METHANE HYDRATES: GEOSCIENCE CHALLENGES

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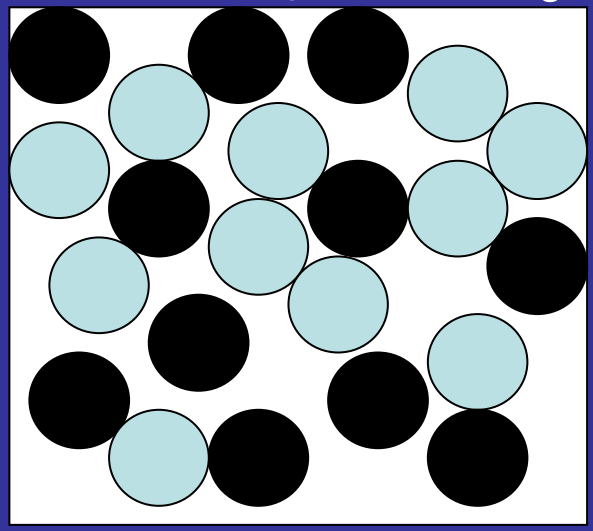
ROCK PHYSICS

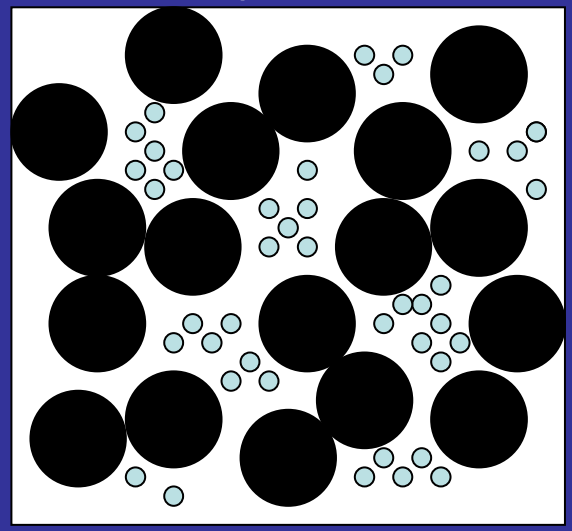
How is hydrate embedded in sediment?

HYDRATE/SEDIMENT GRAIN-TO-GRAIN MORPHOLOGY MODELS

Model A:
Disseminated, Load-bearing



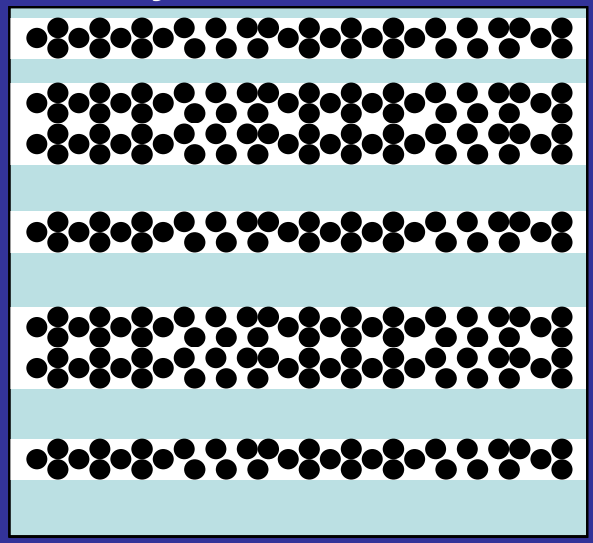
Model B:
Disseminated, Non-Load-Bearing



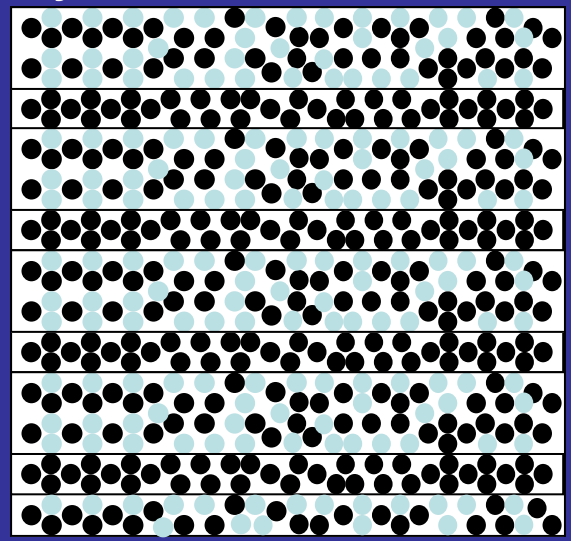
Hydrate

Sediment

Model C:
Layered, Solid Phase



Model D:
Layered, Disseminated Phase



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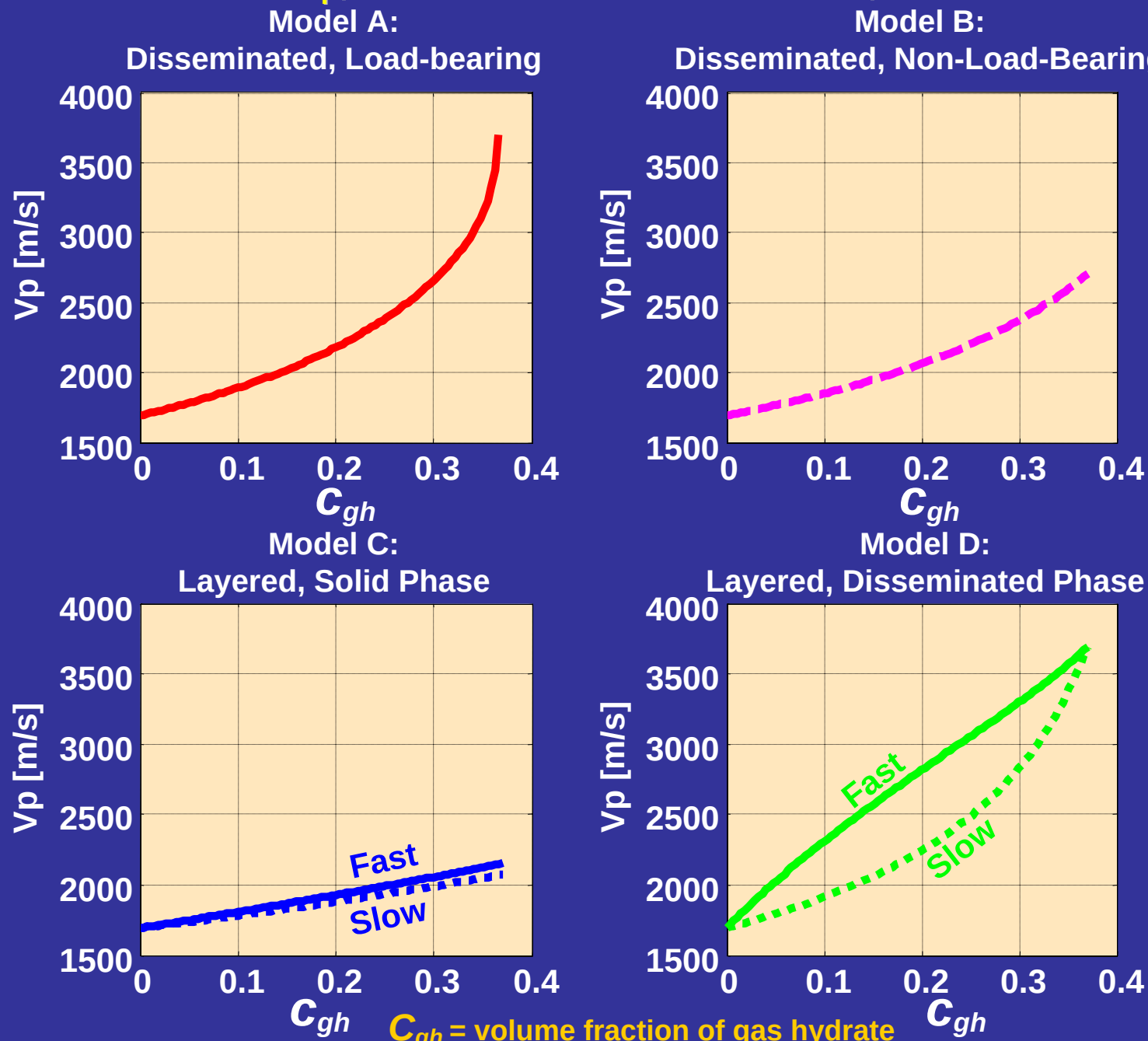
QAd4571x
QAd5515-ppt

MODEL-BASED V_p, HOST SEDIMENT = SAND, POROSITY = 0.37



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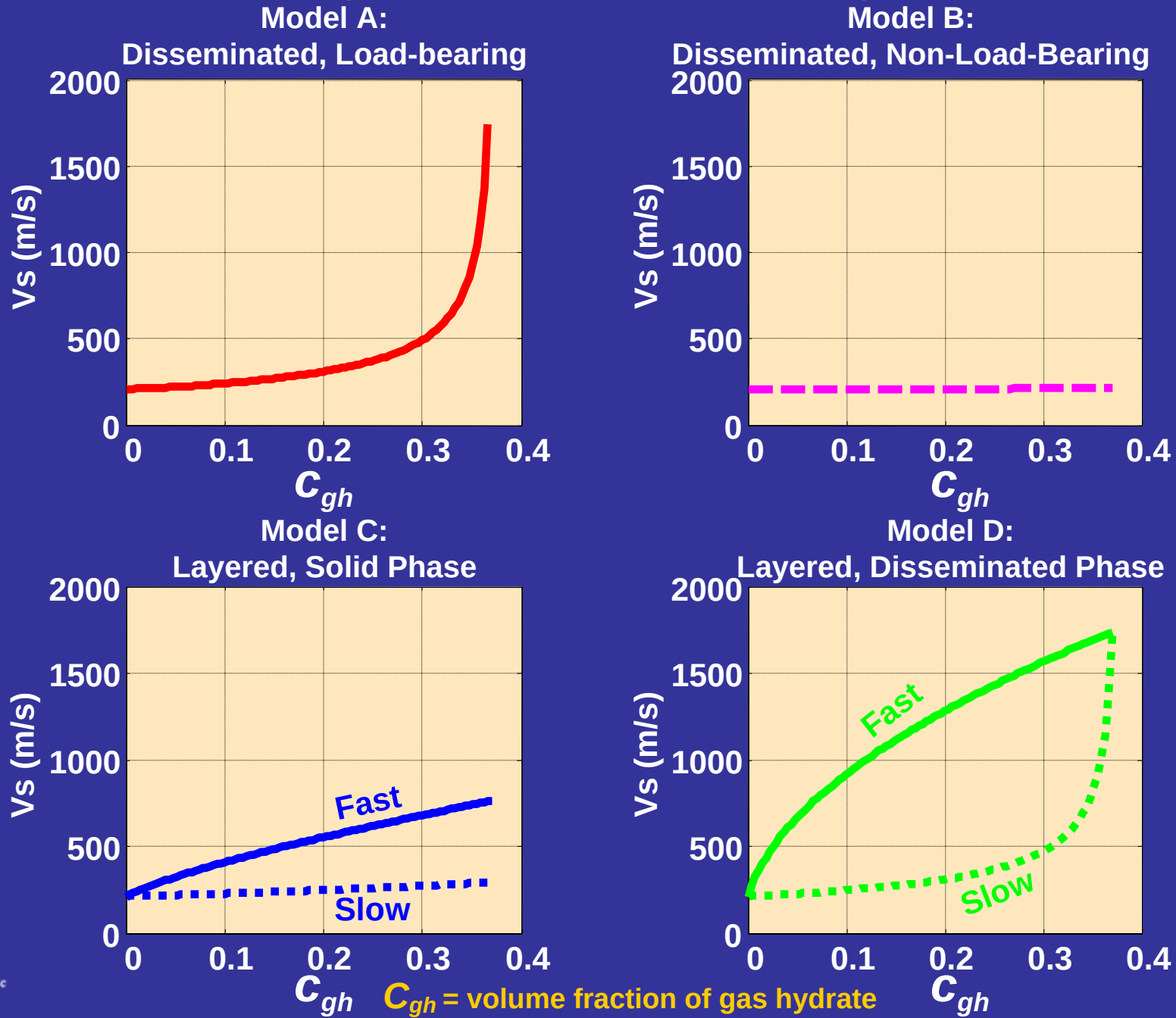
QAd4572x

MODEL-BASED V_s, HOST SEDIMENT = SAND, POROSITY = 0.37



PETROPHYSICS

How much hydrate is in a target interval?

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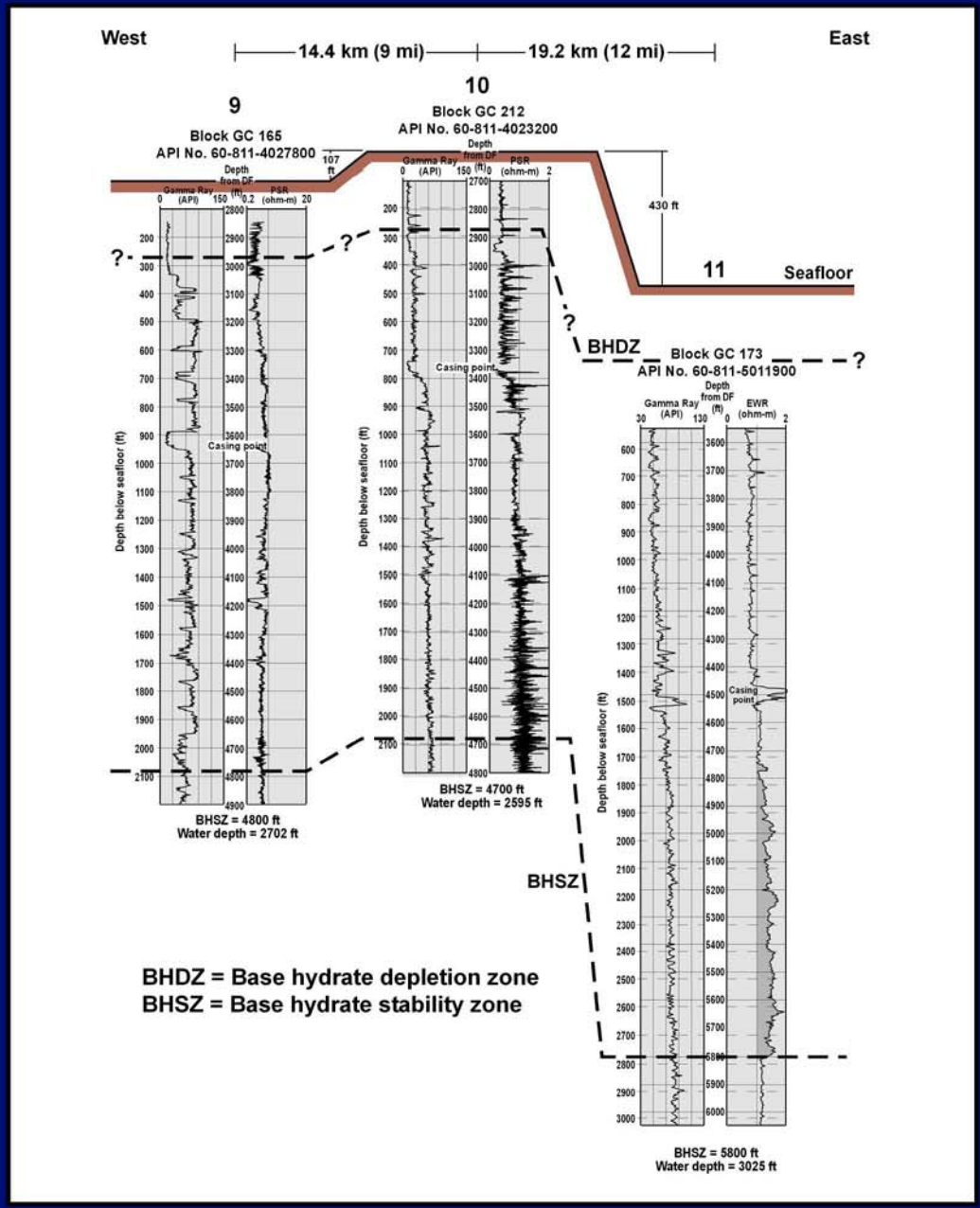
WELL LOG CROSS-SECTION 9-10-11 (Remote)



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QAd5388x

ARCHIE EQUATION FOR DISPERSED HYDRATE

$$R = aR_w \phi^{-m} S_w^{-n}$$

$$c_{gh} = 1 - S_w$$

$$c_{gh} = 1 - \left[\frac{aR_w}{R} \phi^{-m} \right]^{\frac{1}{n}}$$

R = resistivity of rock (measured)

R_w = resistivity of brine

ϕ = porosity

S_w = water saturation

c_{gh} = gas hydrate concentration

a = internal geometric parameter

m = cementation exponent

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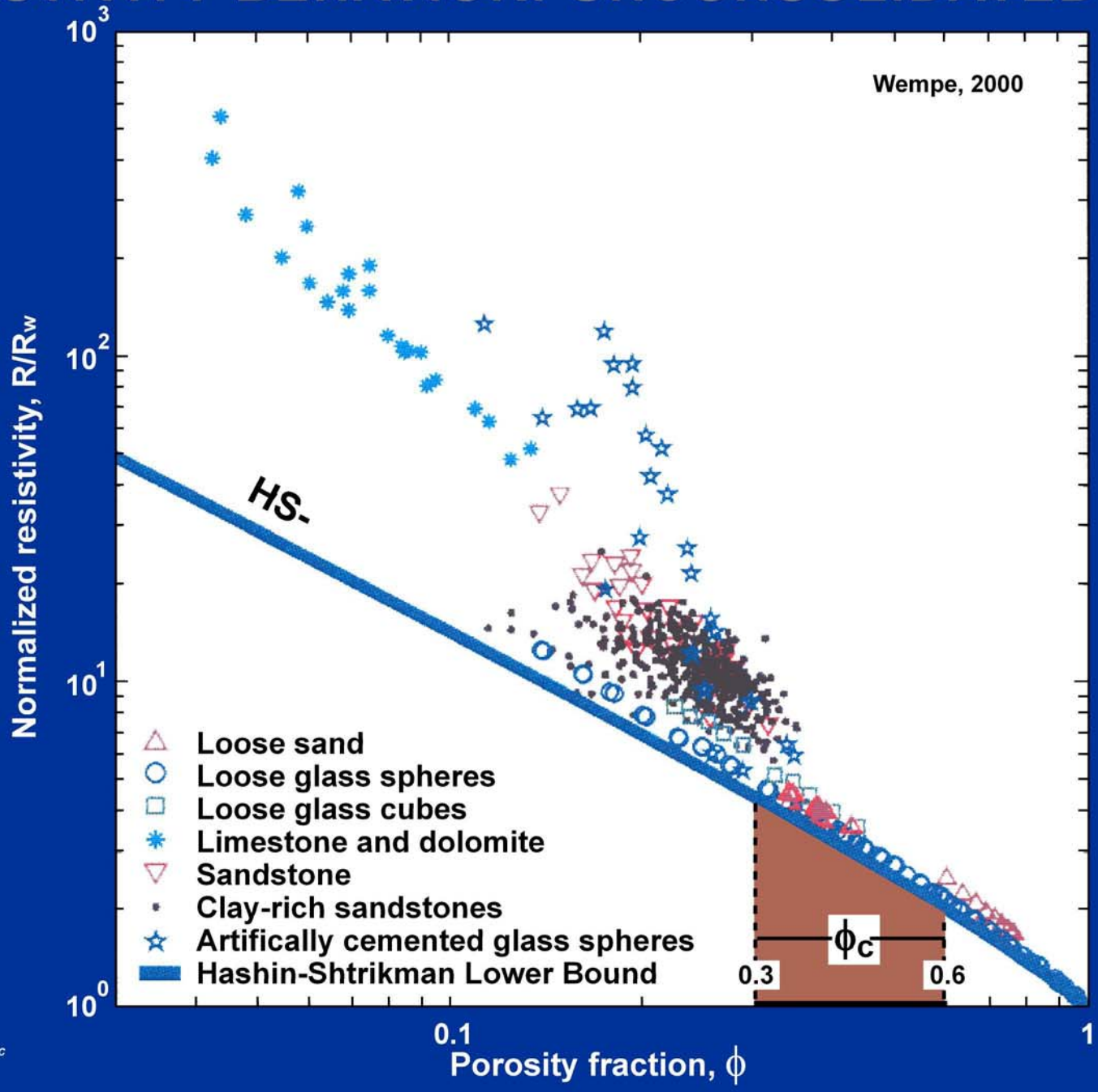
QAd5178(e)x
QAd5515-ppt

RESISTIVITY BEHAVIOR: UNCONSOLIDATED SEDIMENT



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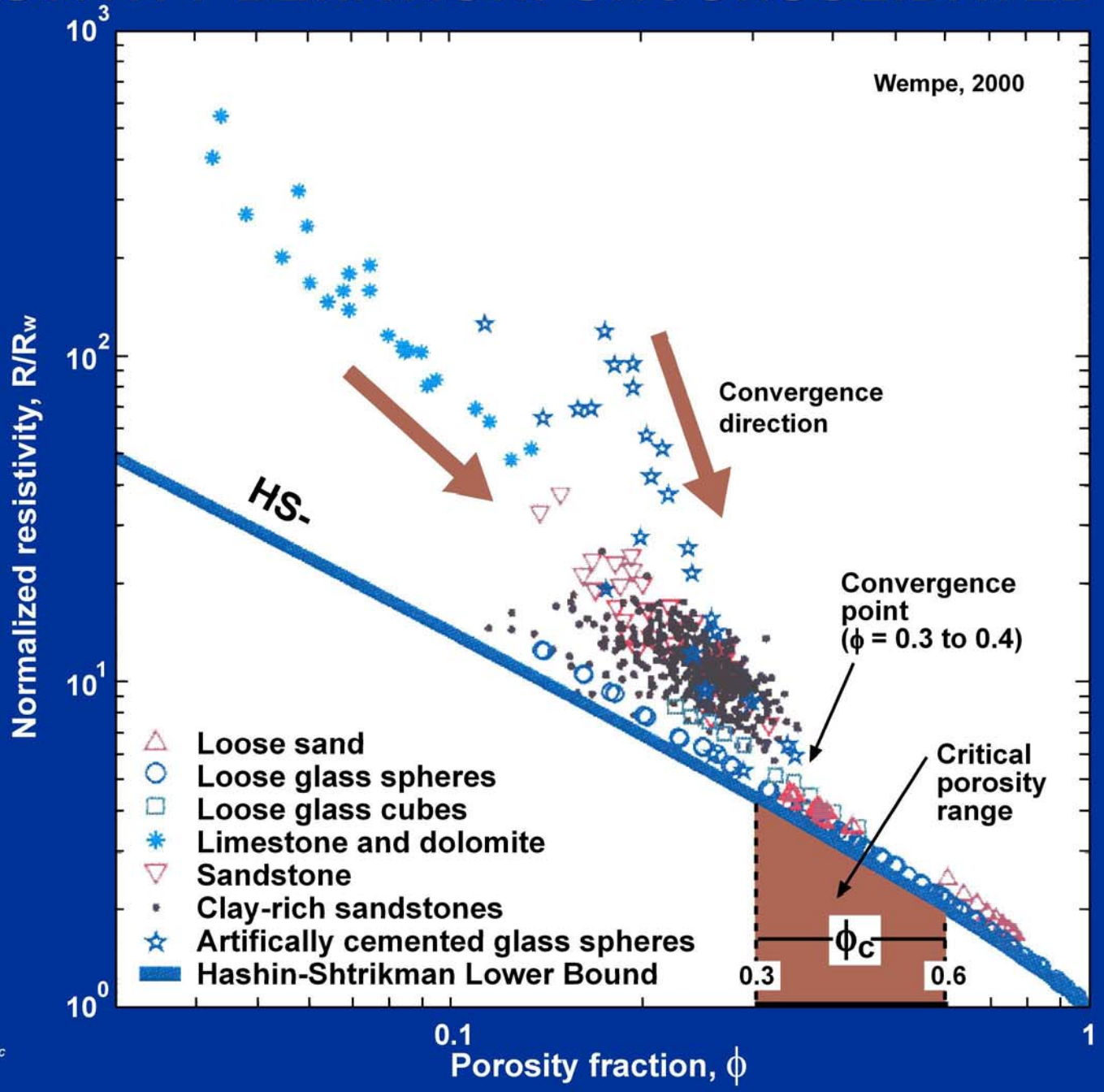
QAd5190(a)x

RESISTIVITY BEHAVIOR: UNCONSOLIDATED SEDIMENT



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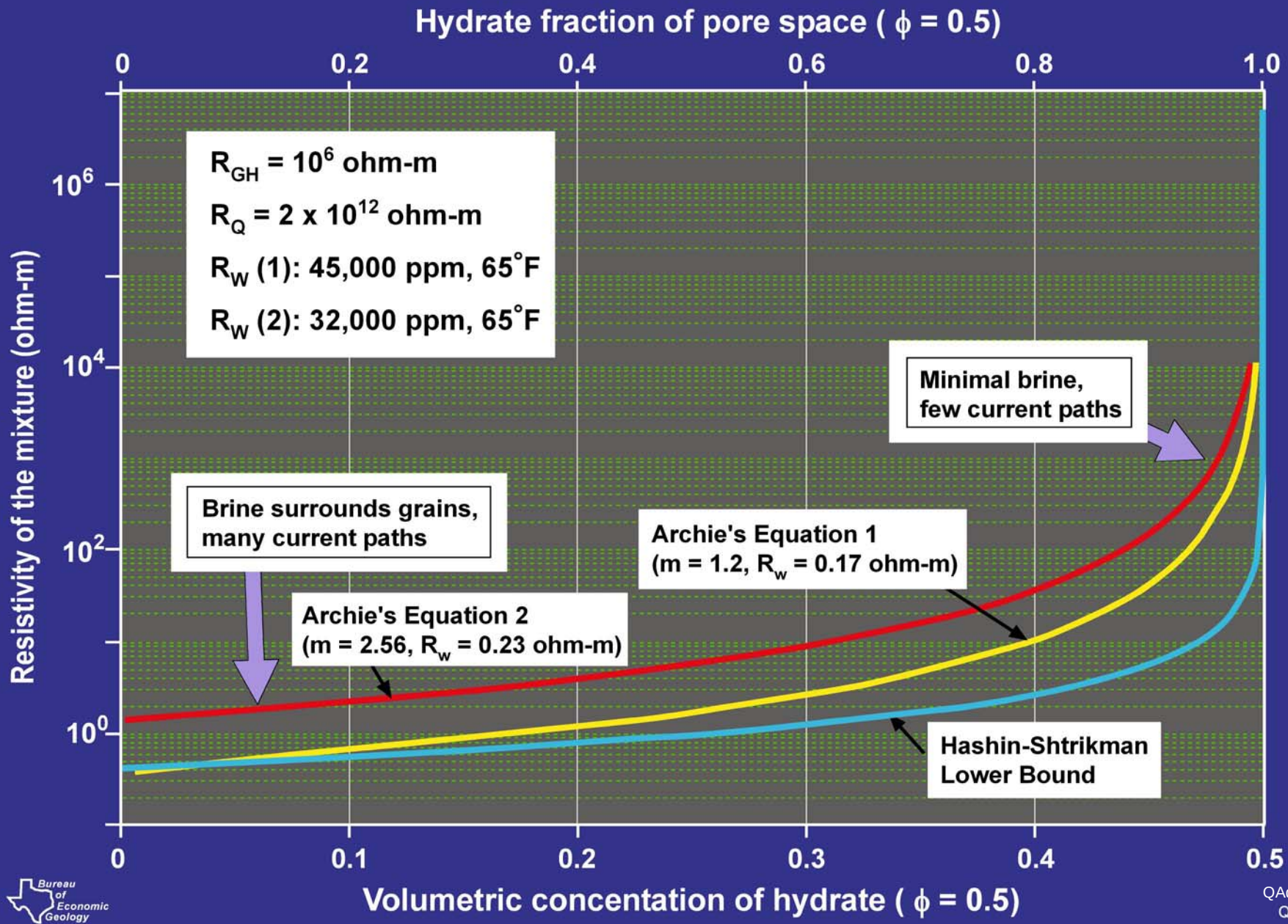
QAd5190x

RESISTIVITY OF SEDIMENT, HYDRATE, BRINE MIXTURE



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QAd5241x

EFFECT OF CLAYS
MODIFIED ARCHIE EQUATION

$$R = \alpha \phi^{-m} R_w (1 - V_{cl}) S_w^{-n} + \frac{R_{cl}}{V_{cl}} S_w^{-n+1}, \quad n = 2$$

V_{cl} = **volume of clay**

R_{cl} = **resistivity of clay minerals**

α = **internal geometric factor (0.25-10)**

m = cementation exponent (~2.5)

ϕ = **porosity**

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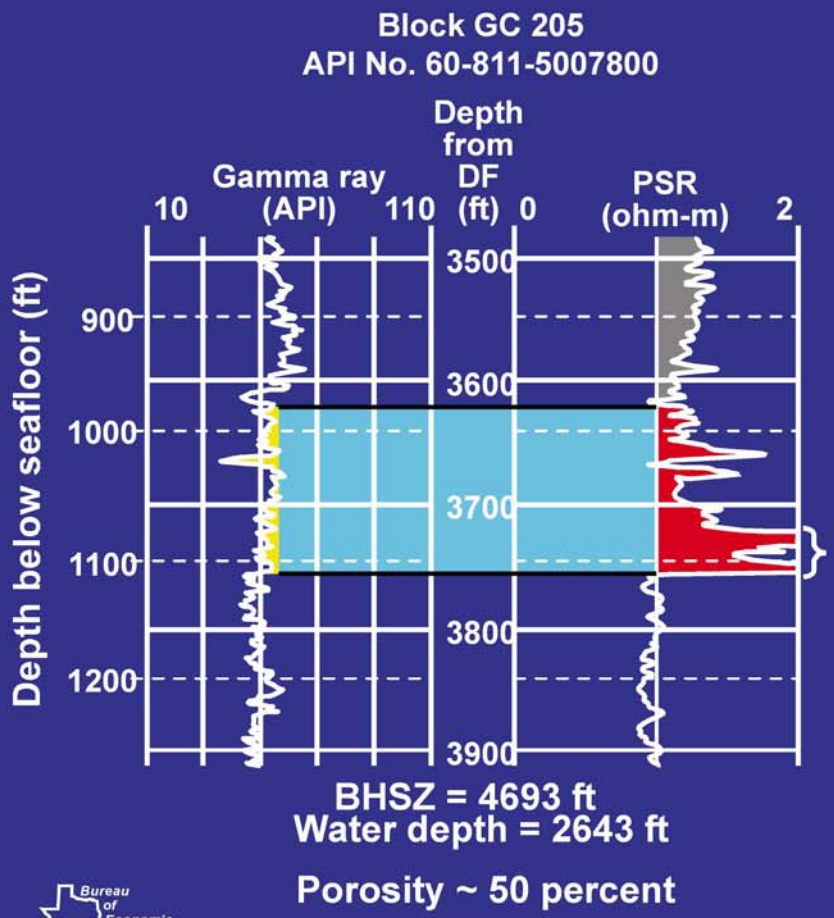
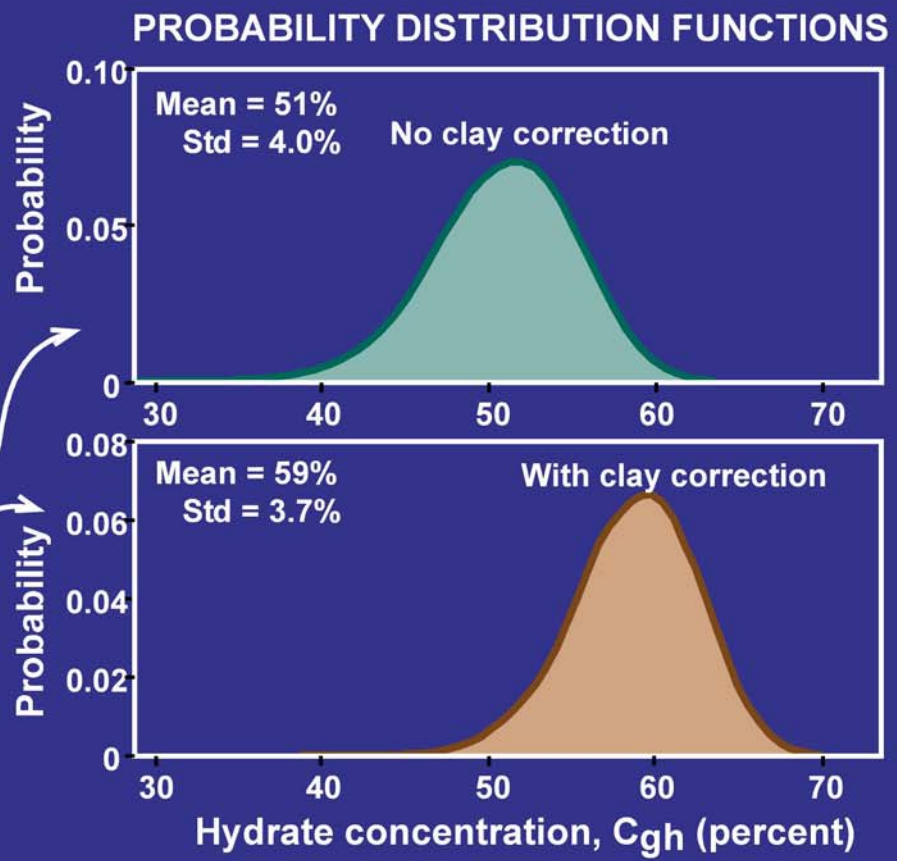
QAd5178(c)x
QAd5515-ppt

PREDICTED HYDRATE CONCENTRATION, WELL W1, R ~ 2.0 OHM-M





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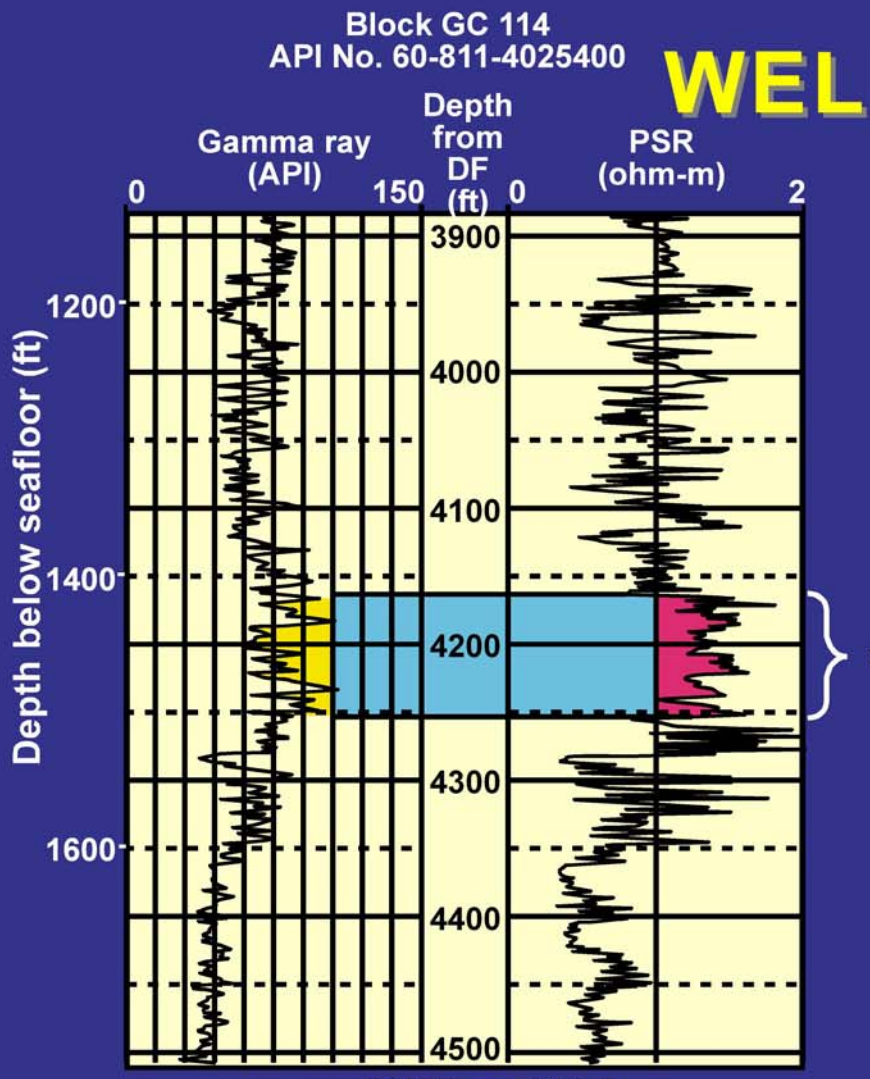
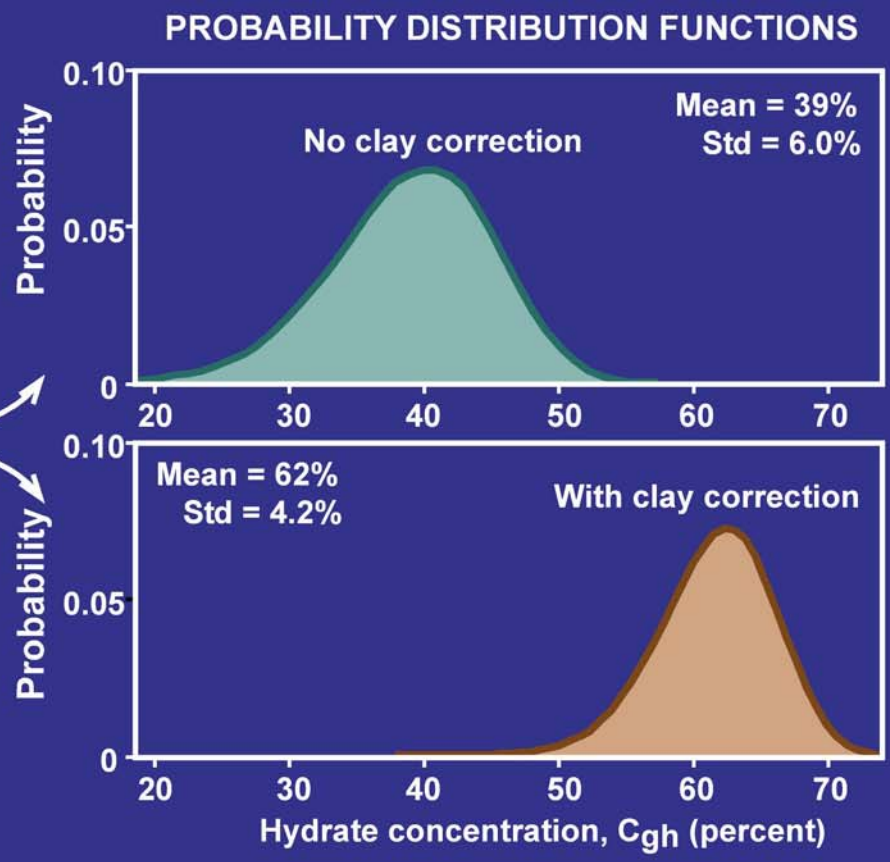
QAd5515-ppt

PREDICTED HYDRATE CONCENTRATION, WELL W3: R ~ 1.5 OHM-M





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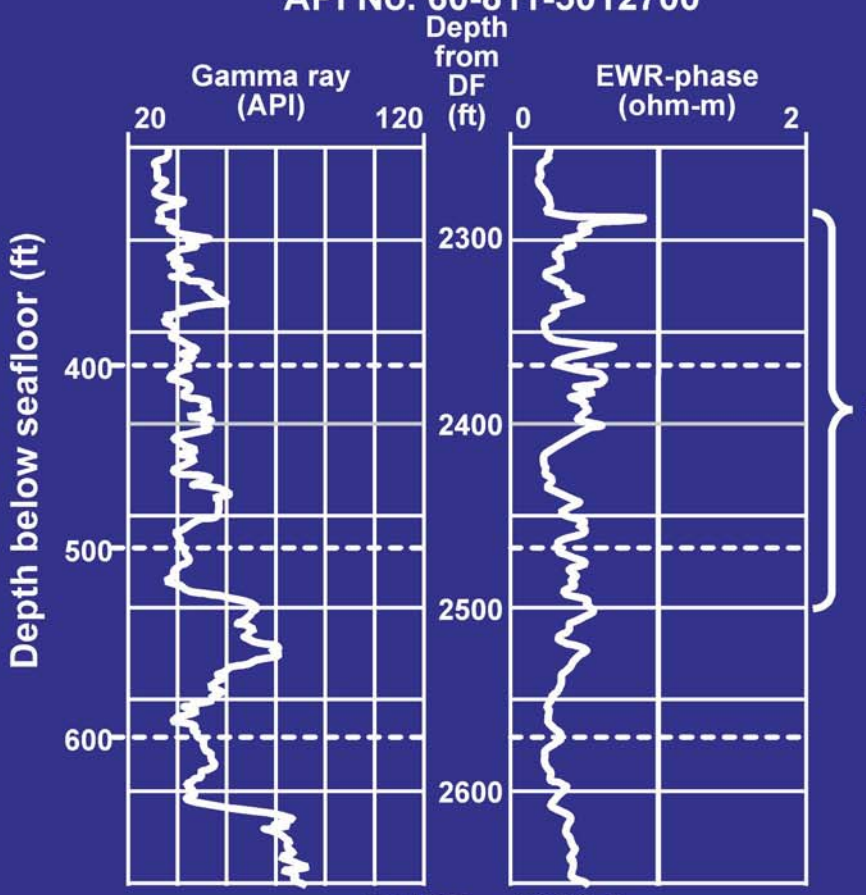
QAd5458

PREDICTED HYDRATE CONCENTRATION, WELL W5, R ~ 0.35 OHM-M

Block GC 113

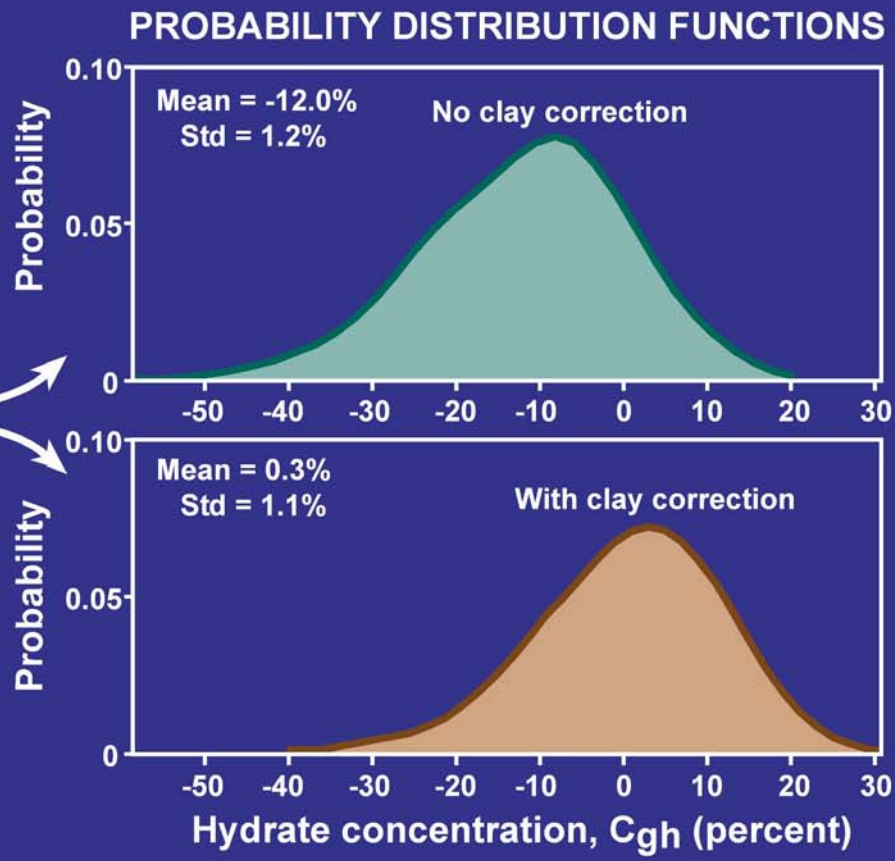
API No. 60-811-5012700



BHSZ = 3280 ft

Water depth =1968 ft

Porosity ~ 55 percent



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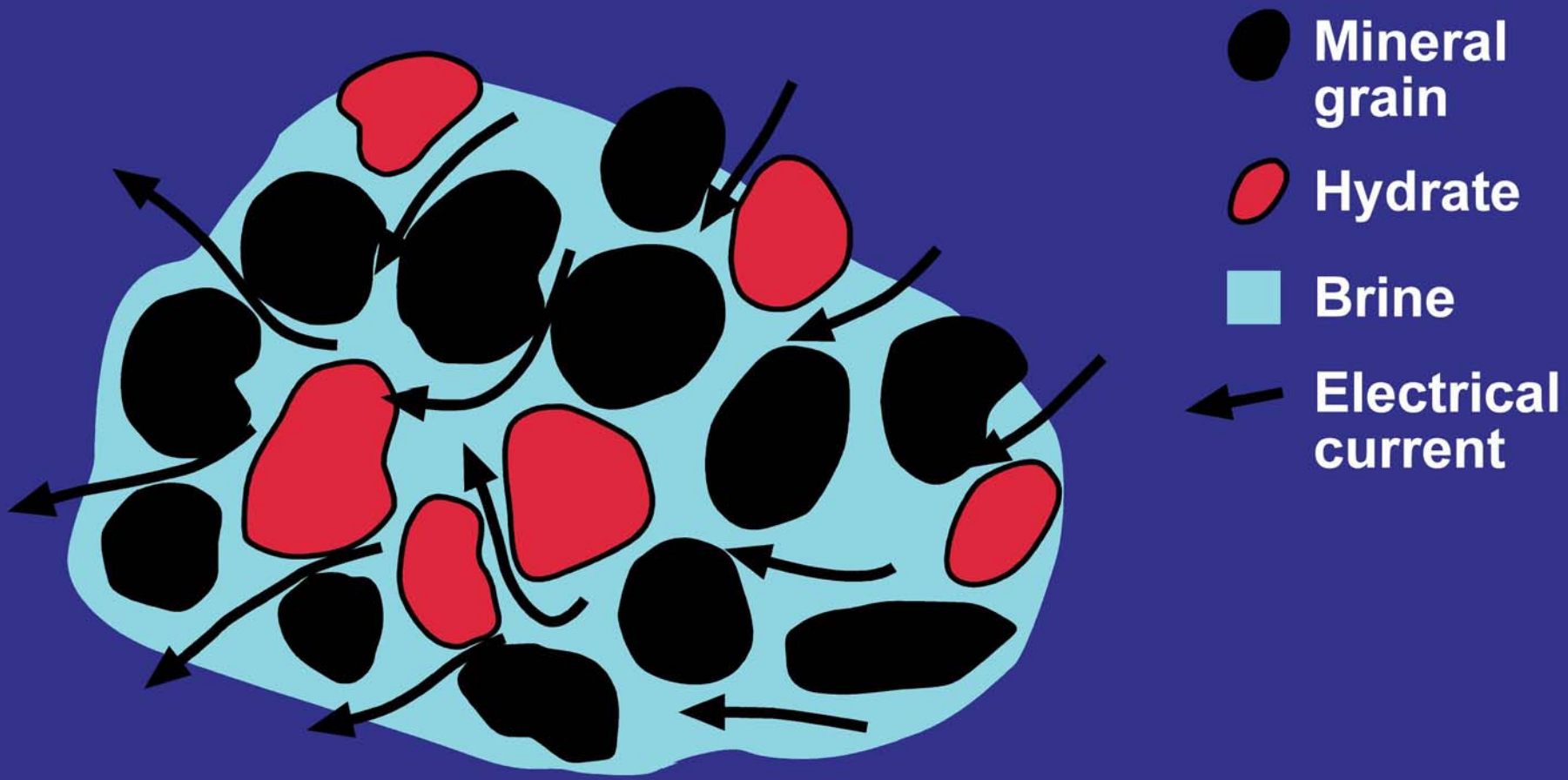
QAd5515-ppt

QAd5460

RESISTIVITY MODEL: UNCONSOLIDATED SEDIMENT AND DISPERSED HYDRATE



RESISTIVITY OF GAS-HYDRATE SYSTEMS

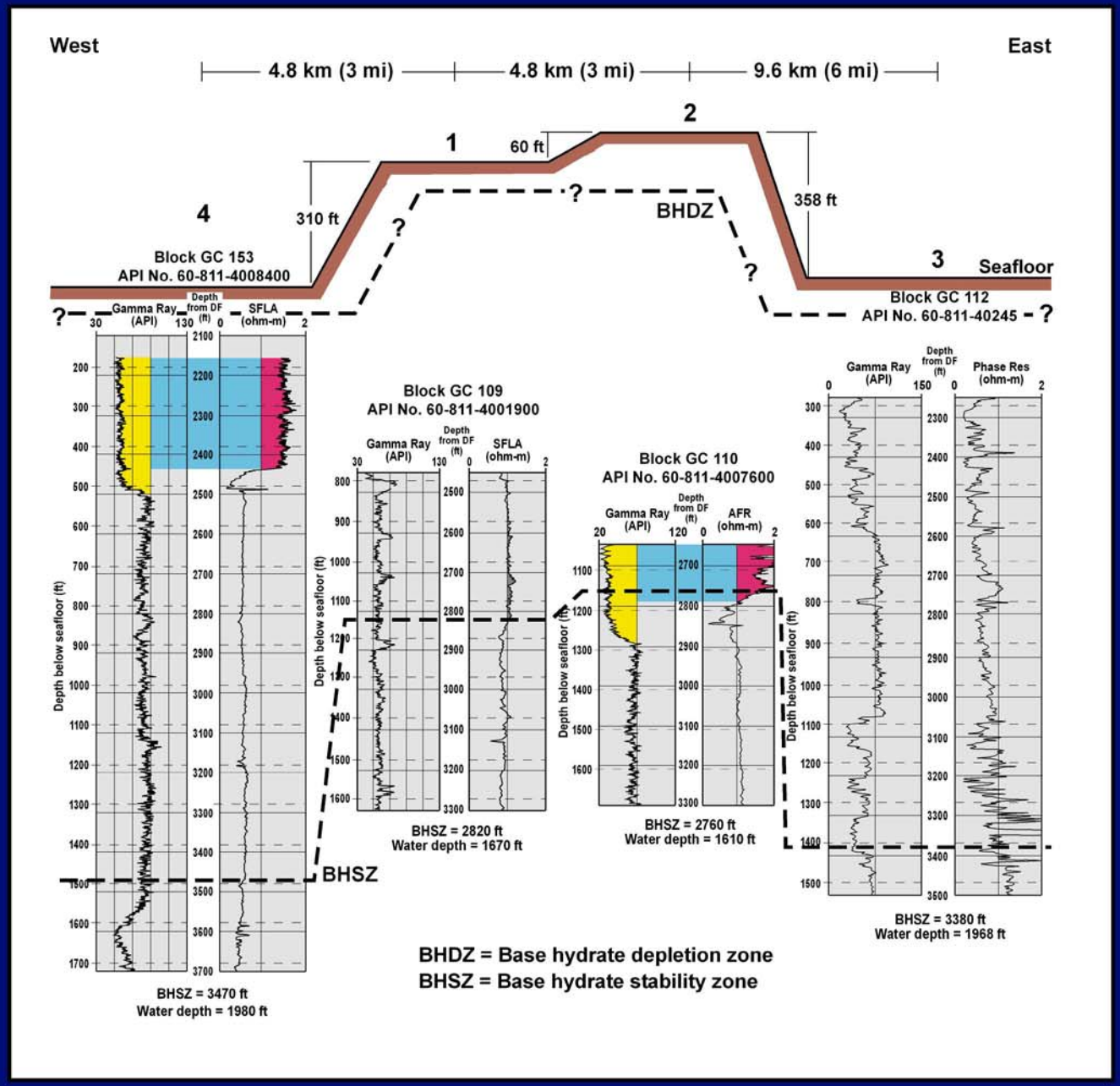
DISPERSED HYDRATE

Option 1: Archie equation
Option 2: Hashin-Shtrikman bounds

LAYERED HYDRATE

New approach needed. Archie equation and Hashin-Shtrikman model do not apply

WELL LOG CROSS-SECTION 4-1-2-3 (Remote)



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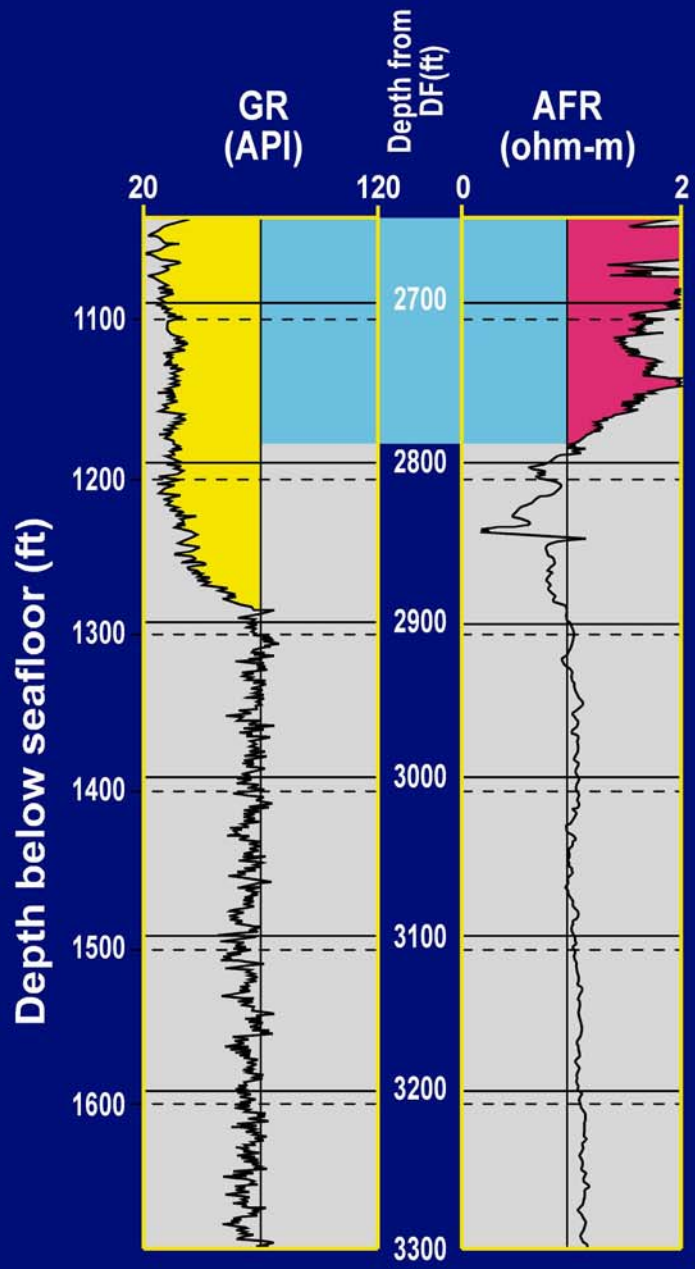
QAd5515-ppt
QAd5387x

BLOCK GC 110
API No. 60-811-4007600



BHSZ = 2760 ft
Water depth = 1610 ft

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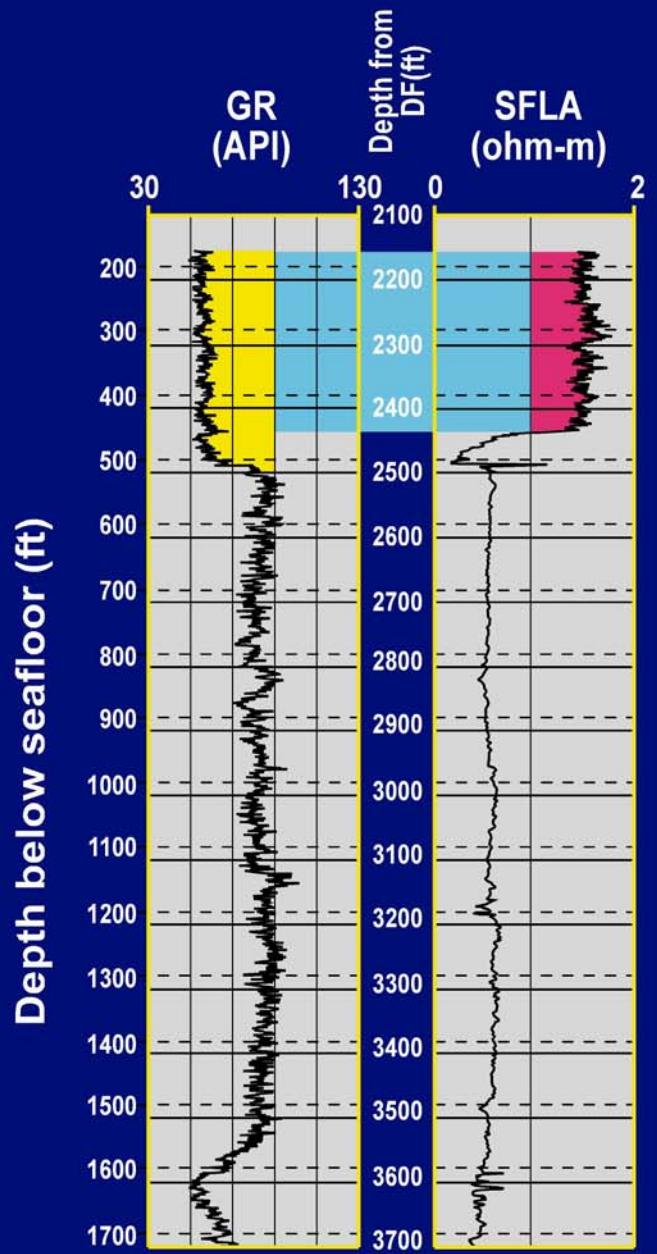
QAd5515-ppt
QAd5359x

BLOCK GC 153
API No. 60-811-4008400



BHSZ = 3470 ft
Water depth = 1980 ft

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QAd5515-ppt
QAd5361x

GEOPHYSICS

Can we improve detection and imaging of hydrate?

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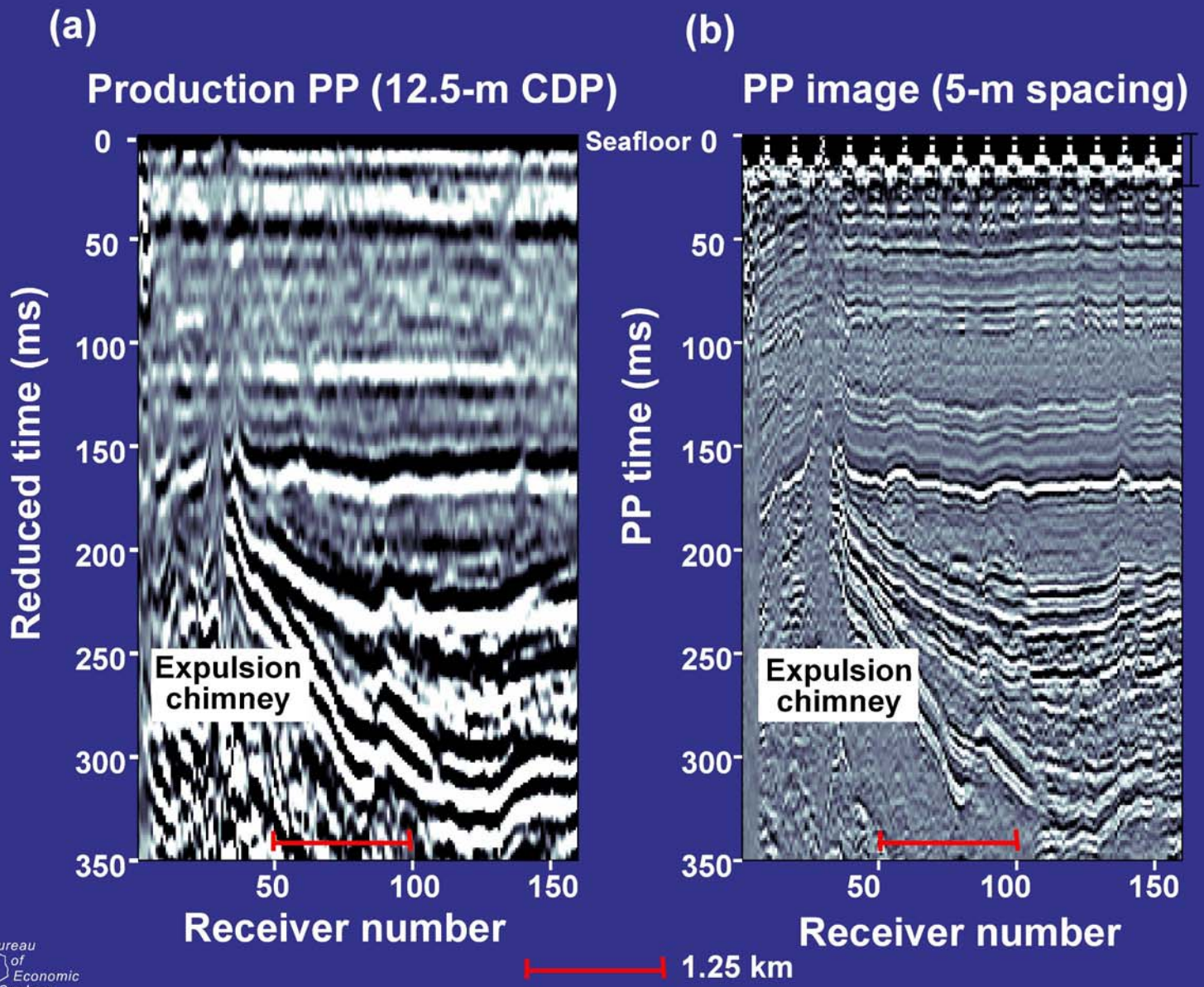
COMPARISON OF PP IMAGES



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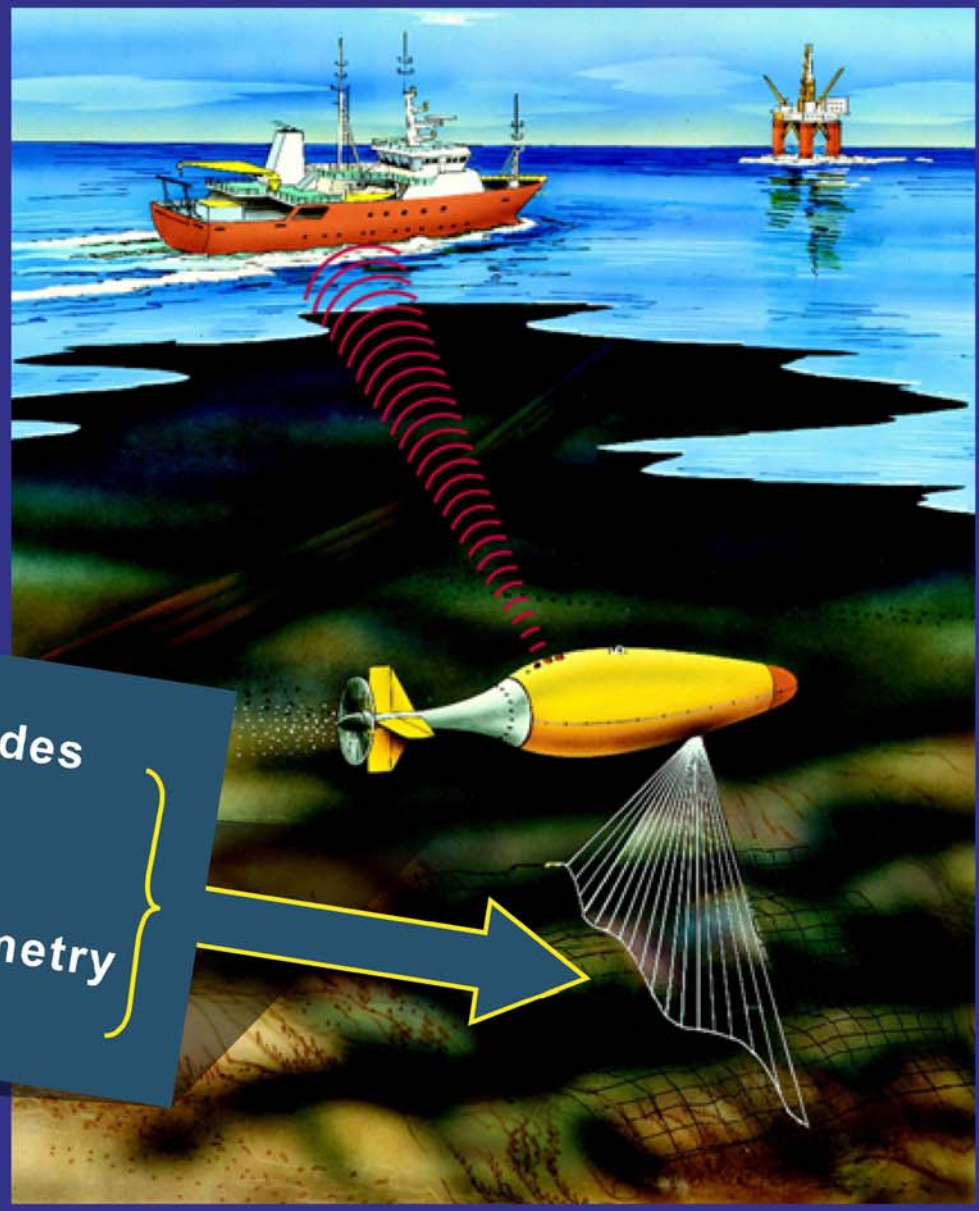
QAd4760
QAd5515-ppt

SEAFLOOR IMAGING WITH AUTONOMOUS UNDERWATER VEHICLE (AUV)



Data-acquisition modes along track:

- Side-scan sonar
- Multibeam bathymetry
- Chirp imaging

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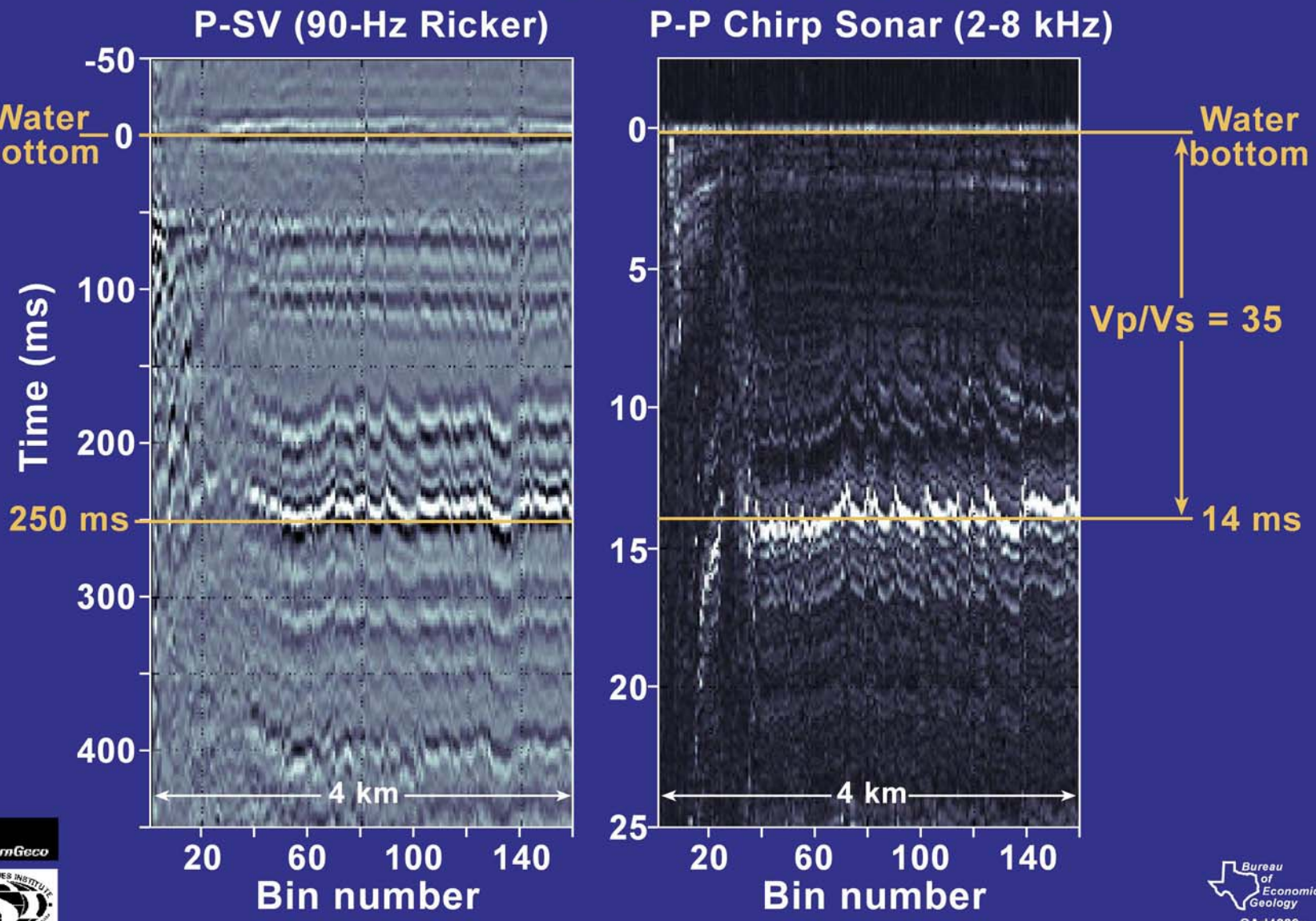
Courtesy C & C Technologies

QAd5515-ppt

QAd3876x

PRESTACK P-SV OBC AND CHIRP-SONAR DATA BLOCK GC204, LINE 549



WesternGeco

COASTAL STUDIES INSTITUTE CSI

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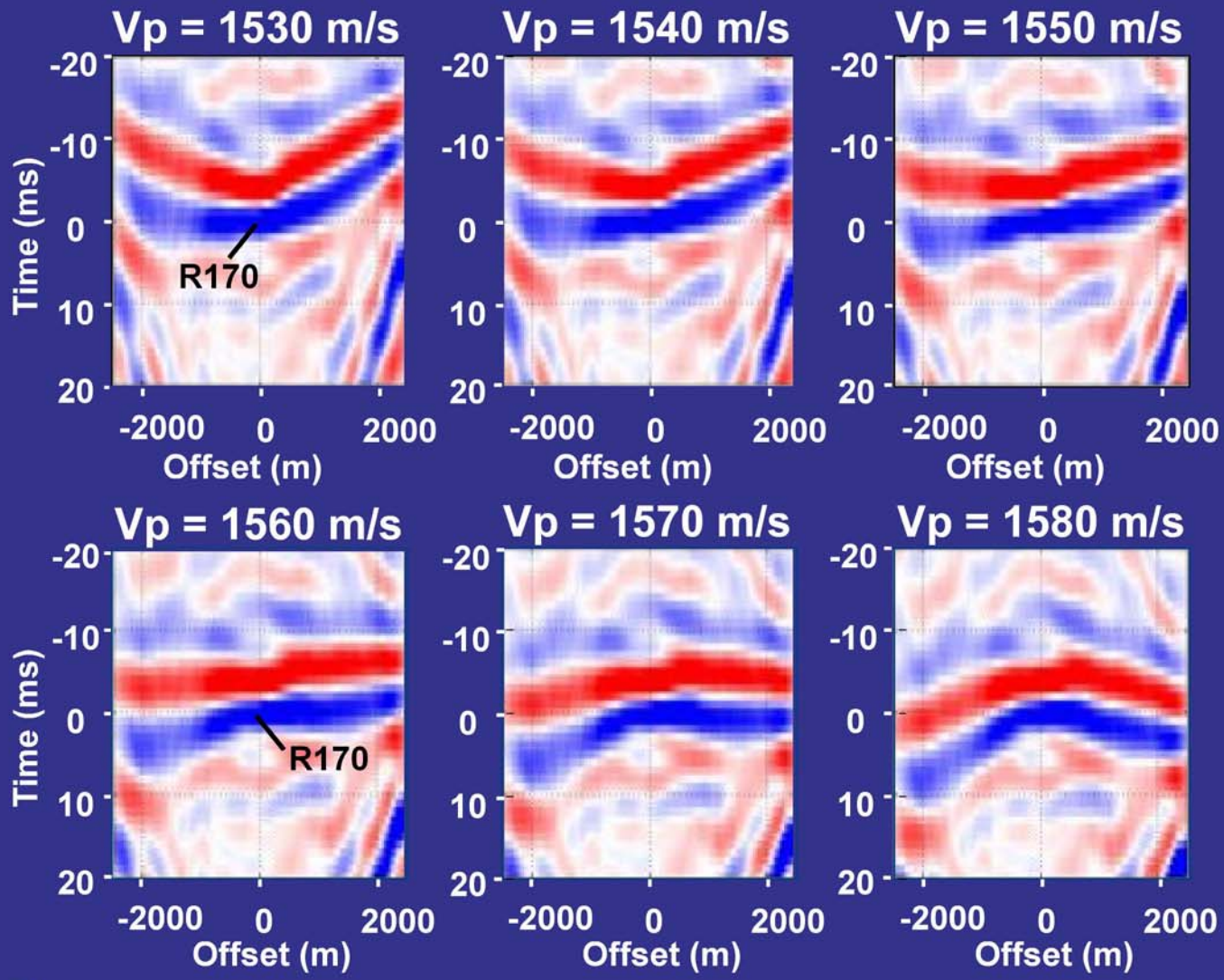
ACCURACY OF INTERVAL Vp (<1%?)



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QAd4757

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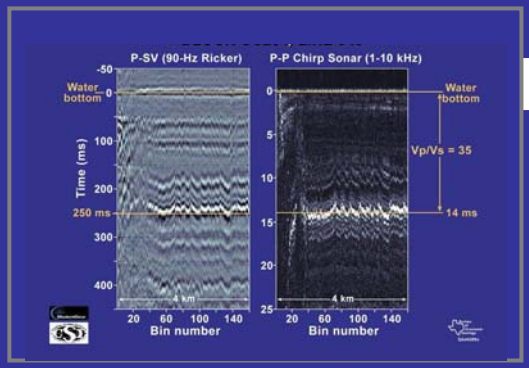
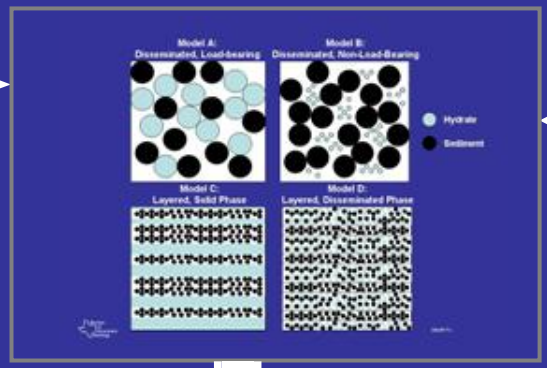
MEASURING THE RESOURCE

Seismic

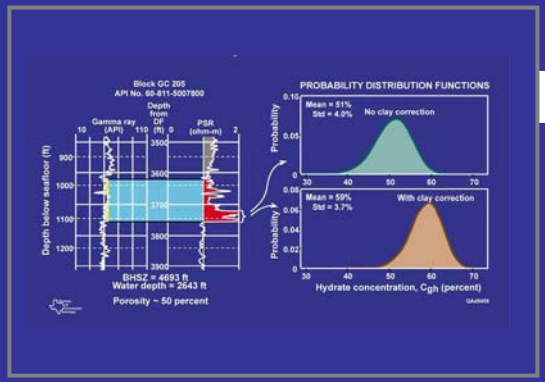


(V_p, V_s)

Rock physics



C_{gh} (seismic)



C_{gh} (log)

Compare C_{gh} (log) and C_{gh} (seismic)

Iterate

C_{gh} = Hydrate concentration

Petrophysics

Calibration

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CONCLUSIONS

- Progress is being made
- Need more core-based data
- Need more “complete” log suites

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ENERGY POLICY ACT OF 2005

Sec. 353. Gas Hydrate Production Incentive

(b) Suspension of Royalties

(3) Amount of Relief

…The maximum suspension volume shall be 30 billion cubic feet of natural gas per lease. Such relief shall be in addition to any other Royalty relief under any other provision….