Water-saturation estimation from seismic and rock-property trends

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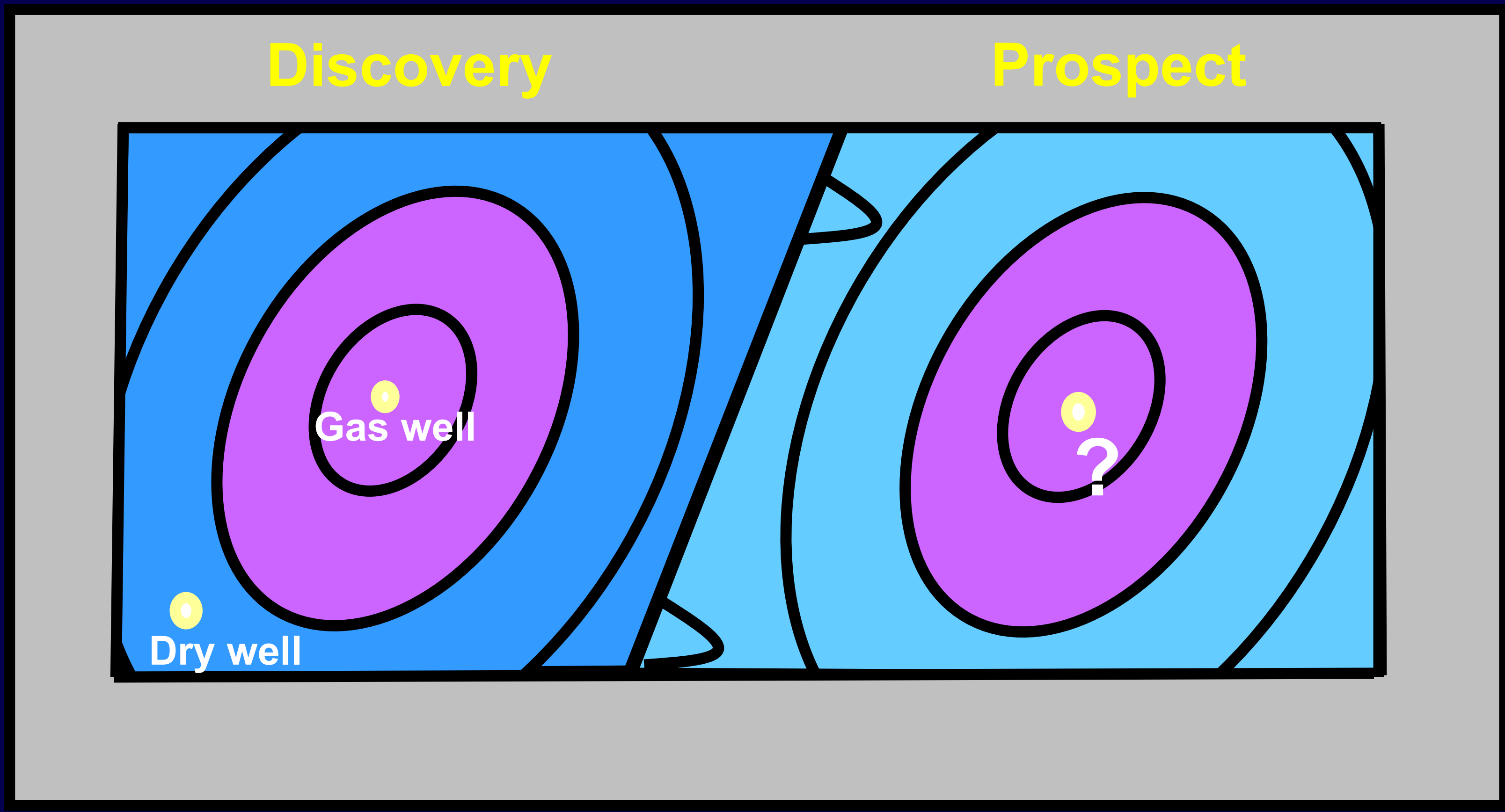
Objective

The objective of this research is to differentiate **Fizz** saturation from **Gas** saturation based on seismic and rock property trends.

“Fizz” ⇒ Low gas saturation
“Gas” ⇒ Economic gas saturation

Motivation

Will you drill the well at prospect location?



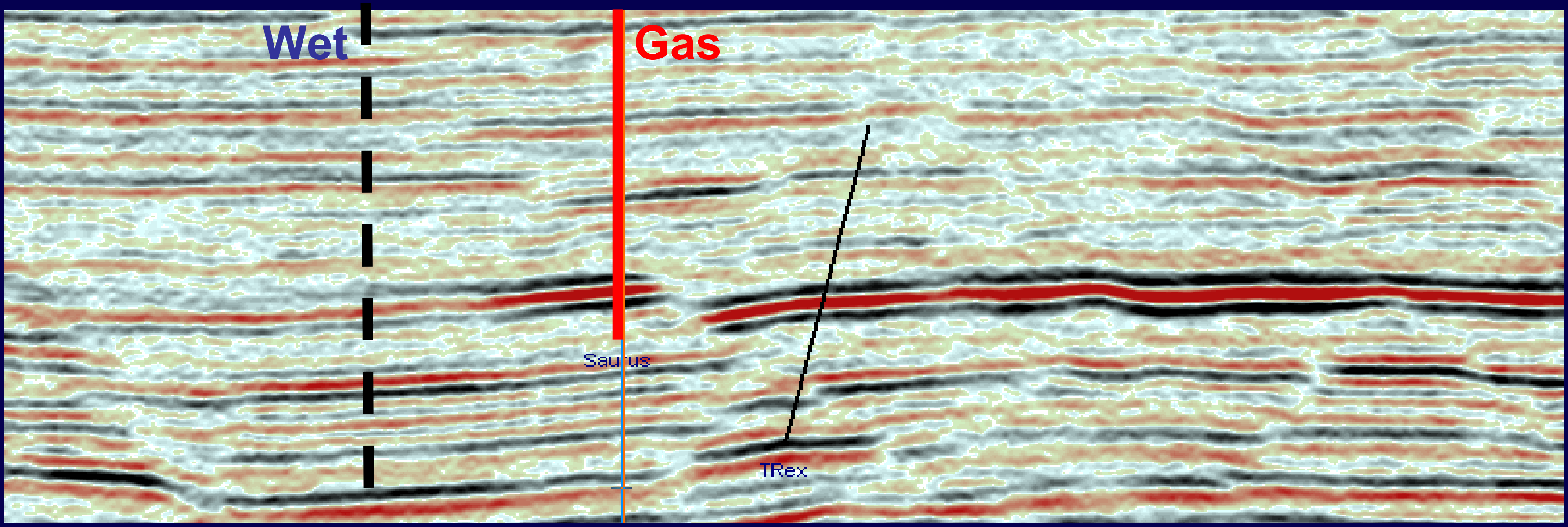
Amplitude map

Outline

- Seismic Field Calibration
- Rock-Property Transforms
- Application of Transforms
- Conclusions

Seismic Field Calibration

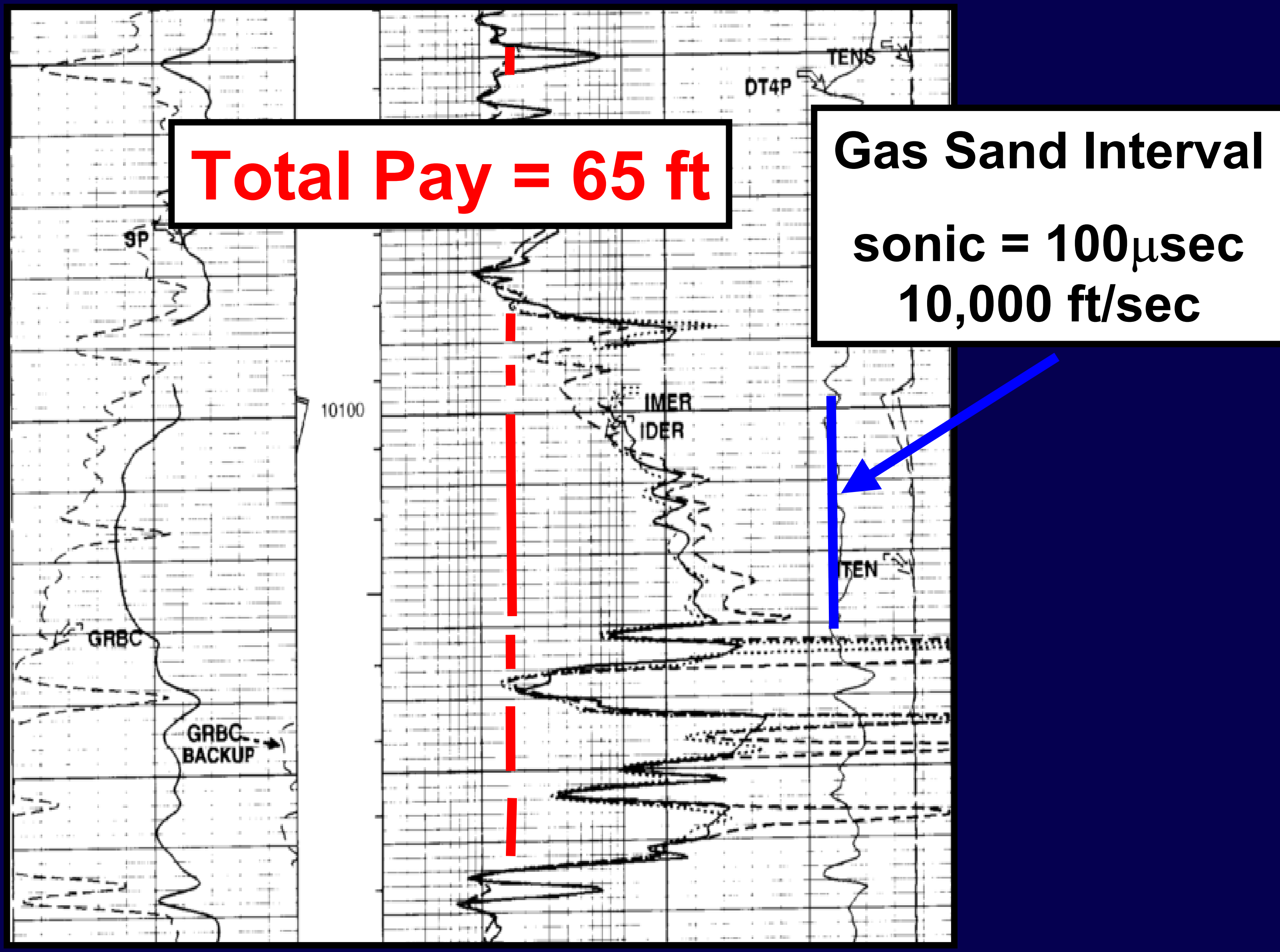
Well B



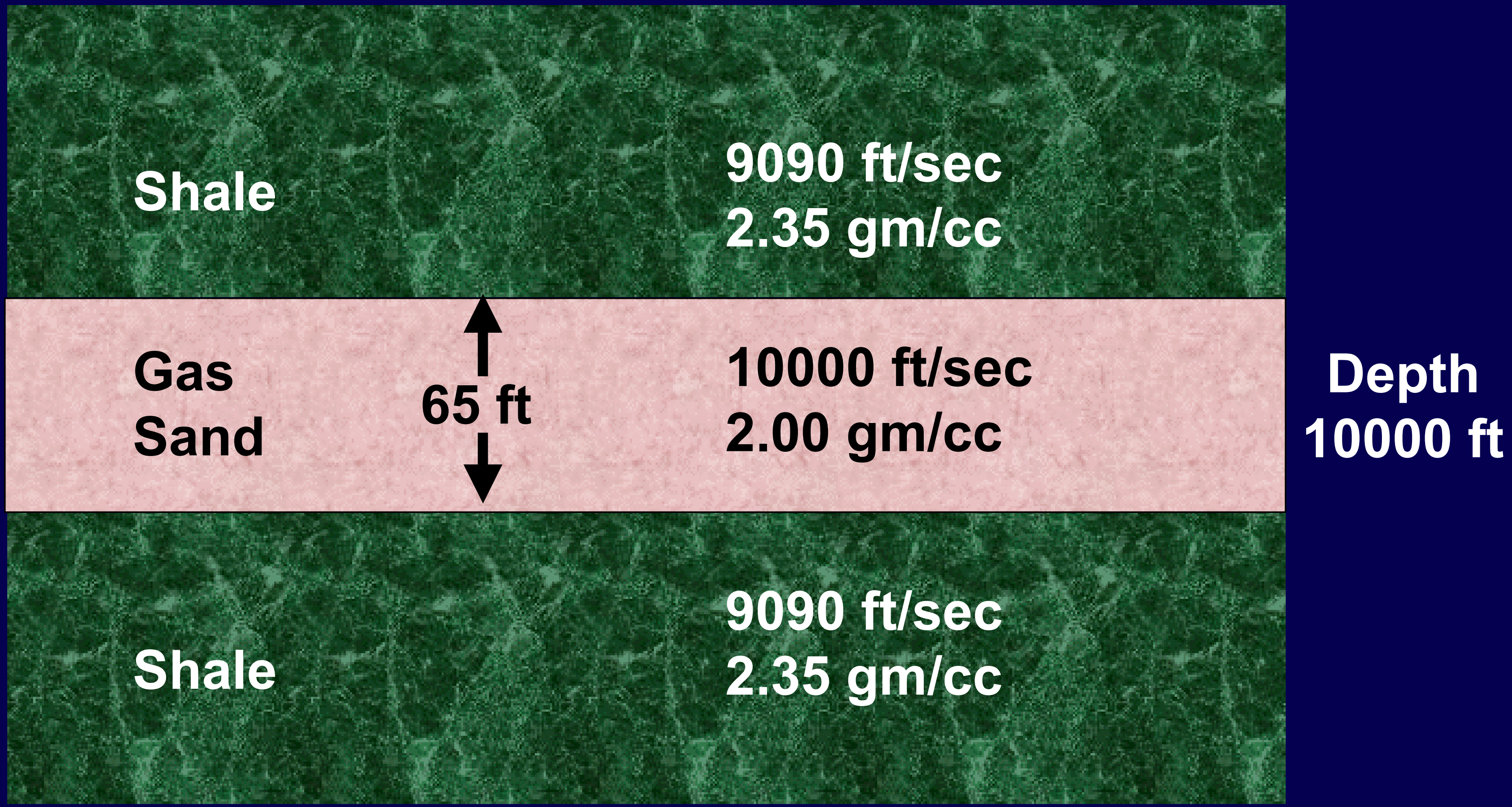
Well B is a known gas reservoir.
At down-dip equivalent, we assume reservoir is wet.

Fairfield data

Well B – Resistivity and Sonic in Pay Zone



Well B – Rock Properties

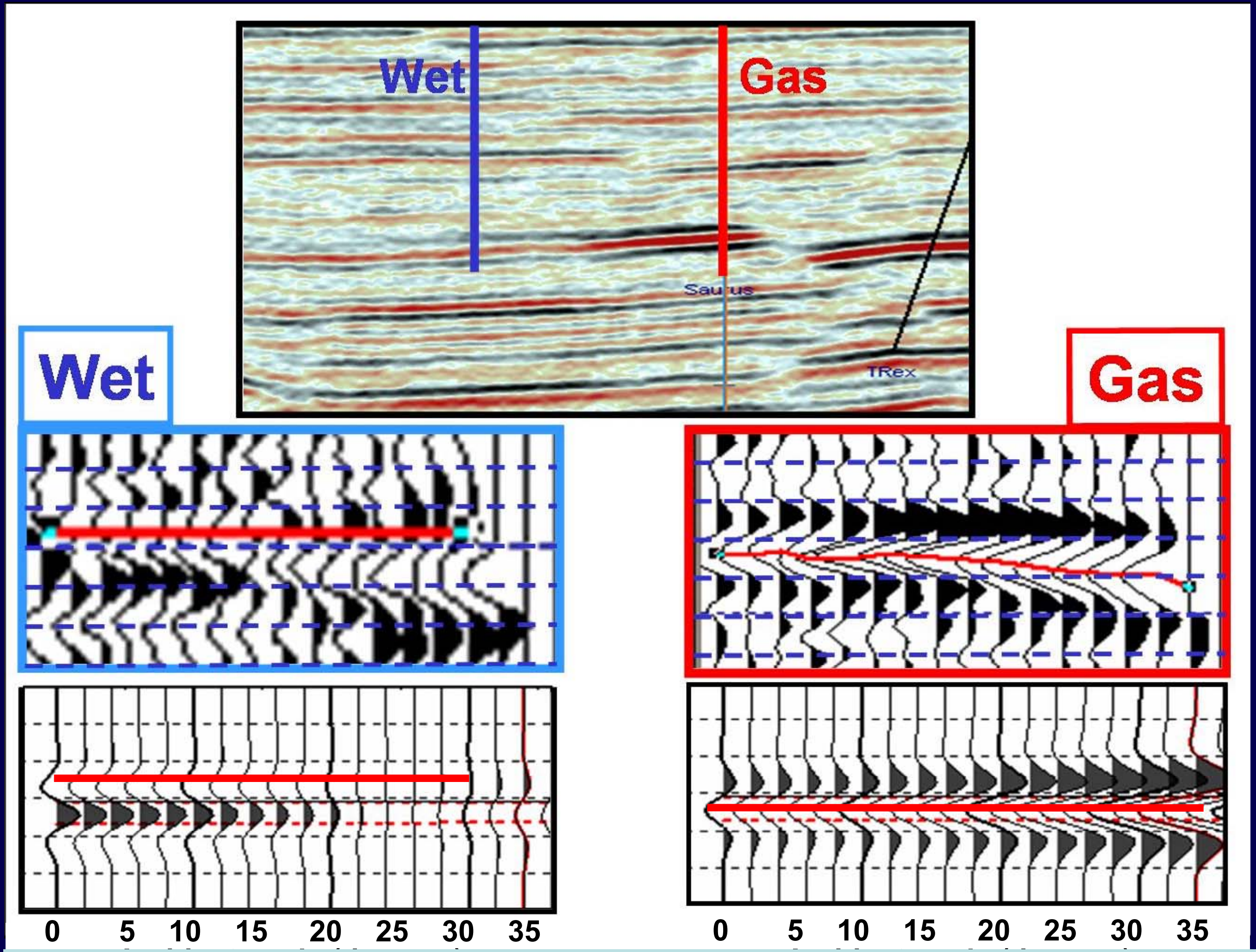


Model created from well-log curves

Thin-Bed Synthetic Match With Migrated CDP Data

Field CDP data

Thin-Bed Synthetics



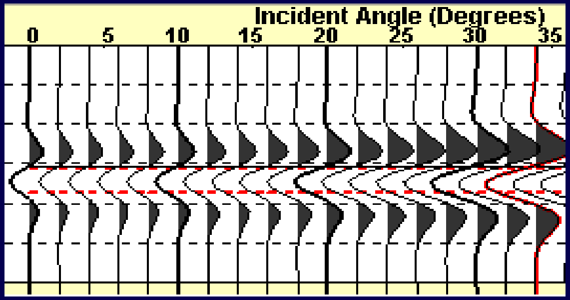
Does the prospect have the same AVO response?

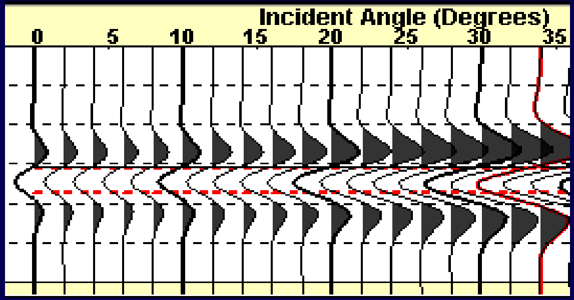
Fairfield data

Discovery versus Prospect AVO Signatures

Discovery

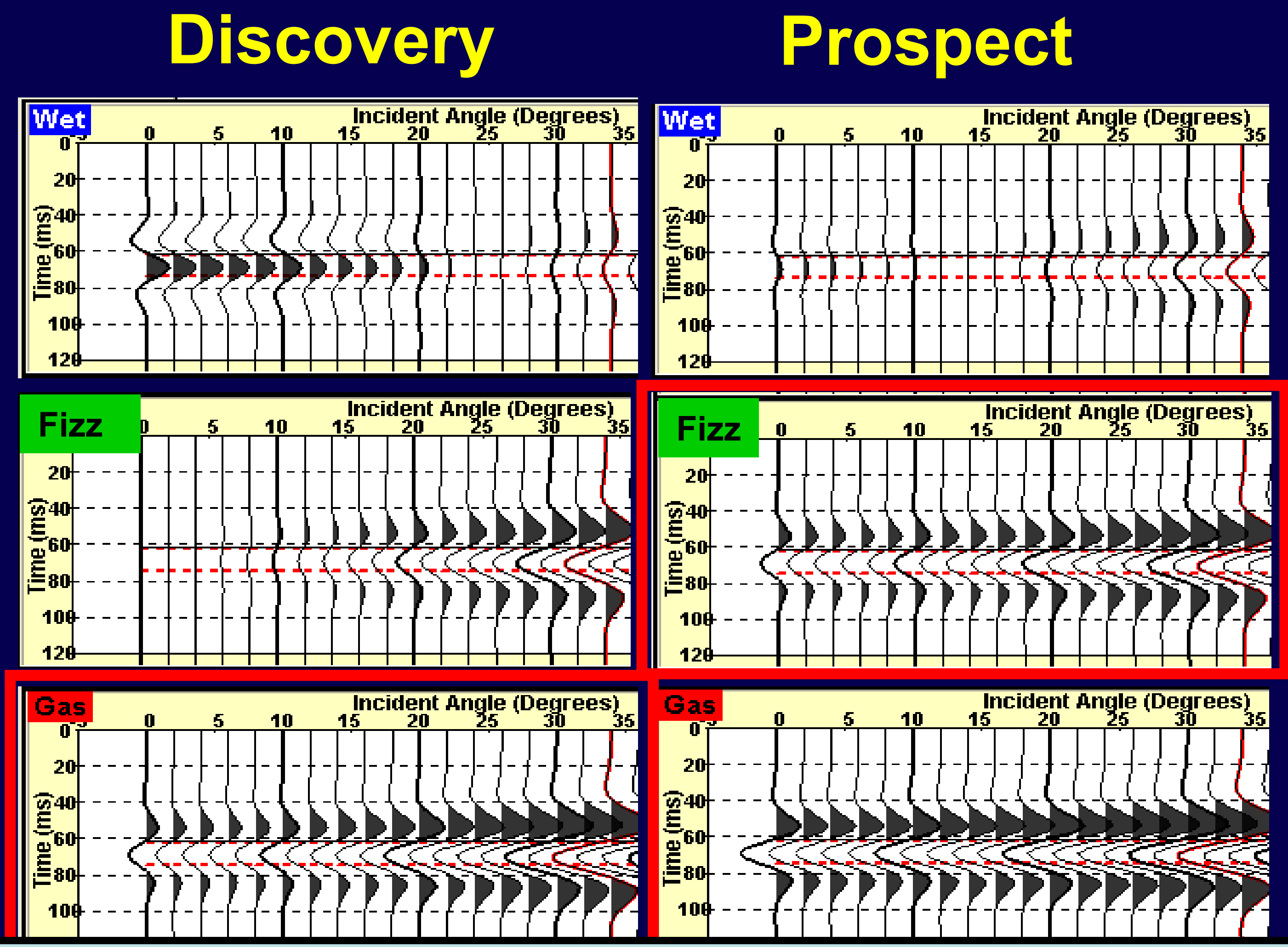
Prospect





Prospect **has same AVO response as** ***Discovery.***

Drilling Results: Hard Shale Over Prospect



Fizz and gas are differentiated by down-dip wet response.

Can we quantify seismic AVO to water saturation ?

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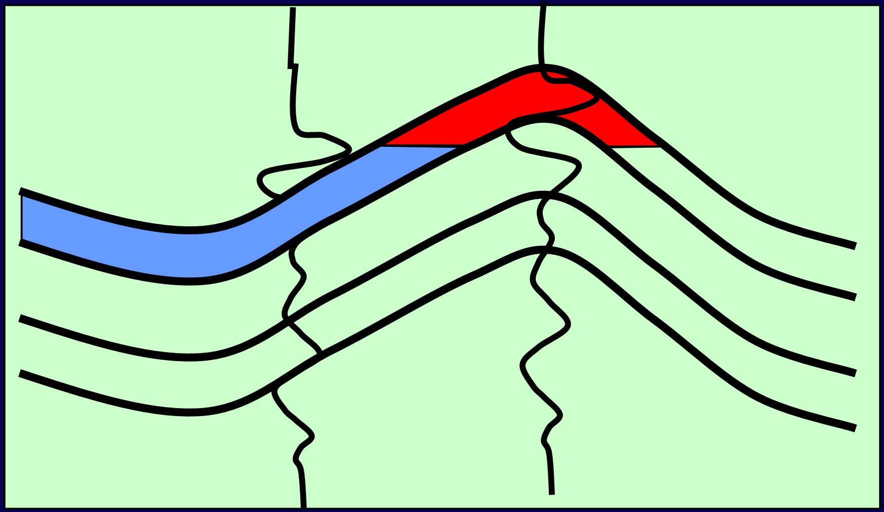
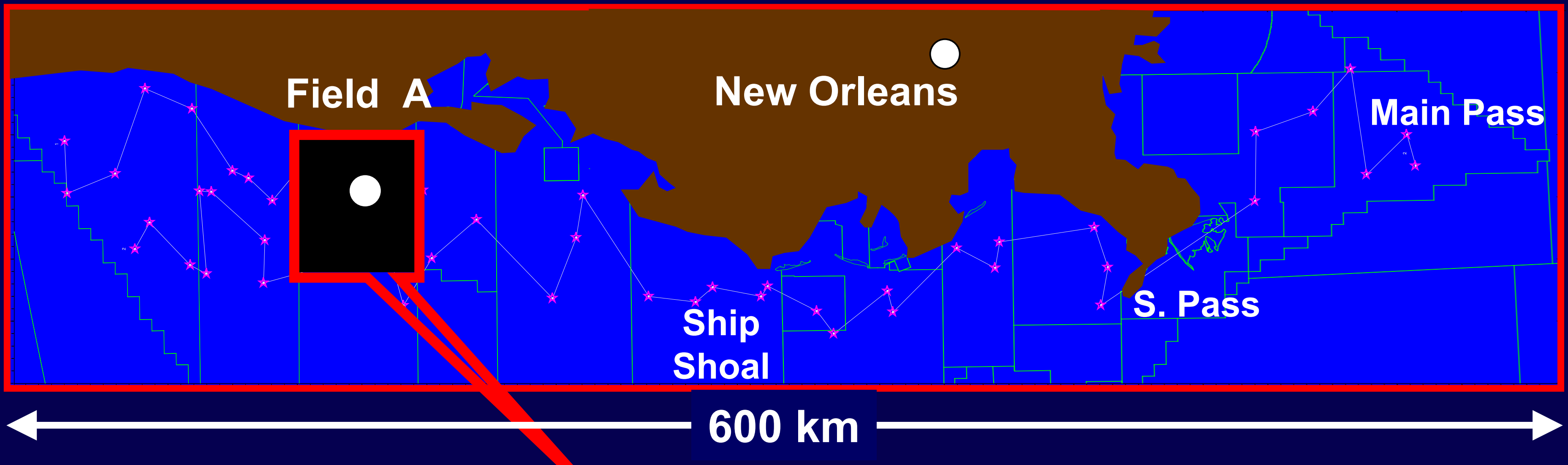
Assumption

For one particular hydrocarbon reservoir, the rock matrix is assumed to be the same as its down-dip equivalent. But the prospect and down-dip equivalent can have different thicknesses.



Local Rock Properties – GOM - Louisiana



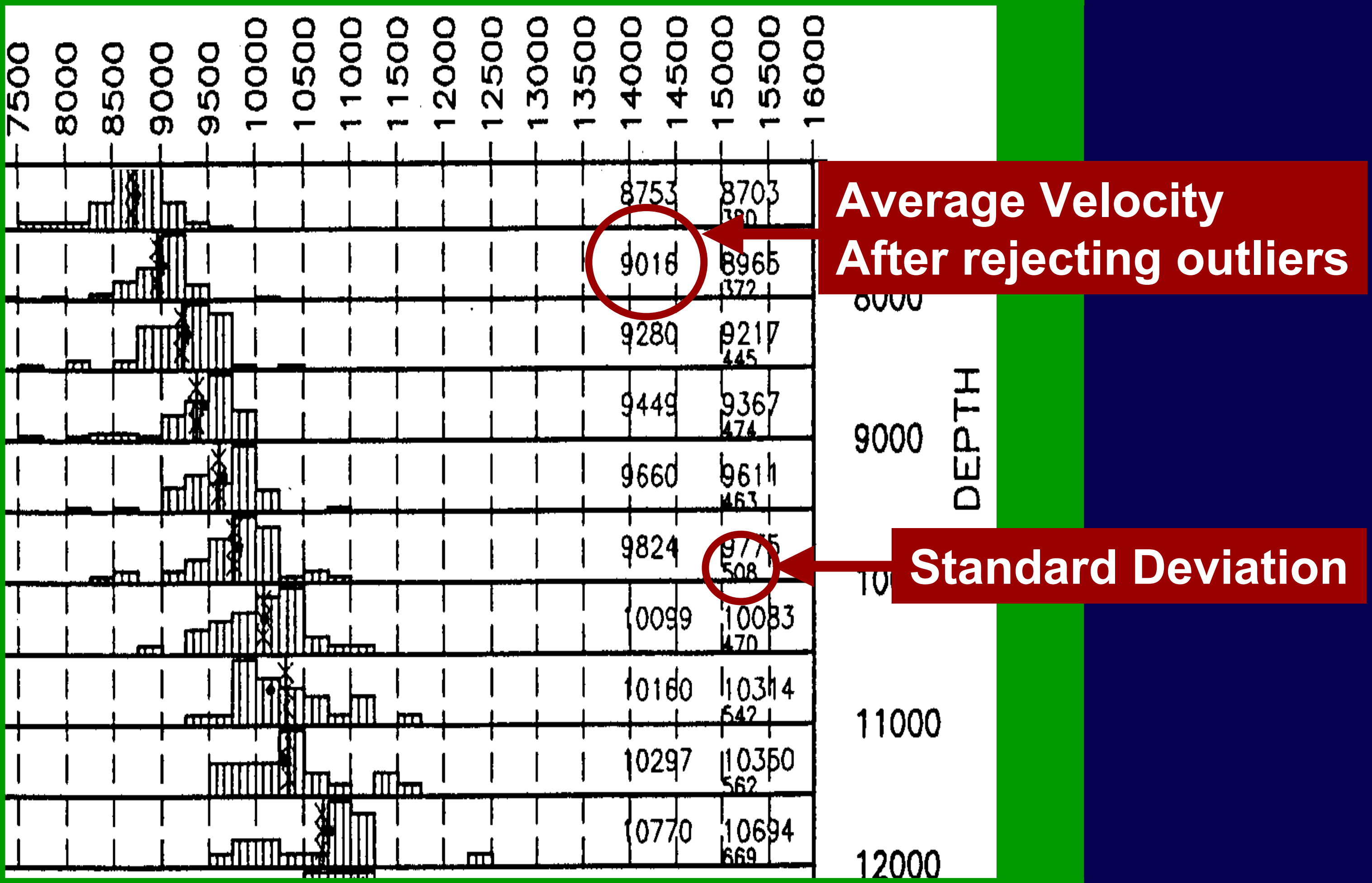
80 wells
Above onset of abnormal pressure

Locally, what are the velocity and density variations for sand and shale?

GDC data

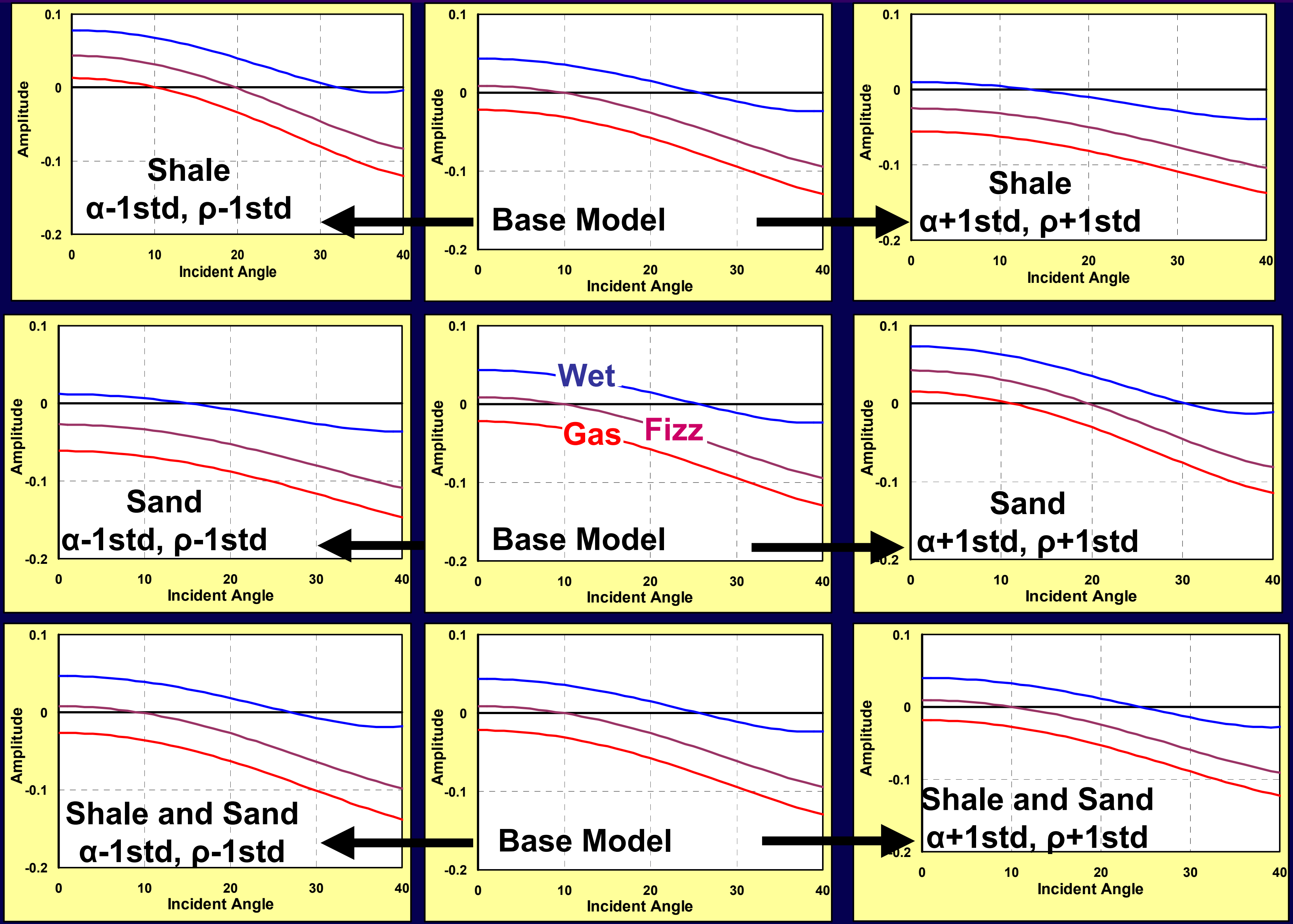
Rock-Property Variations

Sand Velocity (ft/sec)

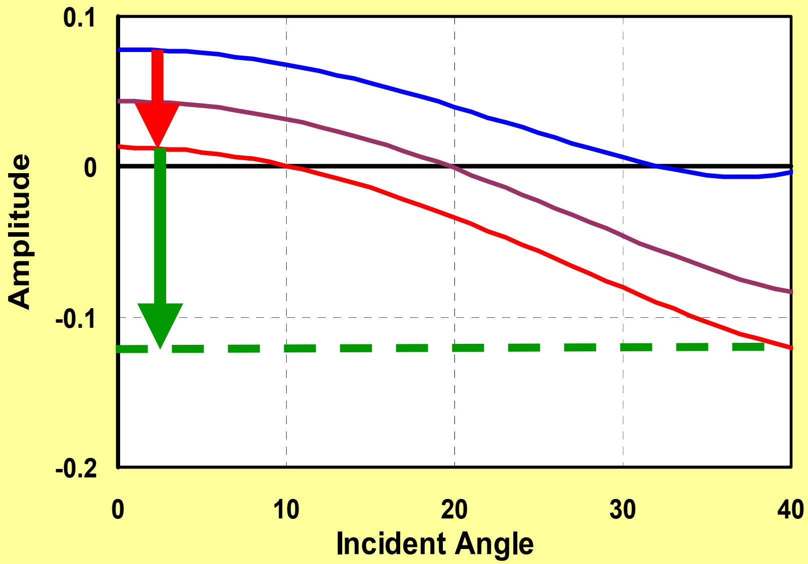


GDC data

Rock-Properties: ± 1 Standard Deviation



Rock-Property Transforms

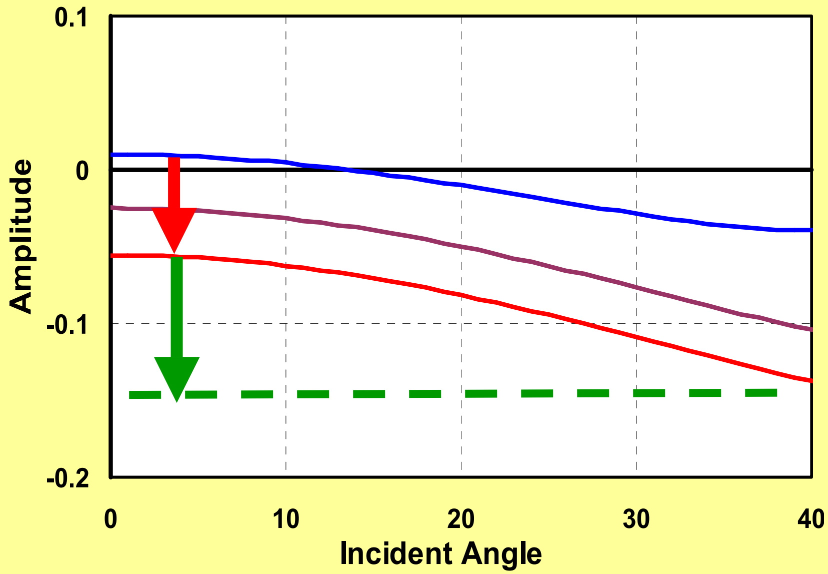


Shale Properties: -1 Std. Deviation

Two Observations:

1. NI(wet) – NI(gas) ≈ Constant

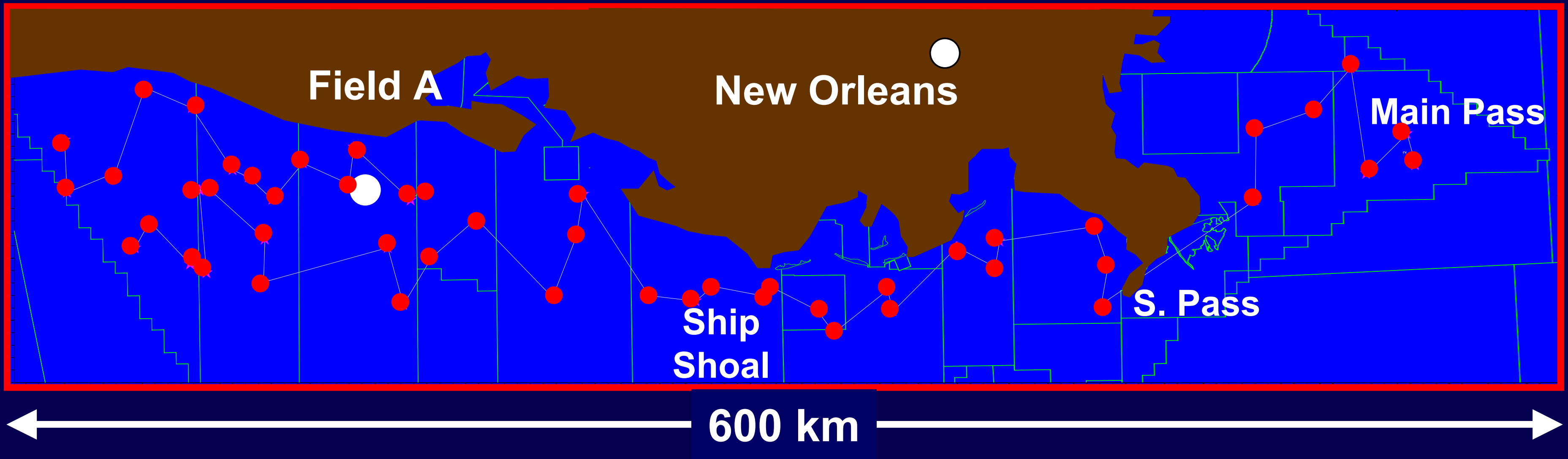
2. Slope is proportional to NI
More positive NI ⇒ Larger Slope
More negative NI ⇒ Smaller slope



Shale Properties: +1 Std. Deviation

Let's quantify these two observations

Miocene Rock Properties – GOM - Louisiana



50 shelf wells, 239 Miocene sand packages

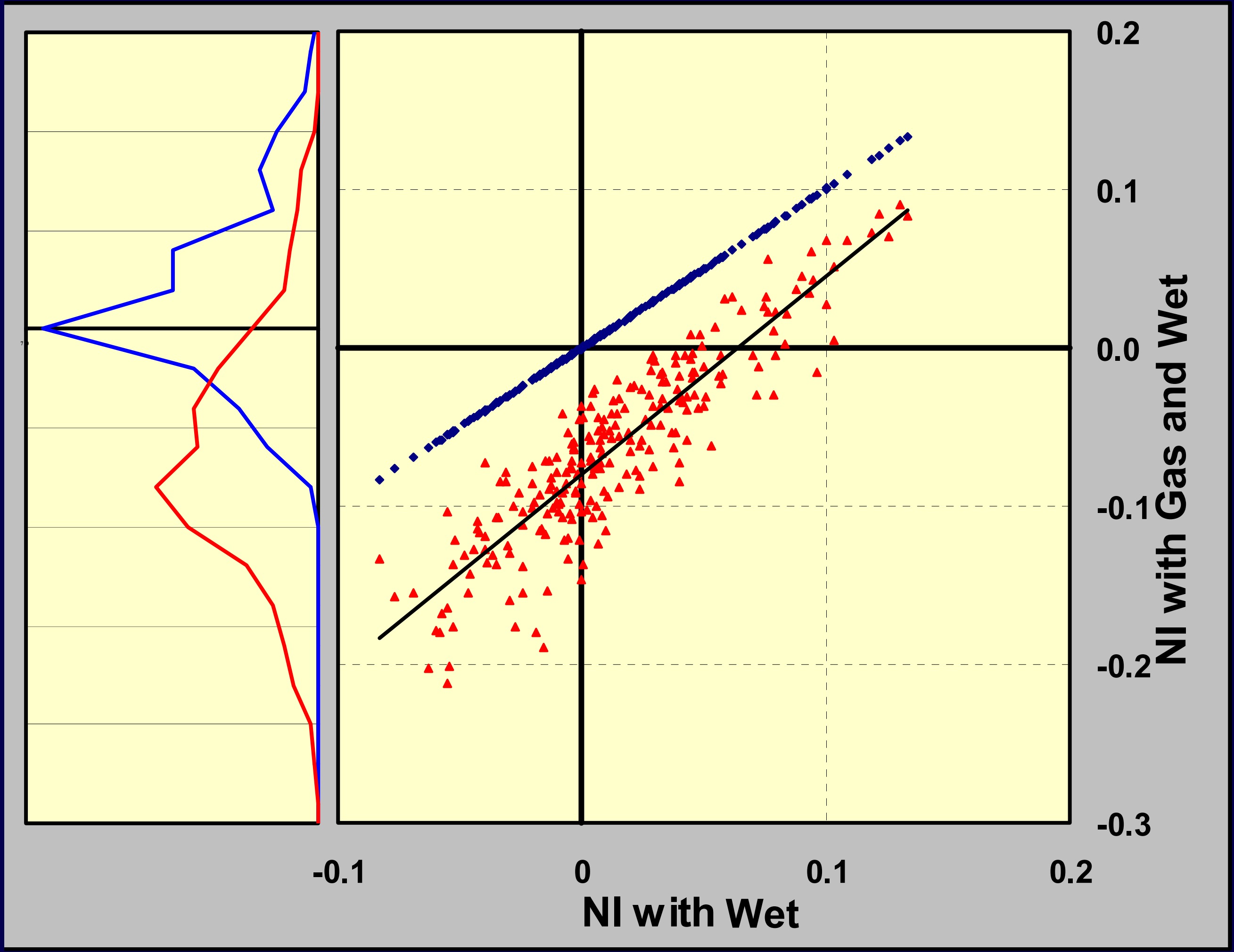
- 149 hydrocarbon charged
- 90 brine filled
- 1600-6500m depths

- Measure sand and encasing shale rock properties
- Fluid substitution:

  Wet-, gas-, and fizz-saturated rock properties

GDC data

NI for 239 Miocene sand packages

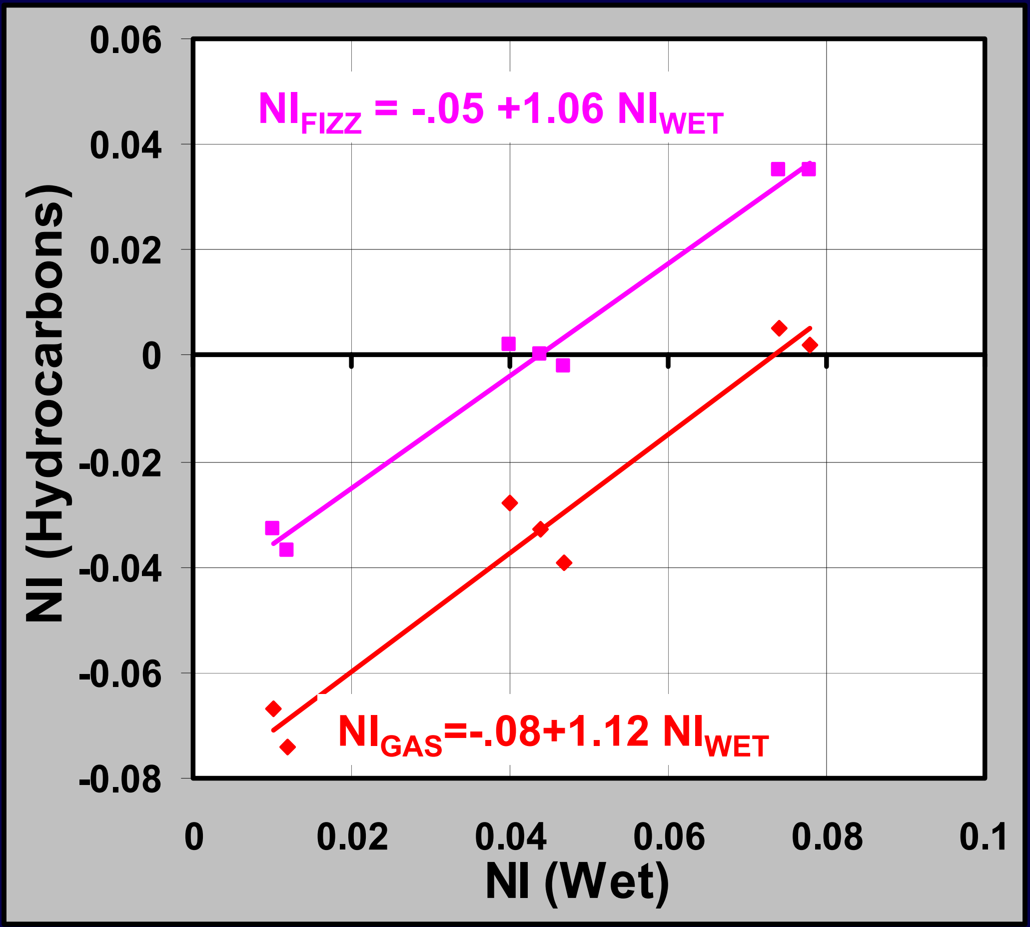


$$NI(Gas) = -.08 + 1.25\, NI(Wet)$$
$$R^2 = 0.8$$

GDC data

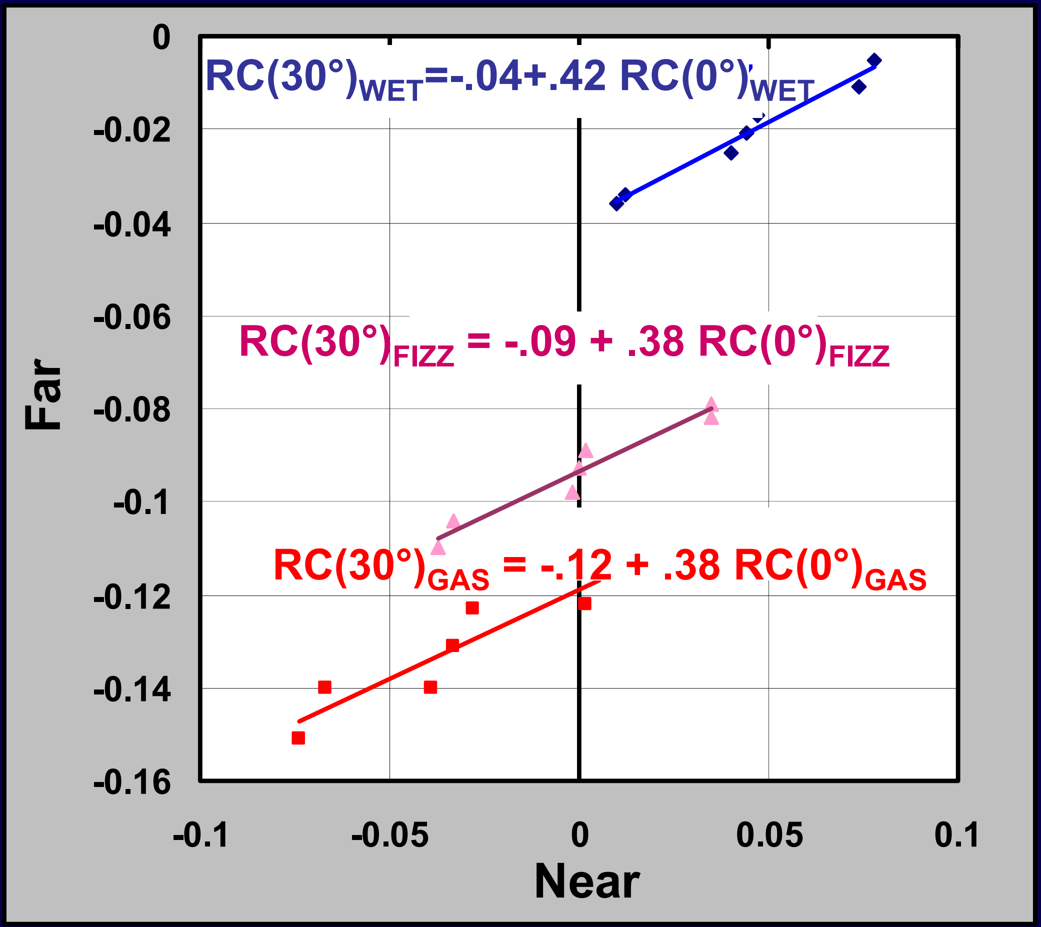
Quantifying Local Reflectivity Transforms

Observation 1



Pore Fluid Transforms

Observation 2



Slope Transforms

How are these transforms applied?

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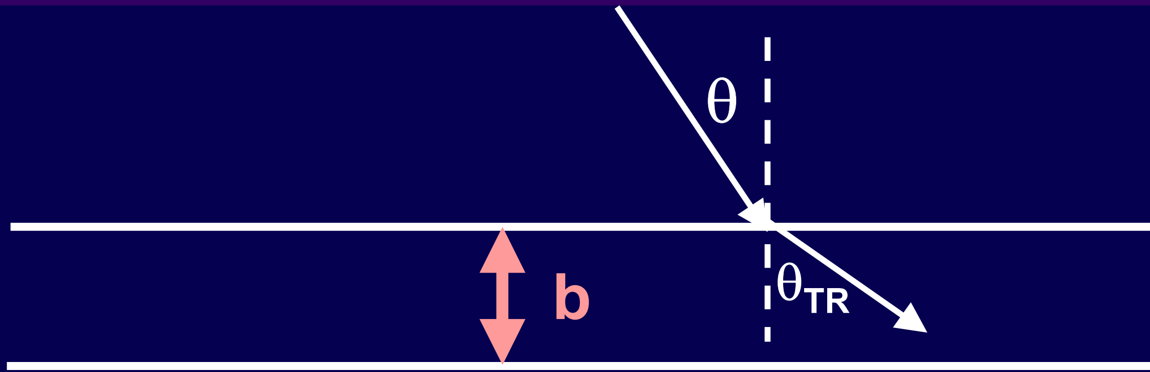
Seismic Amplitude Model



Reflection coefficient

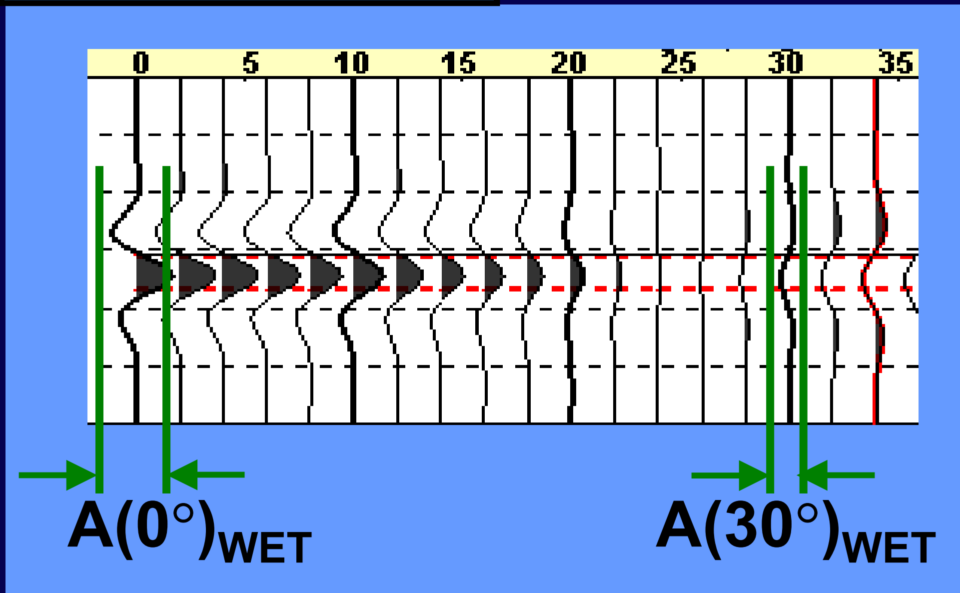
$$A(\theta) \approx k \;\; RC_{ZP\_TOP}(\theta) \;\; \frac{4\pi b}{\lambda} \;\; \cos(\theta_{TR})$$

Seismic amplitude

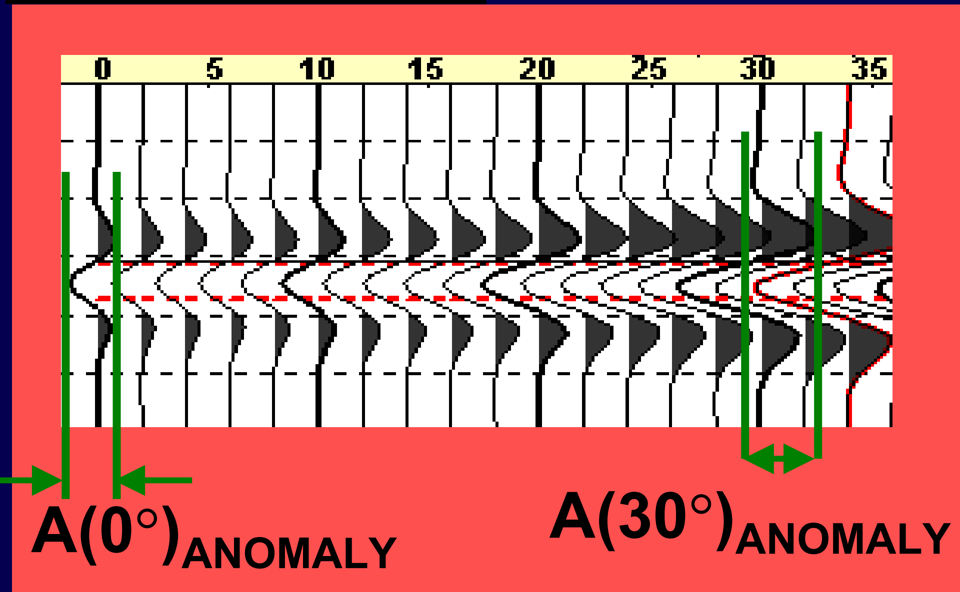
Wavelength
$b < \lambda/4$

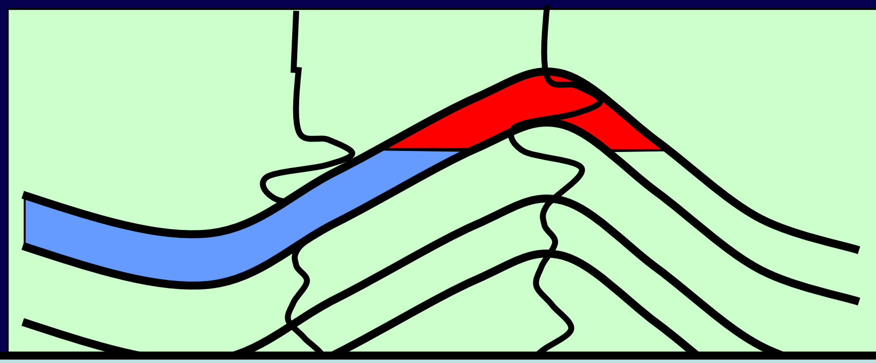
Field Measurements – Amplitude Notation

Down Dip AVO



Prospect AVO





How are seismic amplitudes converted into Reflection Coefficients?

Transforming Seismic Amplitude into NI

Slope Transform
$RC(30°) = b0 + b1\ NI$

+

Thin-bed amplitude response

$$NI = \frac{A(0°) * b0}{A(30°)/\cos(30°) - b1\ A(0°)}$$

Rock property measurements of b0 and b1

$RC(30°)_{WET} = -.04 + .42\ NI_{WET}$
$RC(30°)_{FIZZ} = -.09 + .38\ NI_{FIZZ}$
$RC(30°)_{GAS} = -.12 + .38\ NI_{GAS}$

NI Test Statistic for Gas

$$NI_{GAS} = \frac{-0.12\ A(0°)_{ANOMALY}}{1.15\ A(30°)_{ANOMALY} - 0.38\ A(0°)_{ANOMALY}}$$

Estimation in Wet Area

Amplitude Maps

↓

Slope transform for wet

↓

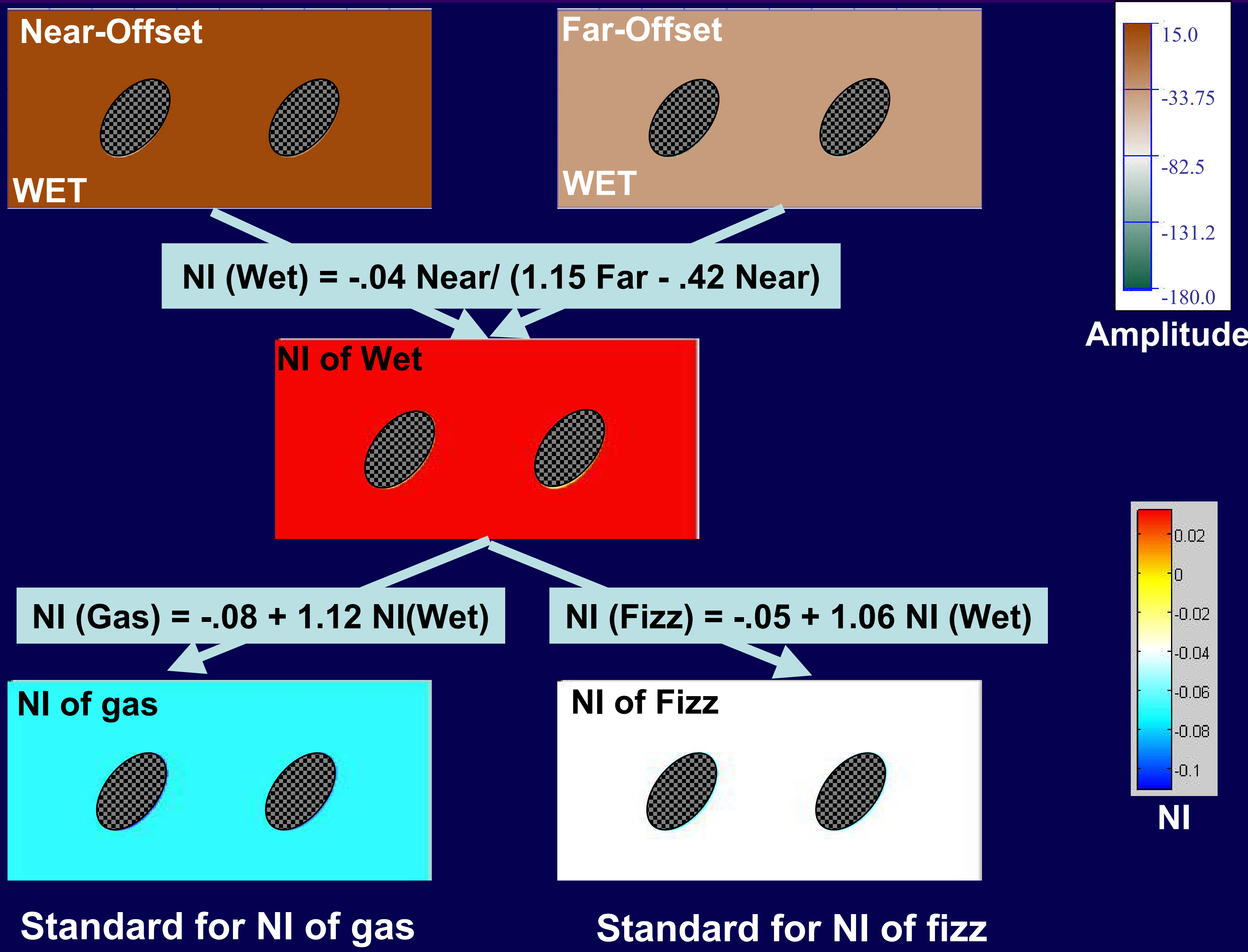
NI of Wet

↓

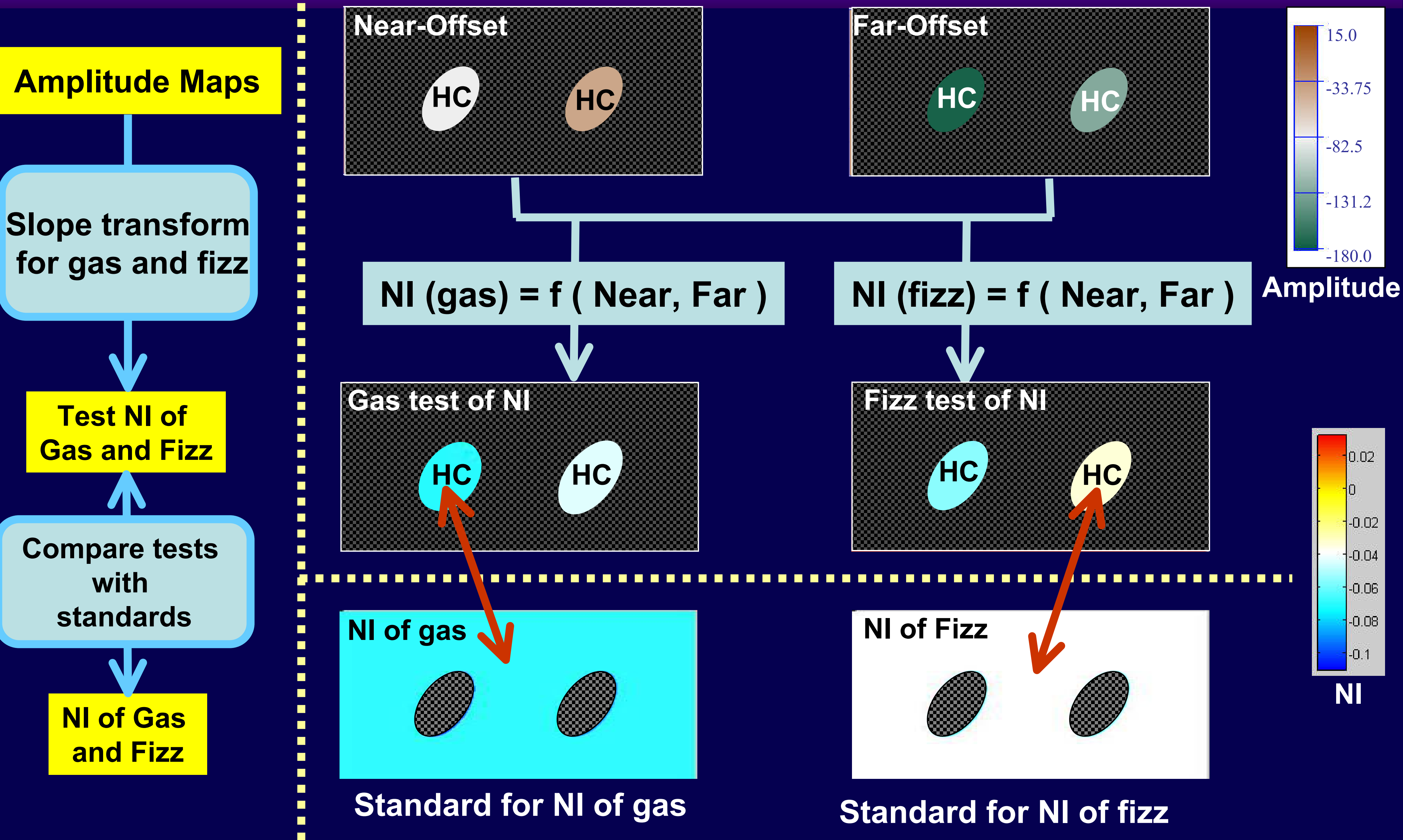
Pore fluid transforms:
Wet → Gas
Wet → Fizz

↓

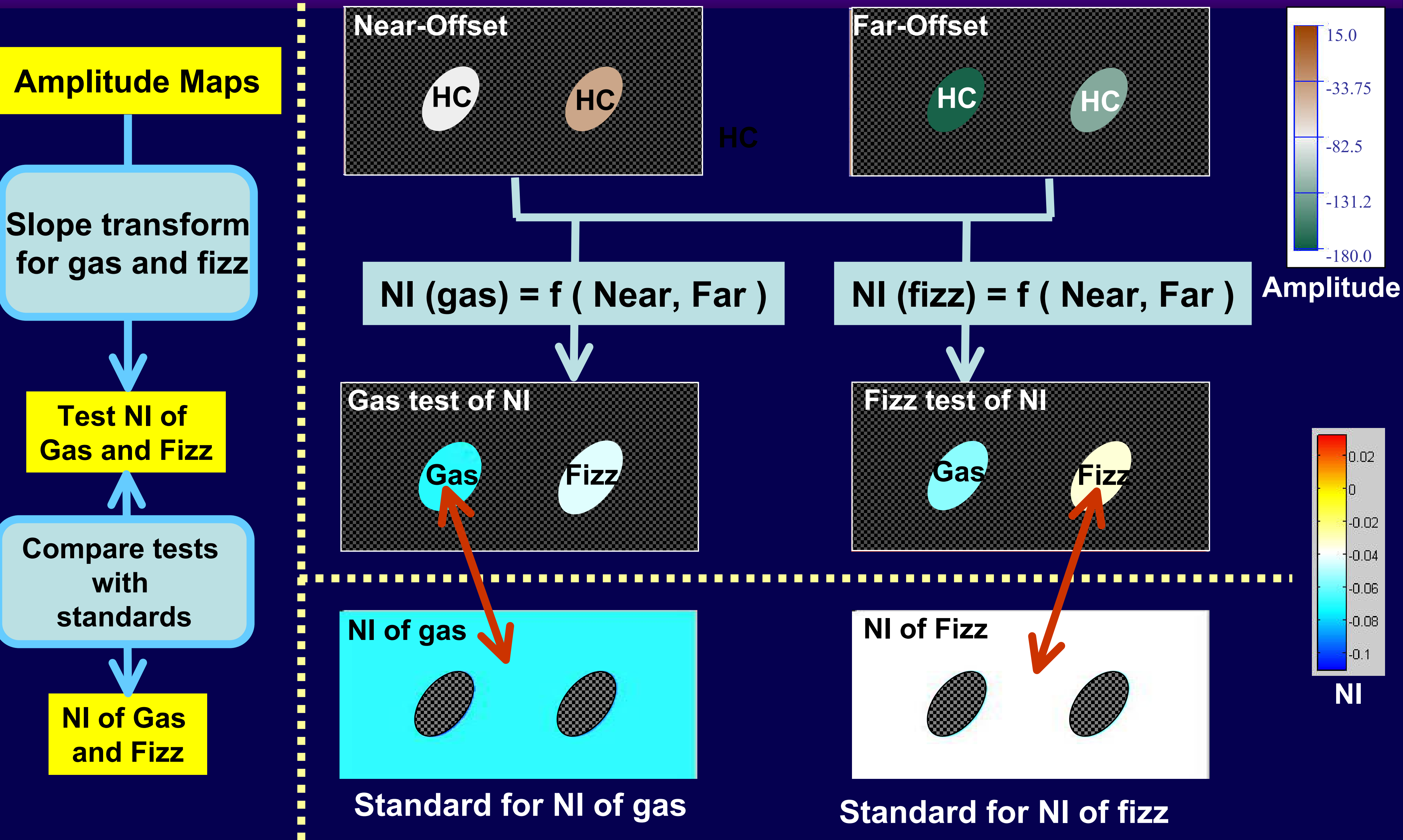
NI of Gas and Fizz



Estimation in Hydrocarbon Area



Estimation in Hydrocarbon Area



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Conclusions

- **Fizz and gas can have the same AVO responses, but down-dip water-saturated AVO response discriminates fizz from gas reservoirs.**
- **NI of wet, gas and fizz saturations vary with changing rock properties. However, the values of (NI_{WET} –NI_{GAS}) and of (NI_{WET} –NI_{FIZZ}) remain fairly stable. In the *Pore-Fluid Transforms,* linear relationships are used to predict NI_{GAS} and NI_{FIZZ} from NI_{WET} .**
- **Near and far amplitude maps combined with *Slope Transforms* estimate the Reflection Coefficients for various pore fluids. Water saturation can be determined by comparing the NI values predicted in wet area and in prospect area.**

Needs field verification !

Acknowledgements

RQL sponsors

Permission to show data:

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Thank you for your attention!