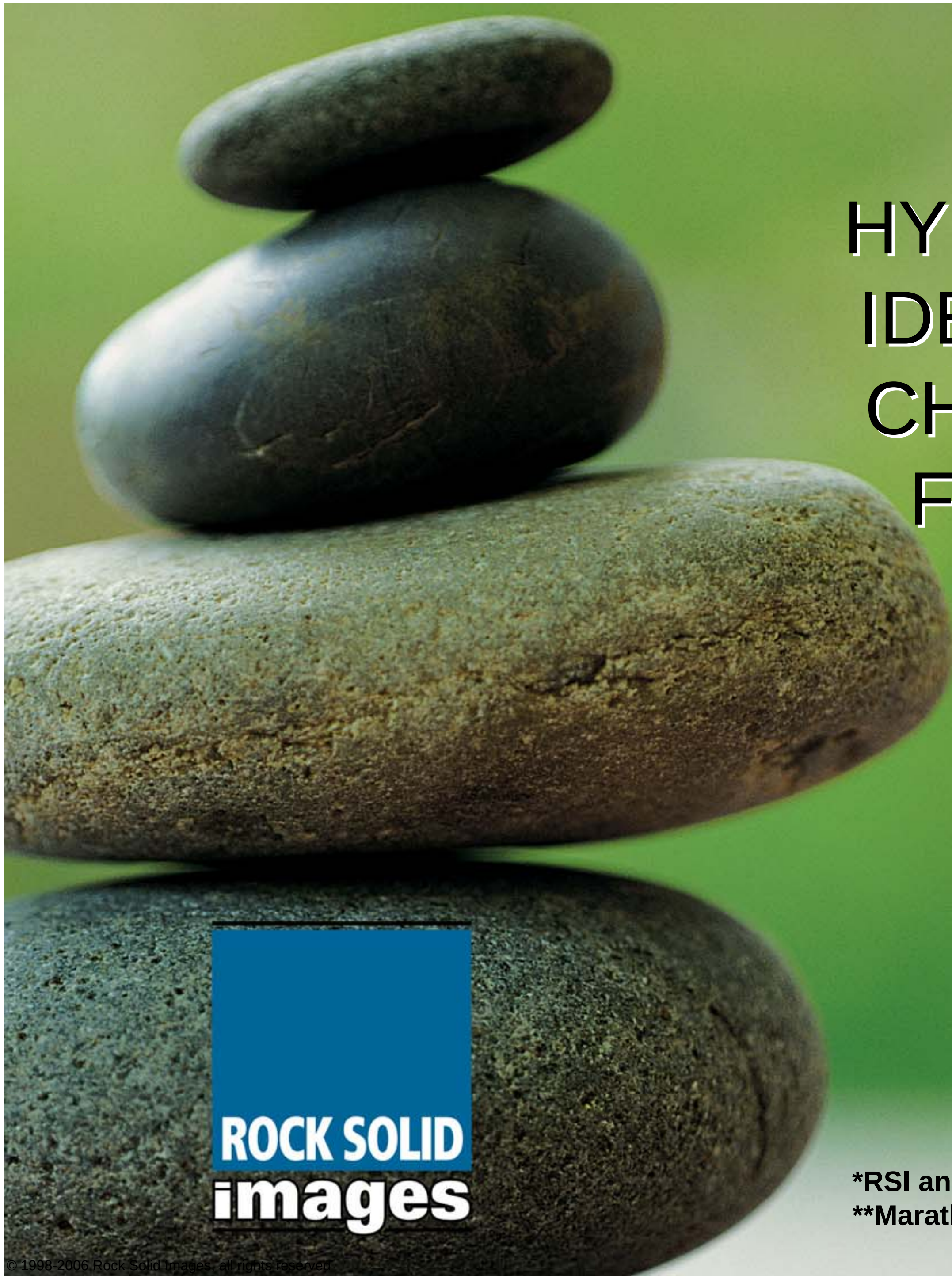


HYDRATE RESOURCE IDENTIFICATION AND CHARACTERIZATION FROM WELL LOGS AND SEISMIC

Joel Walls

Jack Dvorkin*

Richard Uden**

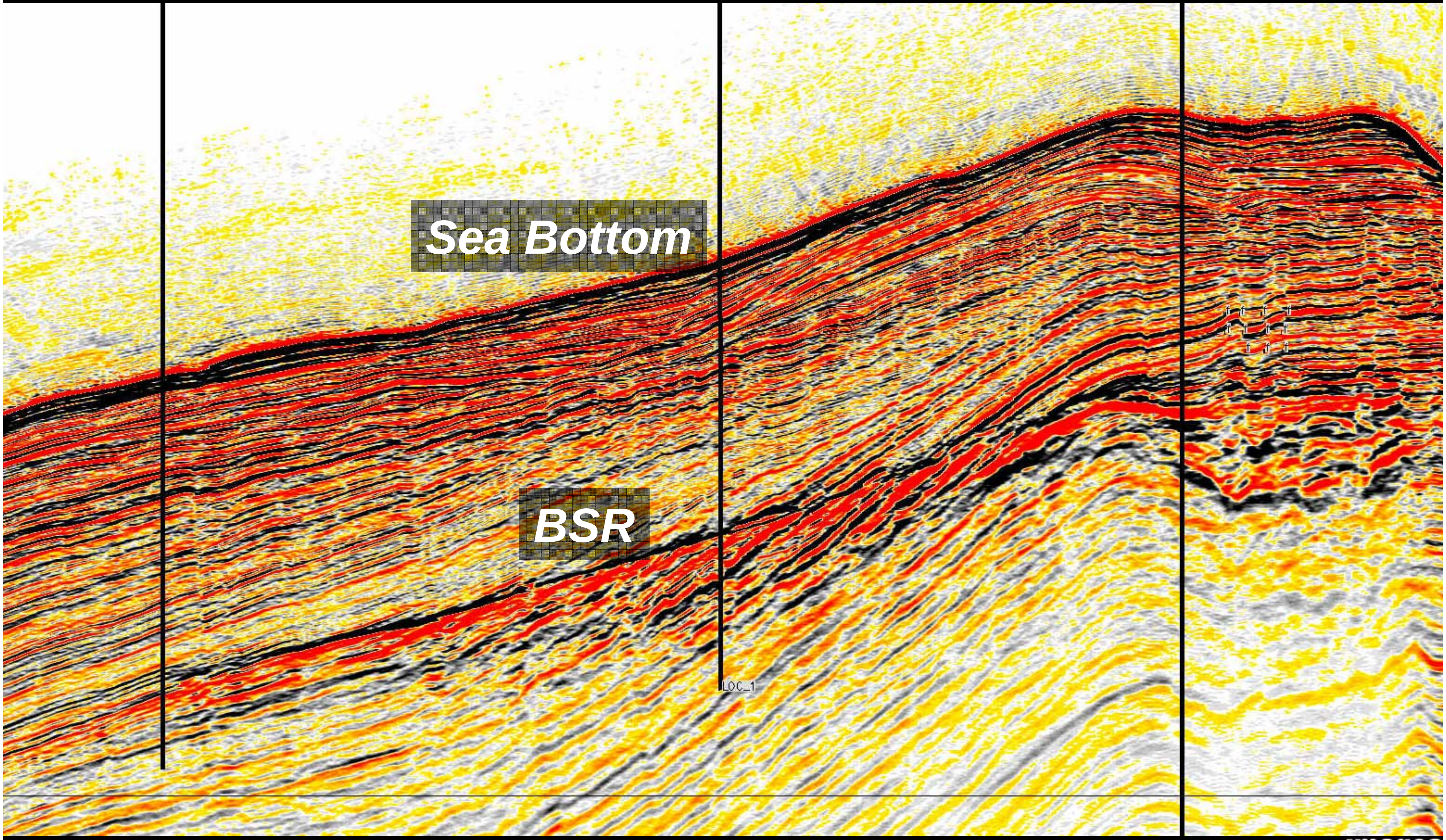
***RSI and Stanford University**
****Marathon Oil Co.**

Outline

- The expanding search for hydrate resources
- Our focus: Mackenzie Delta (Mallik)
- Well logs and rock physics
- Seismic Reconnaissance and Qualitative Interpretation
  - Seismic impedance
  - Seismic attenuation
  - Hybrid attributes
- Quantifying Hydrate Volumes: Future Directions
- Observations and Summary

Expanding Search for Methane Hydrate

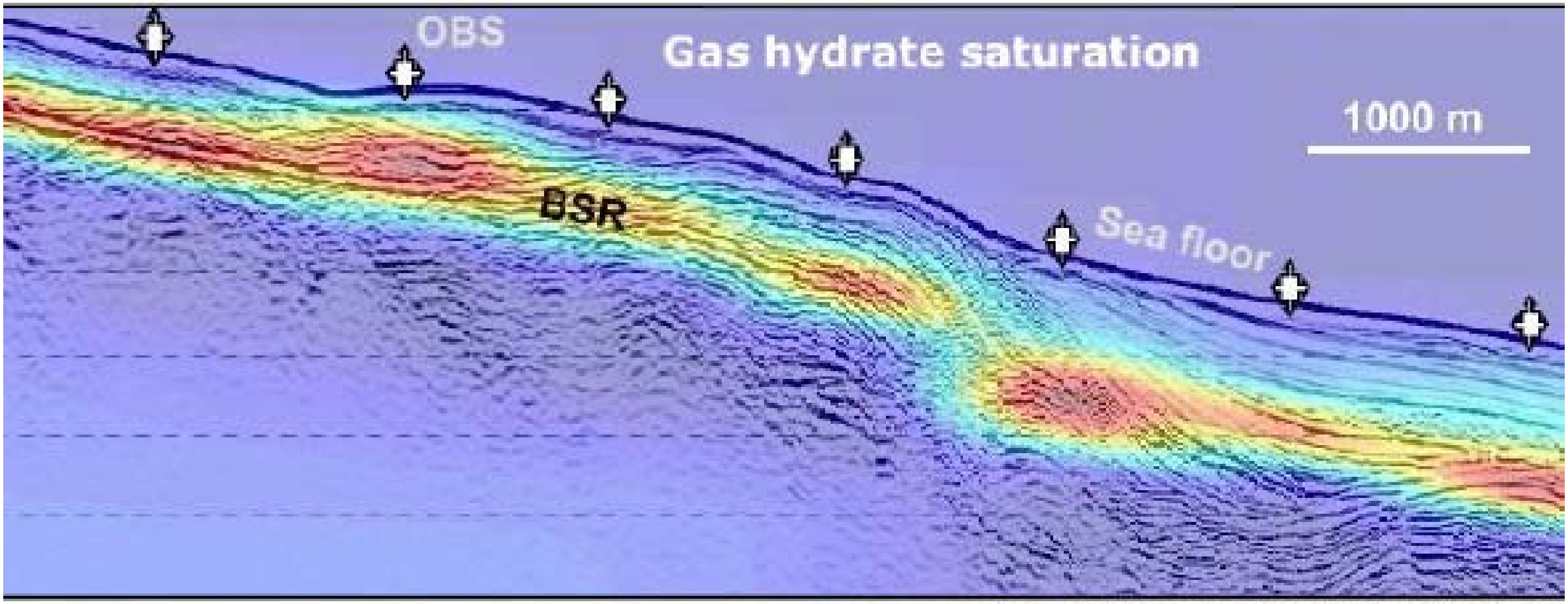
Nankai Trough



images

Expanding Search for Methane Hydrate

Cascadia (Vancouver Island, Hydrate Ridge)



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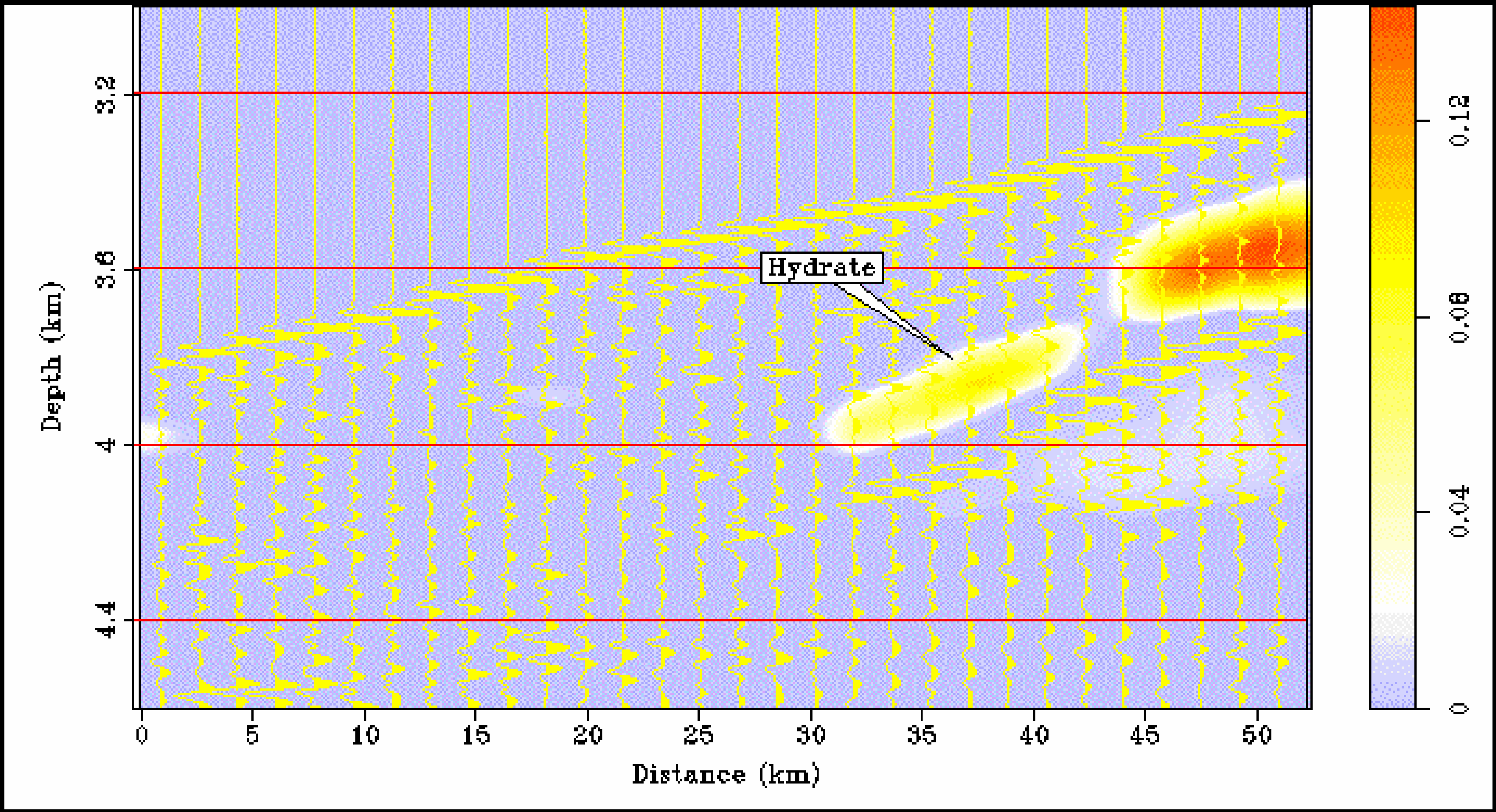
Expanding Search for Methane Hydrate

Outer Blake Ridge



Ecker, 2000

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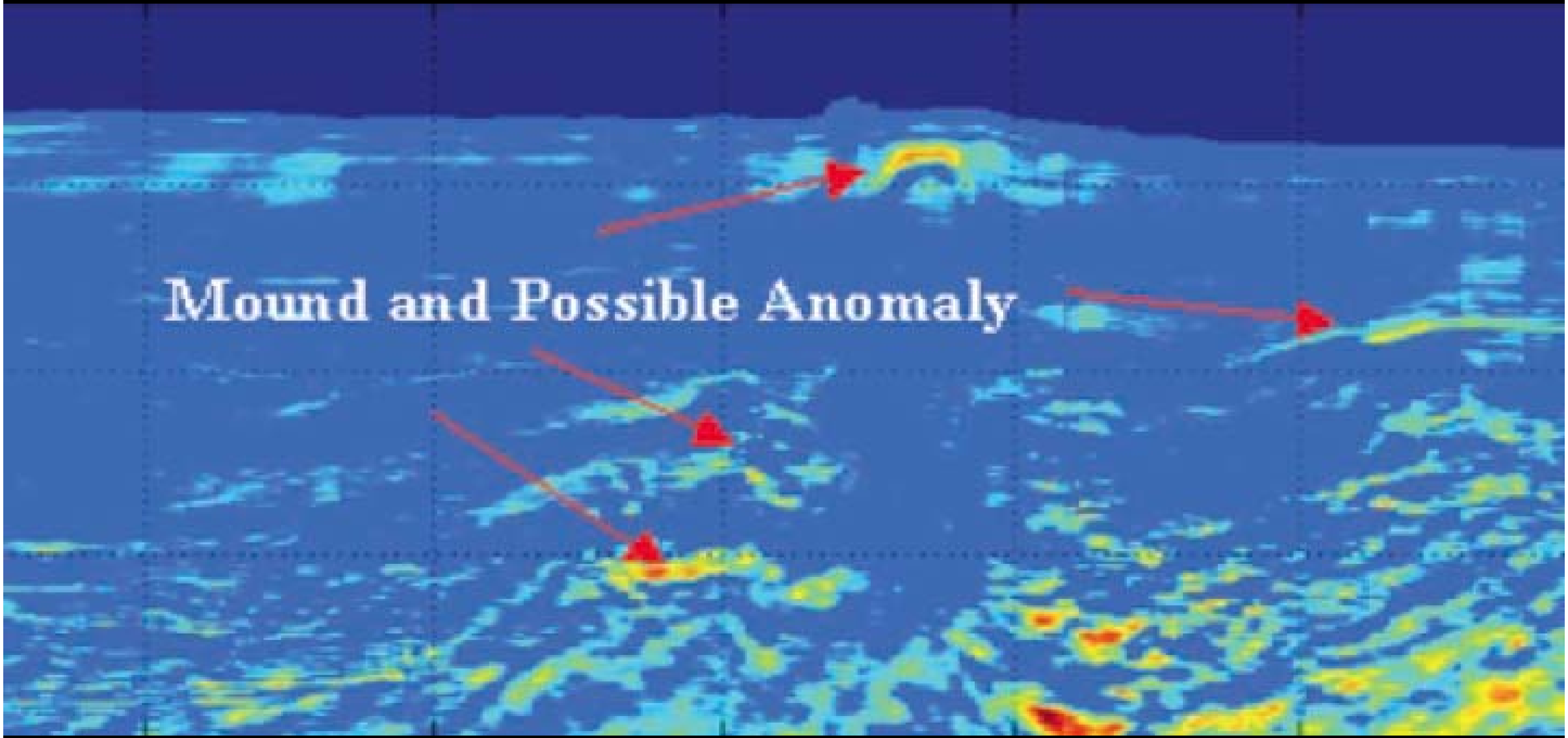
Expanding Search for Methane Hydrate

GOM



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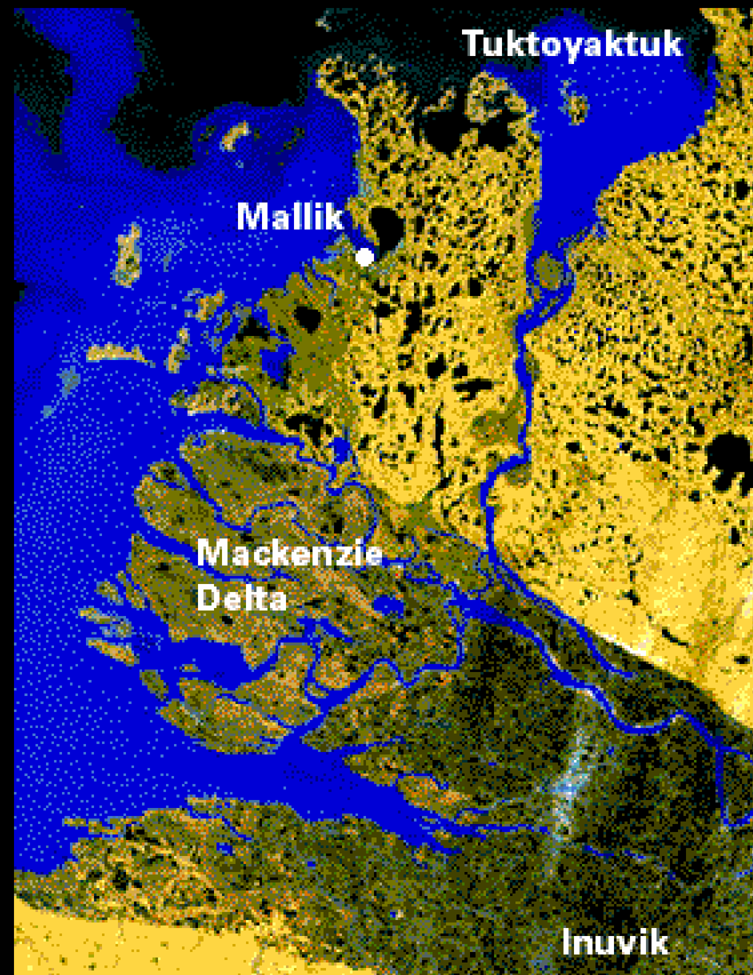
Expanding Search for Methane Hydrate

Mallik Site



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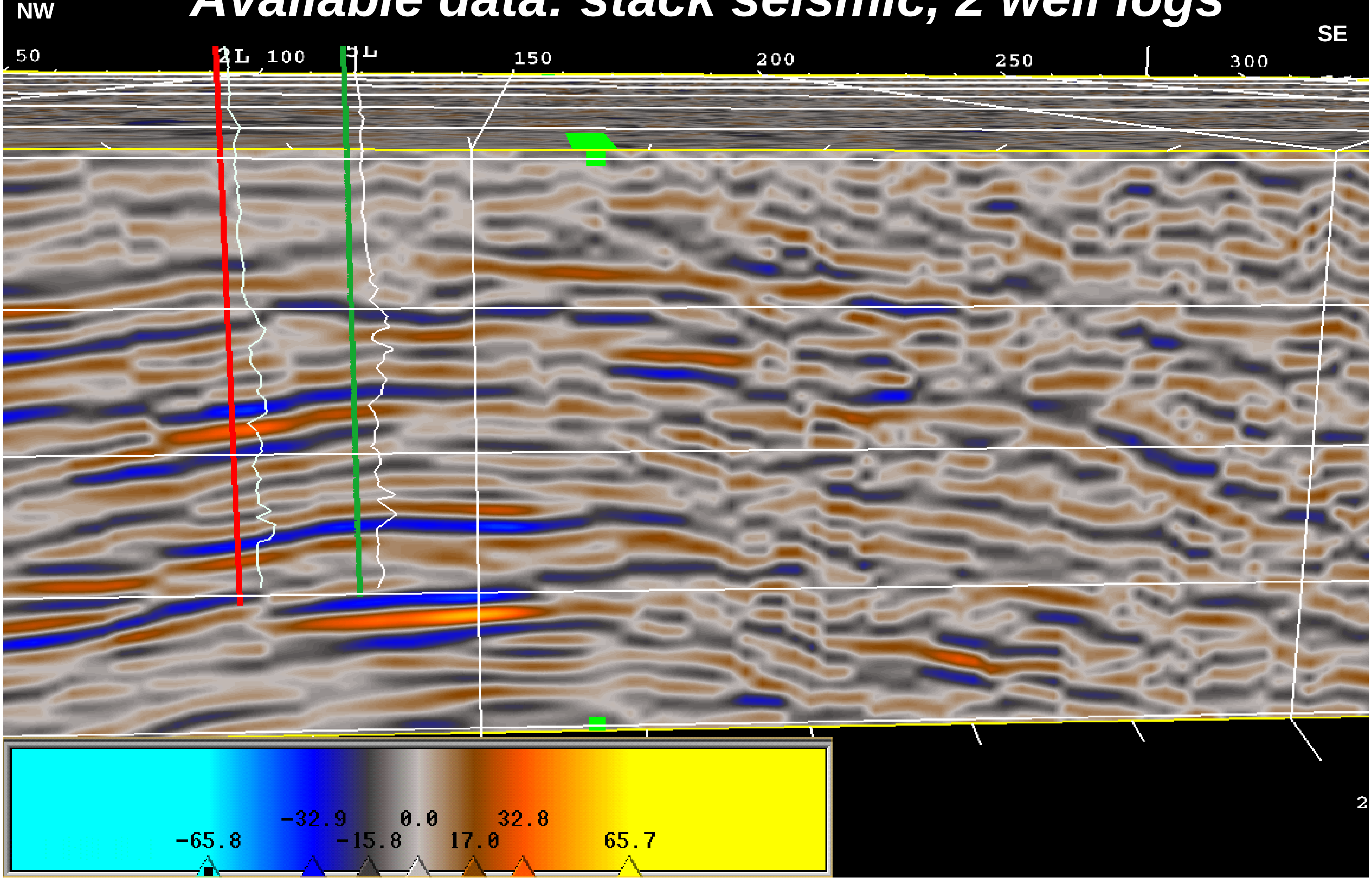
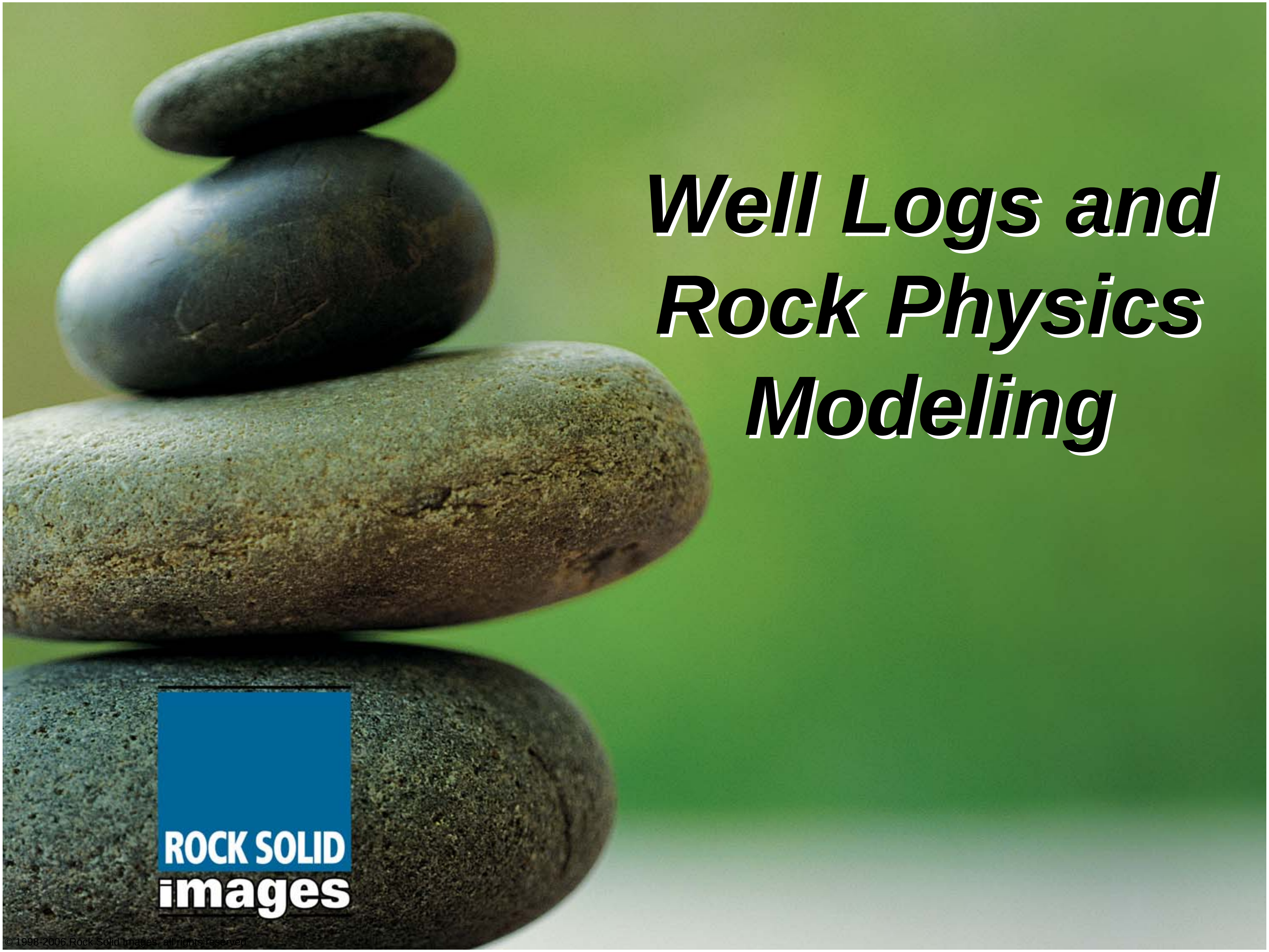
Available data: stack seismic, 2 well logs




Well Logs and
Rock Physics
Modeling
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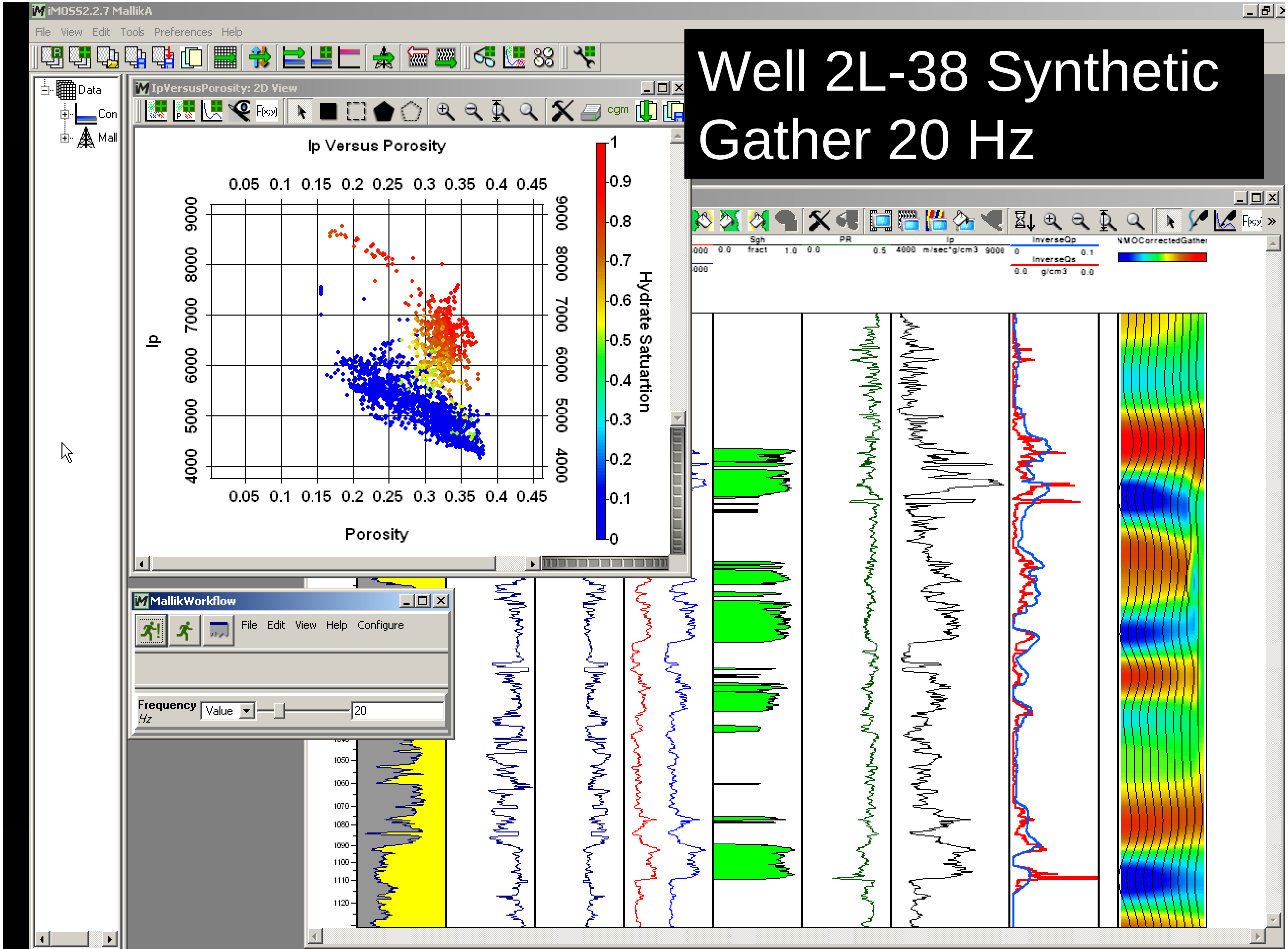
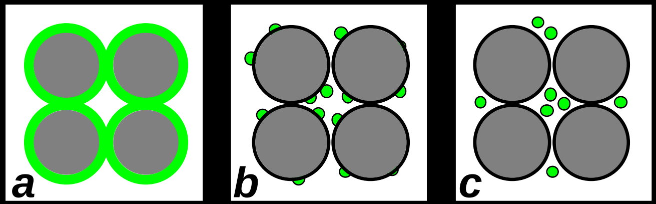
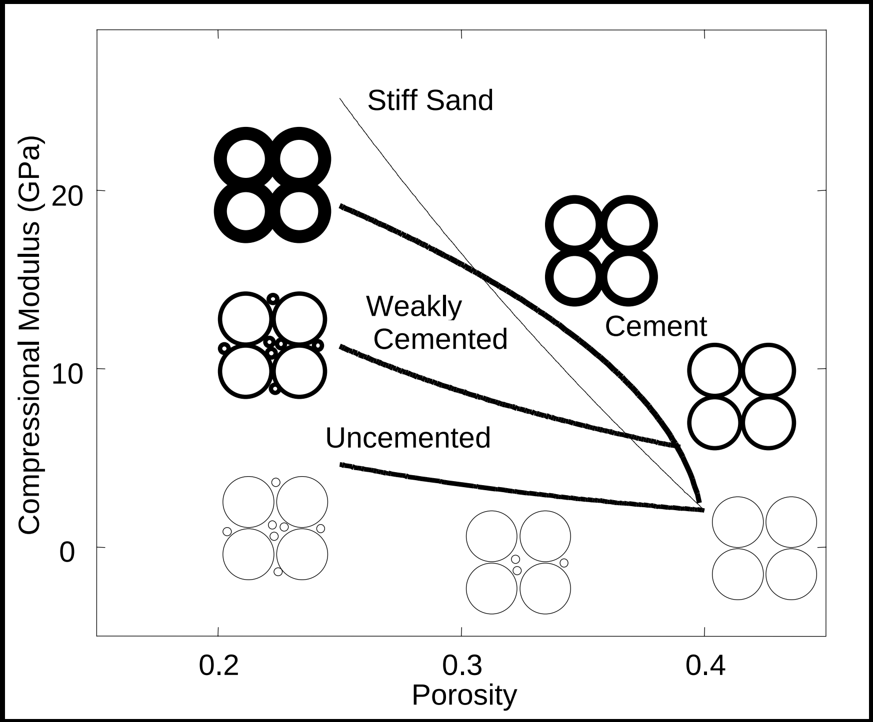
Well 2L-38 Synthetic Gather 20 Hz



Key -- Rock Physics Modeling





Mallik project.

Mathematical models.

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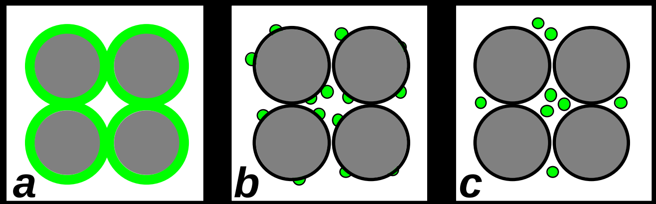
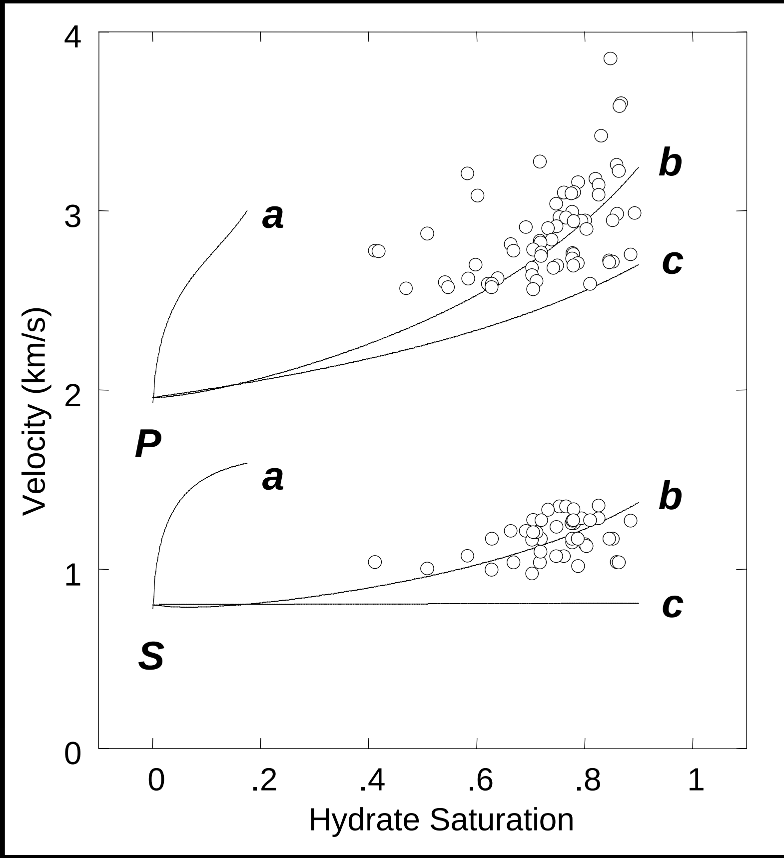
Elastic Properties



Stiff Sand   Weakly Cemented   Unconsolidated

Mallik data.



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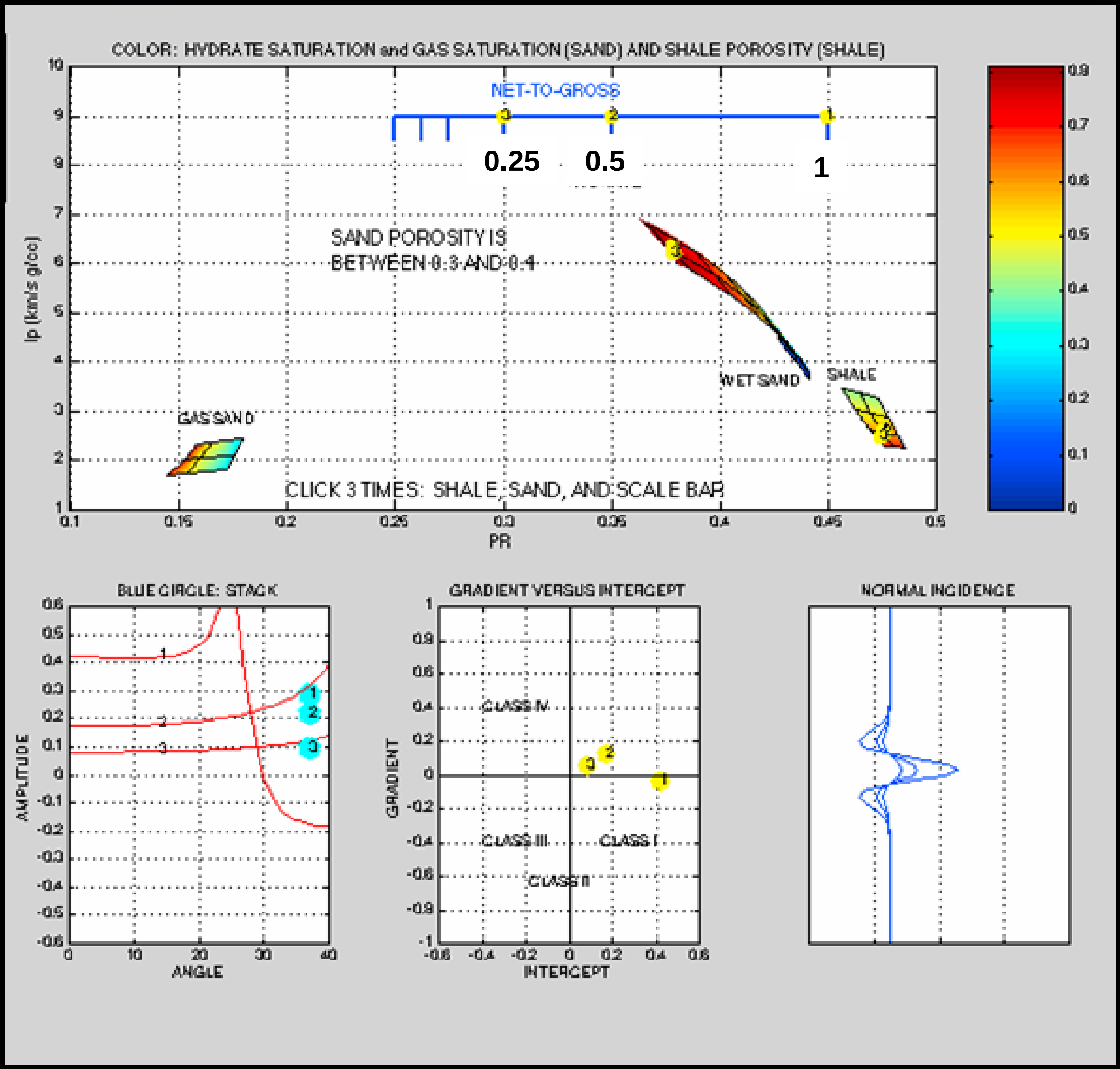
Forward Modeling at an Interface



Shale to sand -- effect of thickness.

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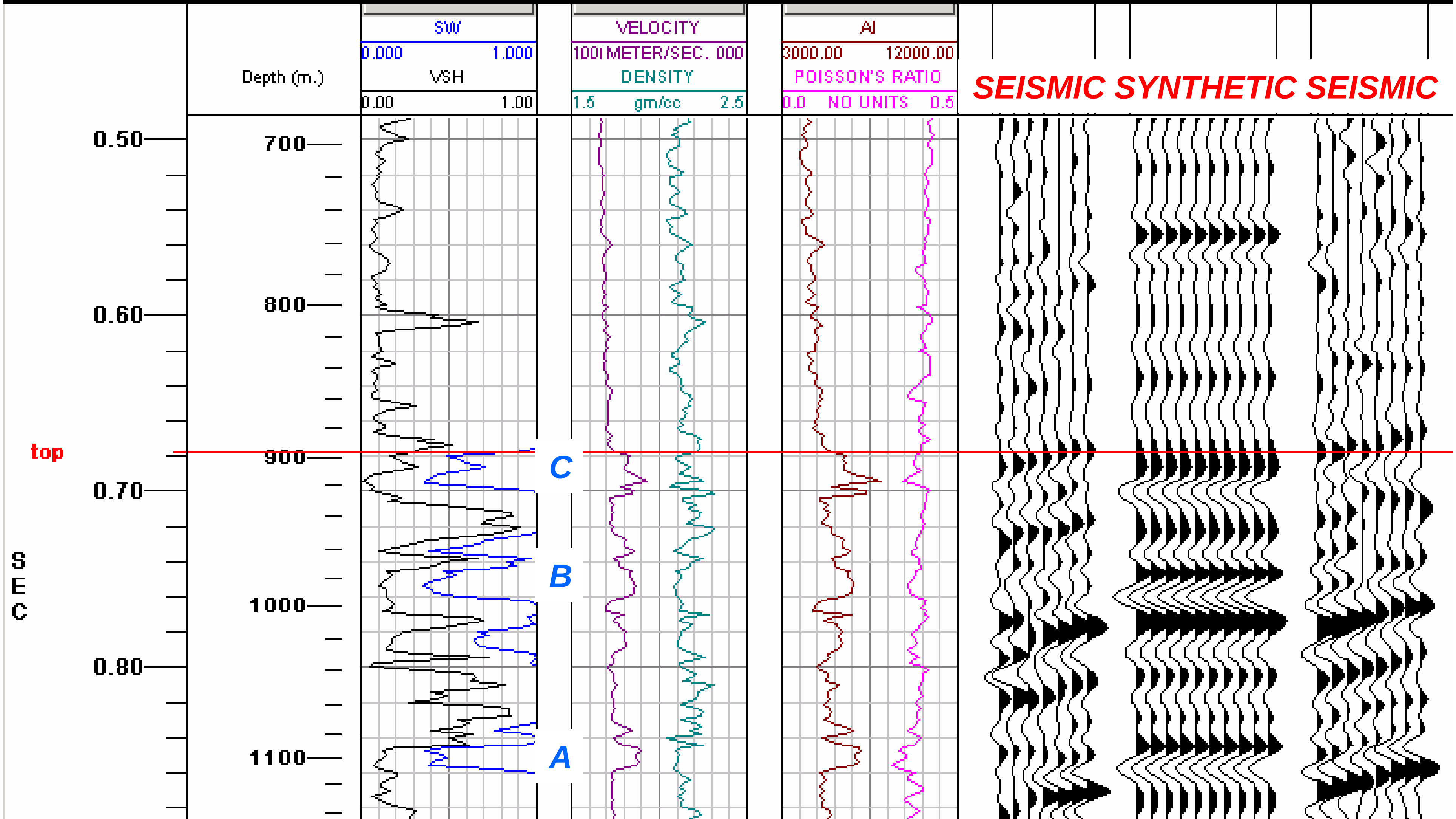
Well Tie – Well 2L-38 : Adjusted Tie



Well Ties – Time Alignment

The middle hydrate zone (B) for each well synthetic was time aligned.

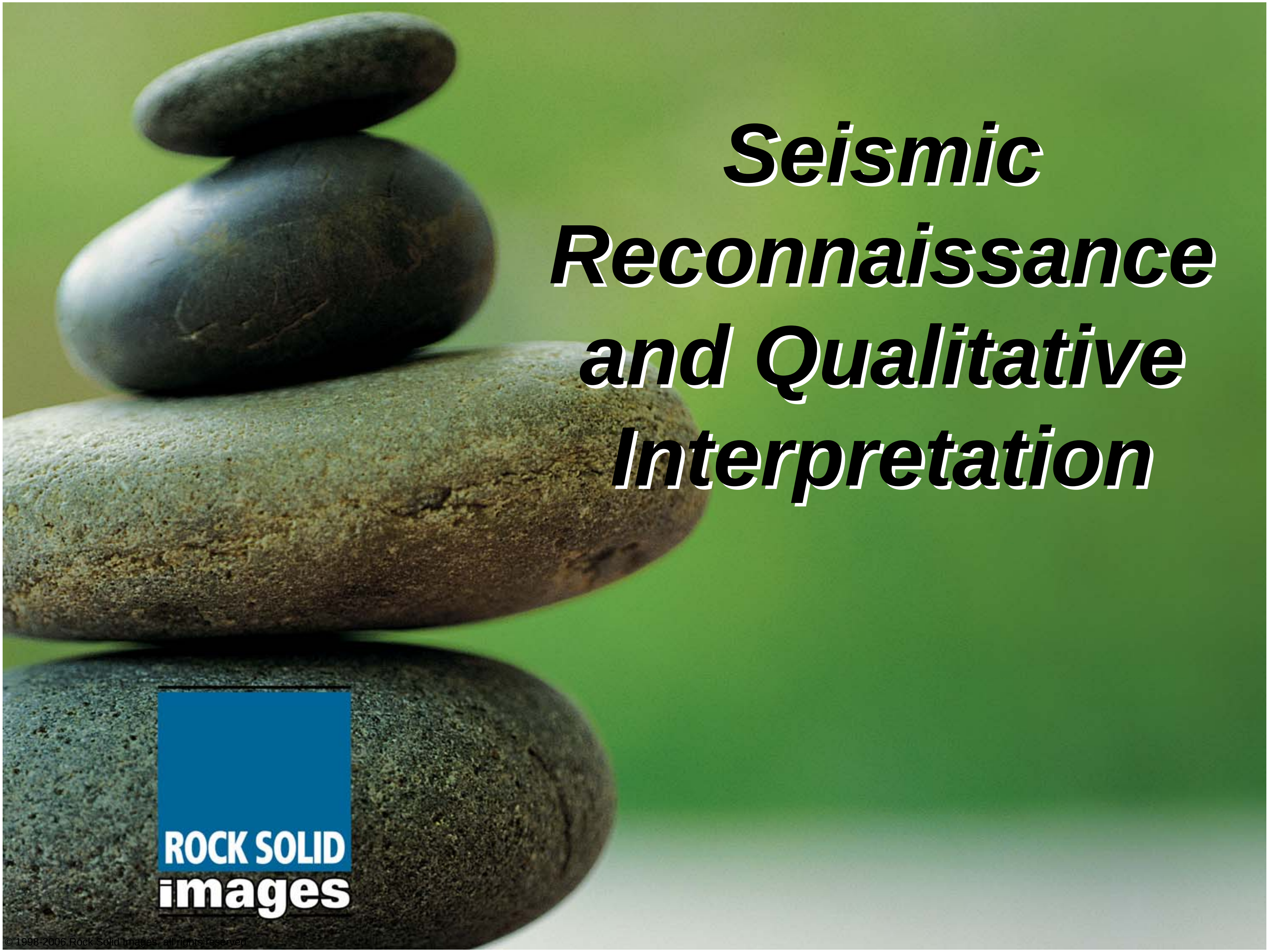
The seismic response at the upper hydrate zone (C) does not match the synthetic response well in either well.

The seismic response at the base of the lower hydrate zone (A) shows a better match to the synthetic response.

Overall well tie not considered adequate for quantitative interpretation

No gathers available for seismic. Limits ability to differentiate free gas and hydrates.

Decision was made to apply qualitative methods using multiple seismic attributes.



Seismic Reconnaissance and Qualitative Interpretation
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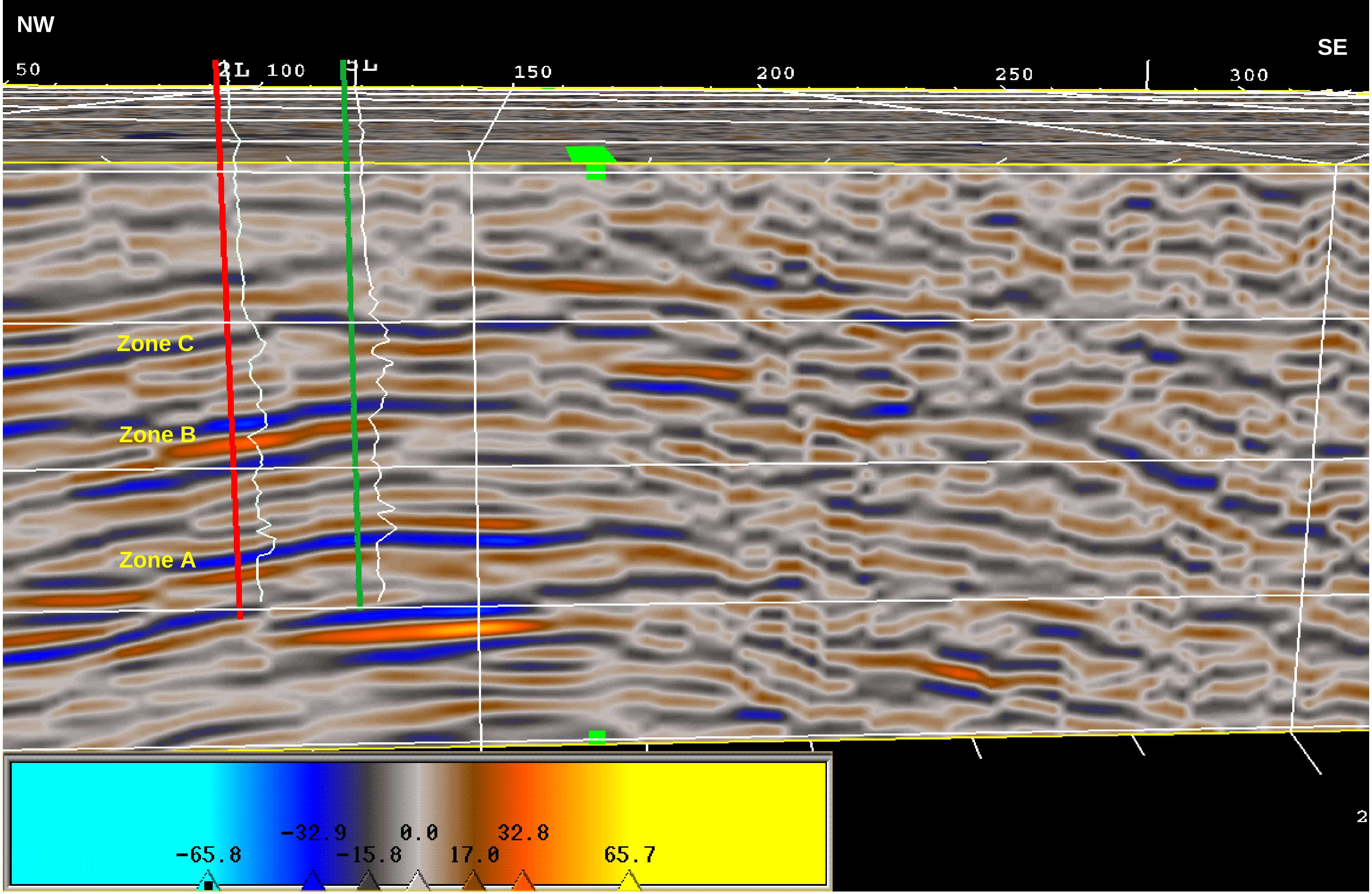
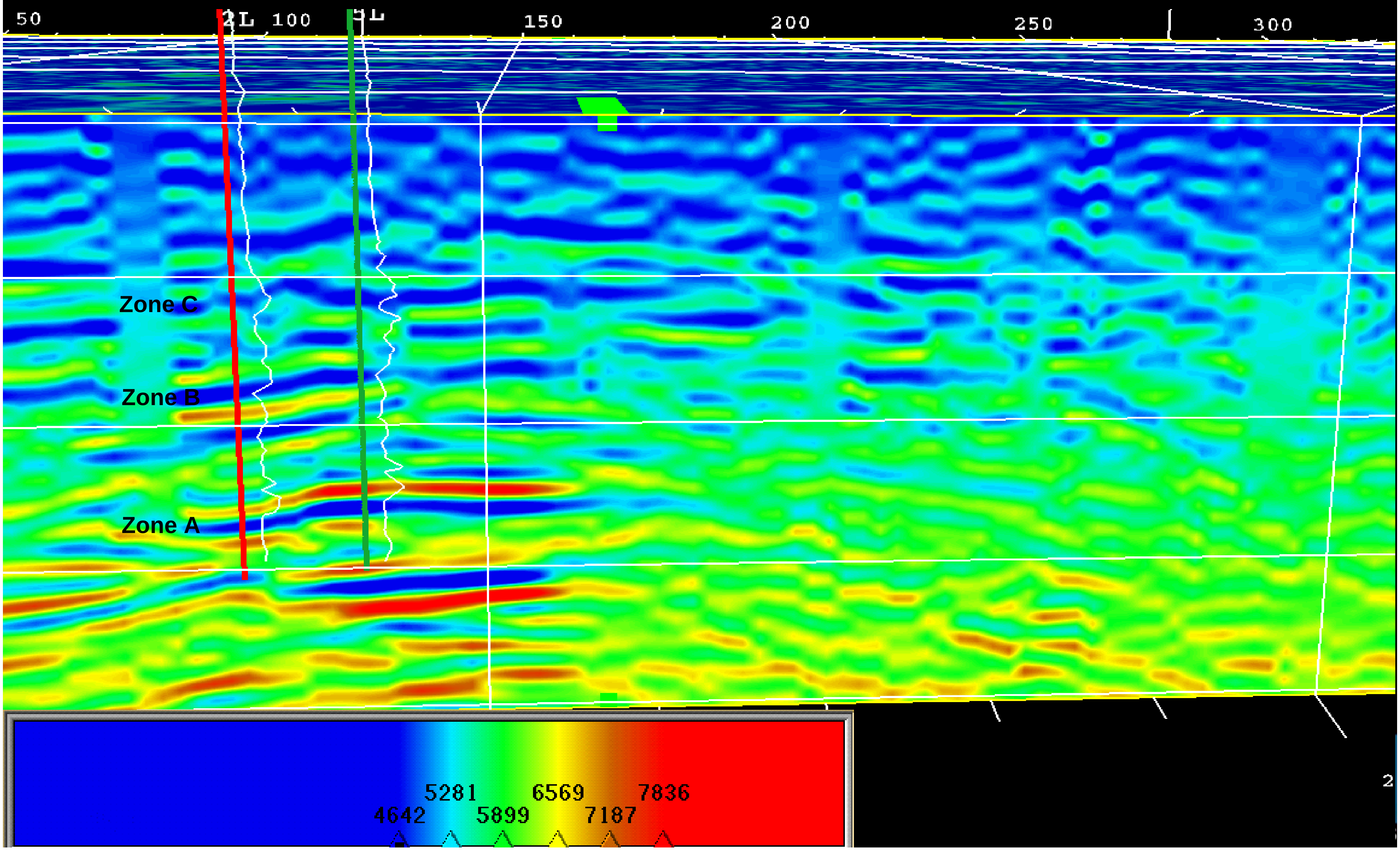
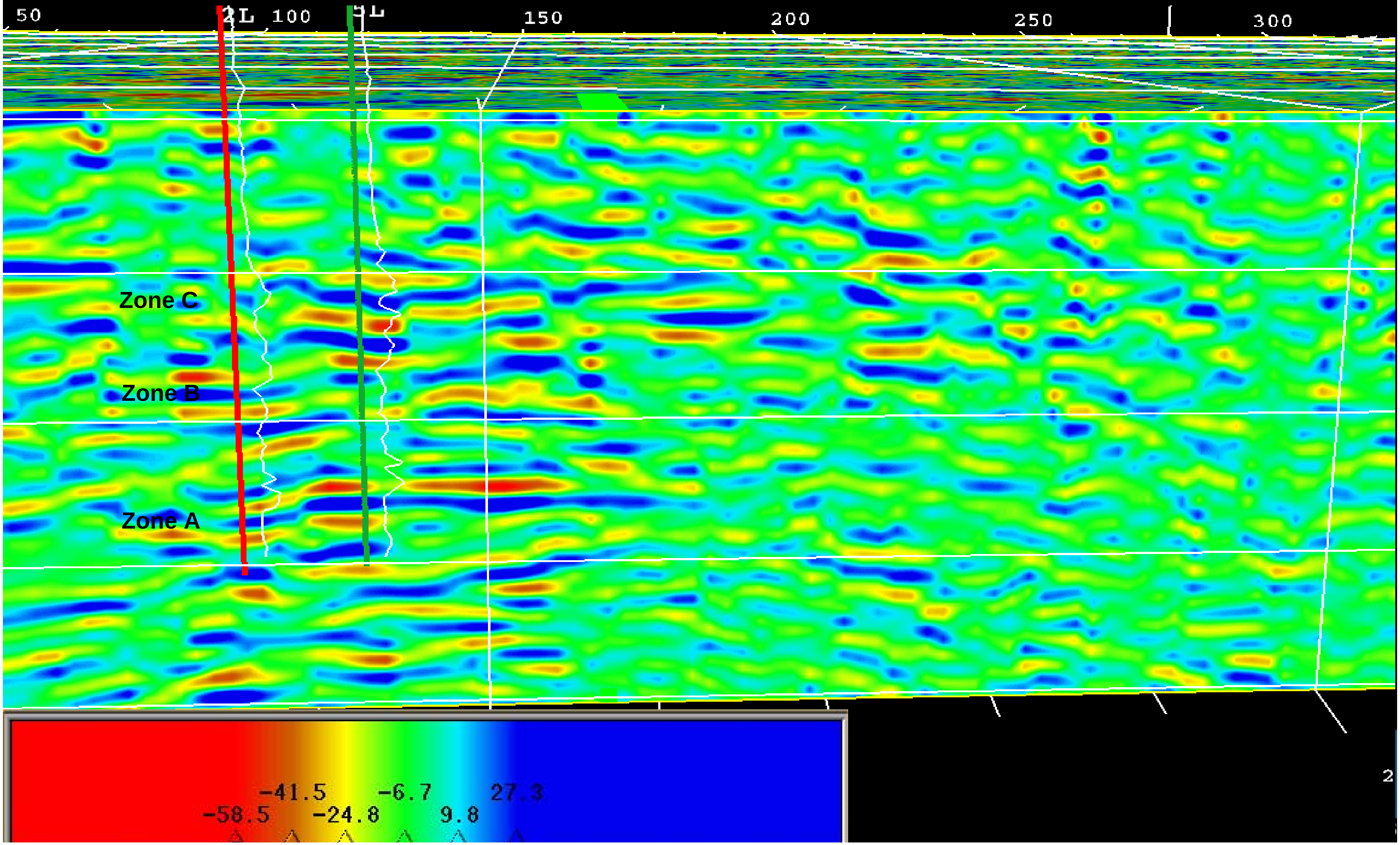
Migration


NW
SE
50
100
150
200
250
300
Zone C
Zone B
Zone A
-32.9
0.0
32.8
-65.8
-15.8
17.0
65.7

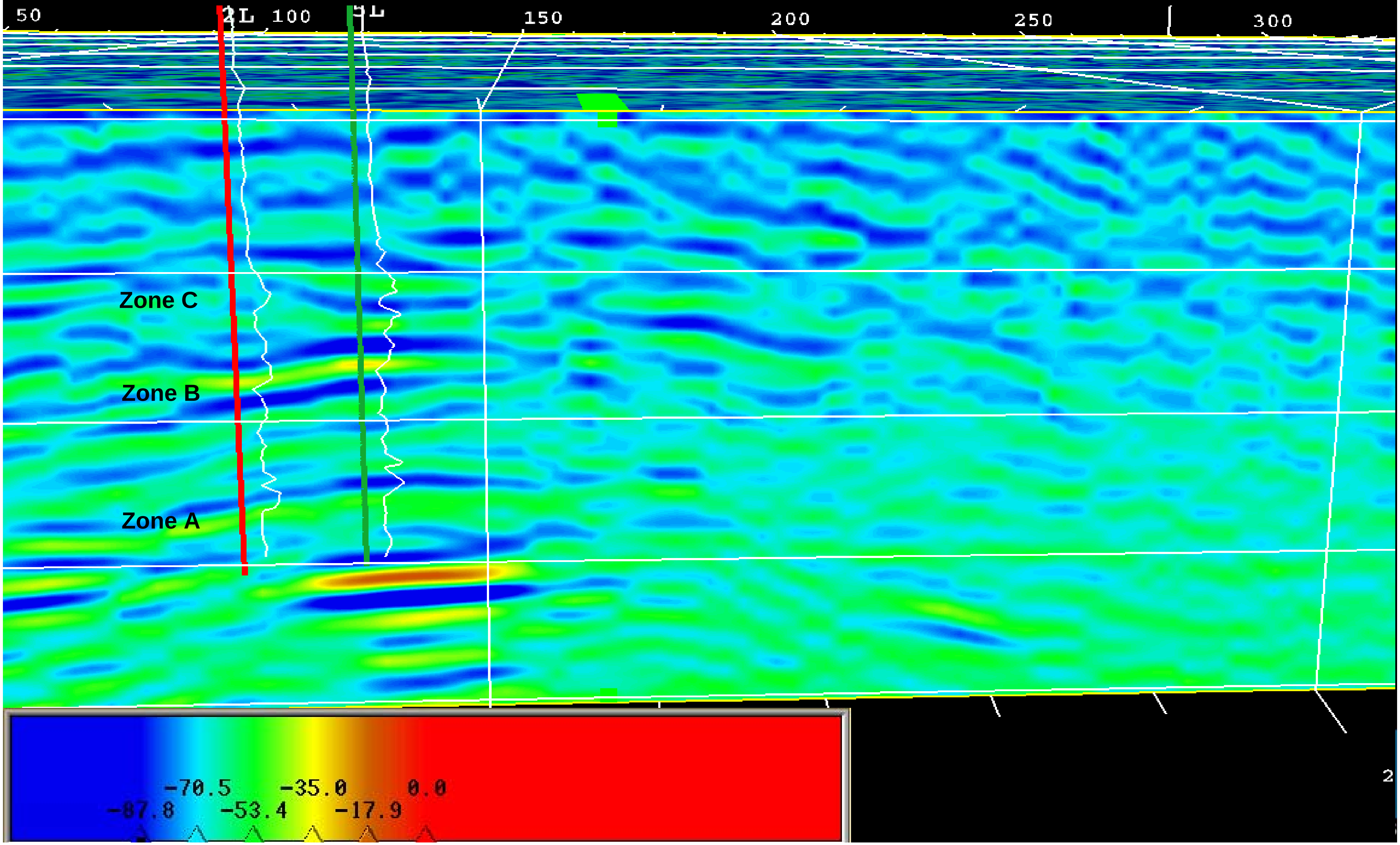
P-wave Impedance (Zp)



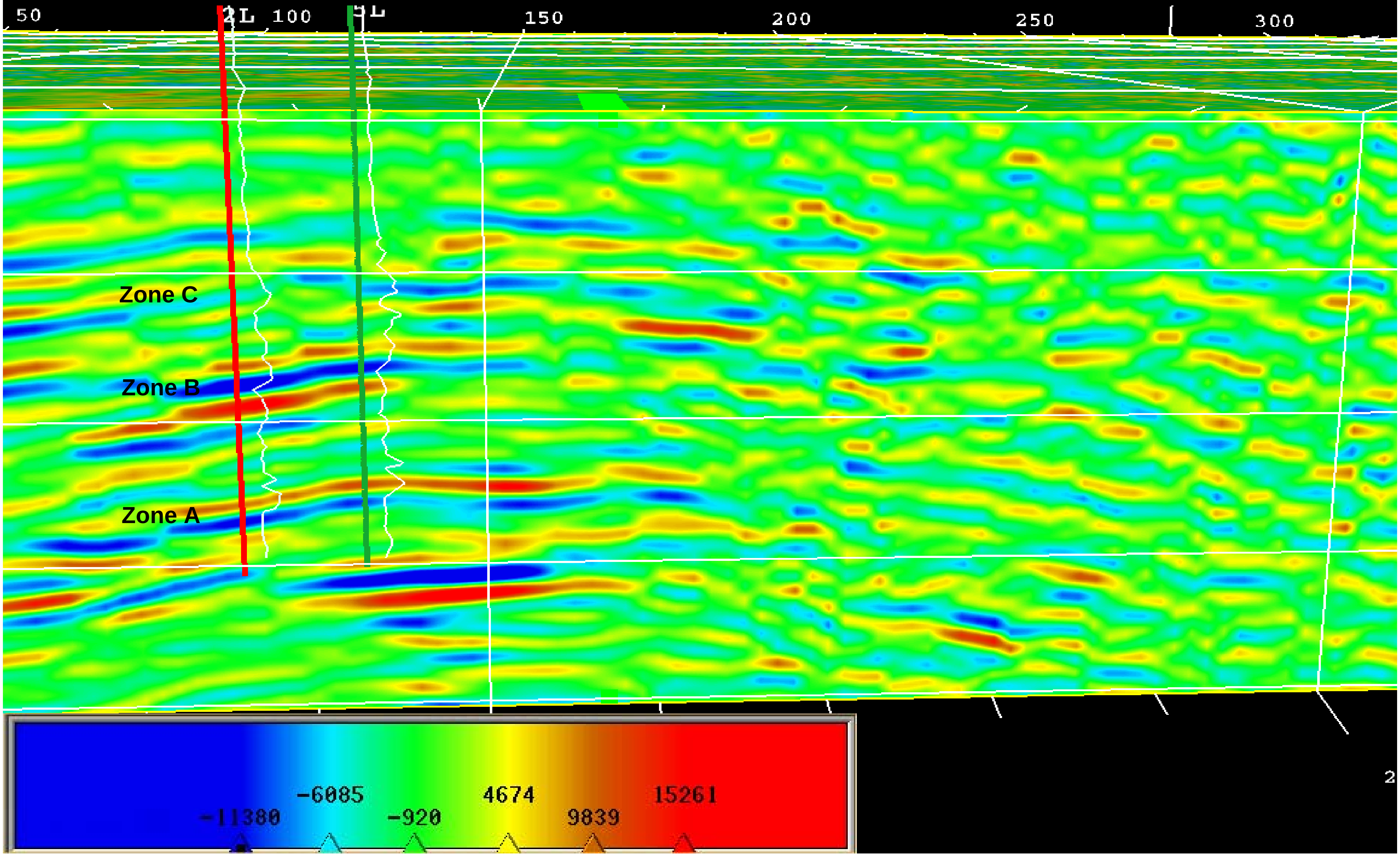
Pseudo Poisson's Ratio



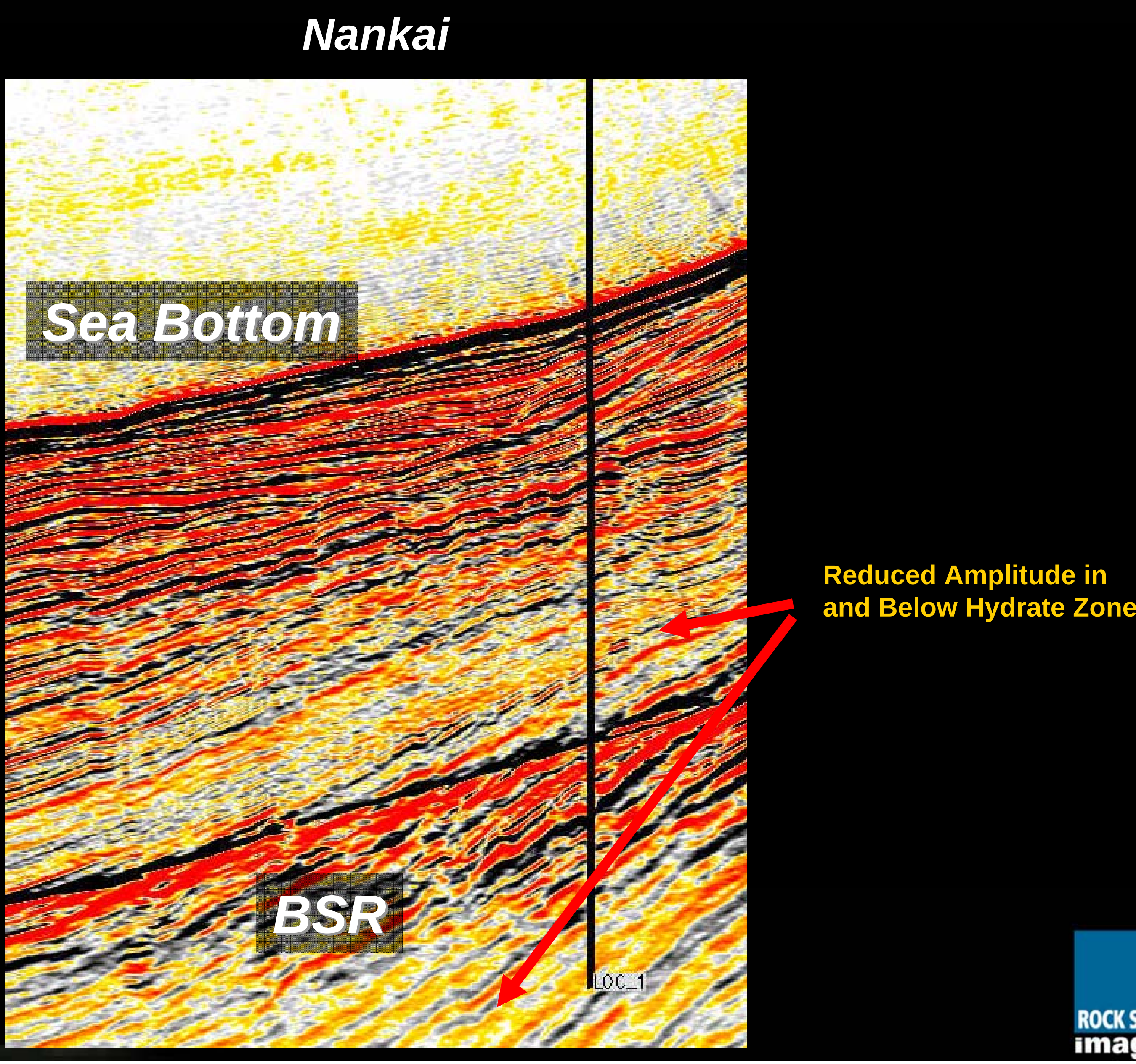
Derivative Attribute, PC2 (typically a gas indicator)



Band-limited Impedance



Muting of the Amplitude



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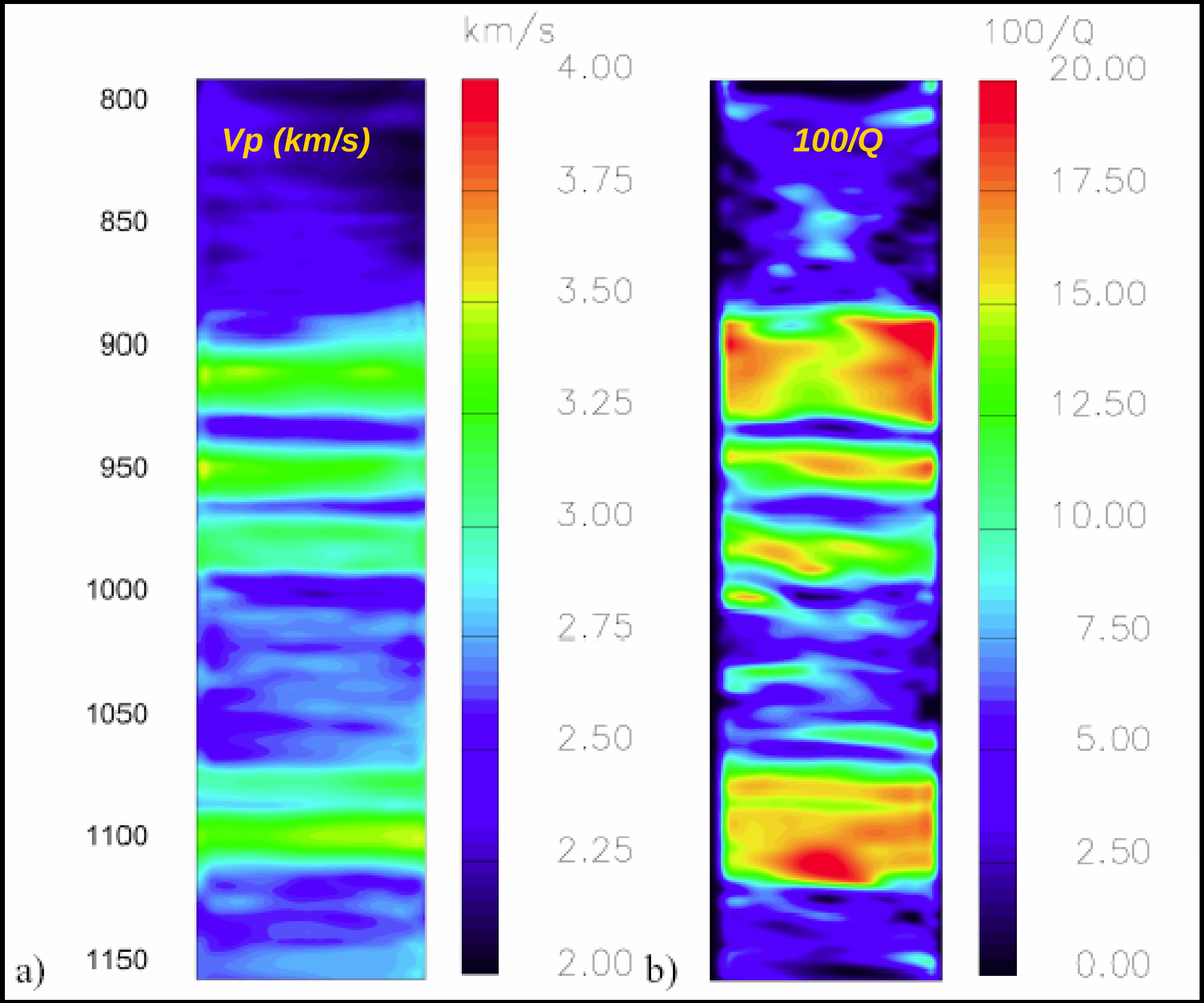
Quality Factor "Q"

Cross-Well in Mallik



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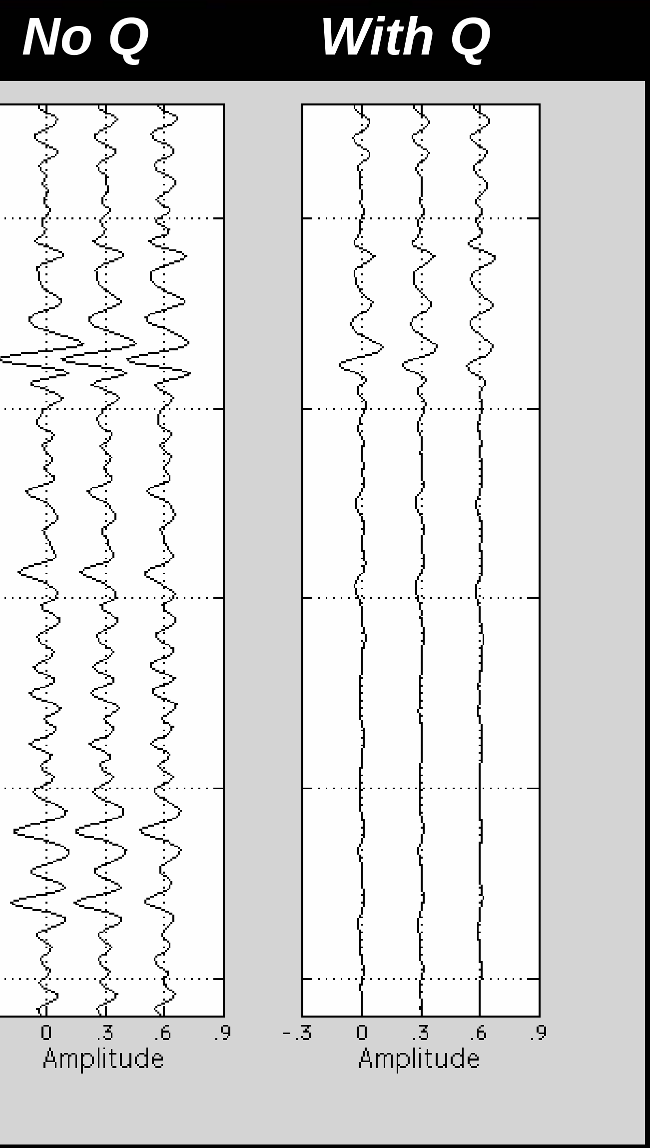
Will Attenuation Matter in Reflection Survey?



Mallik well.

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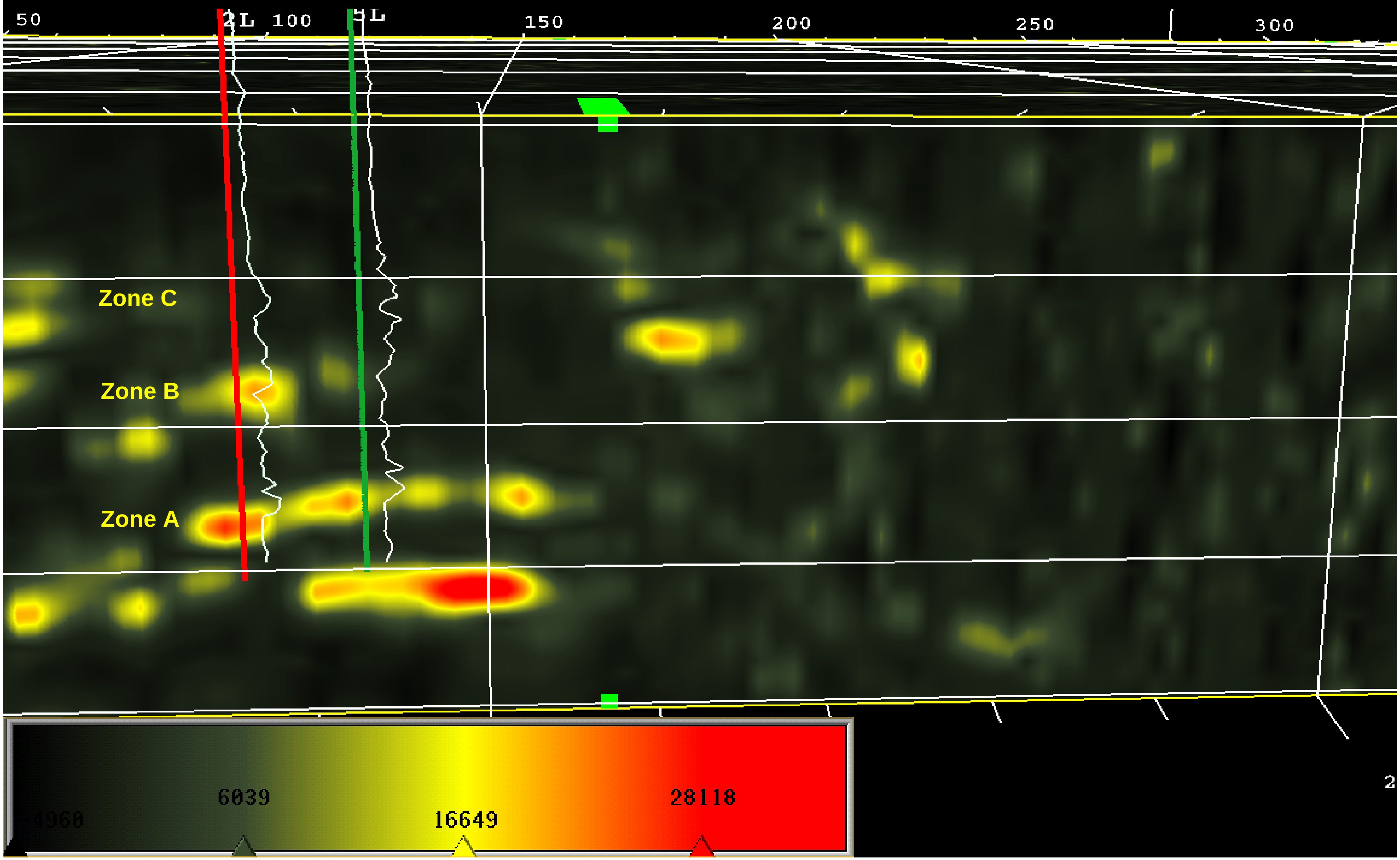
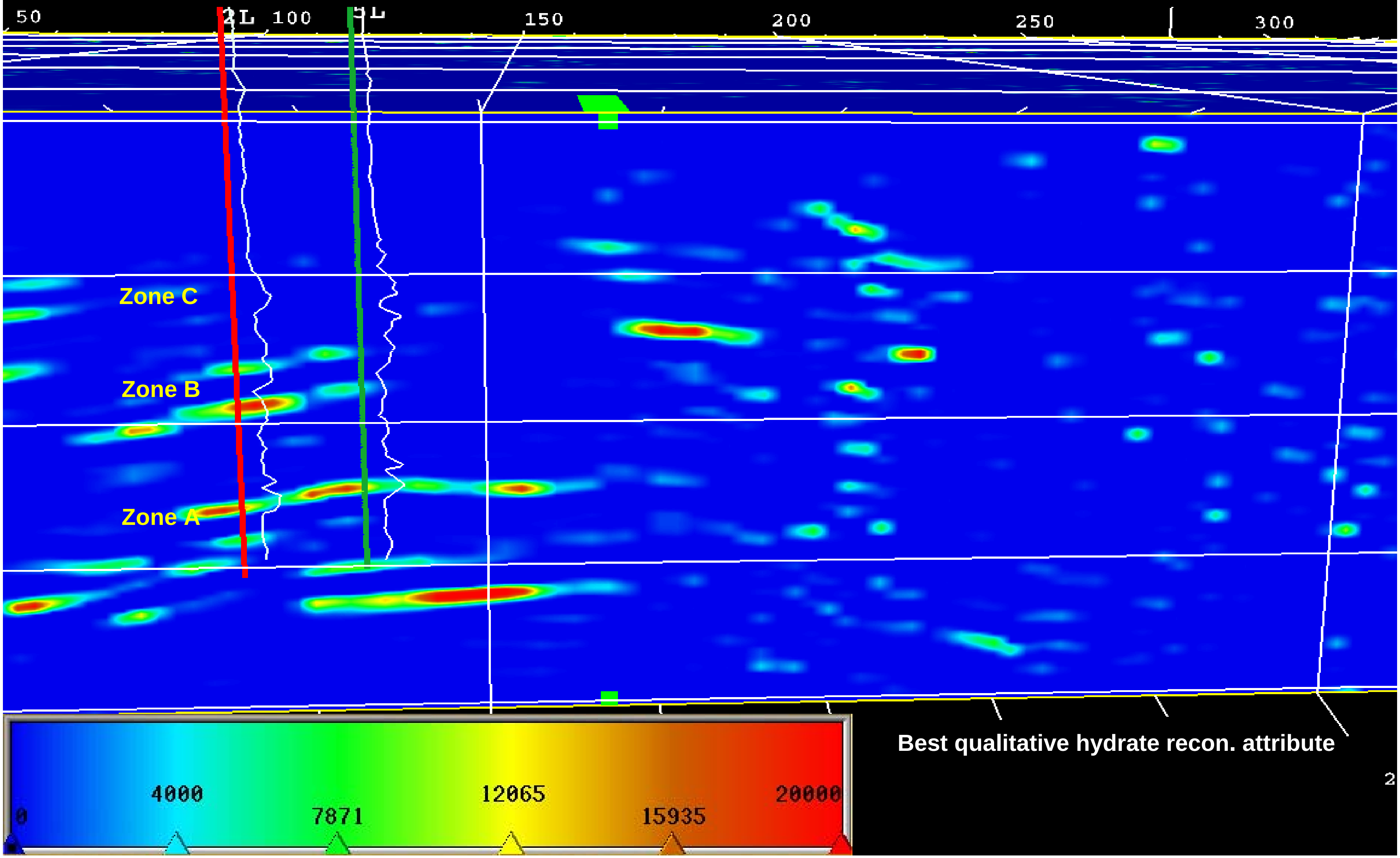
Anomalous Absorption Attribute



Hybrid: High AI, High Attenuation



Best qualitative hydrate recon. attribute


Improving Quantitative Interpretation; The Future
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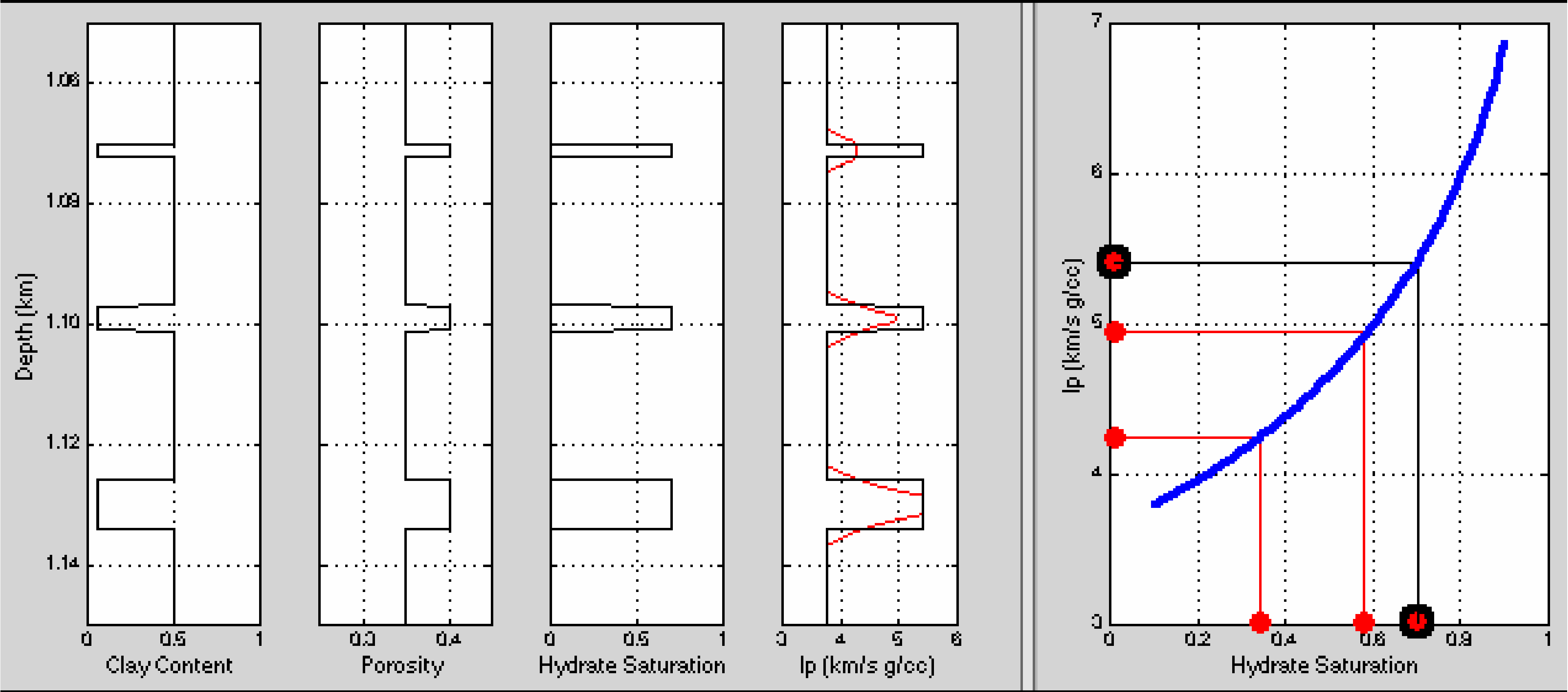
Caveat of Scale



Low impedance at the seismic scale may represent low hydrate saturation in a thick layer or high saturation in thin layer.

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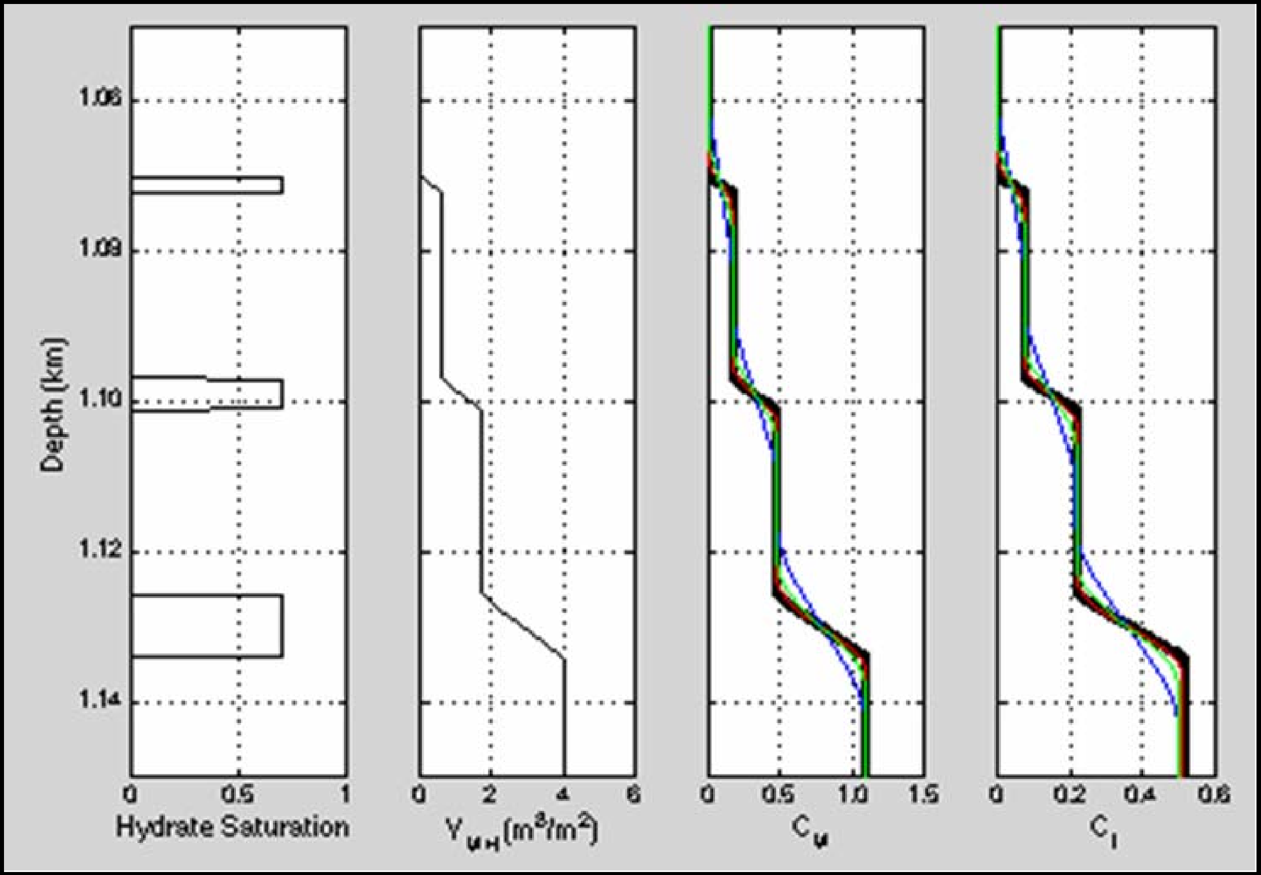
Introducing Cumulative Attributes: CATTS

- What if we want to quantify total hydrate volume?



hydrate saturation

accumulated hydrate volume

integral of anomaly of 1/M (comp. modulus)

integral of anomaly of 1/ AI^2

5-meter (red), 10-meter (green), and 20-meter (blue) running window

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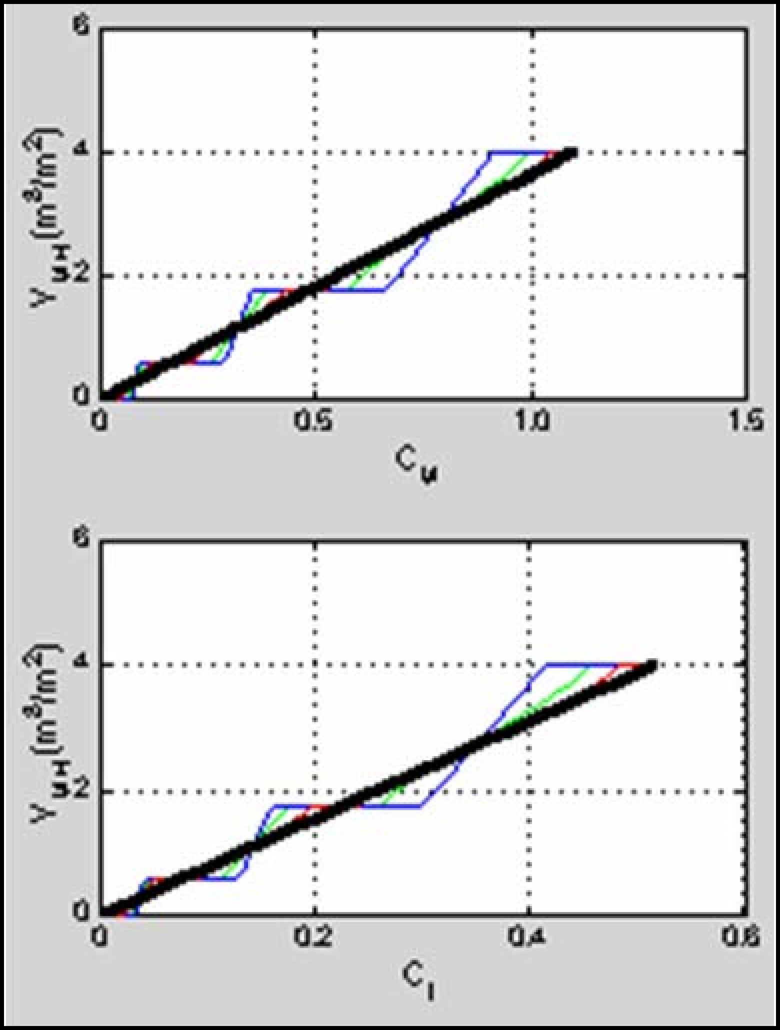
Calibrating CATTS



accumulated hydrate volume vs. integrated inverse modulus anomaly

accumulated hydrate volume vs. integrated inverse AI anomaly

5-meter (red), 10-meter (green), and 20-meter (blue) running window

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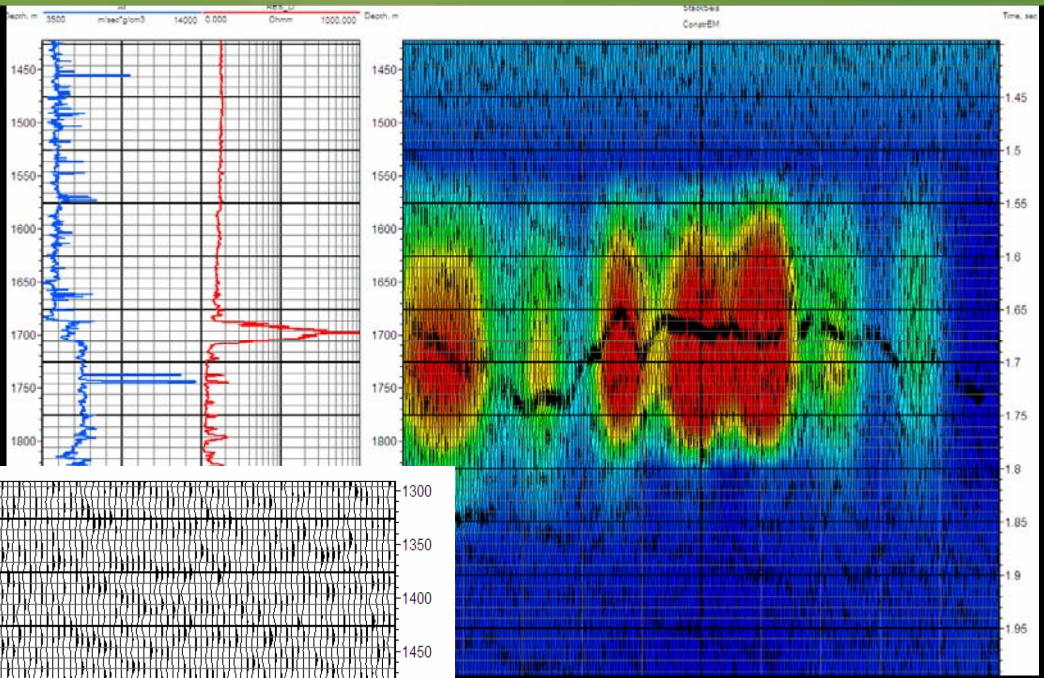
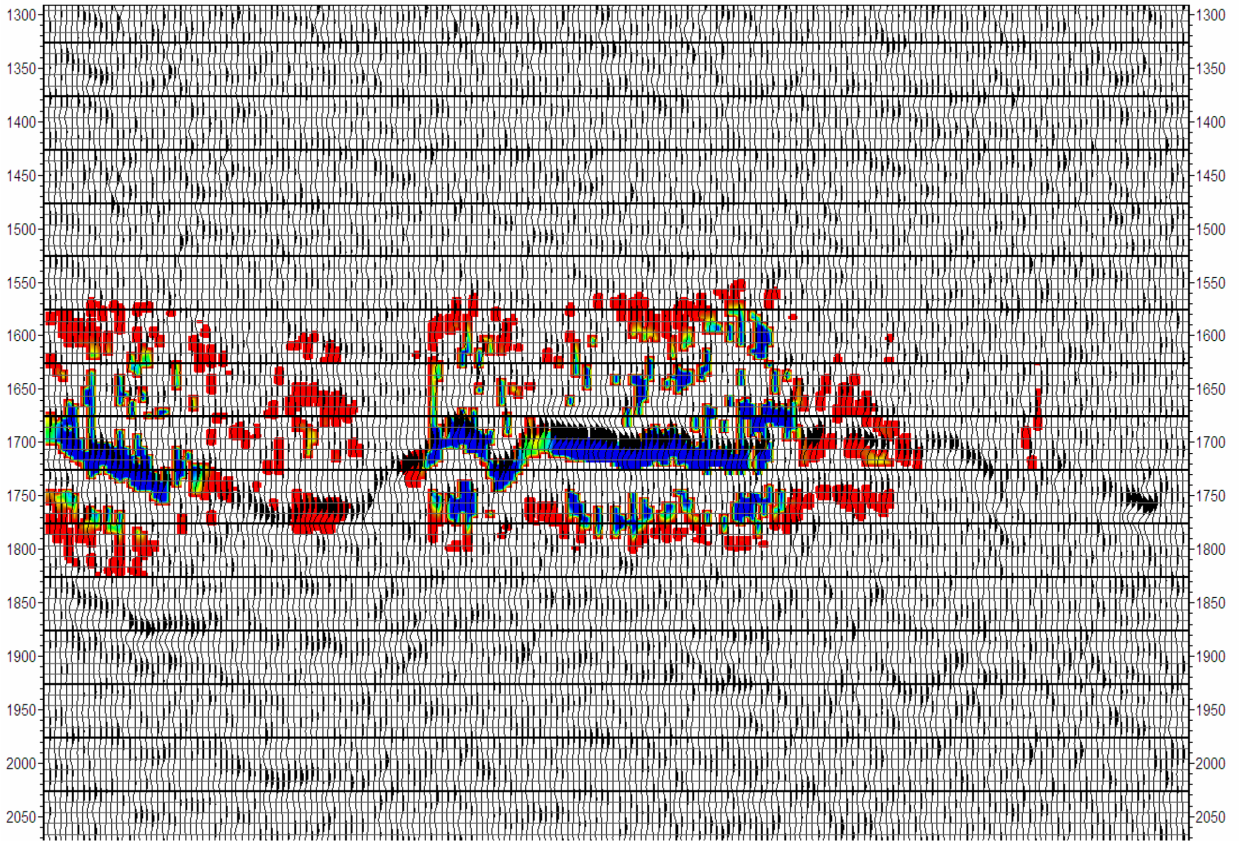
New DOE Research Project

- Topic: Hydrate Characterization from Integrated Well and Seismic Data
- 2 year, $1.2m project started Oct 1, 2006
- Develop and test CATTS approach plus use of other DHI's such as impedance, AVO, and Q
- Currently seeking seismic and well log data sets from hydrate regions
- Seismic data quality and significant hydrate accumulations are key factors in selecting best data set

What About CSEM?

CSEM Inversion superimposed on seismic section





Hydrocarbon Indicator from Integrated Seismic-EM Data

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Observations and Summary

- Existing data sets teach us that
  - (a) the geometry of the reservoir and hydrate distribution in it affect the seismic response;
  - (b) attenuation has to be taken into account during hydrate reservoir characterization; and, most importantly,
  - (c) the competing effects of elastic contrast, geometry, and attenuation make seismic interpretation non-unique.
- Q and Impedance combined are good recon. Tools for hydrates.
- Calibrating seismic to hydrate volume may be improved by assessing accumulated total hydrate volumes

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