reservoir presence and its effectiveness at the pre-Messinian level become the major geological risk, in addition to its being geophysically challenging due to the presence of multiple high contrast lithology at the shallower interval. Historically, bright spots which might be associated with the presence of hydrocarbon potential reservoirs may easily be detected at the Pliocene level (Vaughan et al, 2014). However, it is proven that highly cemented sands by carbonates or quartz over growth are widely distributed along with the presence of tight stringers, sand-shale overpressure, and/or the effect of anisotropy which could also bring false information in the deeper section (Dolson et al, 2014). Early to Late Miocene is known as non-favorable for DHI, therefore quantitative interpretation over these intervals at the West Delta Deep Marine is challenging. Regional rock sensitivity analysis based on wells has been produced to understand the acoustic-elastic response within this area and subsequently tied to the seismic data. It is crucial to understand both the rock compaction trend and the seismic data in order to detect energy changes which may display different polarity for the reservoir as well as the hydrocarbon case. Seismic modelling in 1D and 2D scales from different regional wells at the same interval enabled the interpreter to capture uncertainty in thickness, tuning, and variation in reservoir effectiveness. Anisotropy as another factor was also considered in the model. Detailed seismic data analysis and conditioning were carefully carried out for offset/angle stacks in particular, and this has become a critical part of a QI workflow prior to any geomorphological reconnaissance and AVO/AVA analysis in areas of interest. Amplitude and frequency of the seismic in some areas were lost due to the Messinian evaporite and gas chimneys. Interaction between individual offset/angle stacks to capture the correct response of the rock was carefully observed in the well log and the seismic scale. Dip structural noise removal, amplitude correction, and alignment of seismic offset/angle gather calibrated to the rock physics model were performed to increase reliability of the data and thus the accuracy of the reservoir prediction from seismic. This workflow has resulted in the attenuation of noise while preserving the signal, and ultimately an optimized seismic data.

This iterative and integrated process has resulted in an optimized approach that is suitable for reservoir and hydrocarbon determination through quantitative interpretation. Successful application of this workflow in the lead and prospect maturation campaign could open up more opportunities and increase chance of success to explore this deep pre-Messinian play.

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ABSTRACT

The West Delta Deep Marine concession located approximately 100 km offshore of Alexandria, Egypt is of clastic nature with a variety of tectonic styles. Delineating reservoir presence and its effectiveness at the pre-Messinian level become the major geological risk, in addition to it being geophysically challenging due to the presence of multiple high contrast lithology at the shallower interval. Historically, bright spots which might be associated with the presence of hydrocarbon potential reservoirs may easily be detected at the Pliocene level (Vaughan et al, 2014). However, it is proven that highly cemented sands by carbonates or quartz over growth are widely distributed along with the presence of tight stringers, sand-shale overpressure and/or the effect of anisotropy which could also bring false information in the deeper section (Dolson et al, 2014). Early to Late Miocene is known as non-favorable for DHI, therefore quantitative interpretation over these intervals at the West Delta Deep Marine is challenging. Regional rock sensitivity analysis based on wells has been produced to understand the acoustic-elastic response within this area and subsequently tied to the seismic data. It is crucial to understand both the rock compaction trend and the seismic data in order to detect energy changes which may display different polarity for the reservoir as well as the hydrocarbon case. Seismic modelling in 1D and 2D scales from different regional wells at the same interval enabled the interpreter to capture uncertainty in thickness, tuning and variation in reservoir effectiveness. Anisotropy as another factor was also considered in the model. A combination of well log data evaluation and detailed seismic data analysis including conditioning were carefully carried out for offset/angle stacks in particular, and this has become a critical part of a QI workflow prior to any geomorphological reconnaissance and AVO/AVA analysis in areas of interest. Amplitude and frequency of the seismic in some areas were lost due to the Messinian evaporite and gas chimneys. Interaction between individual offset/angle stacks to capture the correct response of the rock was carefully observed in the well log and the seismic scale. Dip structural noise removal, amplitude correction and alignment of seismic offset/angle gather calibrated to the rock physics model were performed to increase reliability of the data and thus the accuracy of the reservoir prediction from seismic. This workflow has resulted in the attenuation of noise while preserving the signal, and ultimately an optimized seismic data.

This iterative and integrated process has resulted in an optimized approach that is suitable for reservoir and hydrocarbon determination through quantitative interpretation. Successful application of this workflow in the lead and prospect maturation campaign could open up more opportunities and increase chance of success to explore this deep pre-Messinian play.

BACKGROUND

The West Delta Deep Marine concession is a high gas producing area with over 100 wells drilled targeting the Pliocene-Pleistocene intervals. The Pliocene and Pleistocene intervals are proven to be easily detected for gas reservoirs based on only their AVO signature; class III AVO for gas and class I for brine.

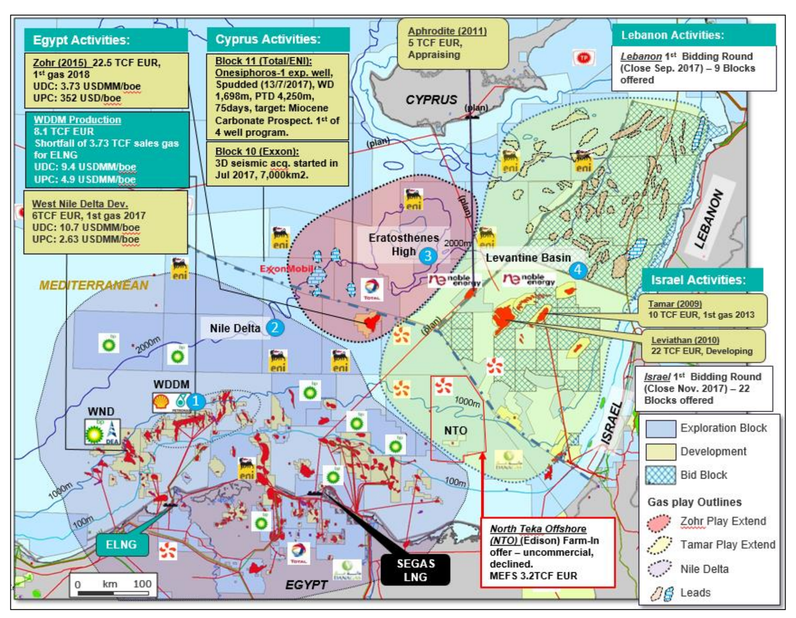

Figure 1 Map showing exploration focus area in the Western Nile Delta and its surroundings.

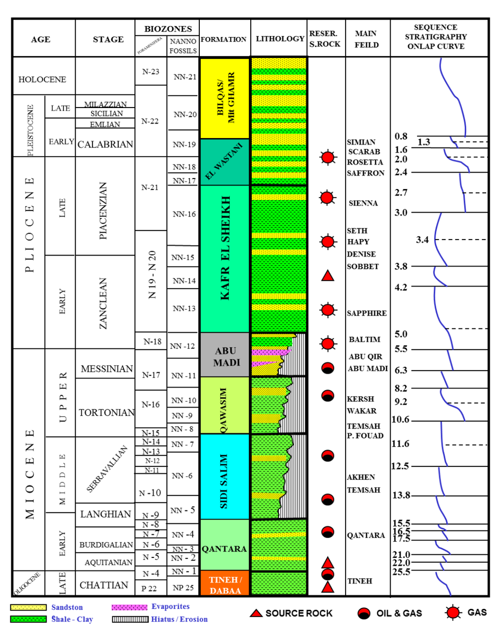

Figure 2 Generalized stratigraphic chart of the Western Nile Delta.

TECHNICAL CHALLENGES

With the gas production in the Pliocene-Pleistocene intervals slowly reaches a plateau, the focus of exploration has now emerged to the unproven interval of pre-Messinian. However, the Miocene interval poses a challenge due to the introduction of highly contrast evaporites in the Upper Messinian interval of Abu Madi, which in some cases, absorbs the energy of the layers below it. XRD samples have also shown that the sands in this interval have quartz overgrowth and are carbonate-cemented, thus higher acoustic impedance response compared to the background is expected.

There are limited amount of well calibrations that are available, with only 9 wells penetrated through the pre-Messinian level. These wells have all shown that the sands have a "hard" character, and that the AVO characters between brine, oil and gas-filled sand have very subtle separation, therefore having the correct amplitude response from the mid to the far offset is critical, particularly from the seismic data.

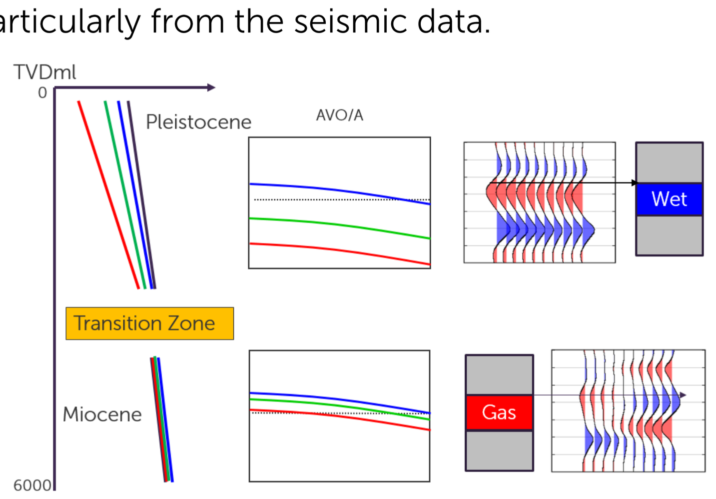

Figure 3 Variation of seismic response and AVO response with depth. Early to Late Miocene is known as non-favorable for DHI therefore quantitative interpretation over this area is quite challenging.

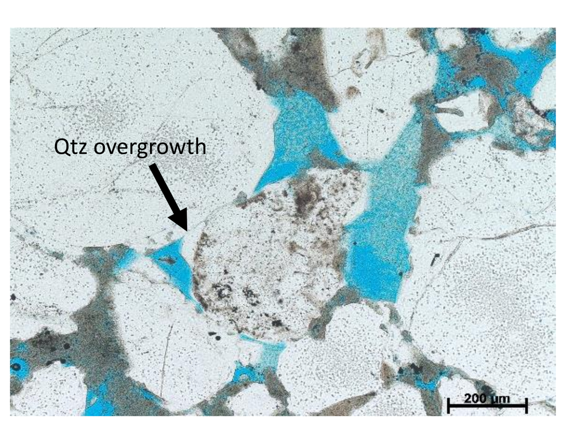

Figure 4 Thin section sample of sand from well A having quartz overgrowth.

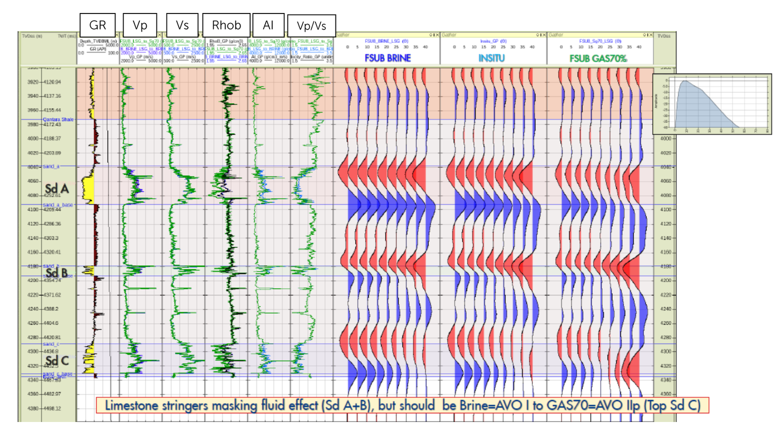

Figure 5 Well A targeted the Middle Miocene found 70m of net wet sand. The insitu case and gas case both showing AVO class I signature due to the masking fluid effect by the limestone stringers in the sand of Well A.

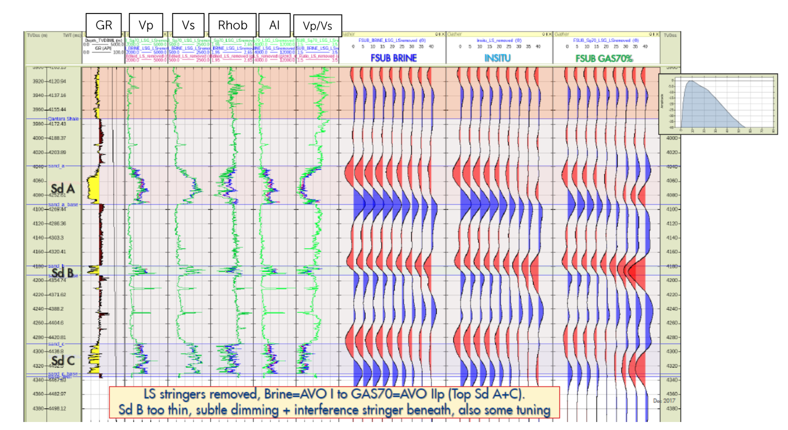

Figure 6 When the limestone stringers are removed, the brine case shows AVO class I while the Gas70 case shows AVO class IIp.

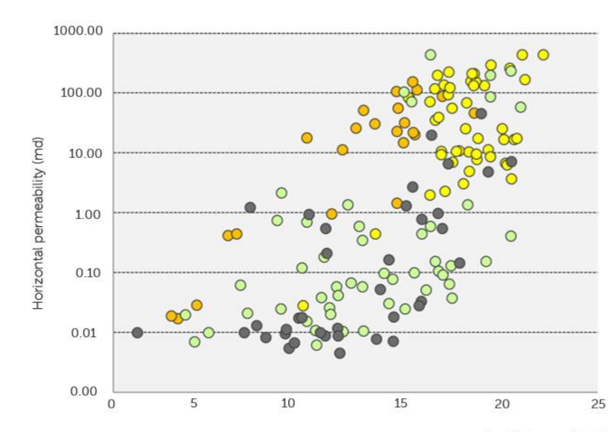

Figure 7 The best reservoir sand is the yellow-colored points. It generally has higher porosity and permeability.

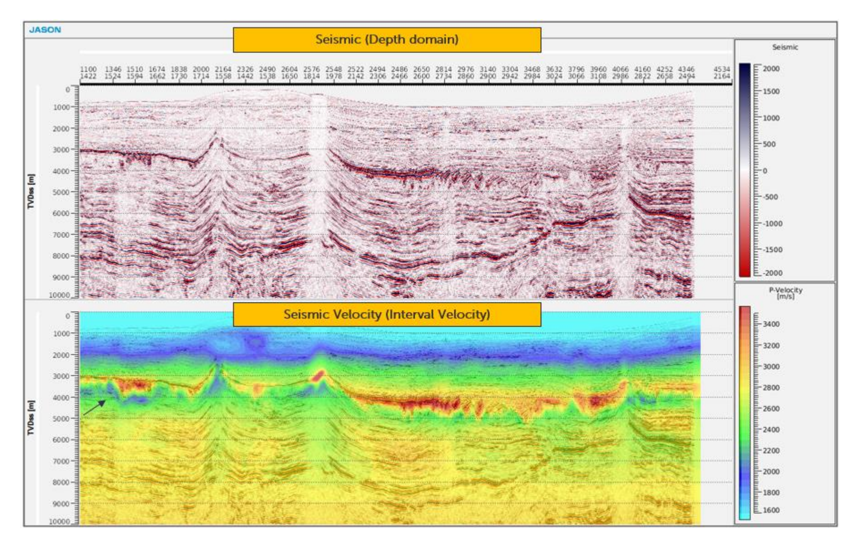

Figure 8 Unbalanced amplitude observed at some particular area due to chimney and possible absorption from highly contrast lithology which is captured by PSDM processing.

METHODOLOGY

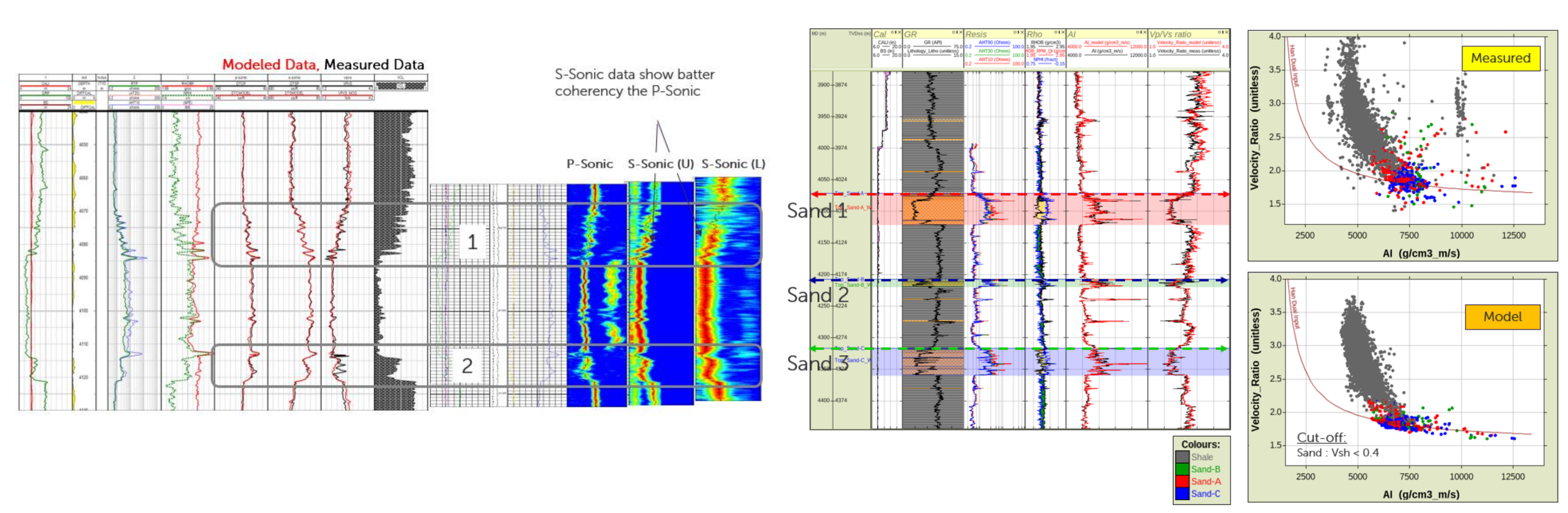

Figure 9 The difference between the Raw and RPM data in the above section 1 & 2 is mainly due the uncertainty in the raw data. The P-Sonic shows low coherency in the STC projection. This similar issue with raw data is observed over Sand-2 and Sand-3. This may cause variation in the AVO response between Raw and RPM logs. In order to mitigate this, RPM log has been generated which resulted in having a log with more systematic trend and easily separated from the background (shale) as compared to the measured log.

Seismic data conditioning of the partial stacks has become a critical part of a workflow prior to doing AVO/AVA analysis in areas of interest, and is especially crucial in West Delta Deep Marine where the amplitude and frequency of the seismic in some areas are lost due to the Messinian evaporite and gas chimneys.

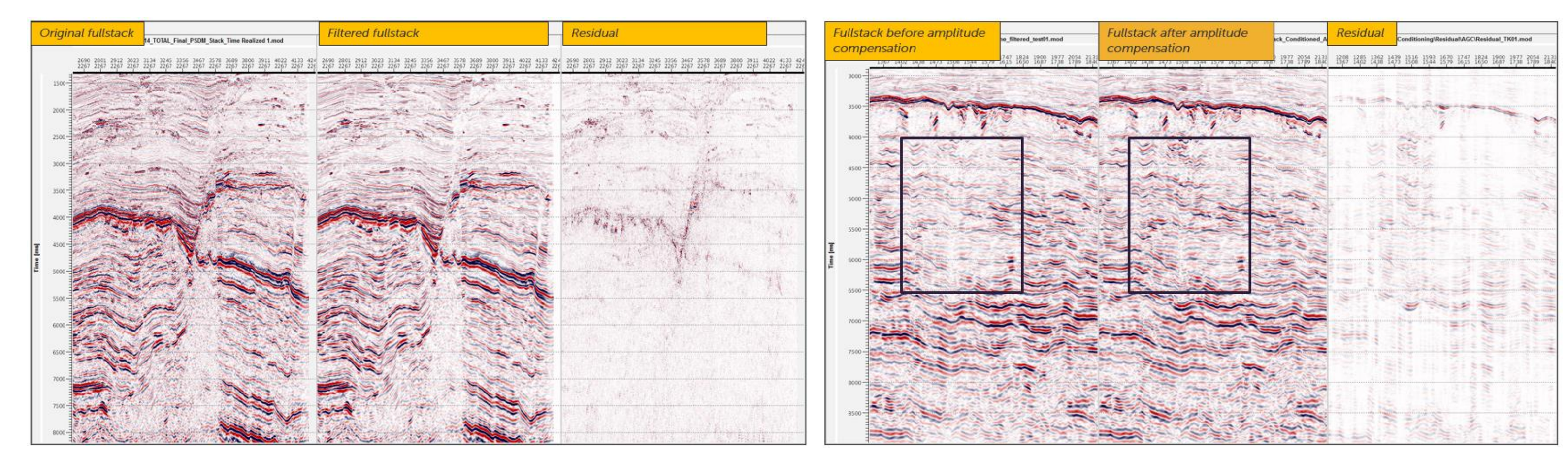

Figure 10 The first key step in the seismic conditioning workflow is to apply dip structural noise removal to improve the structural image. The dip structural noise removal method that was applied here would first require us to calculate the dip values estimation in ms/trace through the inline and crossline direction. Once the dip estimation is acquired, it is then fed to the structure oriented filtering workflow that aims to filter the noise along the structure using the dip provided. Secondly, amplitude compensation was applied in order to correct for the amplitude that were lost due to absorption.

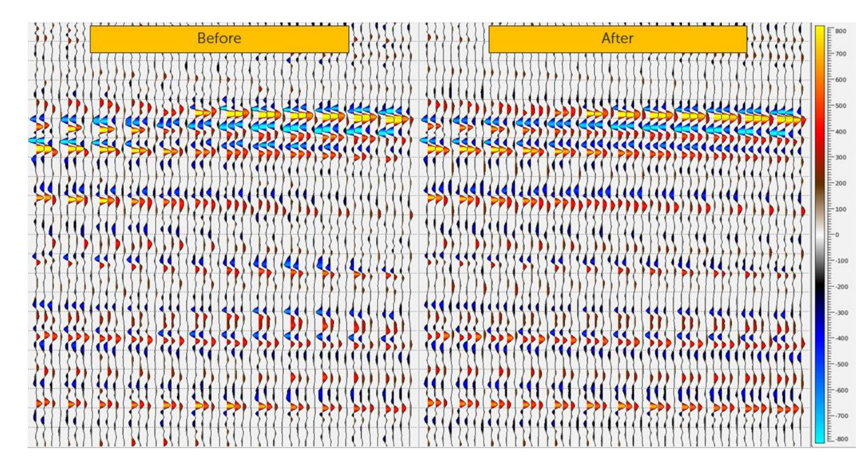

Figure 11 Comparison of angle gathers after conditioning process. Alignment between angle stacks are improved.

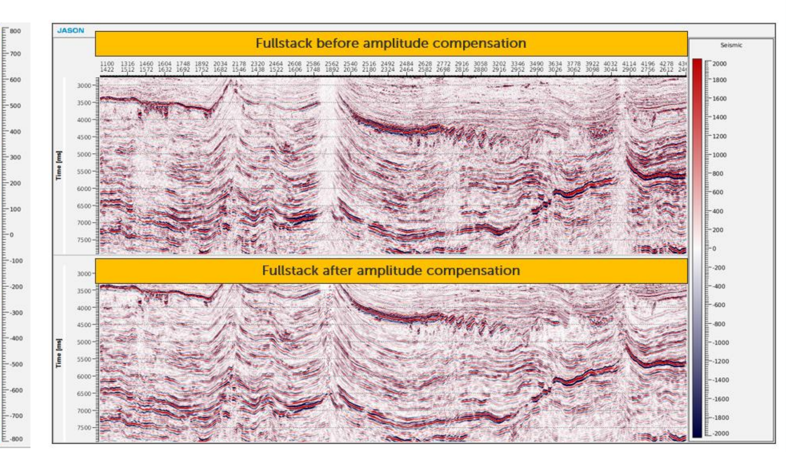

Figure 12 Area where identified to have loss frequency and amplitude has been compensated.

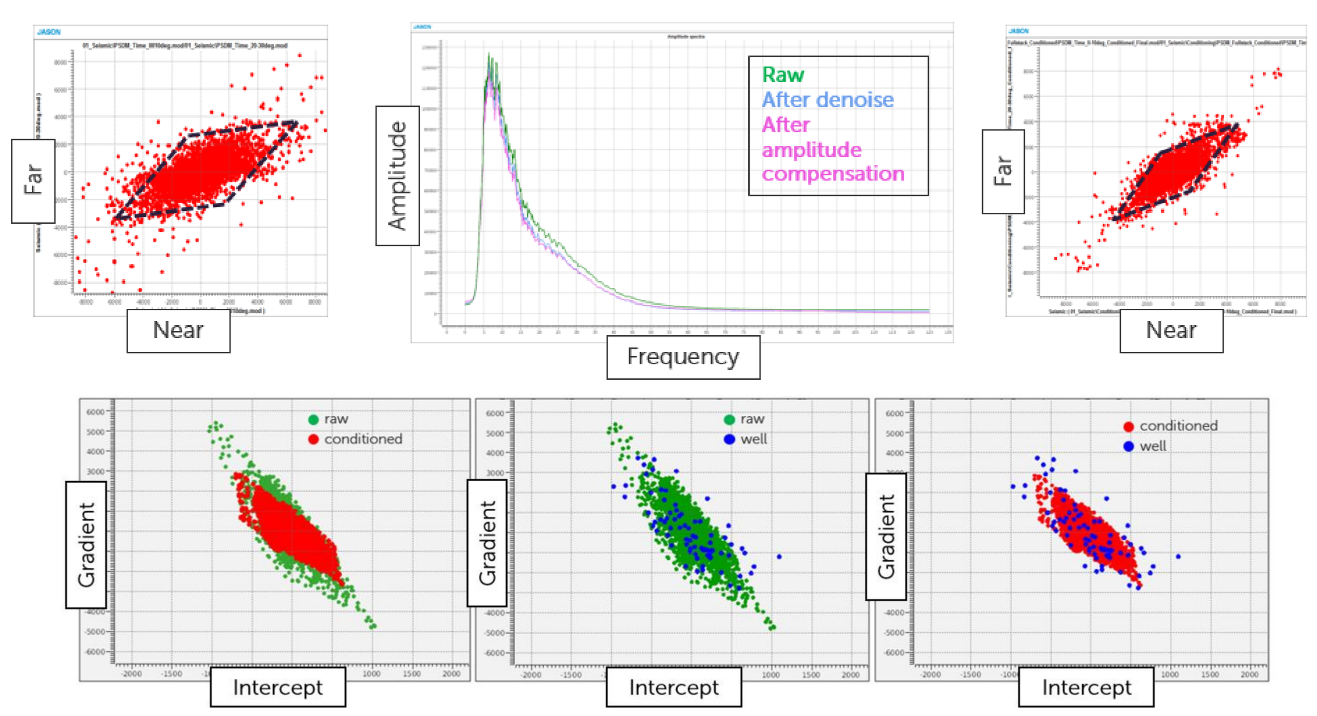

Figure 13 The response of AVA/AVO after conditioning is more confined and follow with the rock physics trend. Upper figure shows the frequency band and the near-far crossplot. Lower figure is the calibration of the Intercept and Gradient conditioned data to the well data.

Conclusion

Quartz overgrowth and limestone stringers are widely distributed over the pre-Messinian interval, however good porosity preservation may exist. This workflow was performed on the West Delta Deep Marine seismic data at the Mid to Late Miocene level and has resulted in an optimized seismic data that is suitable for reservoir and hydrocarbon determination through quantitative interpretation process.

Acknowledgement

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