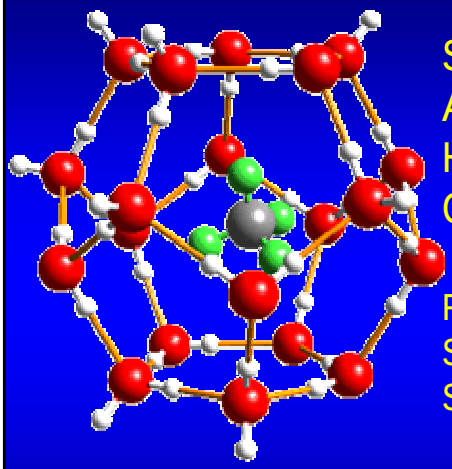

Seismic Interpretation, Analysis and Modeling of Gas Hydrates in the Deepwater Gulf of Mexico

Reservoir Services / DCS
Schlumberger
September 30, 2003

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Gas Hydrates Team at WesternGeco

Fred Snyder*, Lecia Muller, Jianchun Dai,
Haibin Xu, Adam Koesoemadinata, Diana Gillespie,
Gary Wool, Chung-Chi Shih, Paul Hultzsch and
Nader Dutta+

***Project leader**
+ QC / Advisor

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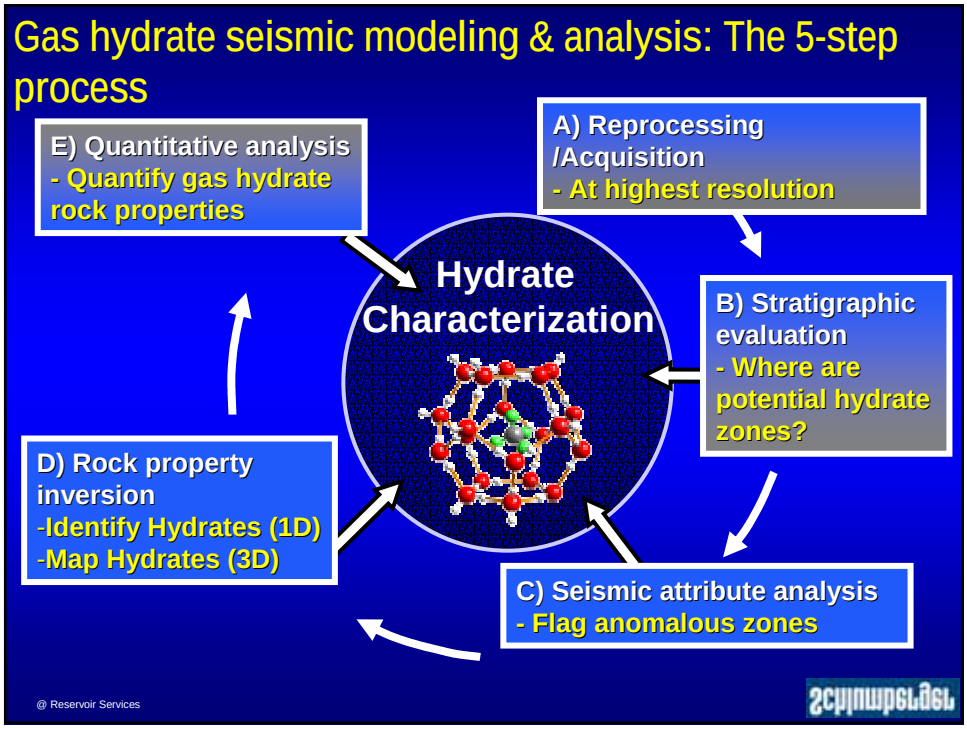
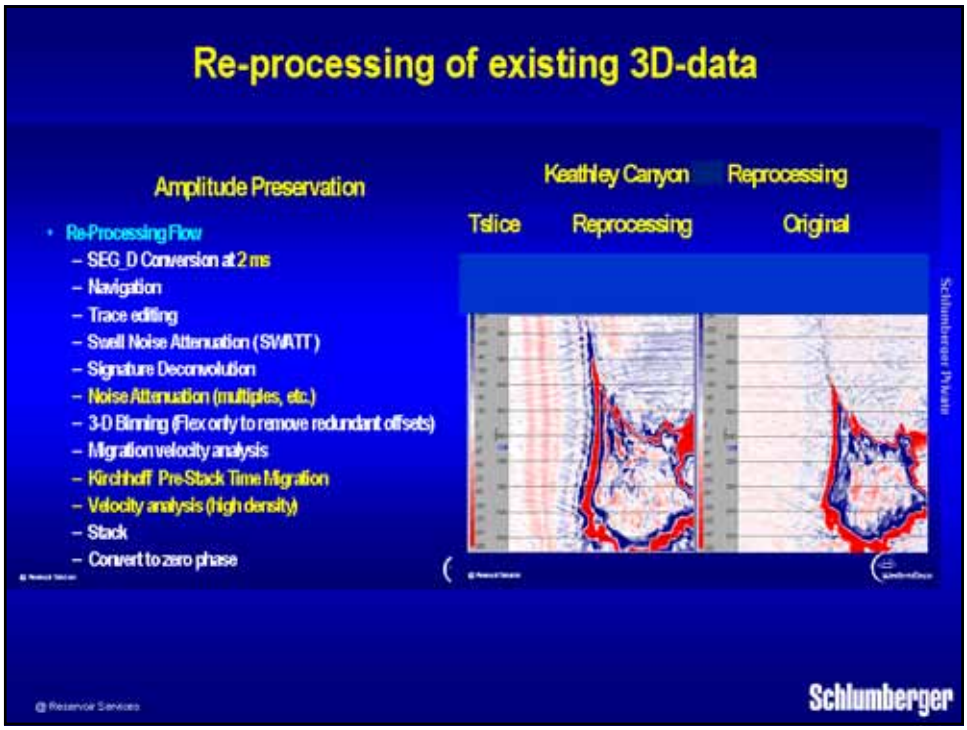
Overview

- Introduction — Nader Dutta
  - Goals of the seismic project
- Re-processing 3D-seismic data — Nader Dutta
  - Highlights
- Seismic interpretation — Fred Snyder
- Quantitative modeling — Jianchun Dai
  - Seismic inversion (FWPI)
  - Rock modeling
  - Gas hydrate saturation mapping
- Summary and Recommendations — Nader Dutta

Goals of the Seismic Program

- Establish a geologic framework for gas hydrates detection
- Show whether available seismic data is adequate for gas hydrate detection and quantification
- Define processing flow of seismic data (shallow targets)
- Develop a procedure of gas hydrate characterization
- Help decide JIP drilling sites





Seismic Interpretation

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Keathley Canyon

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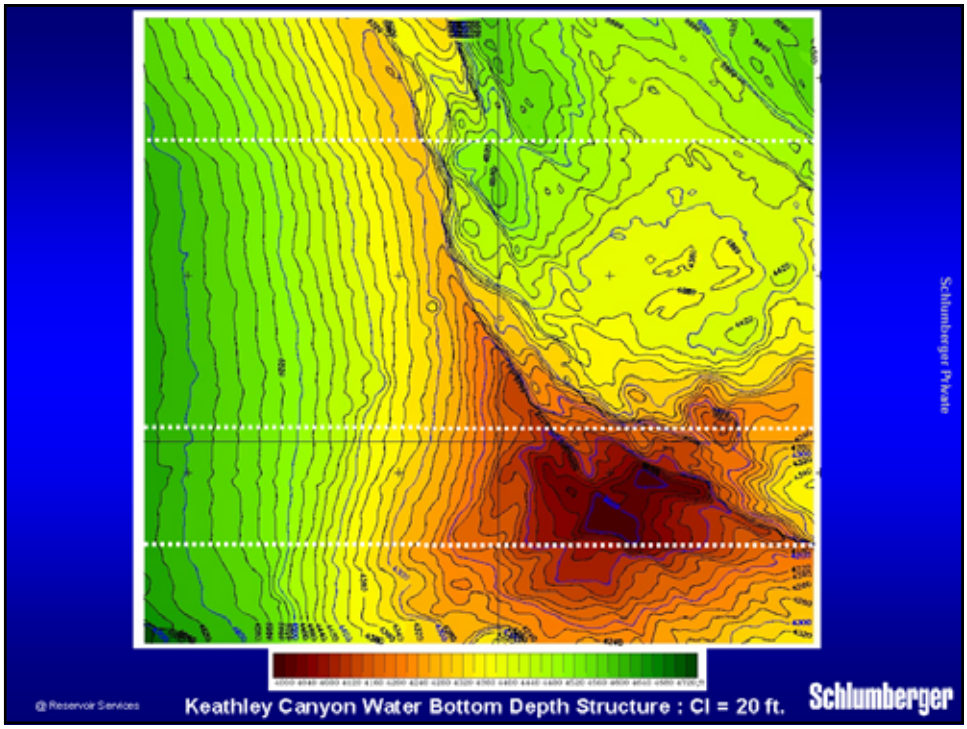

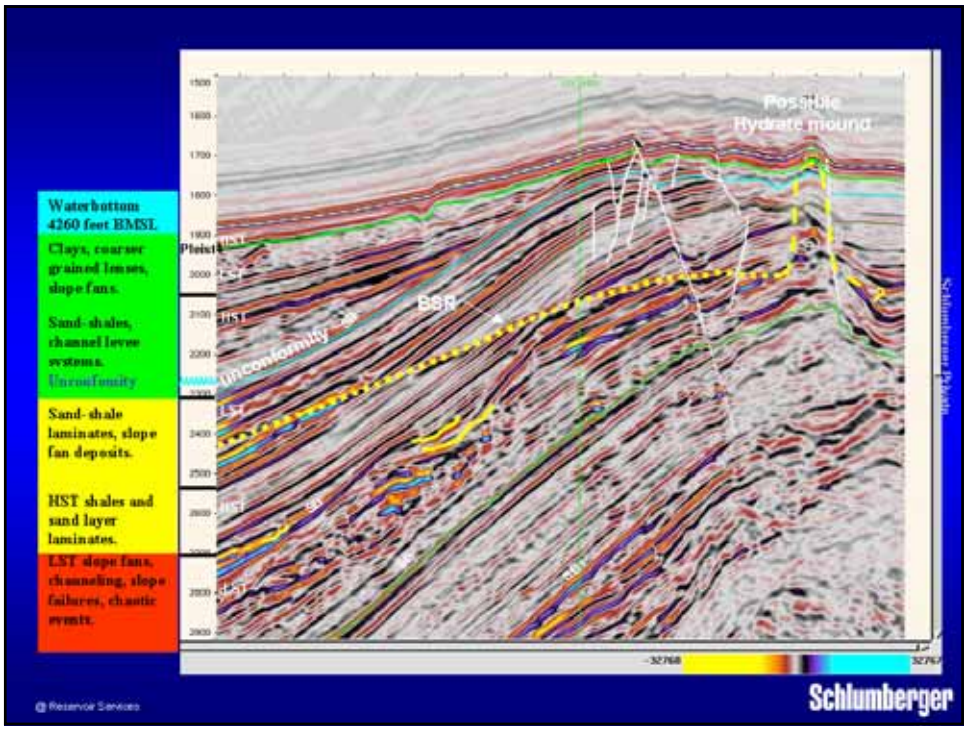

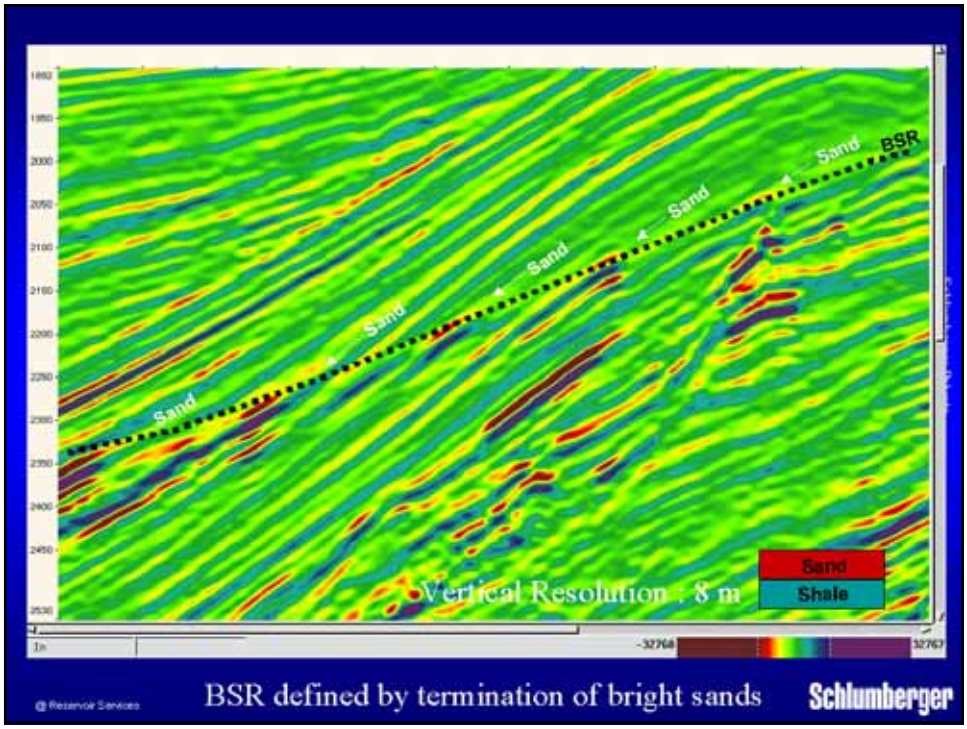

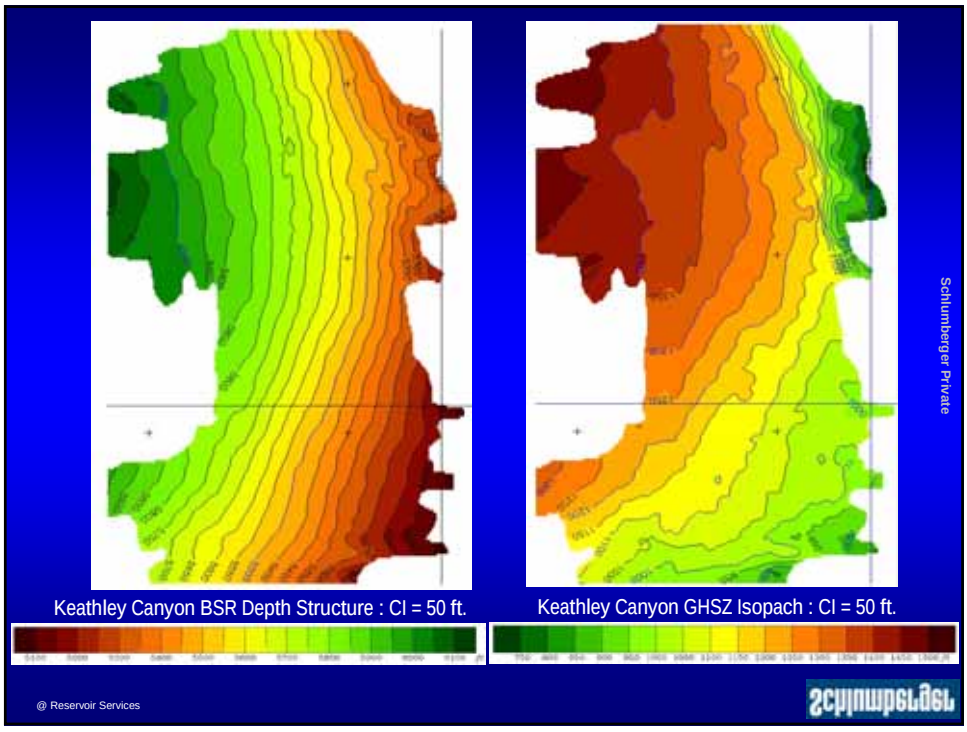

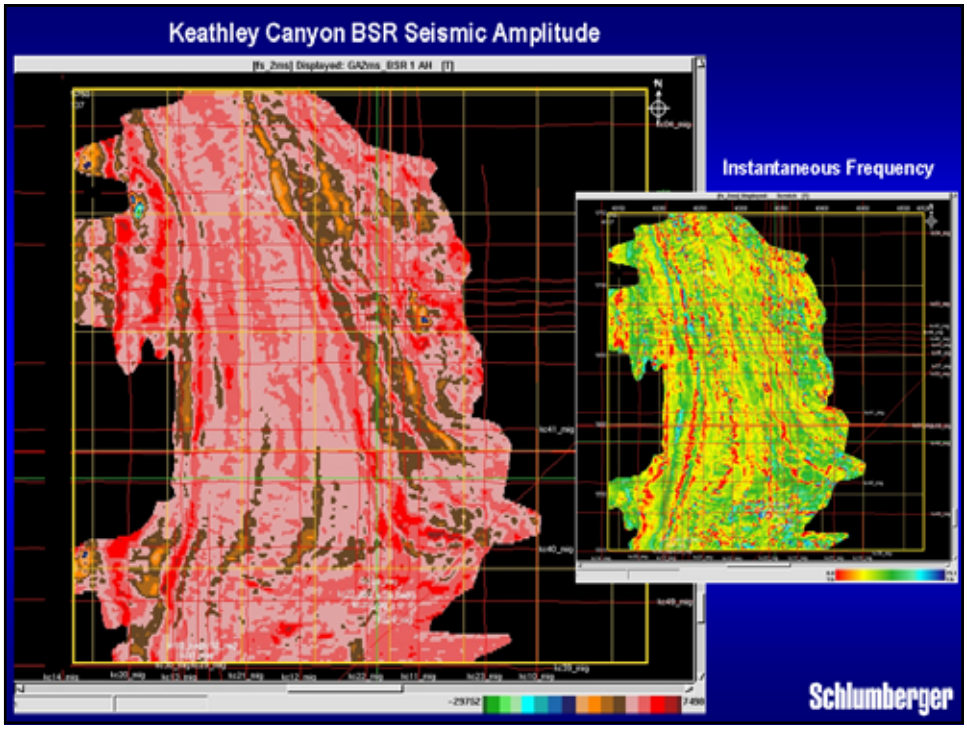

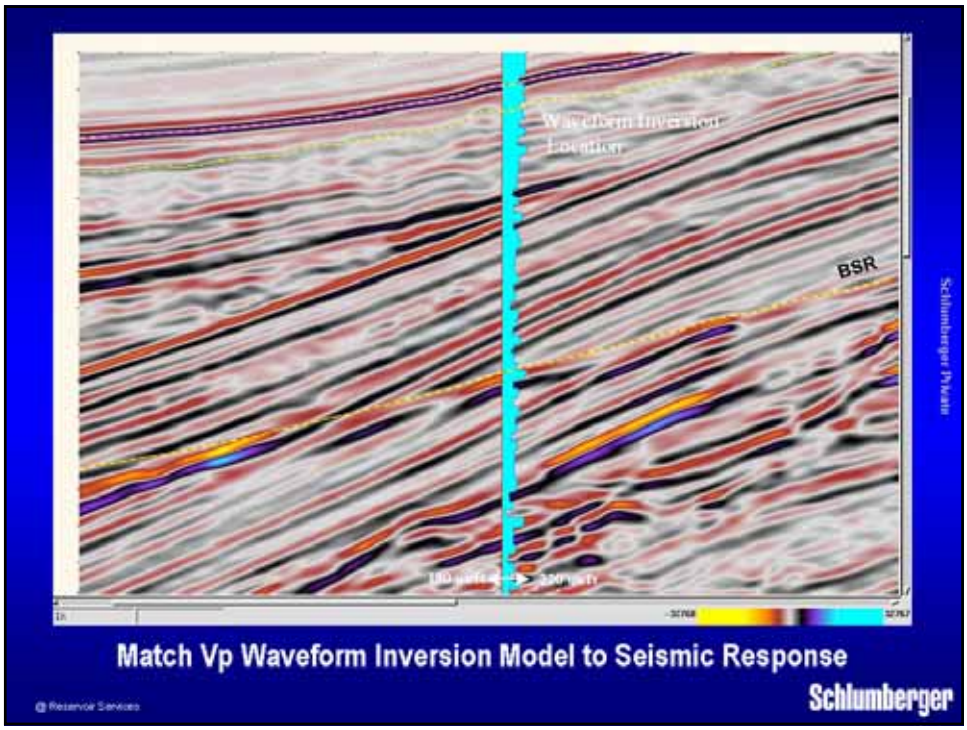

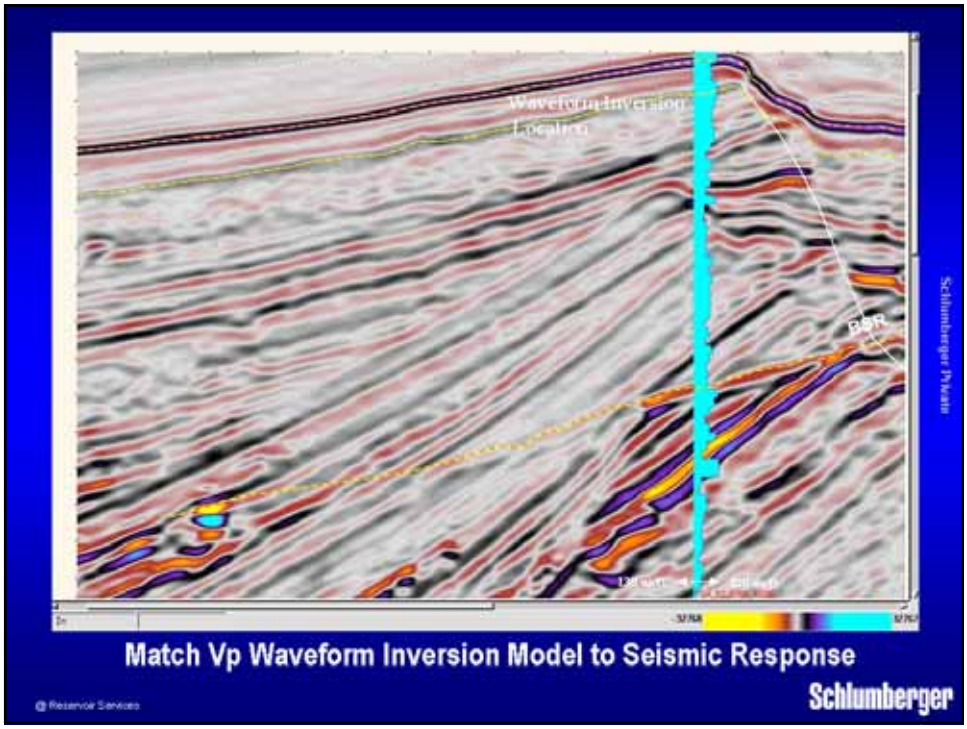

Atwater Valley

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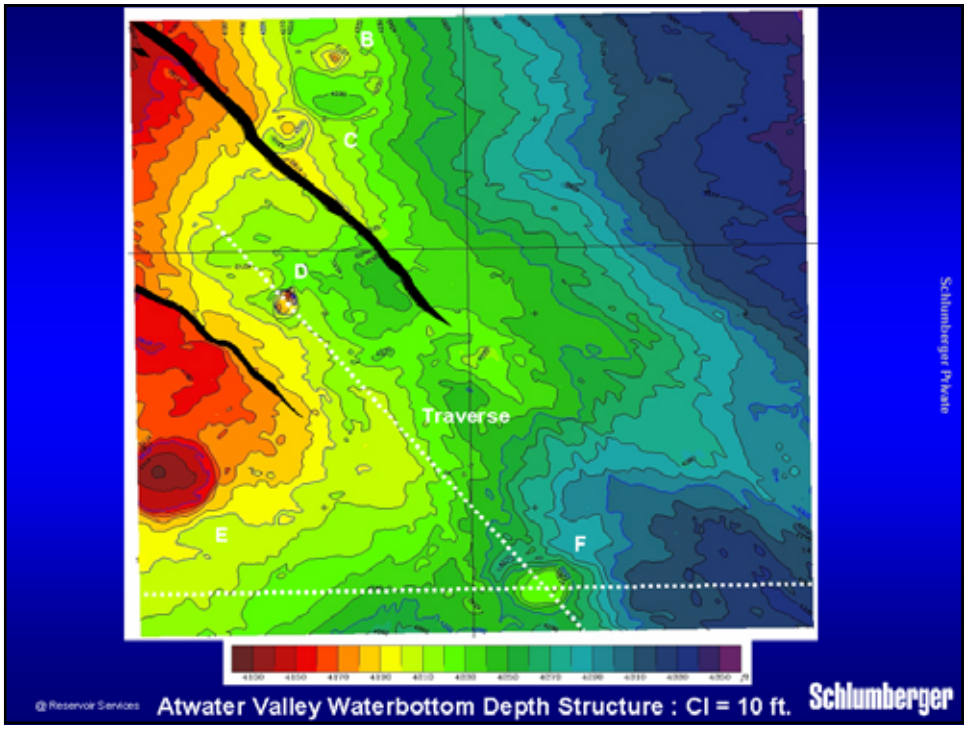

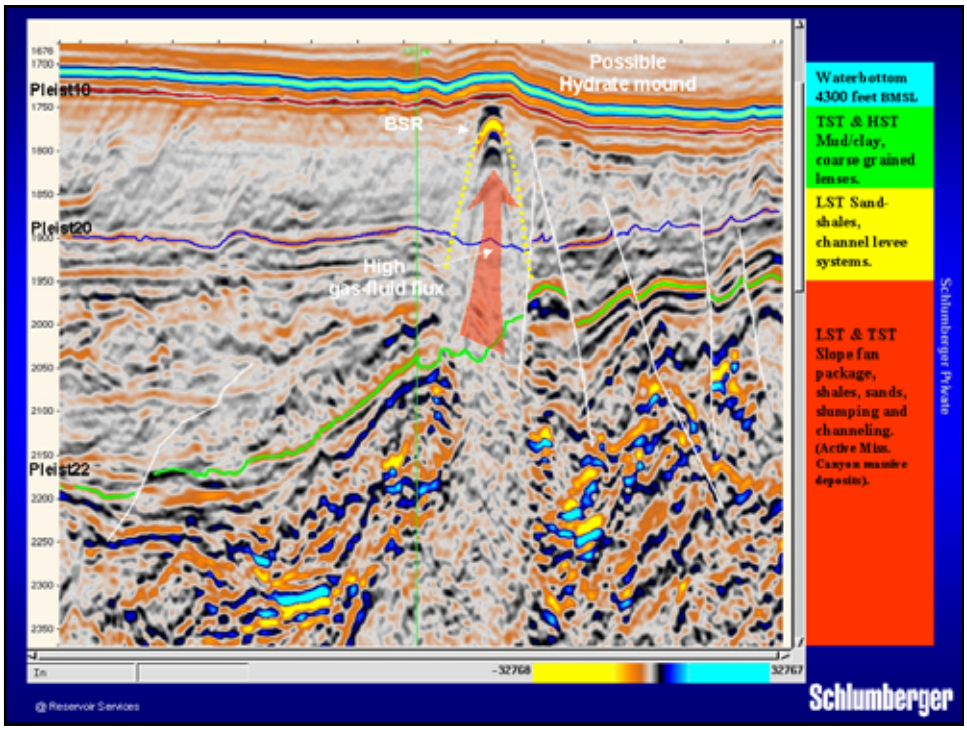

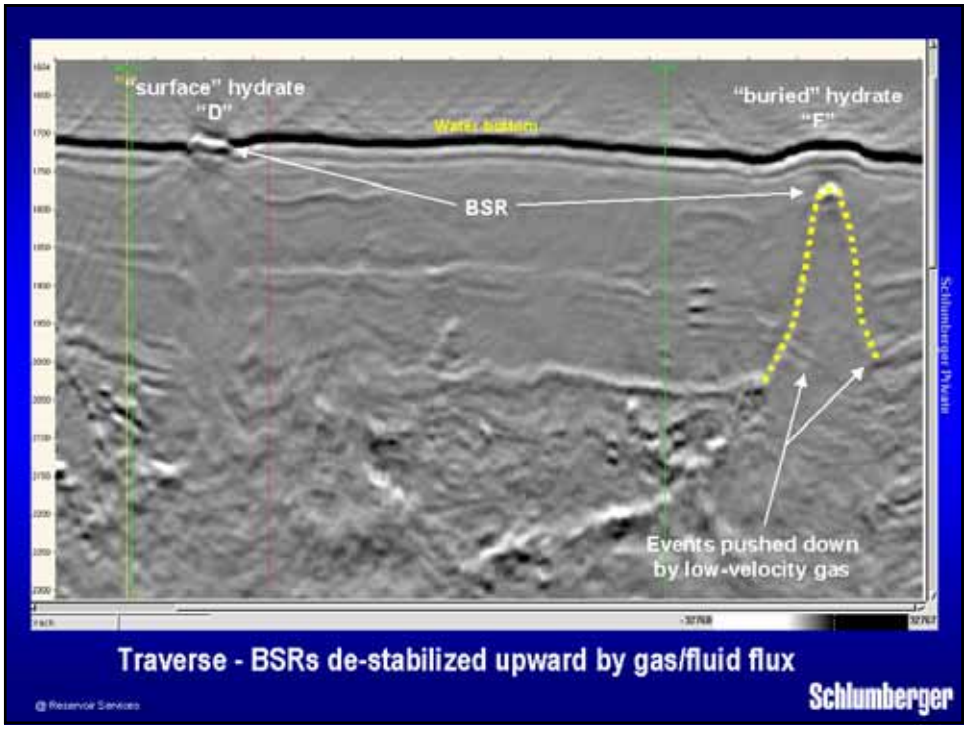

Quantitative Modeling

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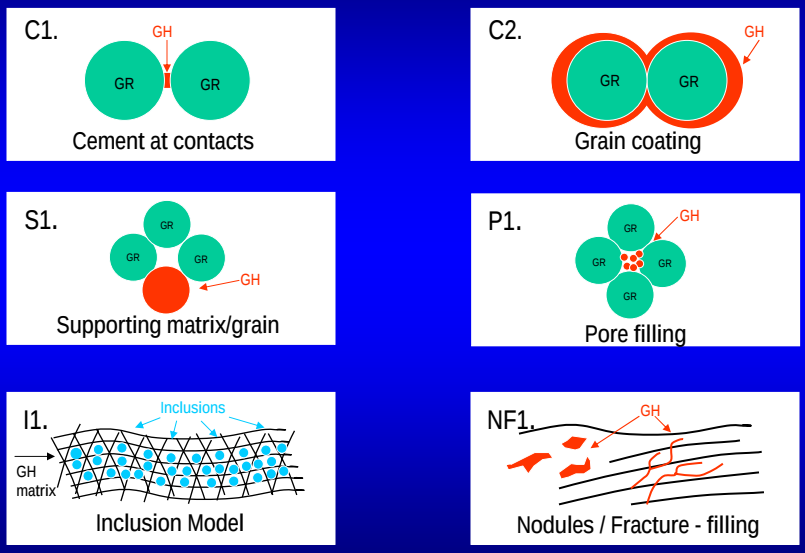
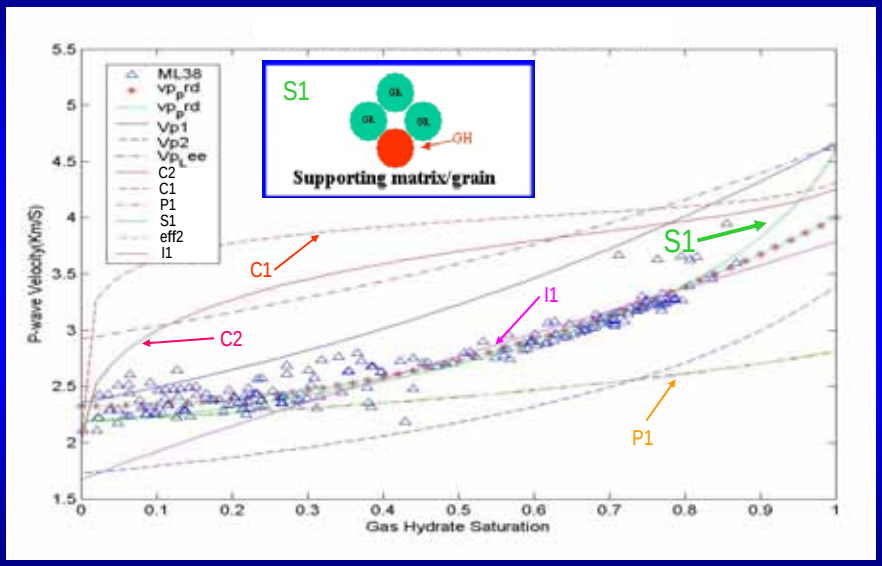
The Workflow Overview

- Rock physical models of gas hydrate bearing sediments.
- Full waveform prestack modeling and inversion (vp, vs, density)
- Hybrid inversion of gas hydrate bearing sediments (3D)
- Gas hydrate saturation estimation

Major models of gas hydrate distribution in sediments



Vp estimation of all models



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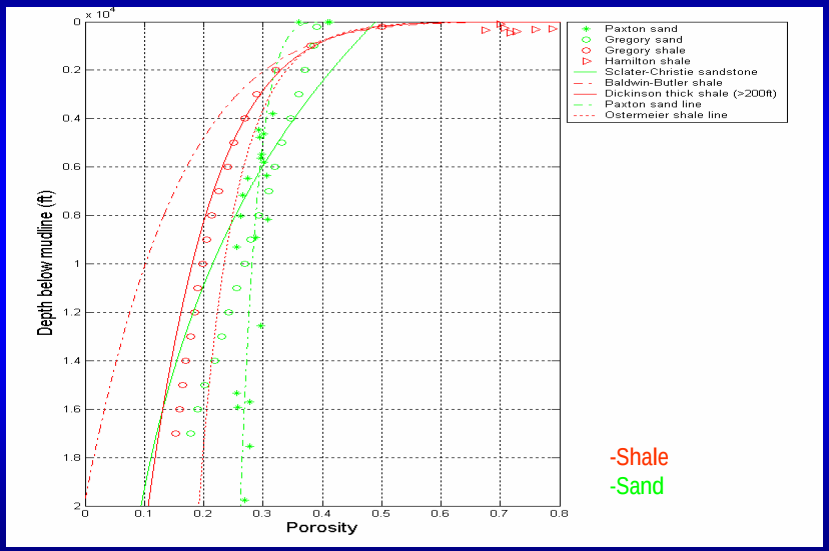
Depth trend construction, porosity profile



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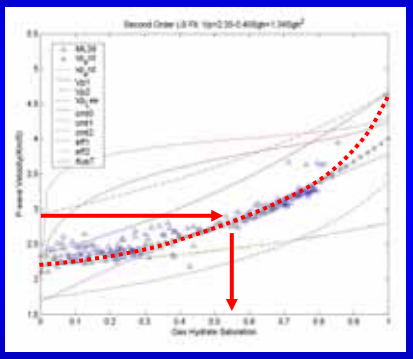
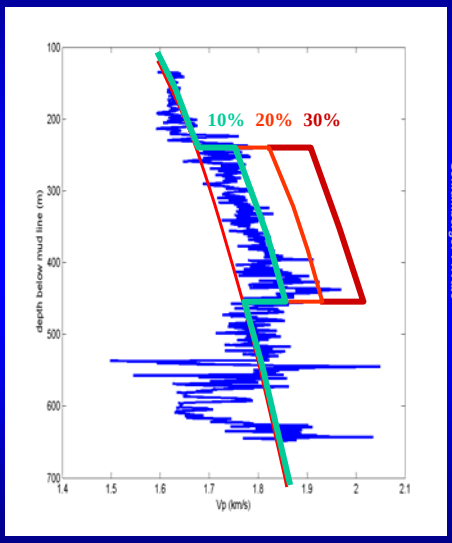
Validation of gas hydrate saturation estimation using Blake Ridge well





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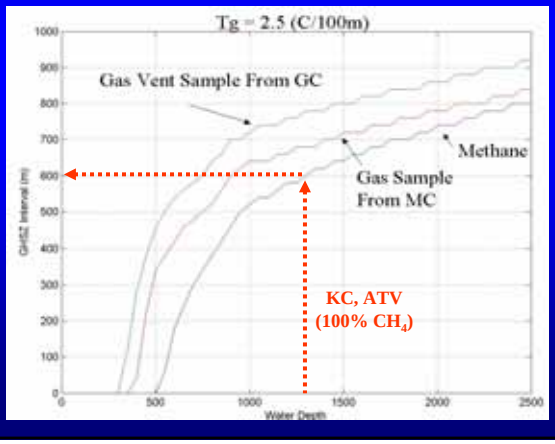
Gas hydrate stability zone

GHSZ is determined by:

- Temperature (thermal gradient & sea floor temperature)
- Formation pressure (burial depth below mudline)
- Chemical composition of natural gas
- Fluid properties



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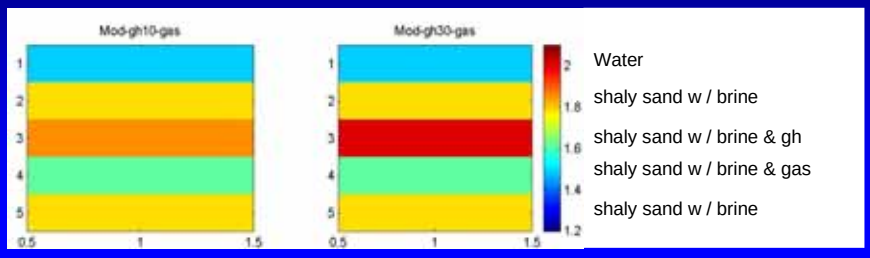
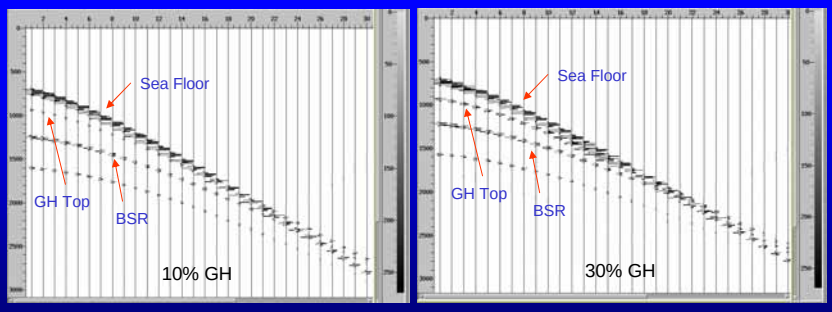
Example case for full waveform modeling





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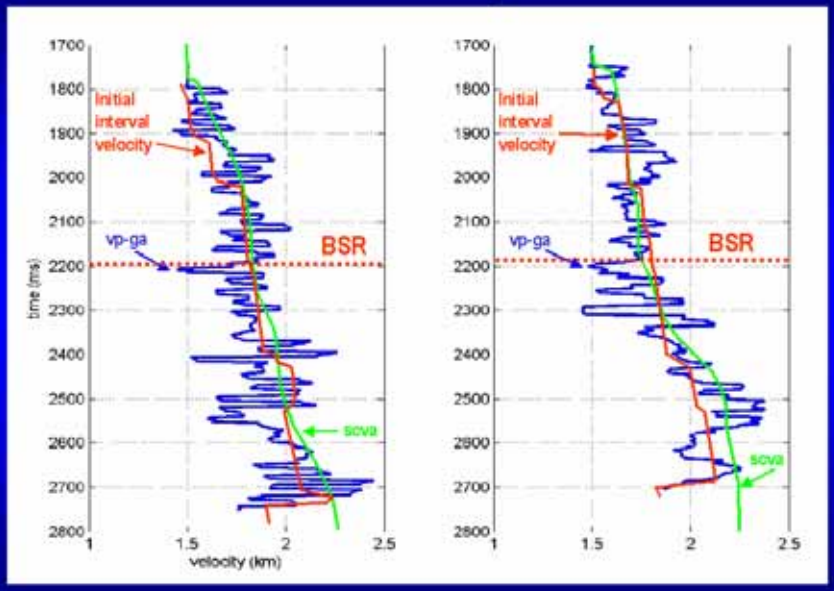
Mechanism of full waveform prestack inversion



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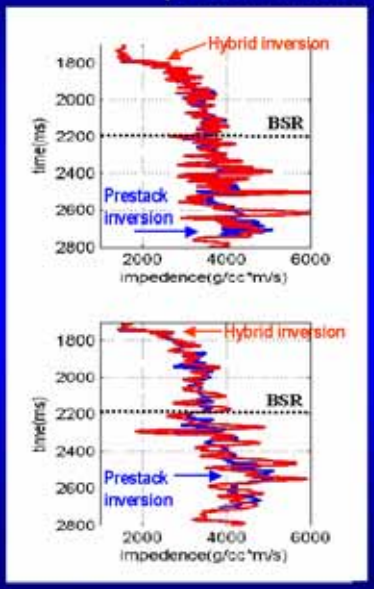
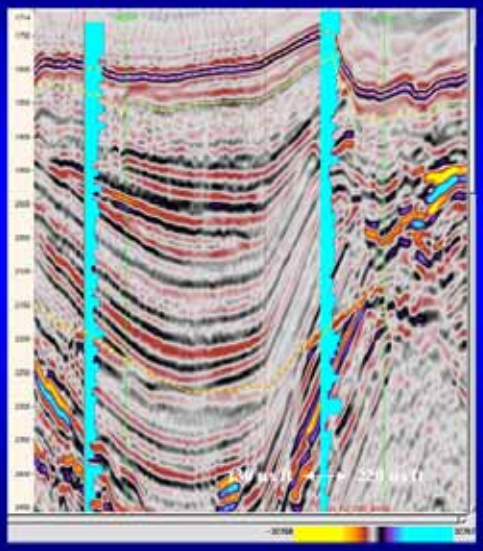
Examples of P wave impedance from full waveform prestack inversion & hybrid inversion





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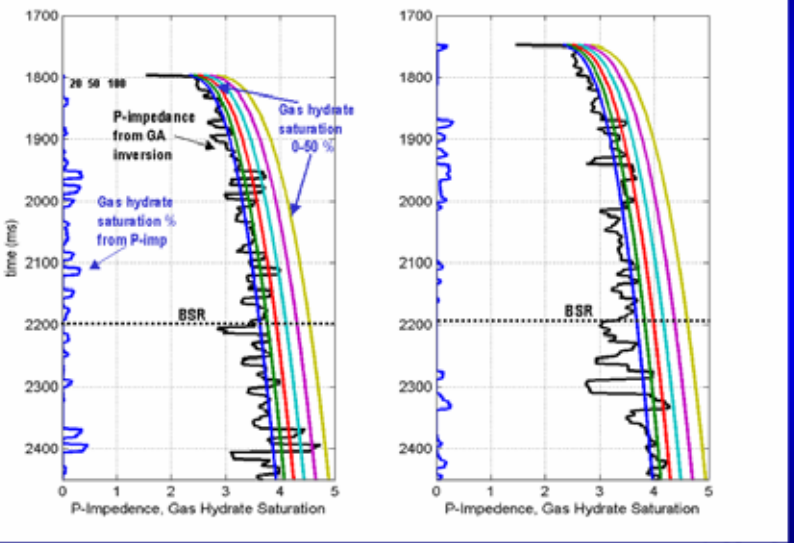
Gas hydrate estimation from P-wave impedance derived from full waveform inversion



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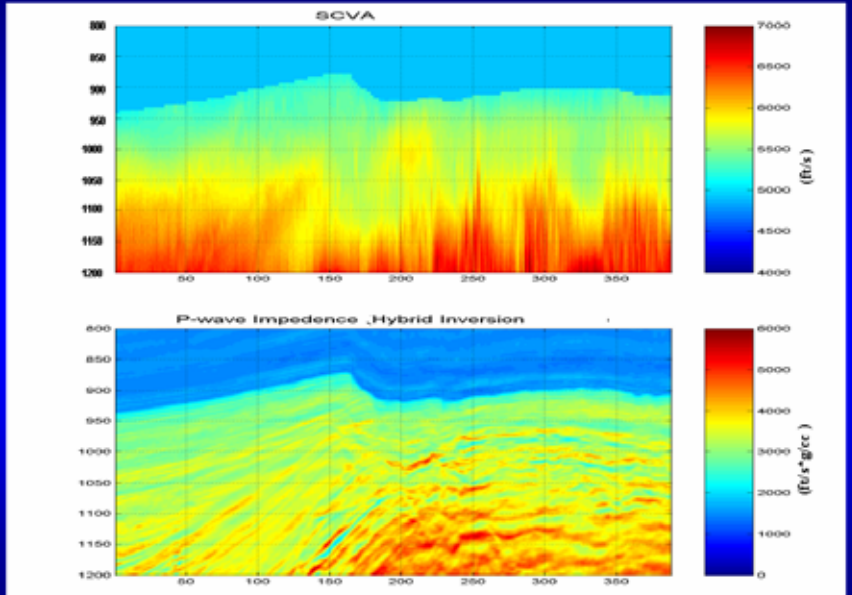
Keathley Canyon SCVA and P-impedance



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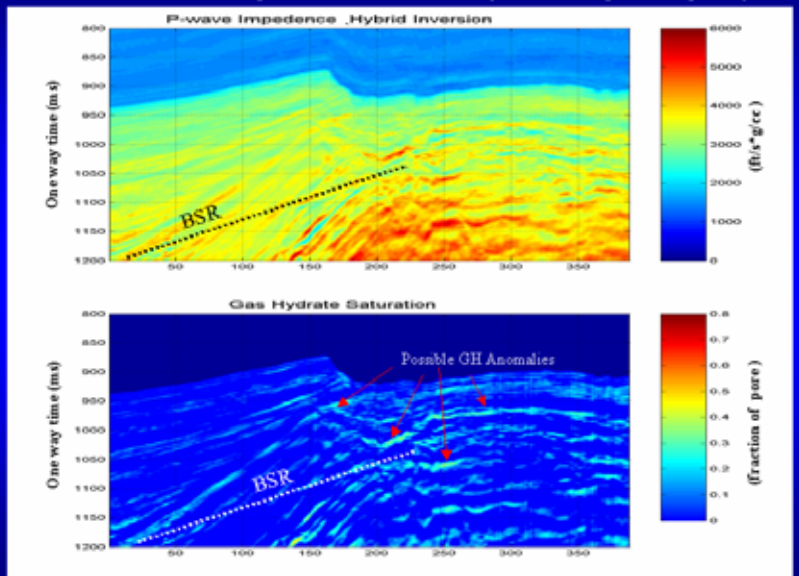
P-wave impedance and gas hydrate estimation derived from hybrid inversion (Keathley Canyon)



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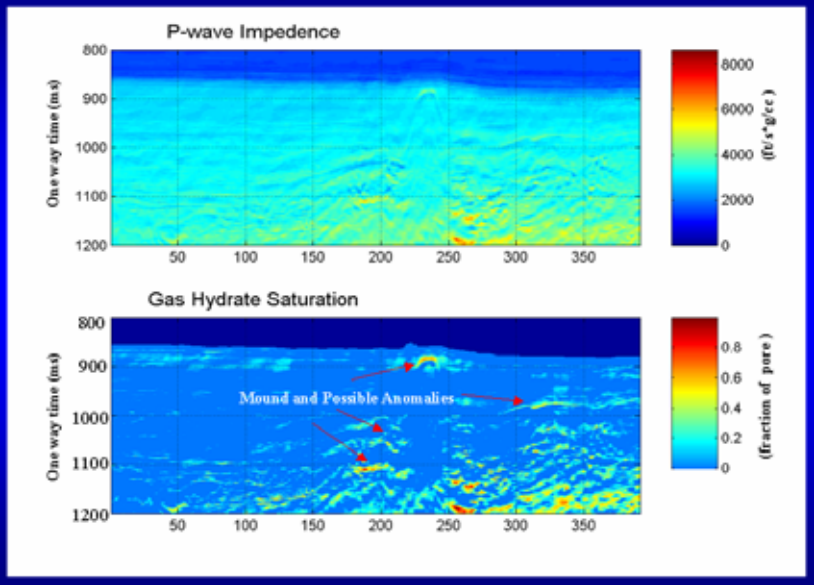
P-wave impedance and gas hydrate estimation derived from hybrid inversion (Atwater Valley)



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Summary and way forward

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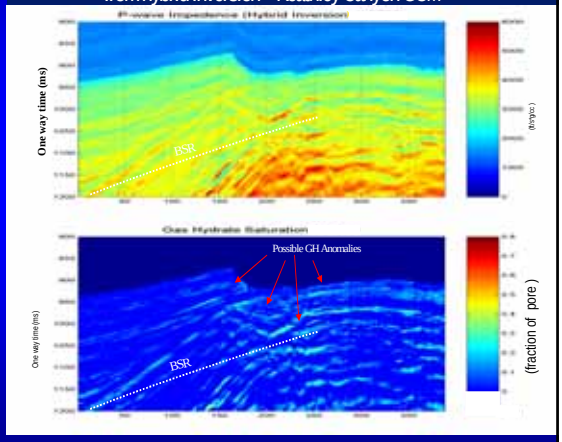
Summary

- New processing flow
- Assessment of rock physics models for gas hydrates
- Acoustic parameter extraction from inversion of prestack seismic data
- Gas hydrate saturation mapping in 3D
- Selection of coring sites

P-wave impedance and Gas Hydrate Saturation derived from hybrid inversion – Keathley Canyon GOM



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Summary

- Seismic detection using quality, high resolution data is the key for identifying and characterizing gas hydrates.
- The gas hydrate stability zone and hydrate occurrences can be reasonably predicted using seismic data interpretation techniques and attributes.
- Full waveform prestack inversion correctly ties to the seismic data without the benefit of actual well data.
- Potential drilling locations can be picked as a result of this study.
- Integration of geology, geophysics, gas hydrate rock physics and geochemistry is necessary for properly delineating gas hydrate occurrences.
- Gas hydrate rock physics provides the link between the elastic anomaly derived from the seismic analysis and the quantitative estimation of gas hydrate.
- Fullwave prestack inversion and hybrid inversion generate elastic volumes that can be used to estimate gas hydrate saturation in shallow sediments.
- All gas hydrate models need to be tied to REAL DATA (well logs, soil studies, cores, thermal and geochemical data, etc.) to ensure that the models are properly calibrated to the seismic response.

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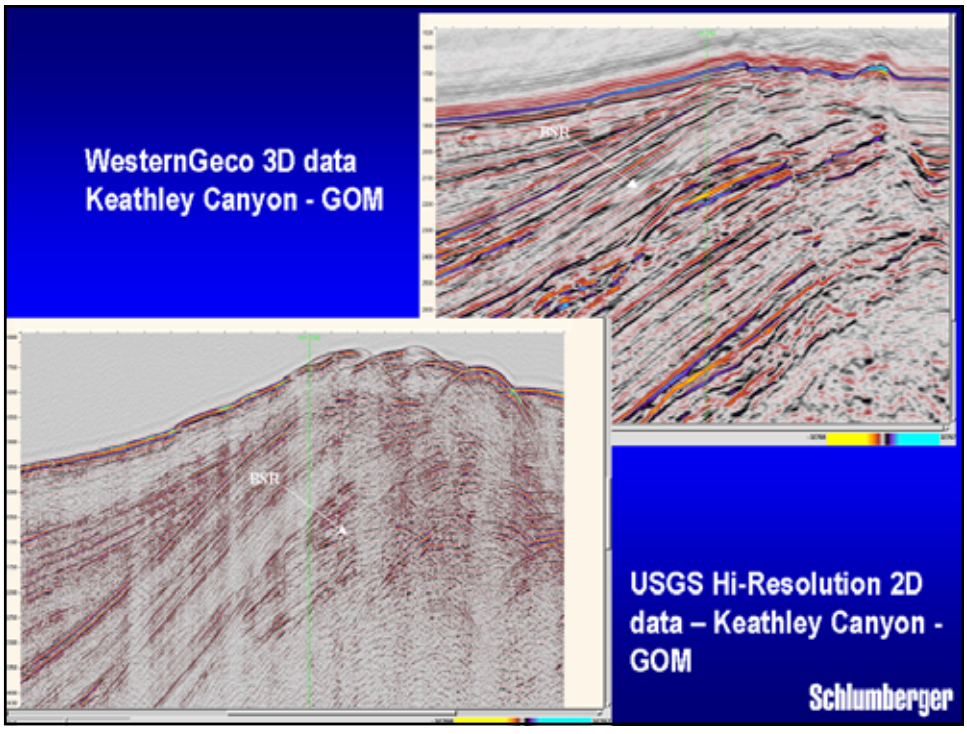
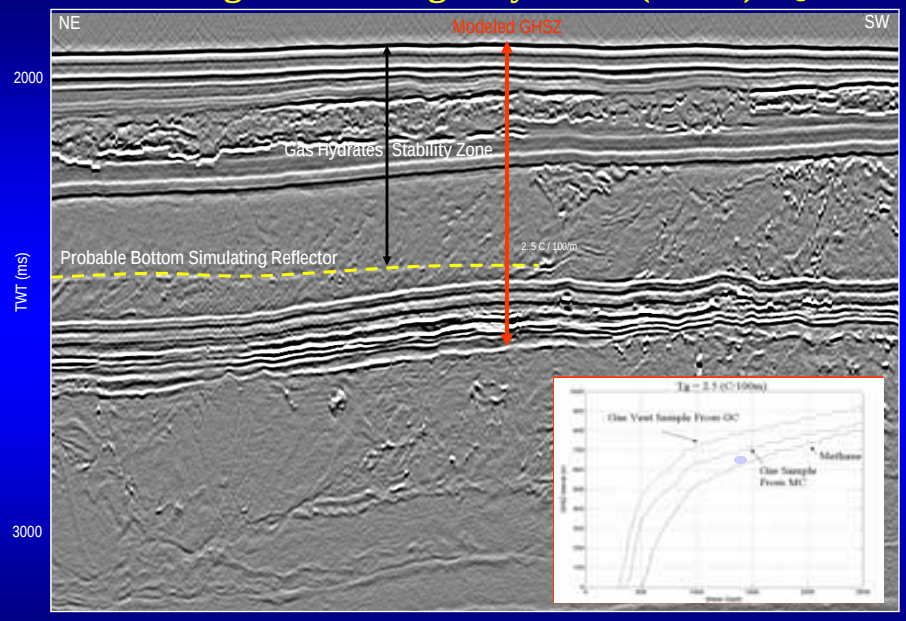
Observations

- High resolution data will add value for shallow seismic applications
- Multi-component data will add value in areas where imaging is difficult (gas chimneys, e.g.)
- Processing and modeling techniques developed in this study can be applied to other areas for gas hydrate identification



Shallow drilling hazards & gas hydrates (GOM): Q-data



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Recommendations

- Carry out detailed pseudo-logs (inversion) and high-density VA at drill sites for well planning
- Use pre-stack depth migration at drill sites for accurate imaging and T/D analysis
- Integrate seismic results with those from Georgia Tech laboratory work
- Calibrate the results of this study with the well information obtained in the Phase 2 drilling program to verify and modify the results, as needed.
- Identify, screen and model new areas for gas hydrate identification using the methods and processes developed in this study for Phase 2

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