Petrophysics and Rock Physics Modeling to Improve Seismic Reservoir Characterization — Case Study of Lower Hackberry Sandstone*

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Abstract

An integrated workflow of Petrophysical Analysis and Rock Physics Modeling has been applied to improve the reservoir characterization in lower Hackberry sands. Fluid replacement was applied to assess sensitivity of elastic rock properties to pore fluid type in the reservoir. It was found that a layer of abnormally soft shale overlies the sand unit in the investigated well, resulting in a large contrast in acoustic impedance that overshadowed the fluid effect. Shale replacement with normal shale properties was applied to examine sensitivity to the overlying shale type. Fluid replacement was applied again after shale replacement to evaluate fluid sensitivity. Synthetic seismic traces were generated for the different fluid types before and after shale replacement. Seismic responses were estimated by comparing synthetic seismic traces from the combinations of overlying shale and fluid types.

Further study involved AVO(Amplitude vs. Offset) attribute analysis to estimate the feasibility of reservoir characterization by seismic inversion. The integrated process also included study of porosity and sand-thickness sensitivity. Reservoir bodies captured in different cases were examined and compared to evaluate the sensitivities at seismic resolution.

The integrated process was also applied to the deeper Nodosaria sand unit. Applying this process in the Hackberry Embayment area provided geophysicists and geologists with detailed petrophysical and rock physics information and, therefore, greater confidence in reservoir characterization.

Petrophysics and Rock Physics Modeling to Improve Seismic Reservoir Characterization

- Case Study of Lower Hackberry Sandstone

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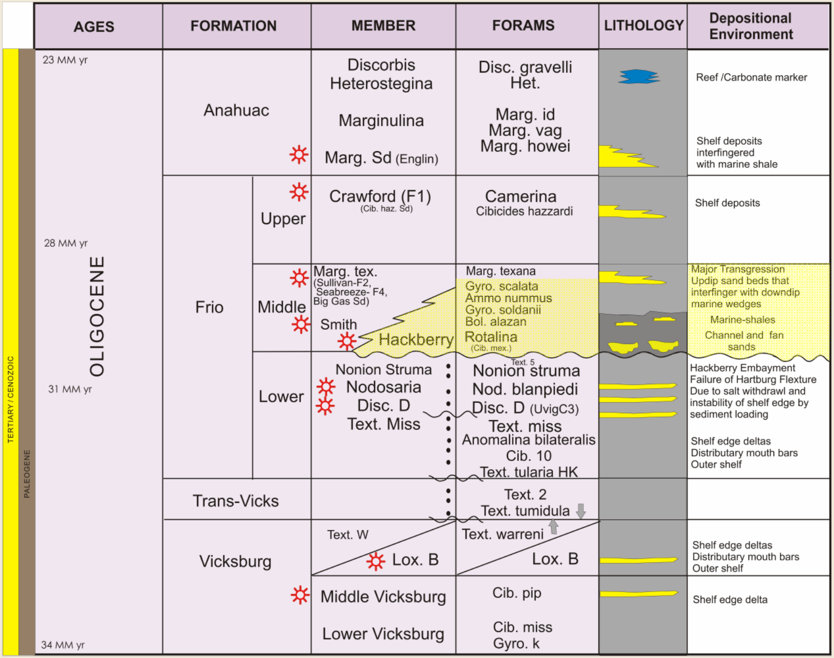
Hackberry Deposition System



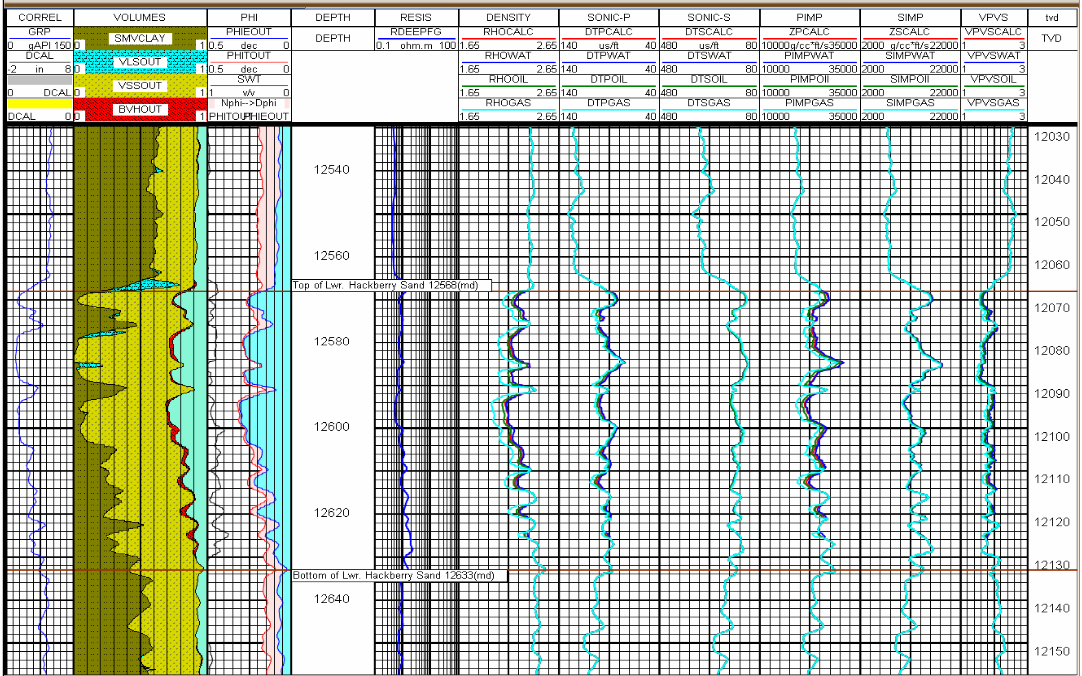
- Oligocene-Middle Frio
- Channel-filled sandstone encased in marine shales

Strat Column courtesy of Amy Vanderhill, PXP

Petrophysics/Rock Physics Modeling

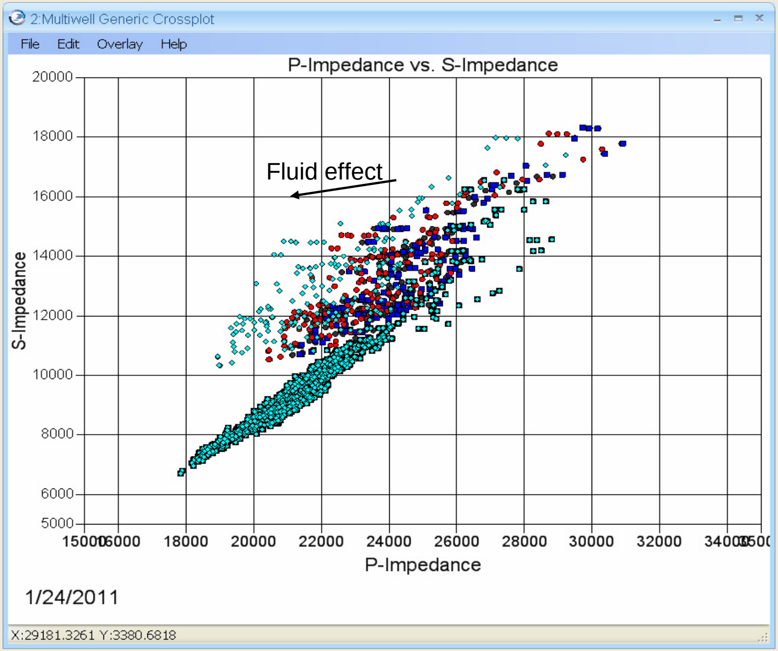
- Fluid replacement to test fluid sensitivity
- Shale/Sand replacement to test lithology sensitivity
- Increase/decrease sand thickness to test reservoir thickness sensitivity
- Increase/decrease porosity to test porosity sensitivity

Fluid Substitution Results in Log Plot over Lower Hackberry Sand



Presenter’s notes: We routinely compare fluid replacement results in log plots and cross plots.

Fluid Replacement in Cross Plot

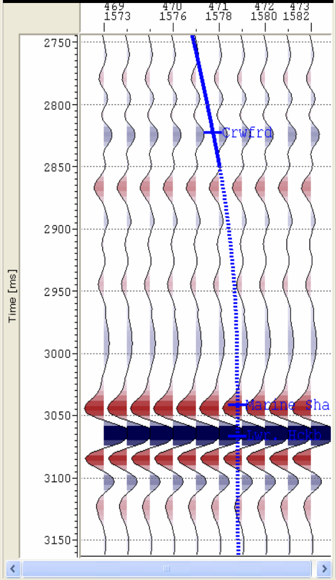


- In-Situ fluid
- Water in Place
- Oil in Place
- Gas in Place

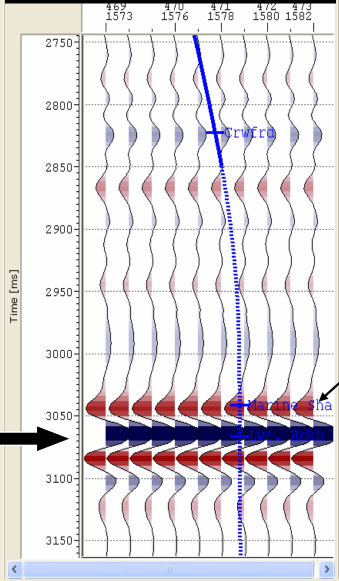
Presenter's notes: In cross plot, we can see fluid effect by overlying data points from different fluid scenarios.

Compare Synthetics Derived from In-situ and Water-Replaced Logs

Synthetics derived from in-situ logs



Synthetics derived from water-replaced logs

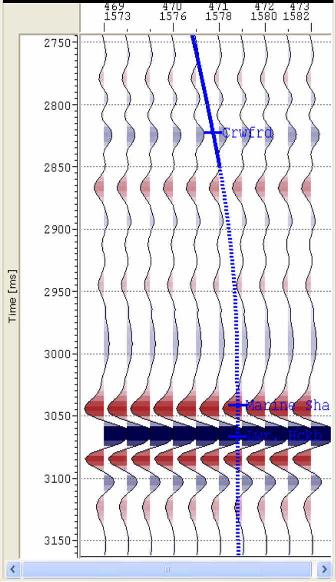


Slow marine shale sitting on top of the relatively fast Lwr. Hackberry sand

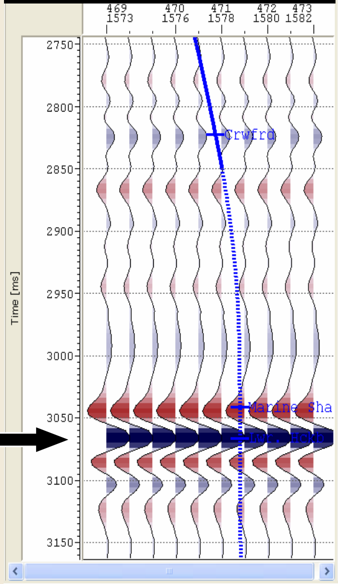
Presenter's notes: The way, from seismic perspective, to look at the fluid effect is to compare synthetics.

Compare Synthetics Derived from In-situ and Gas-Replaced Logs

Synthetics derived from in-situ logs



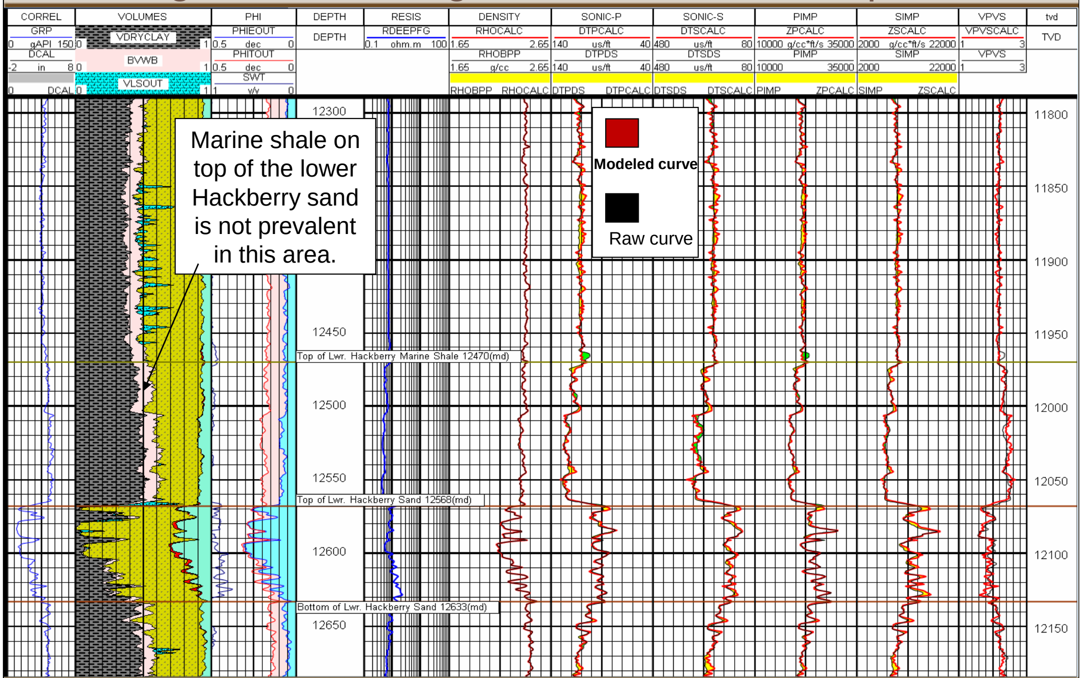
Synthetics derived from gas-replaced logs



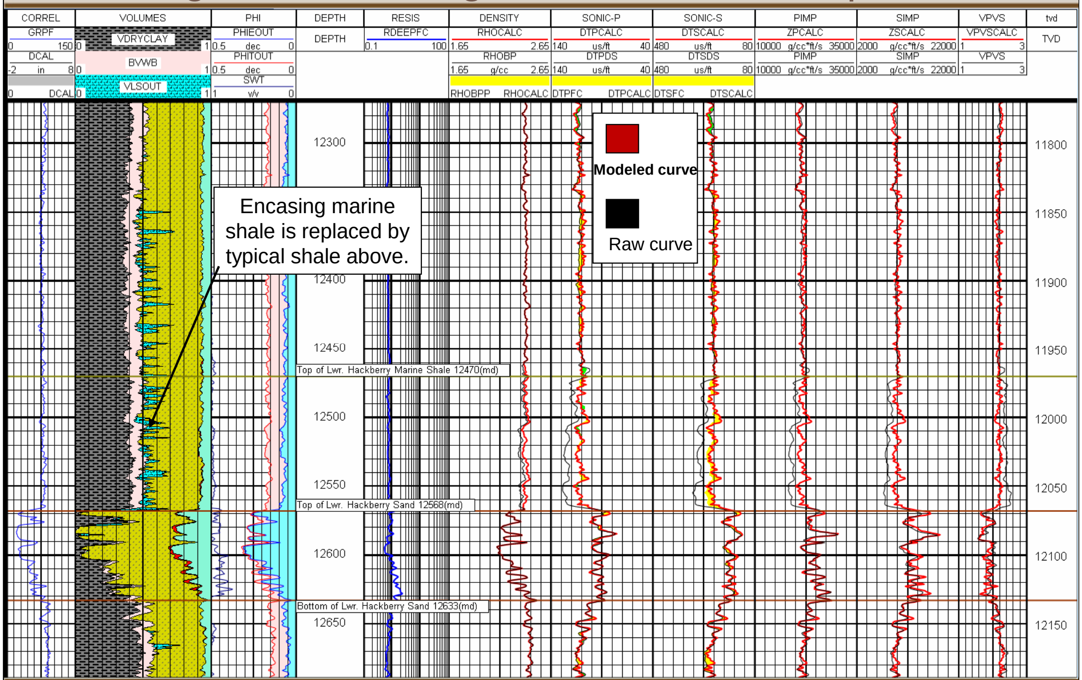
Seismic is not very sensitive to fluid type because the response of low-velocity shale is so strong that it over-shadows the fluid effect.

Presenter's notes: Comparison does not show much difference; so fluid sensitivity is not high in this case.

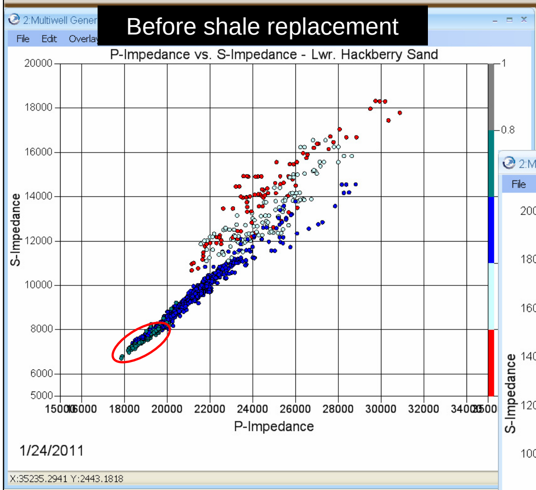
Modeling Results in Log Plot before Shale Replacement

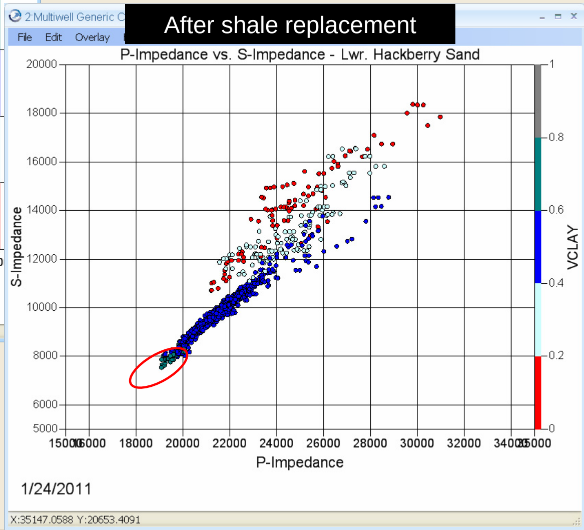


Modeling Results in Log Plot after Shale Replacement



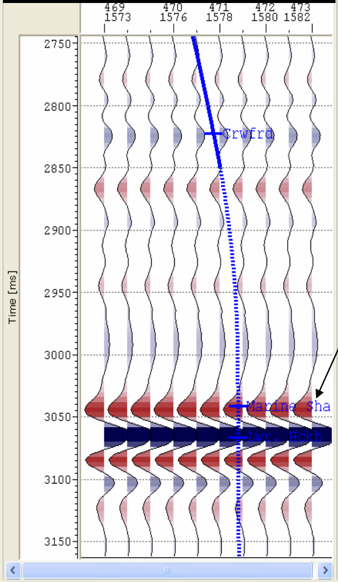
Modeling Results in Cross Plot before and after Shale Replacement





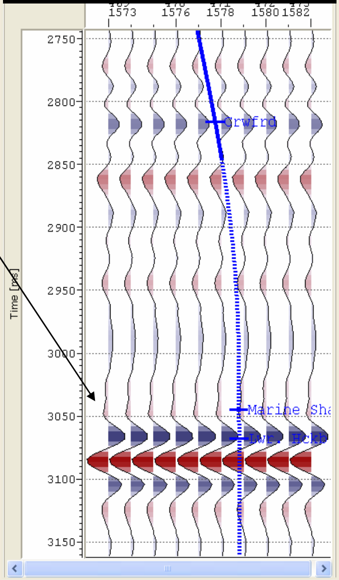
Compare Synthetics Derived from In-situ and Shale-Replaced Logs

Synthetics derived from in-situ logs



Lithology sensitivity is high

Synthetics derived from shale-replaced logs

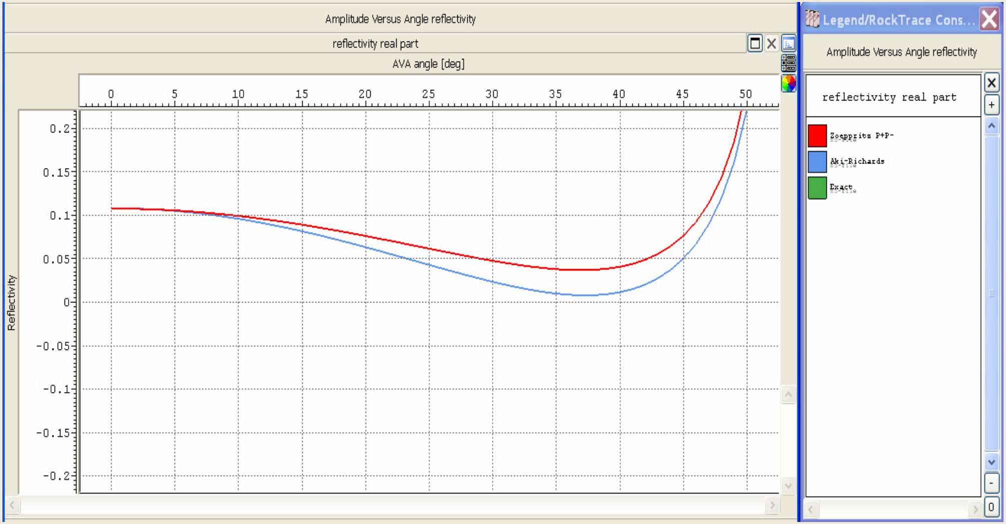


FUGRO PXP FUGRO JASON

Presenter's notes: Lithology sensitivity is very high, as shown in the synthetics.

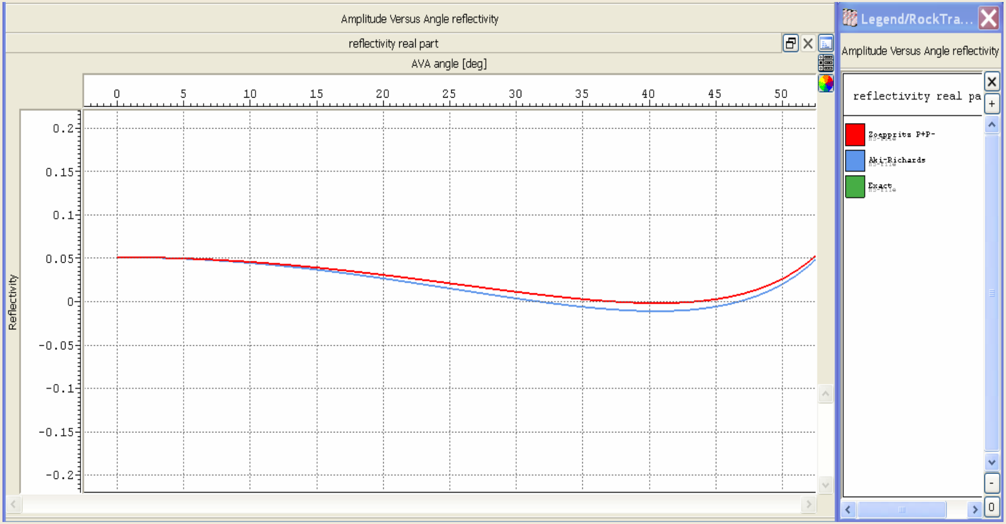
AVO Attributes in Half-Space before Shale-Replacement

Half-Space Modeling can be used as reference to estimate AVO/AVA attributes in the absence of gathers



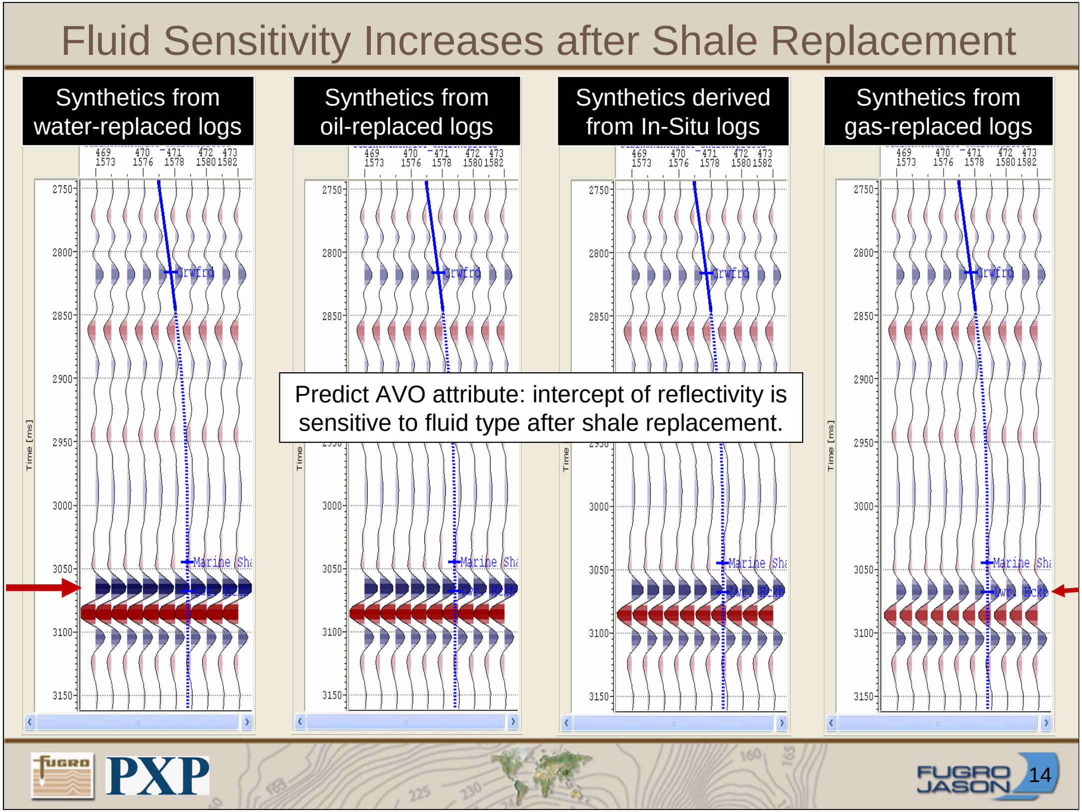
Predict AVO response: reflectivity intercept and slope are not very sensitive to fluid type.

AVO Attributes in Half-Space after Shale-Replacement



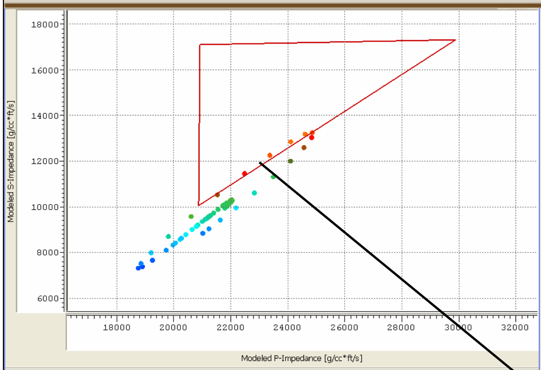
Both intercept and slope are reduced after shale replacement indicating the impact on AVO attributes.

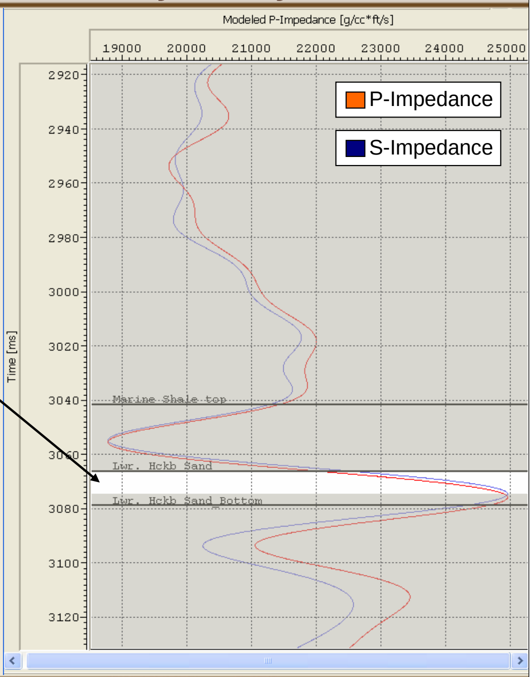
Presenter's notes: Half-Space Modeling can be used to estimate AVO/AVA property in the absence of seismic data. However, it is just an estimation with the assumption that the event is isolated.



Presenter's notes: Lithology effect overshadows fluid effect. After shale replacement, fluid sensitivity increases.

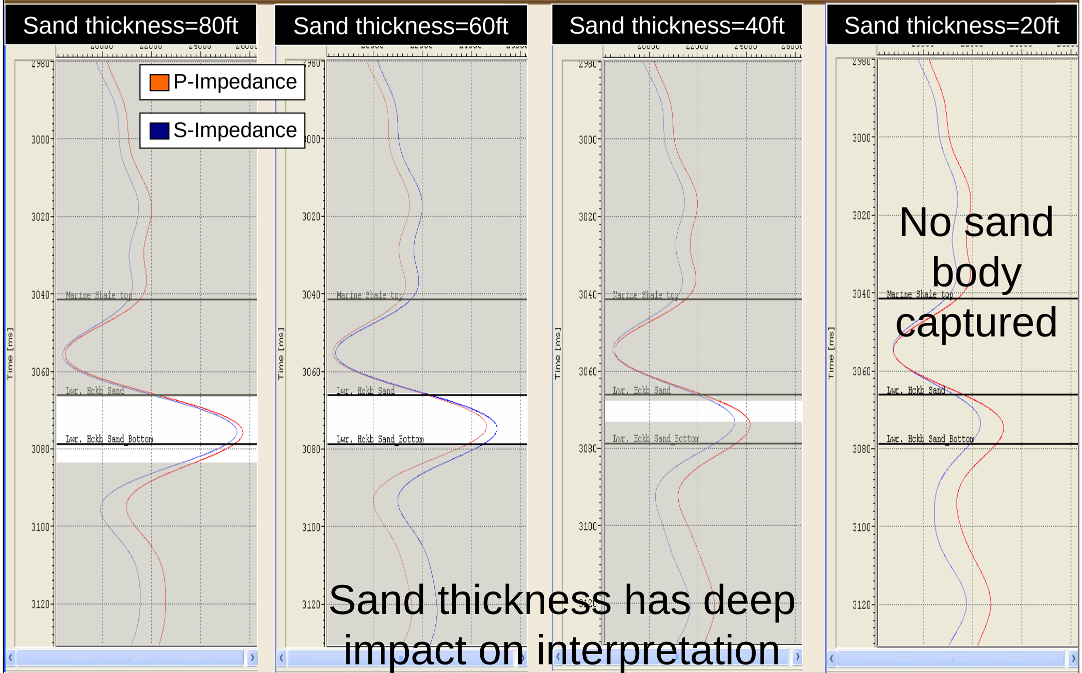
Sand Thickness Sensitivity Study





Highlighted In-situ sand thickness in seismic resolution.

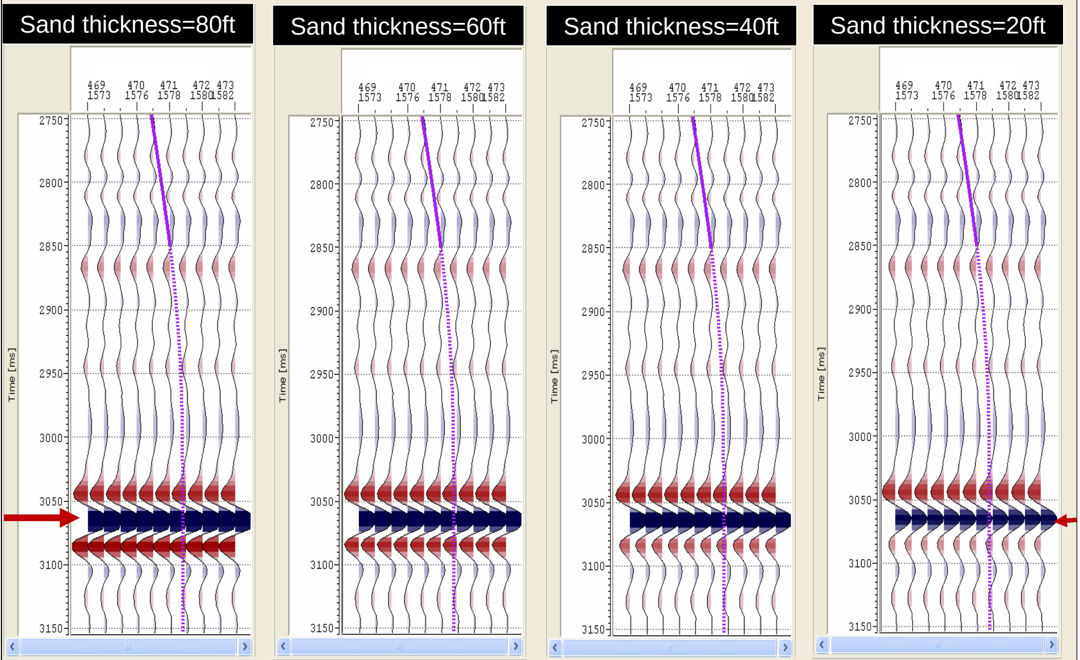
Captured Sand Body in Seismic Resolution



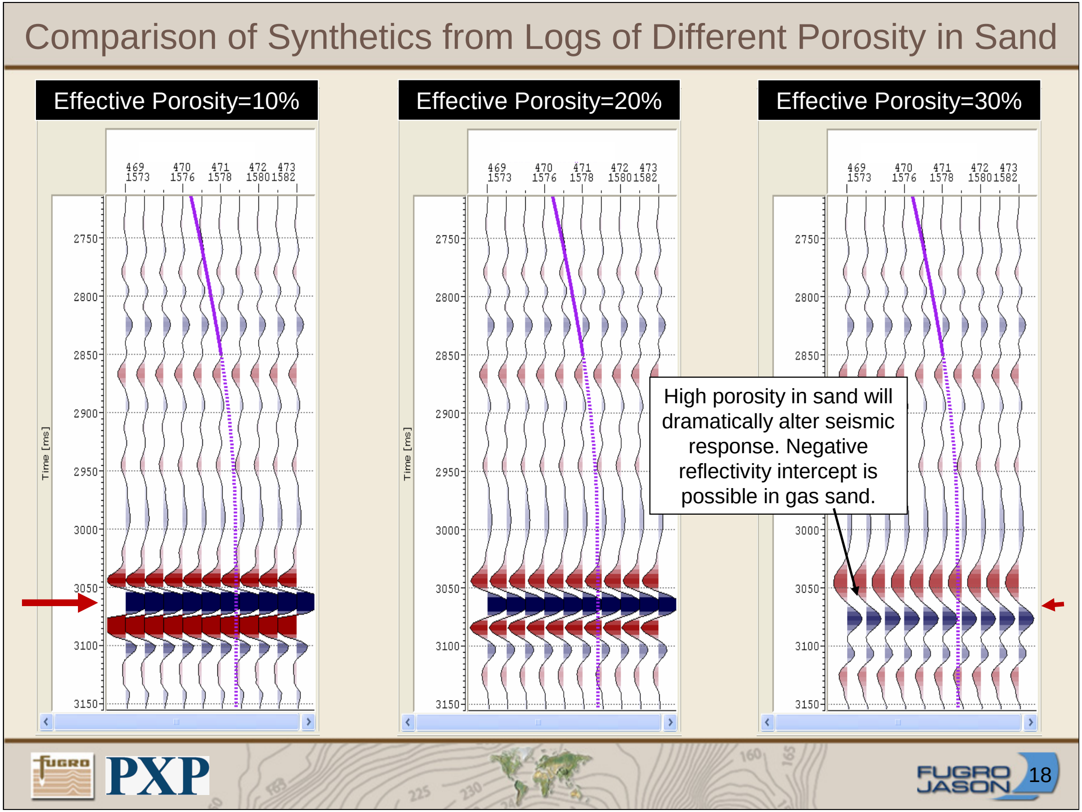
No sand body captured

Sand thickness has deep impact on interpretation

Comparison of Synthetics from Logs of Different Sand Thickness



Presenter's notes: Generate synthetics to predict seismic response for different sand thickness.



Presenter's notes: Similar study will show how porosity affects seismic response. Negative reflectivity intercept is possible in gas sand; this means AVO type II or III sand.

Conclusions

- Integrated Petrophysics and Rock Physics modeling is important to understand lithology, porosity and fluid effect in different scenarios and can improve reservoir characterization.
- Interpreter can estimate seismic responses by Rock Physics modeling and evaluate the effect of lithology, porosity and fluid types.
- Areas like this are perfect for seismic inversion as they will help the interpreter discriminate unusual sand/shale packaging from good quality sand.
- Lithology effect can overshadow fluid effect. Lithology replacement can differentiate the effects and reveal the fluid effect for better assessment.