COMBINING MULTICOMPONENT SEISMIC ATTRIBUTES, NEW ROCK-PHYSICS MODELS, AND IN SITU DATA TO ESTIMATE GAS-HYDRATE CONCENTRATIONS IN DEEP-WATER, NEAR-SEAFLOOR STRATA OF THE GULF OF MEXICO

Bureau of Economic Geology
The University of Texas at Austin

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QUALIFICATIONS OF RESEARCH TEAM

- 8 professional researchers
- 228 years of research experience
- 2 Maurice Ewing Medals
- 3 SEG Honorary Members
- 3 SEG Special Commendation Awards
- 3 Best Paper Awards
- 2 students

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INSIGHT AND INNOVATION

- New seismic imaging approach
- New application of resistivity logs
- Comprehensive rock physics
- Joint inversion of velocity and resistivity

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AWARENESS OF STATE OF THE ART

- Up to date on work of Roberts and Sassen
- Polygonal faulting
- Hydrate-sediment morphologies
- Rock-physics concepts

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INTERAGENCY LONG-RANGE PLANS

- Arctic resources (NOT!)
- Marine resources
- Hydrate and its role in the natural environment

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PRODUCTS, PROGRESS, AND BUDGET

- All tasks completed for budget period
- 6 papers published
- 2 Hedberg papers in press
- 4 articles published
- 3 workshops at BEG
  (Schlumberger, Scripps, UT)
- 3 companies requested assistance with hydrate studies
  (Norway, Mexico, U.S.)

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PROJECT REPORTS

- Selection of study sites
- Research database
- Well log evidence of hydrate
- 4C OBC seismic data processing
- PP and PS imaging
- Rock-physics models
- Continuation report
- Numerous minor reports

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KEY TASKS: PHASE I

1. Select study areas (2)
2. Prove hydrate is present
3. Create P and S images
4. Develop rock physics model(s)

$(V_p, V_s) \longrightarrow (C_{gh})$

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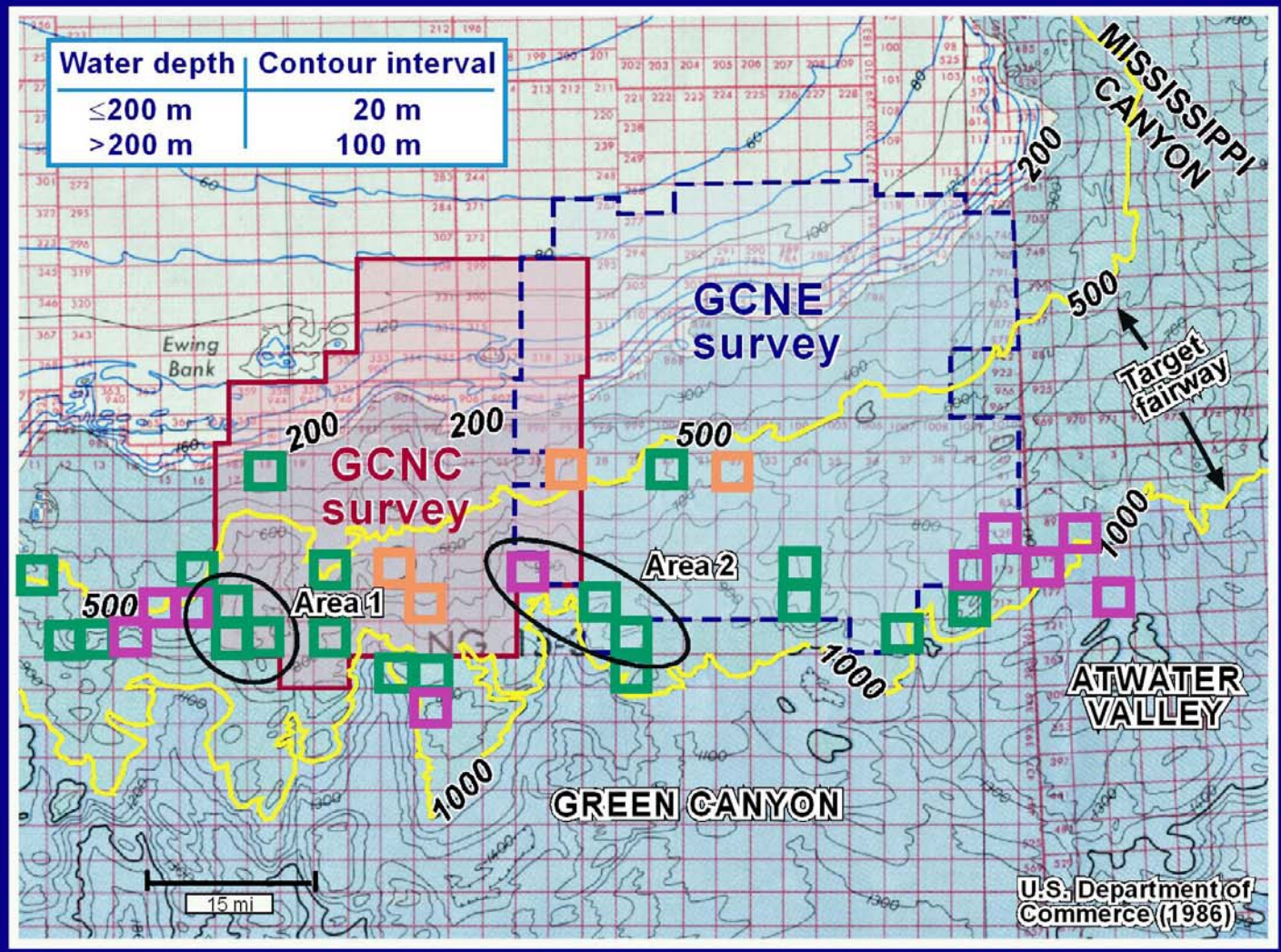
HARD EVIDENCE OF HYDRATE ACROSS STUDY AREA



Seafloor bright spot (Roberts) | Hydrate outcrop (Sassen) | Gas vent (Sassen)

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KEY TASKS: PHASE I

1. Select study areas (2)
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$(V_p, V_s) \longrightarrow (C_{gh})$

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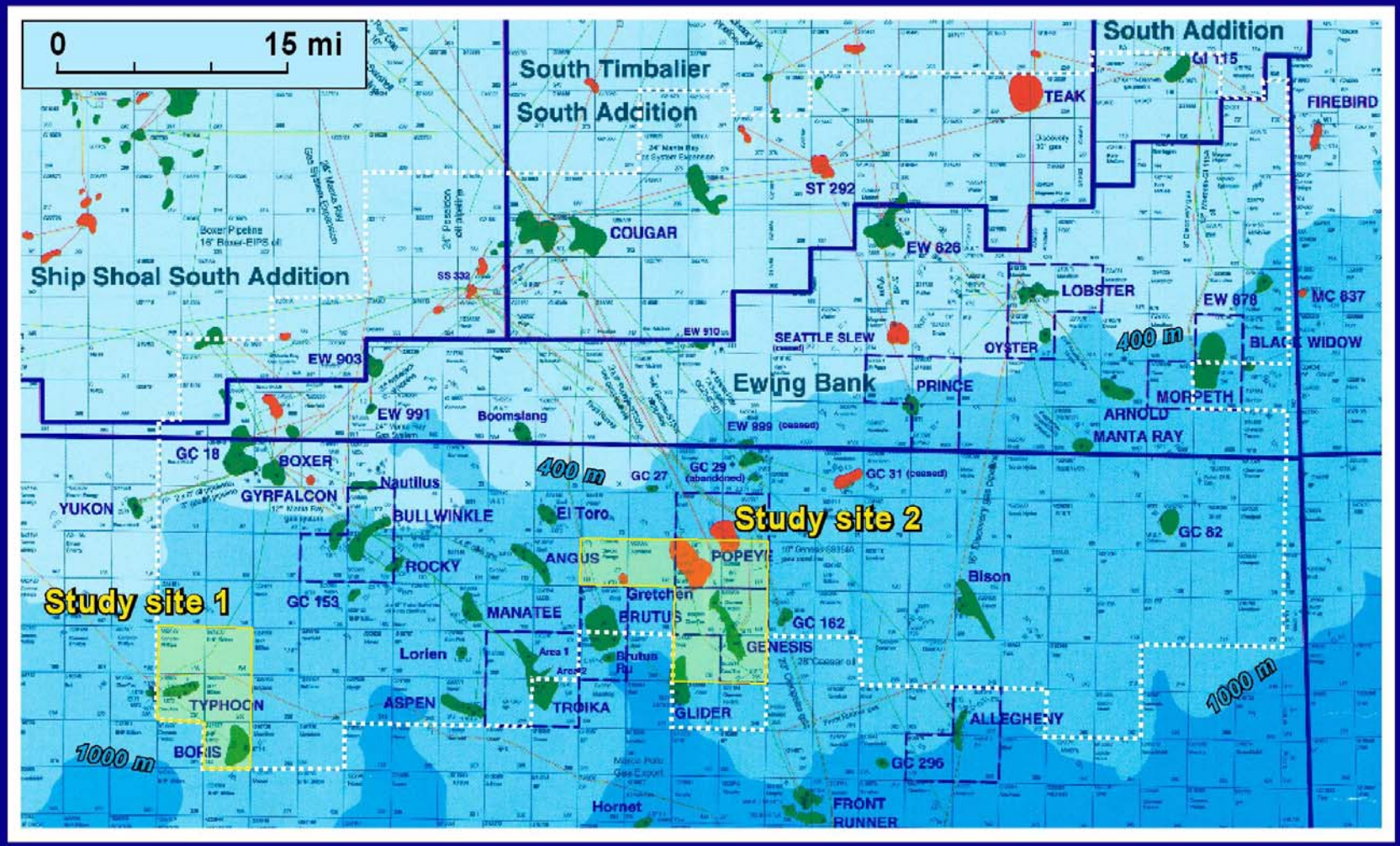
PRODUCTION ACROSS STUDY AREA



OBC seismic data

Oil or oil/gas

Gas or gas/condensate

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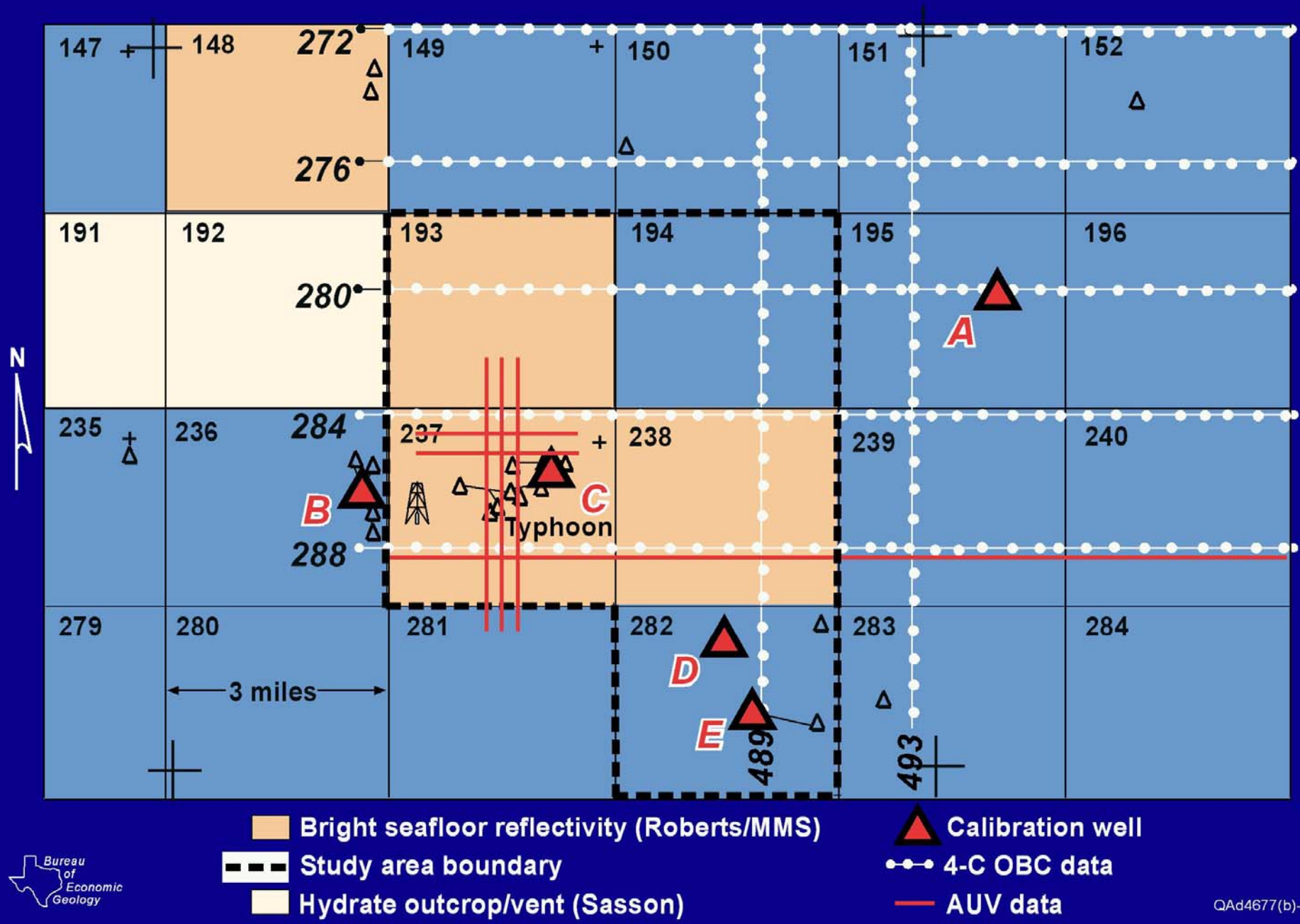
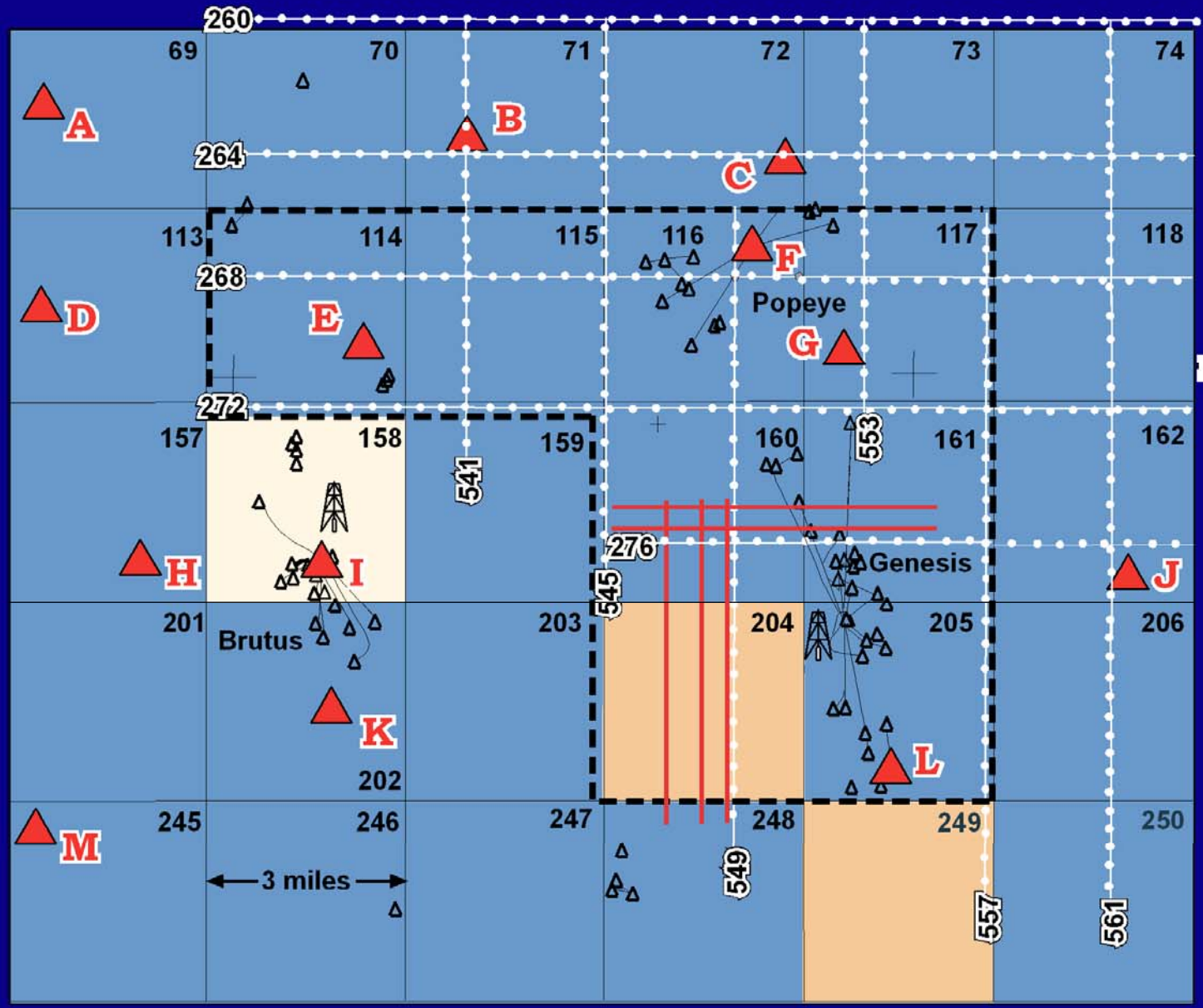
HYDRATE CALIBRATION WELLS: STUDY SITE 1



STUDY AREA 2: GREEN CANYON



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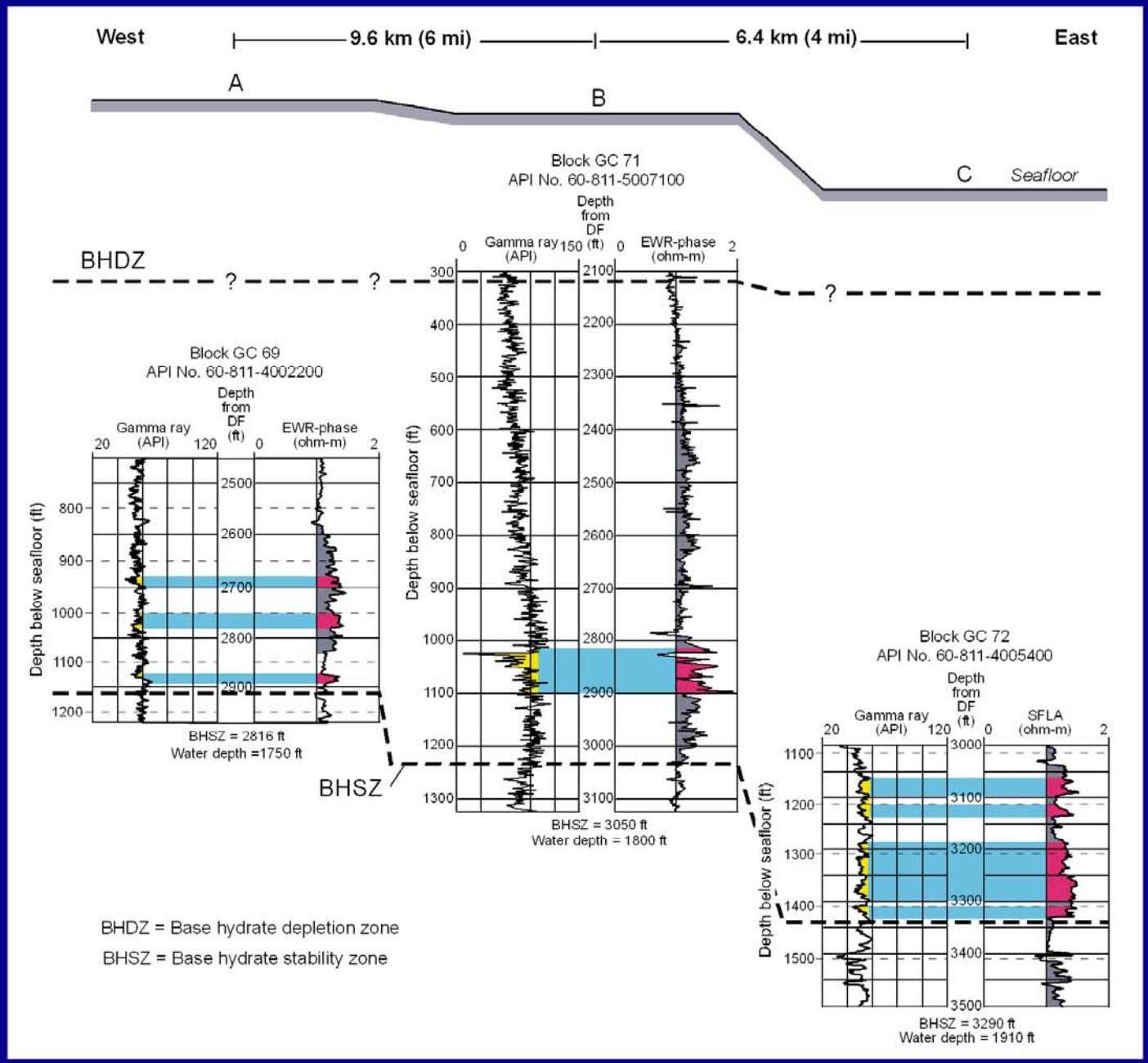
WELL LOG CROSS SECTION ABC, STUDY SITE 2



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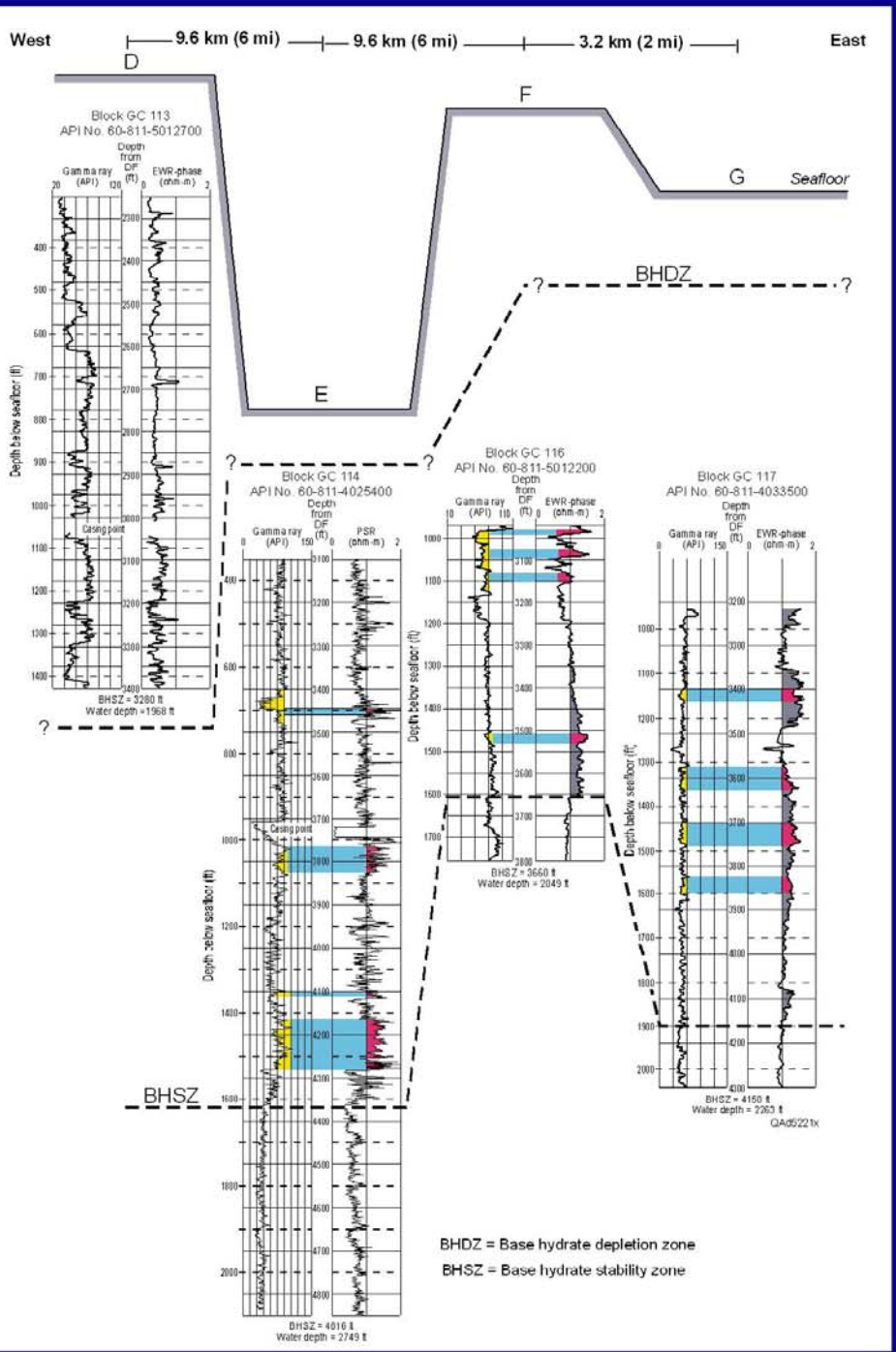

WELL LOG CROSS SECTION DEFG, STUDY SITE 2

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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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EFFECT OF CLAYS
MODIFIED ARCHIE EQUATION

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

V_{cl} = volume of clay

R_{cl} = resistivity of clay minerals

α = internal geometric factor

m = cementation exponent

ϕ = porosity

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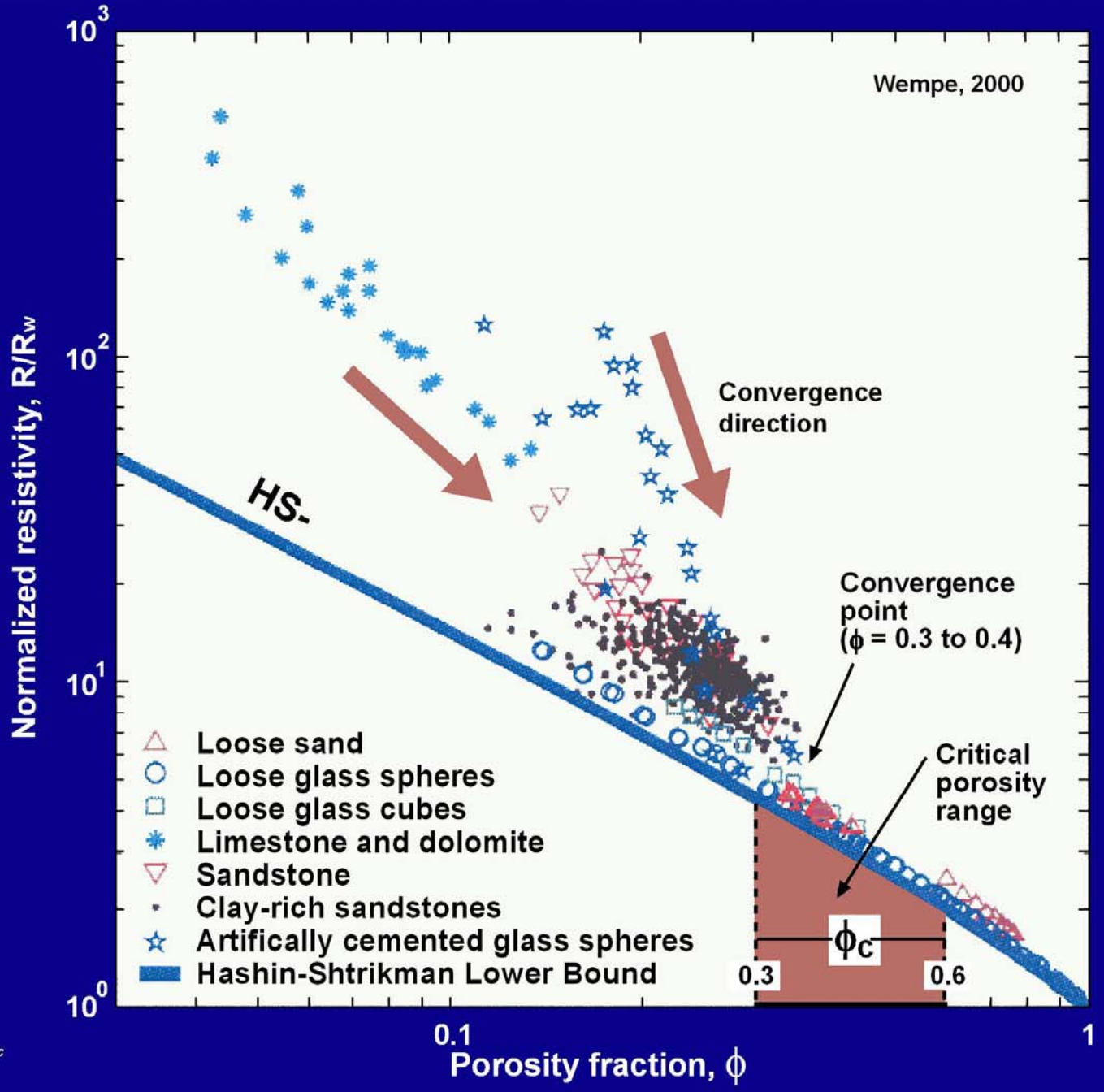
RESISTIVITY BEHAVIOR: UNCONSOLIDATED SEDIMENT



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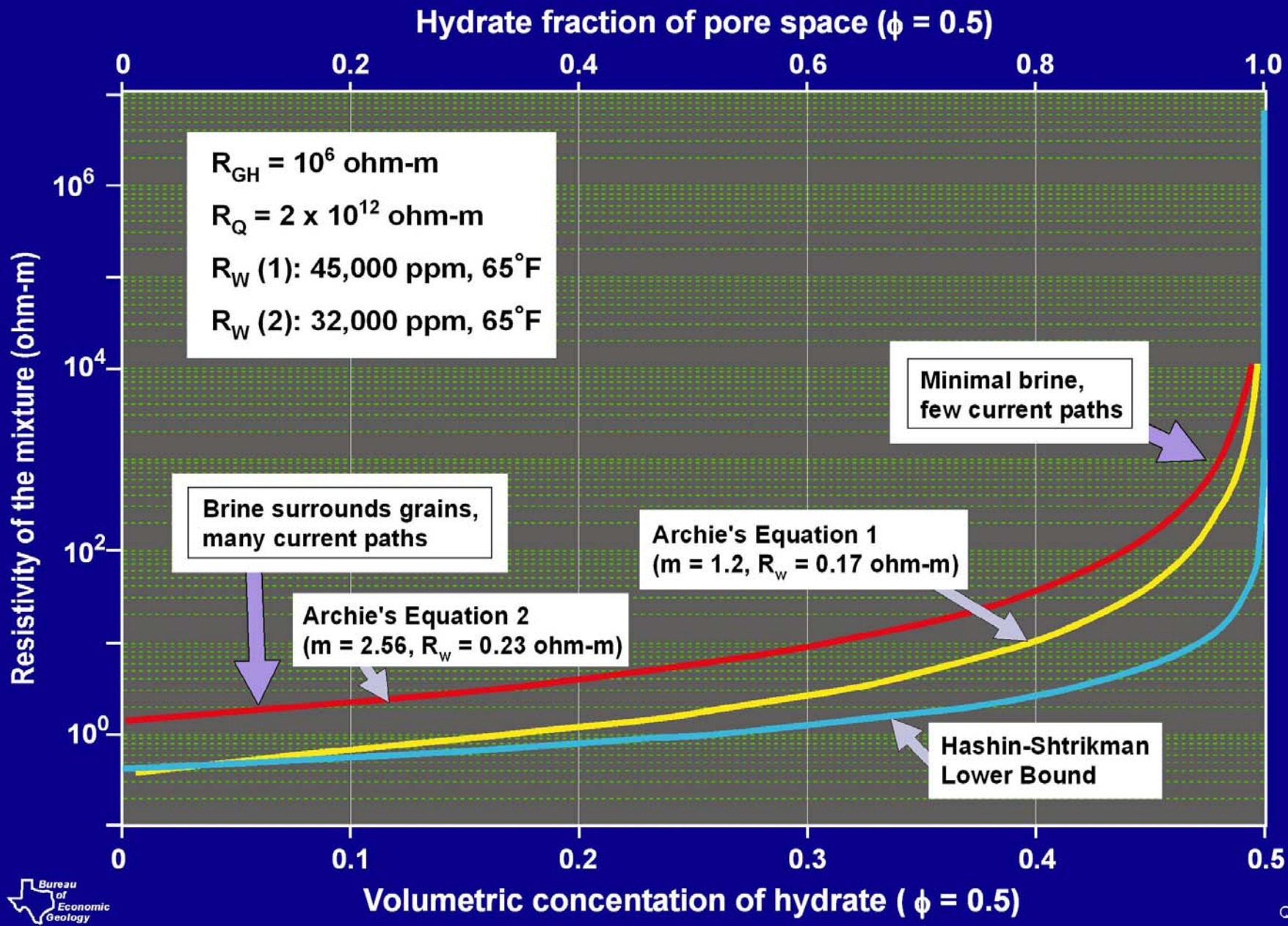
RESISTIVITY OF SEDIMENT, HYDRATE, BRINE MIXTURE



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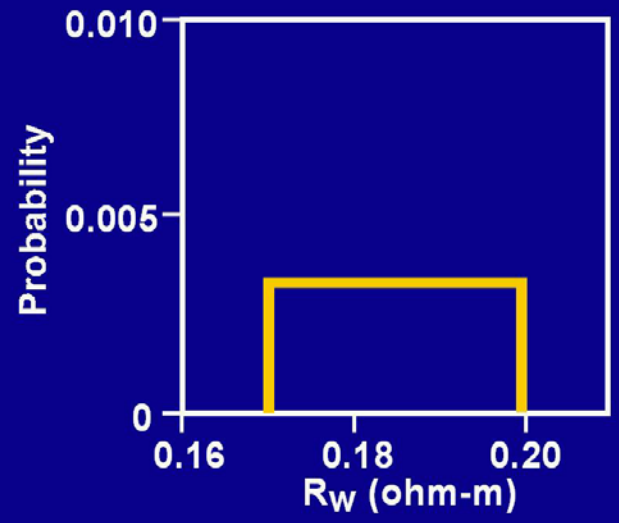
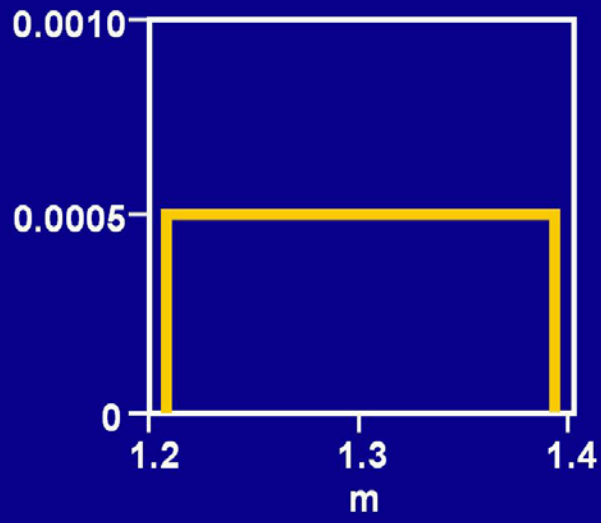
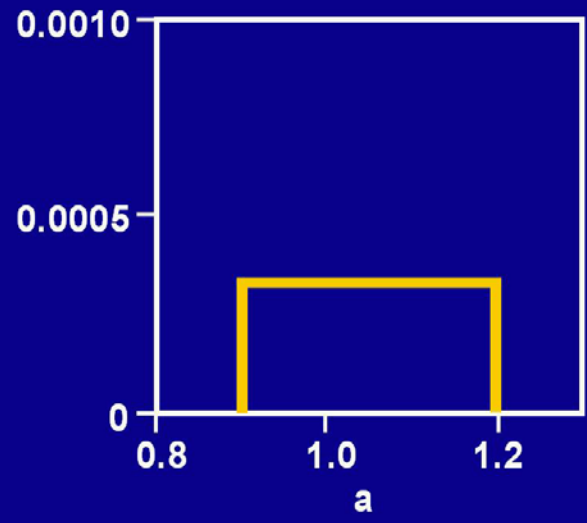
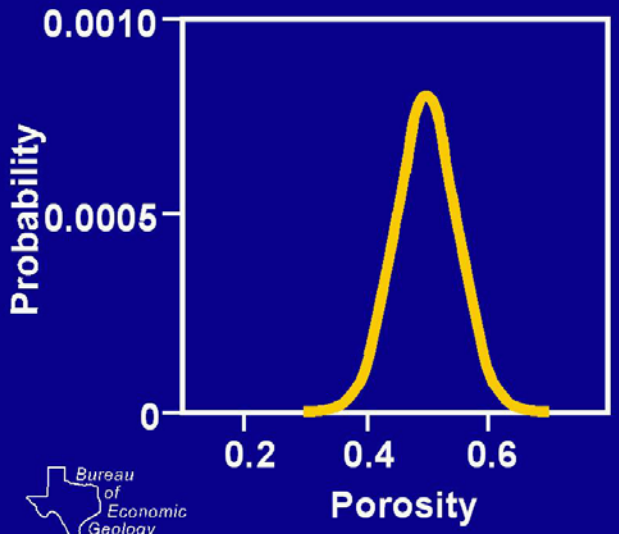
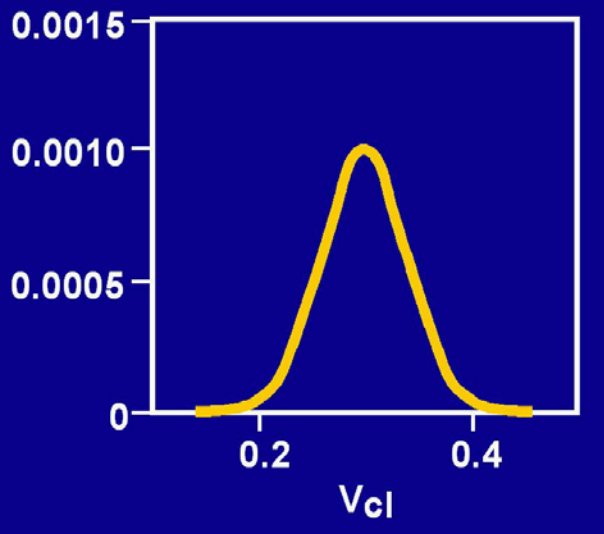
DISTRIBUTIONS FOR INPUT PARAMETERS IN ARCHIE'S EQUATION AND MODIFIED ARCHIE'S EQUATION

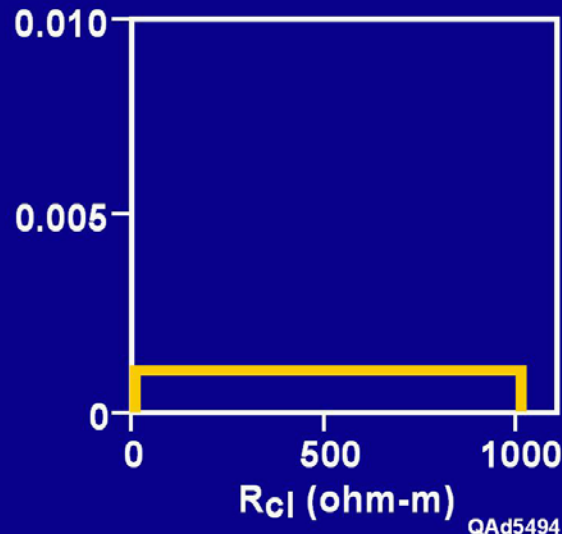












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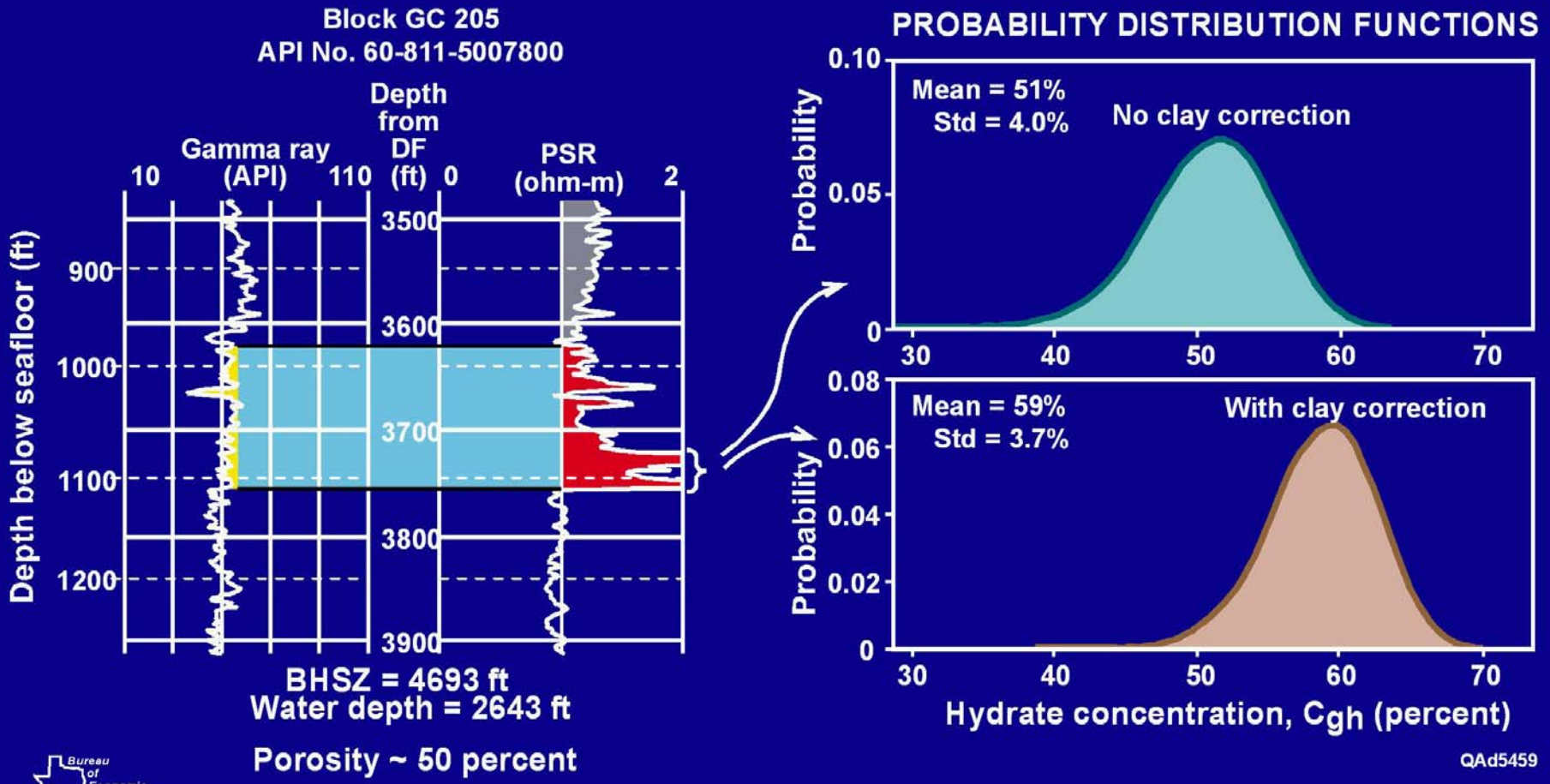
PREDICTED HYDRATE CONCENTRATION
WELL W1, R ~ 2.0 OHM-M



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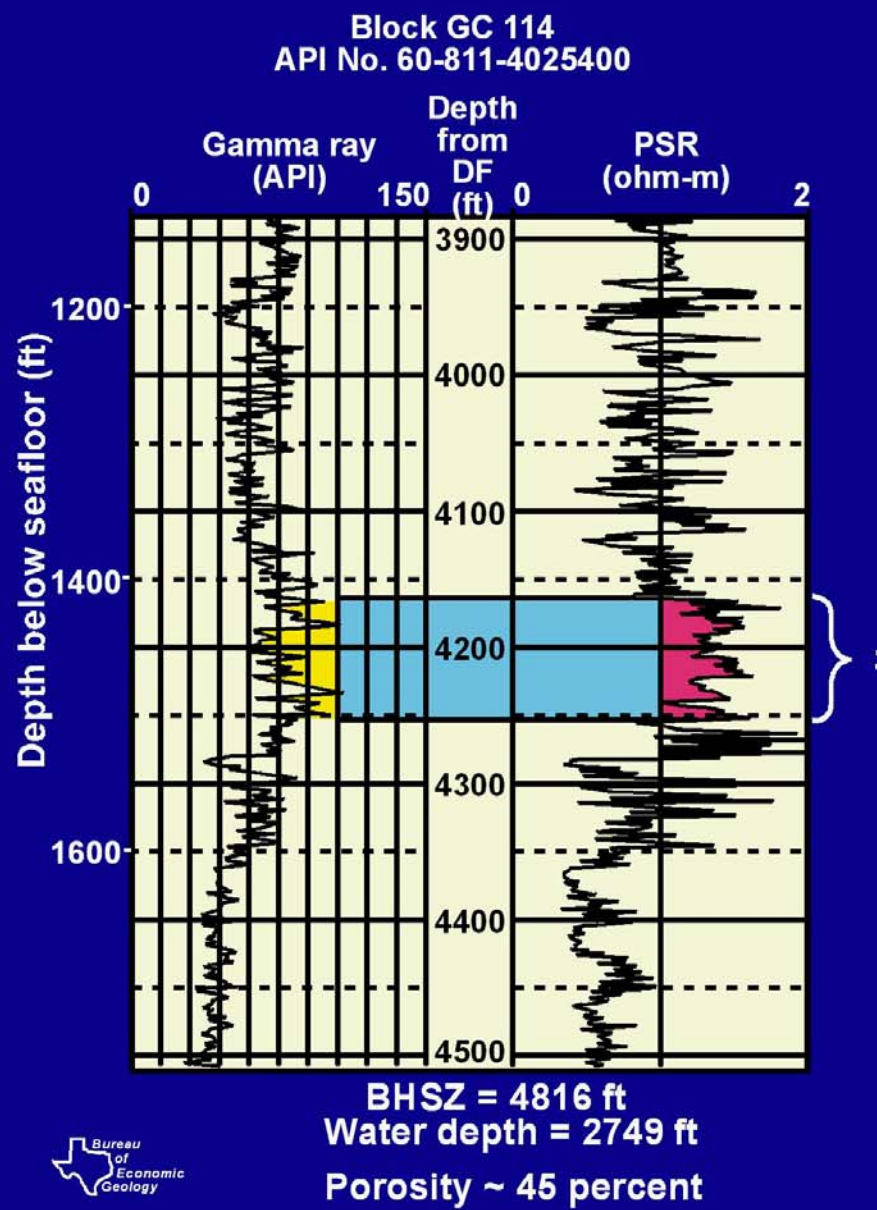
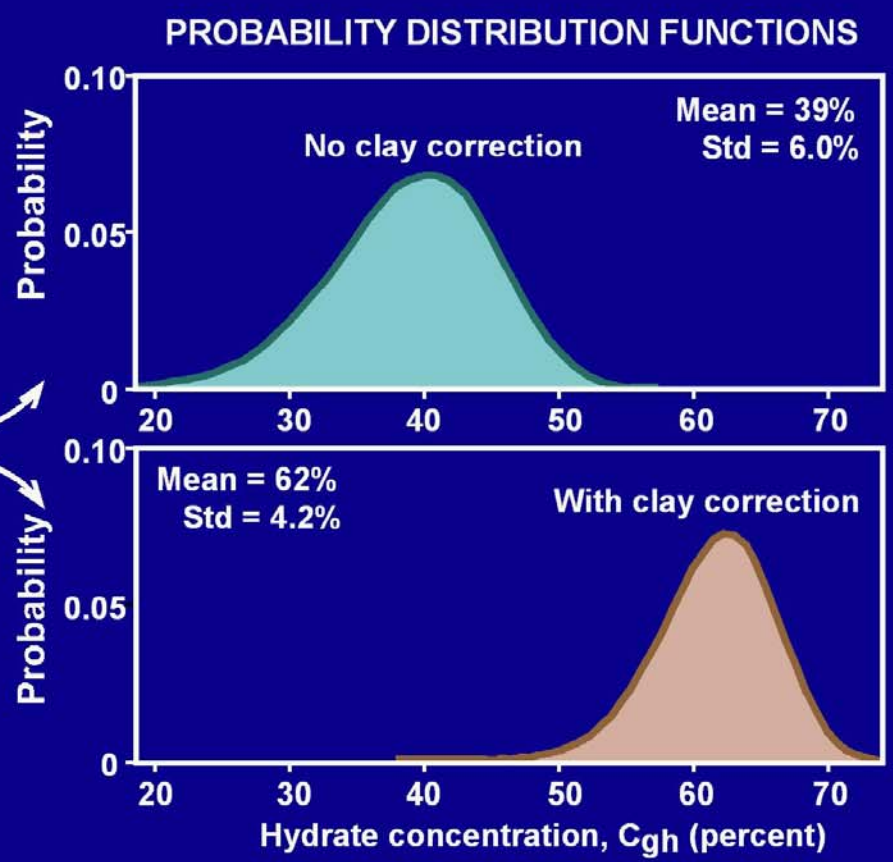
PREDICTED HYDRATE CONCENTRATION, WELL W3: R ~ 1.5 OHM-M





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KEY TASKS: PHASE I

1. Select study areas (2)
2. Prove hydrate is present
3. Create P and S images
4. Develop rock physics model(s)

$$(V_p, V_s) \longrightarrow (C_{gh})$$

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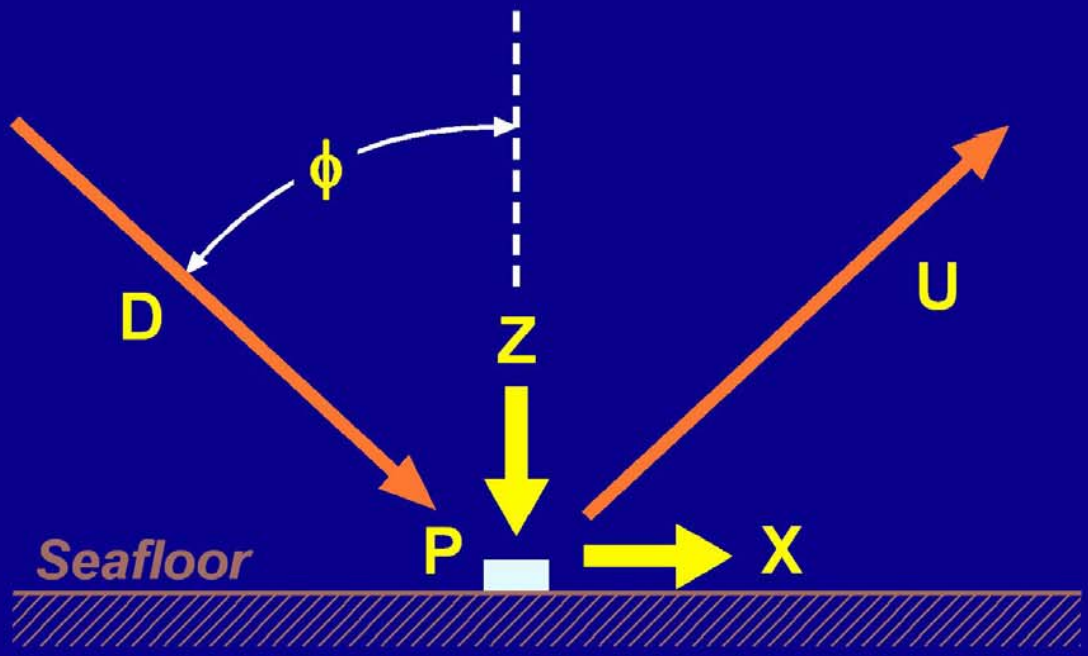
BASIC RESPONSES OF OBC SENSORS



P = Hydrophone response

Z = Vertical geophone response

X = Radial horizontal geophone response

ϕ = Angle of incidence

D = Downgoing wavefield

U = Upgoing wavefield

$P = D + U$

$Z = (D - U) \cos(\phi)$

$X = (D + U) \sin(\phi) + SV \text{ waves}$

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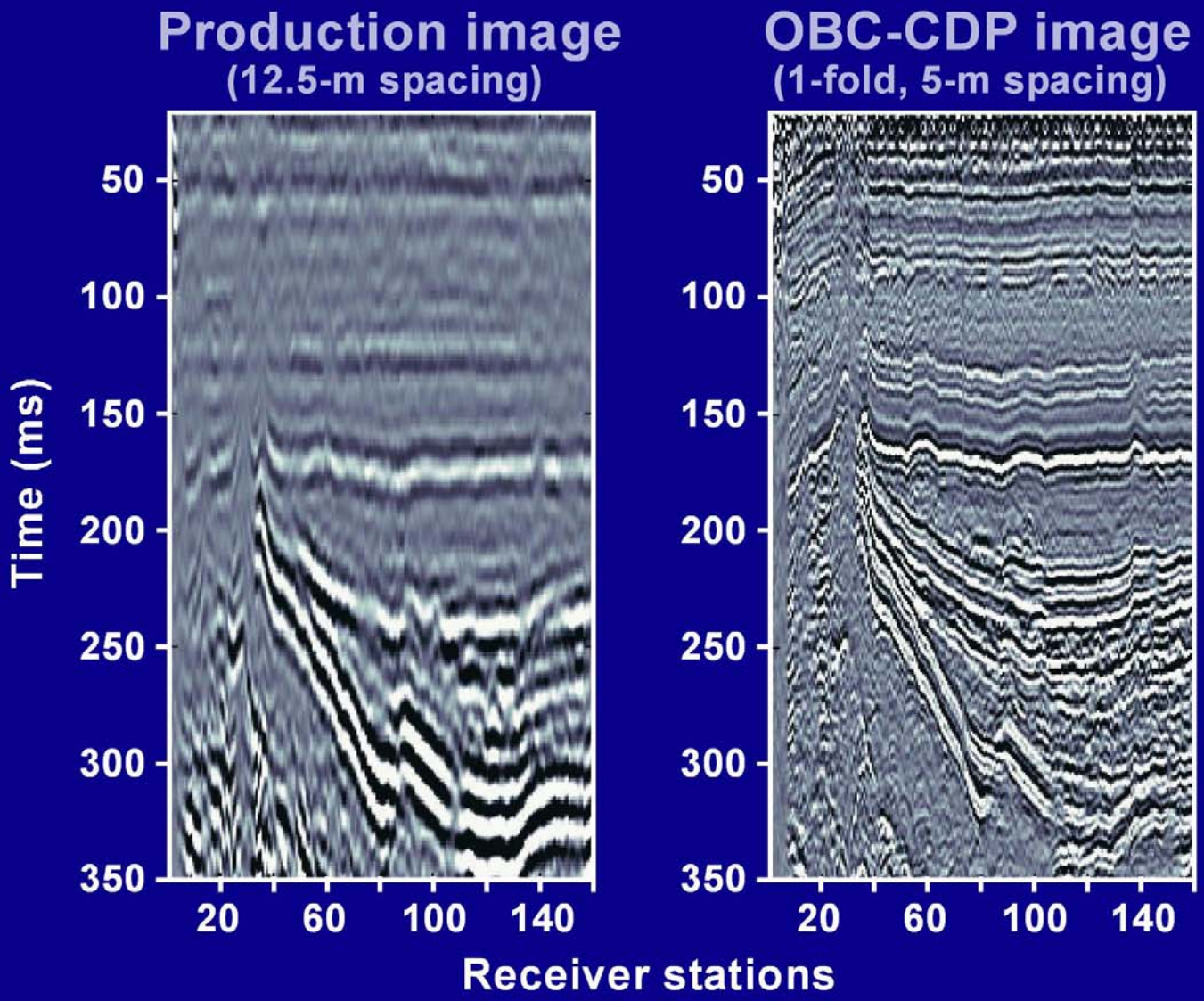
OBC LINE 549, BLOCK GC204



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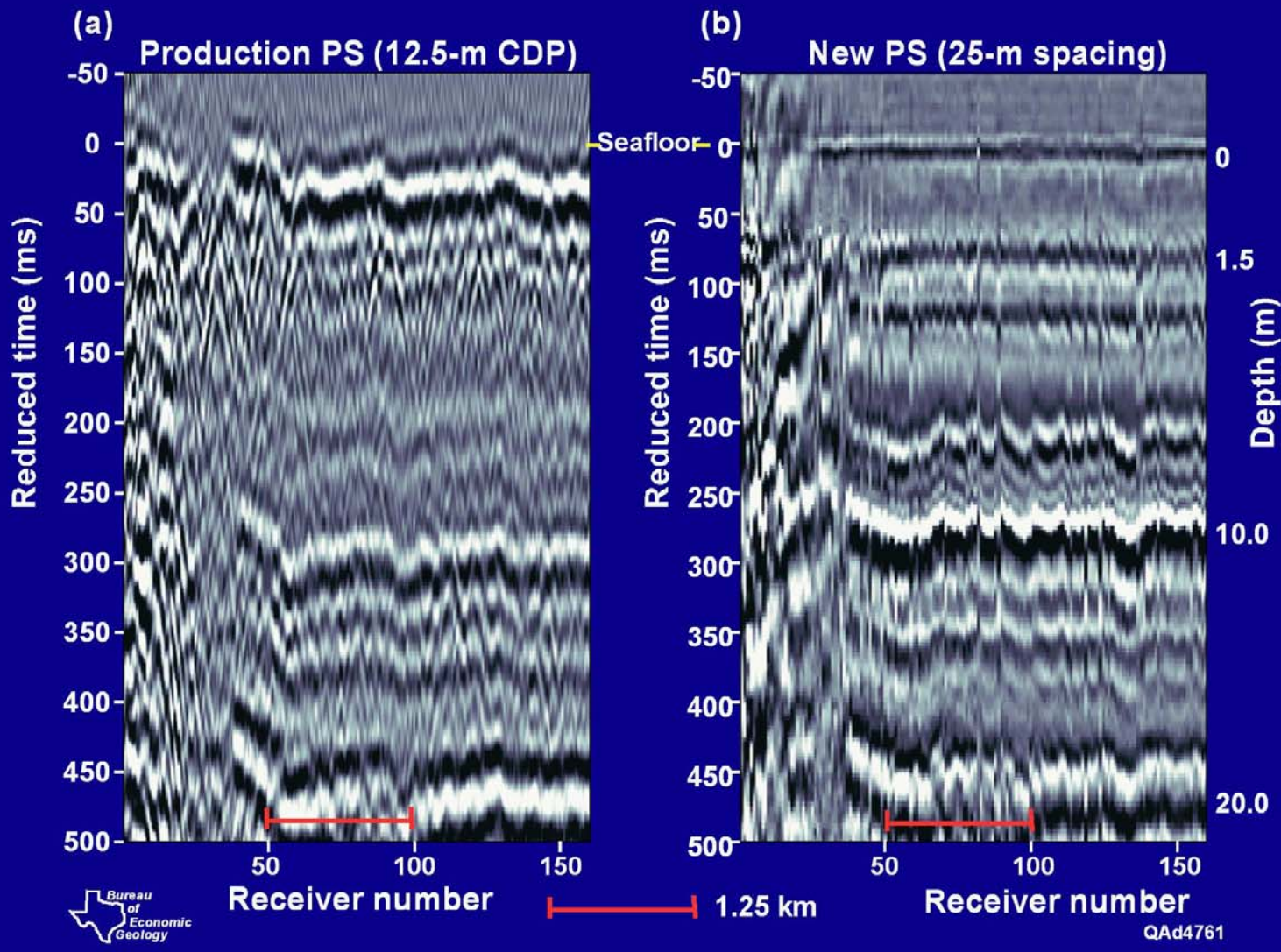
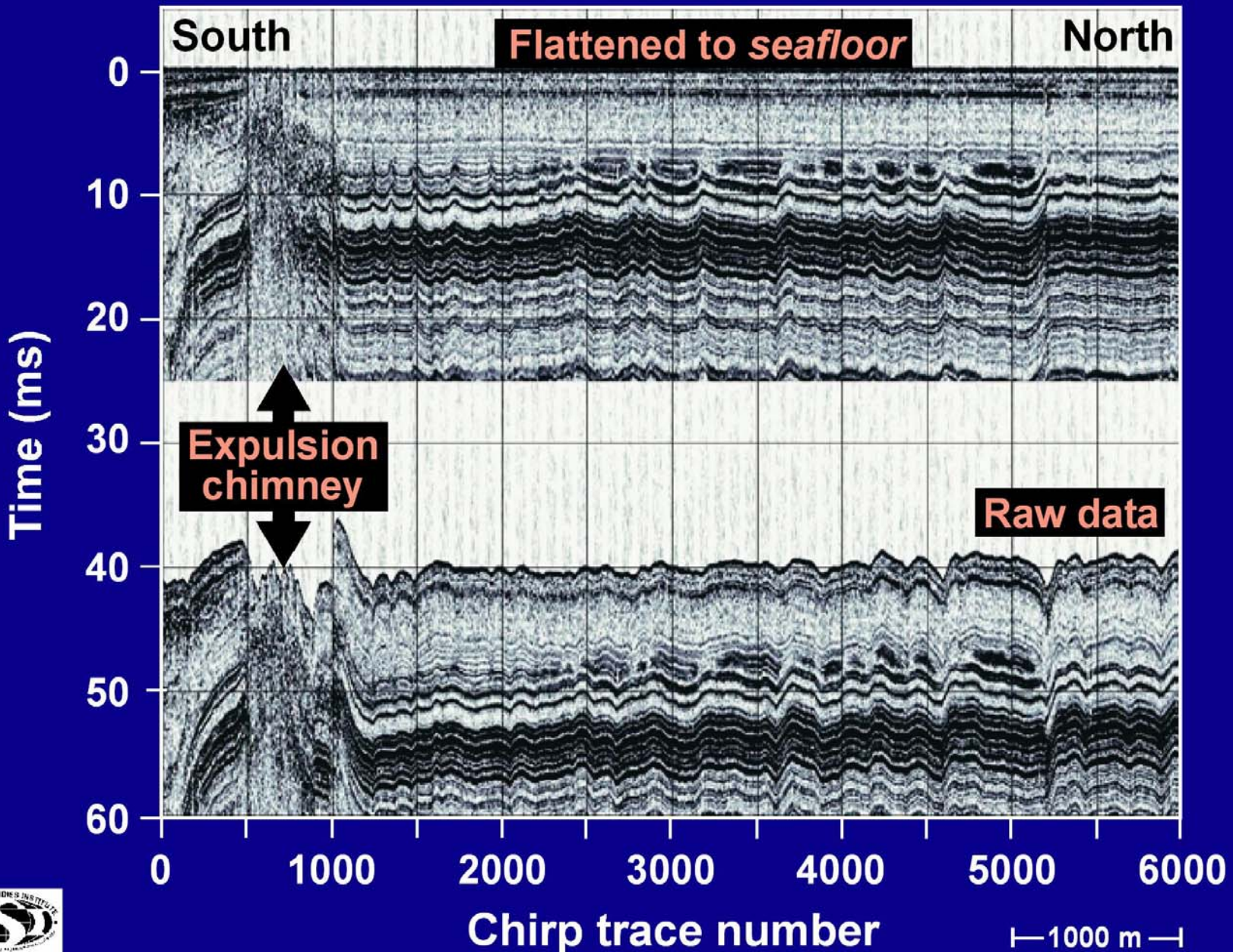
COMPARISON OF PS IMAGES



CHIRP SONAR DATA, LINE 549



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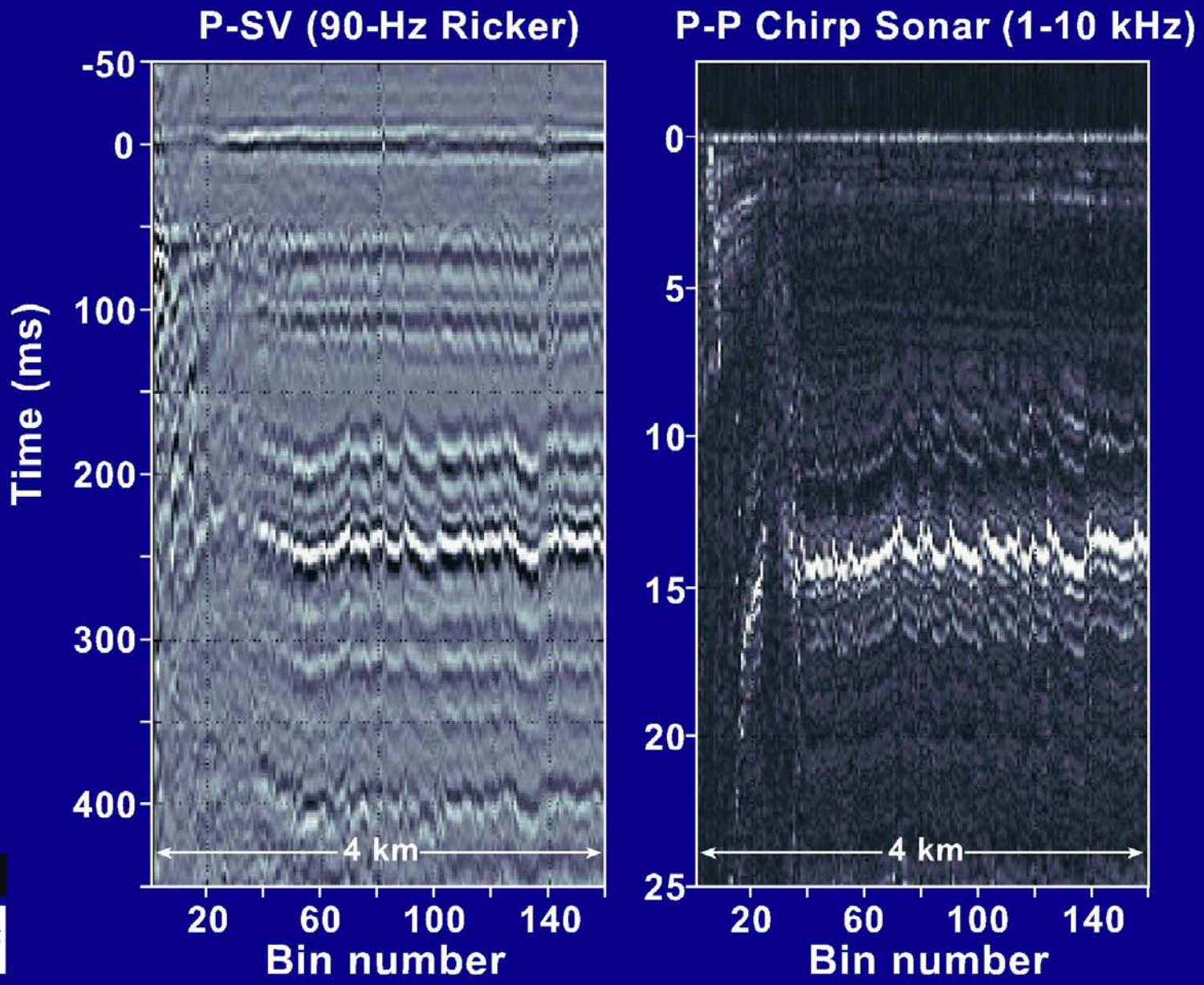
PRESTACK P-SV OBC AND CHIRP-SONAR DATA
BLOCK GC204, LINE 549



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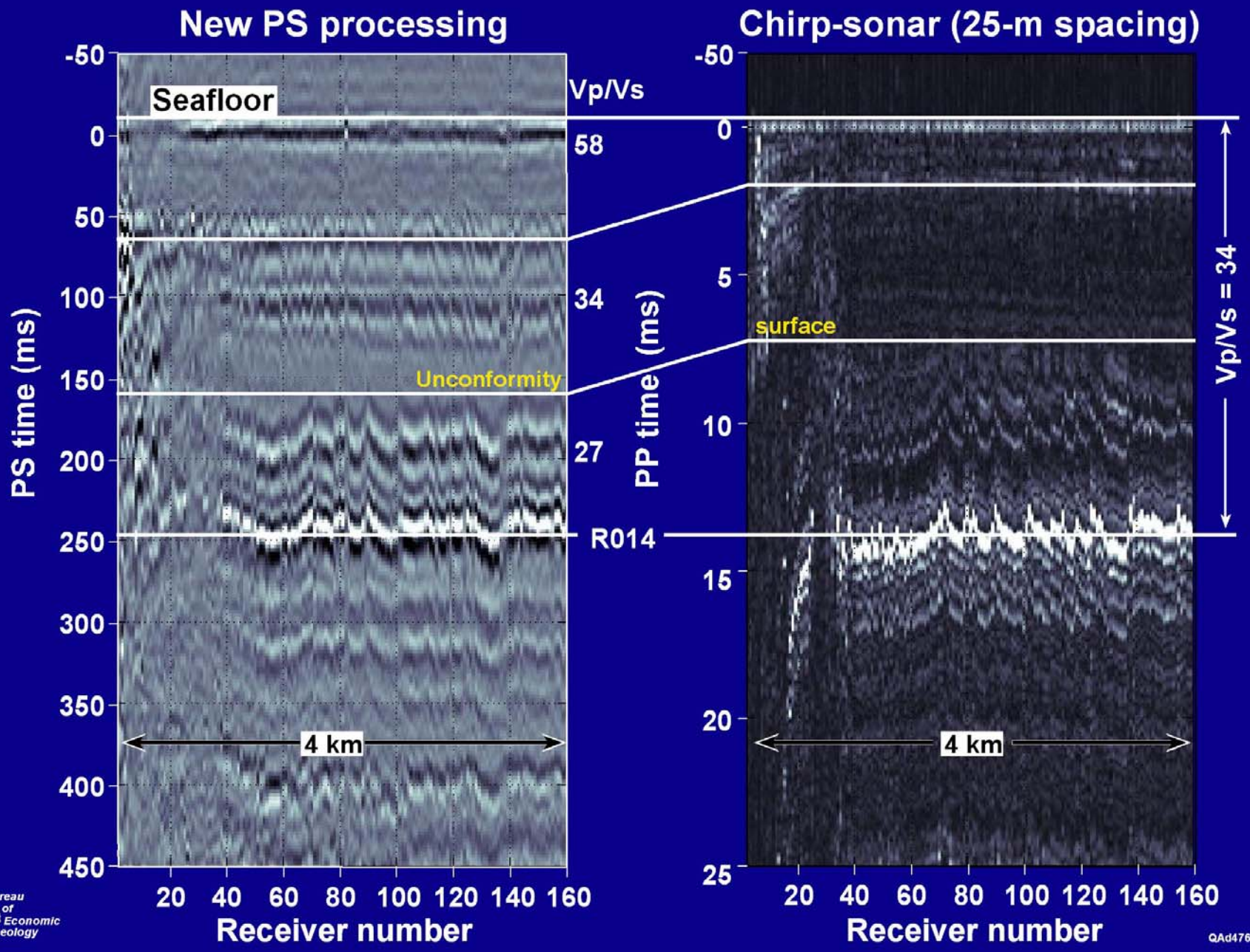
COMPARISON OF P-SV IMAGE WITH AUV P-P IMAGE



KEY TASKS: PHASE I

1. Select study areas (2)
2. Prove hydrate is present
3. Create P and S images
4. Develop rock-physics model(s)

$$(V_p, V_s) \longrightarrow (C_{gh})$$

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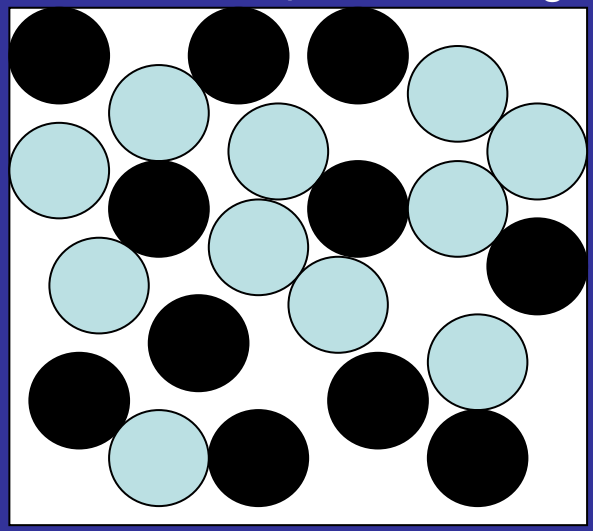
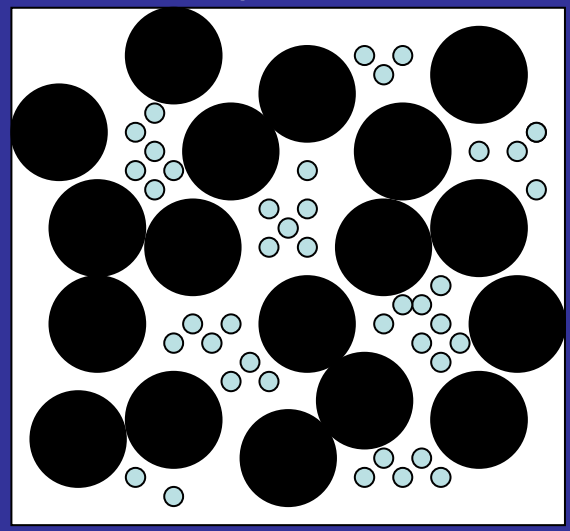
HYDRATE/SEDIMENT GRAIN-TO-GRAIN MORPHOLOGY MODELS

Model A:
Disseminated, Load-Bearing



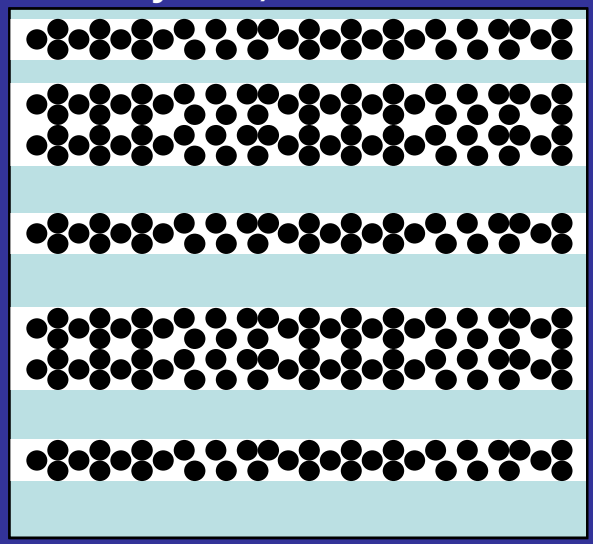
Model B:
Disseminated, Non-Load-Bearing



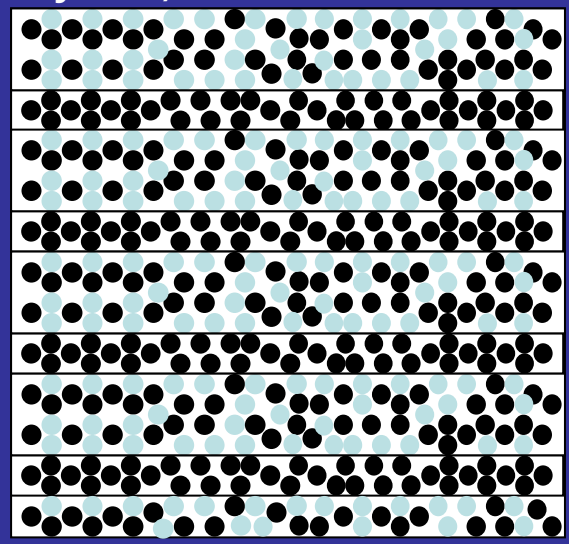
Hydrate

Sediment

Model C:
Layered, Solid Phase



Model D:
Layered, Disseminated Phase



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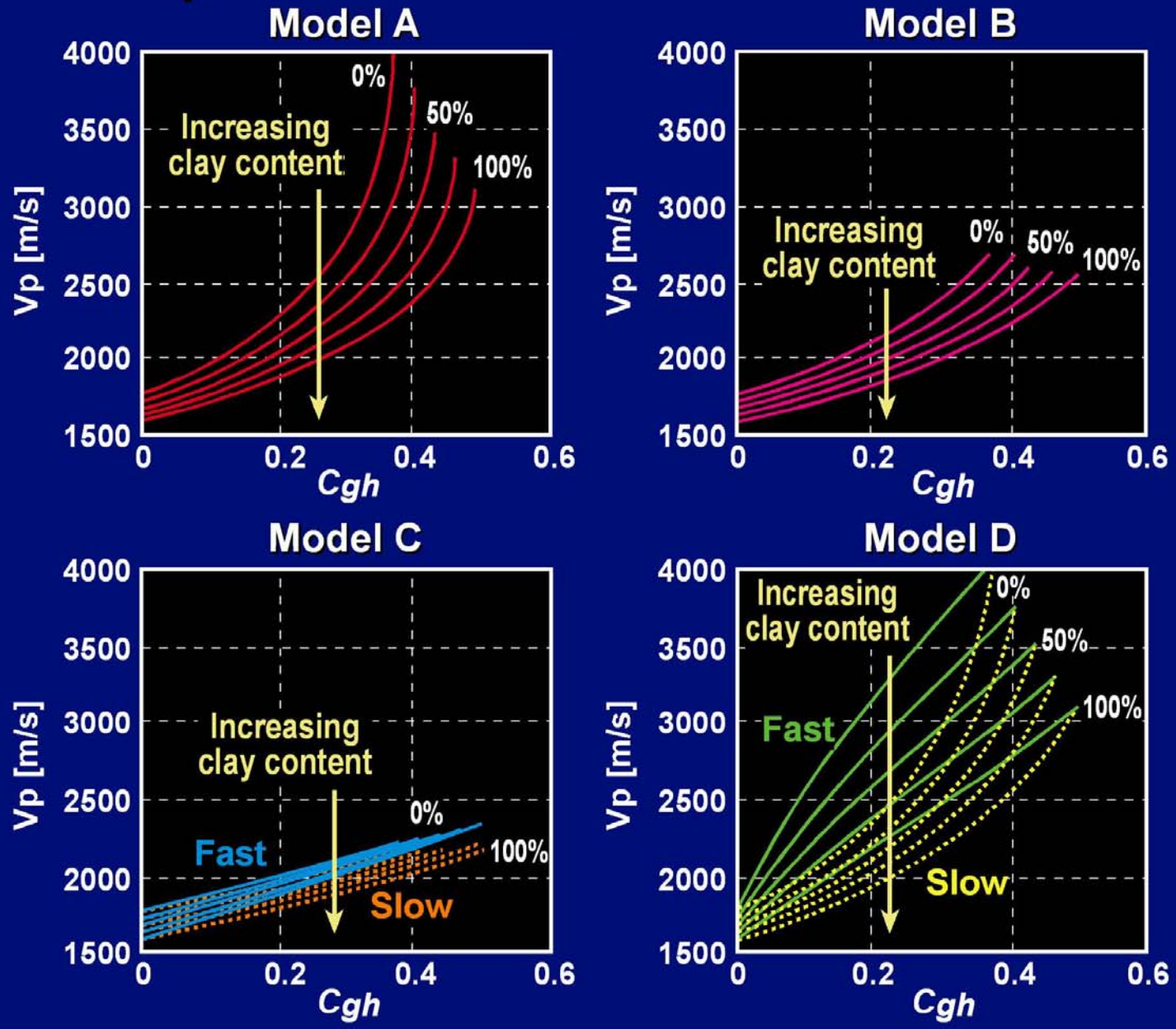
V_p AND HYDRATE CONCENTRATION



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ϕ_{crit} = 0.37, 0.445, 0.52, 0.595, 0.67 C = 8, 7, 6, 5, 4 P_{eff} = 0.5 MPa ϕ = 0.37, 0.41, 0.44, 0.47, 0.50

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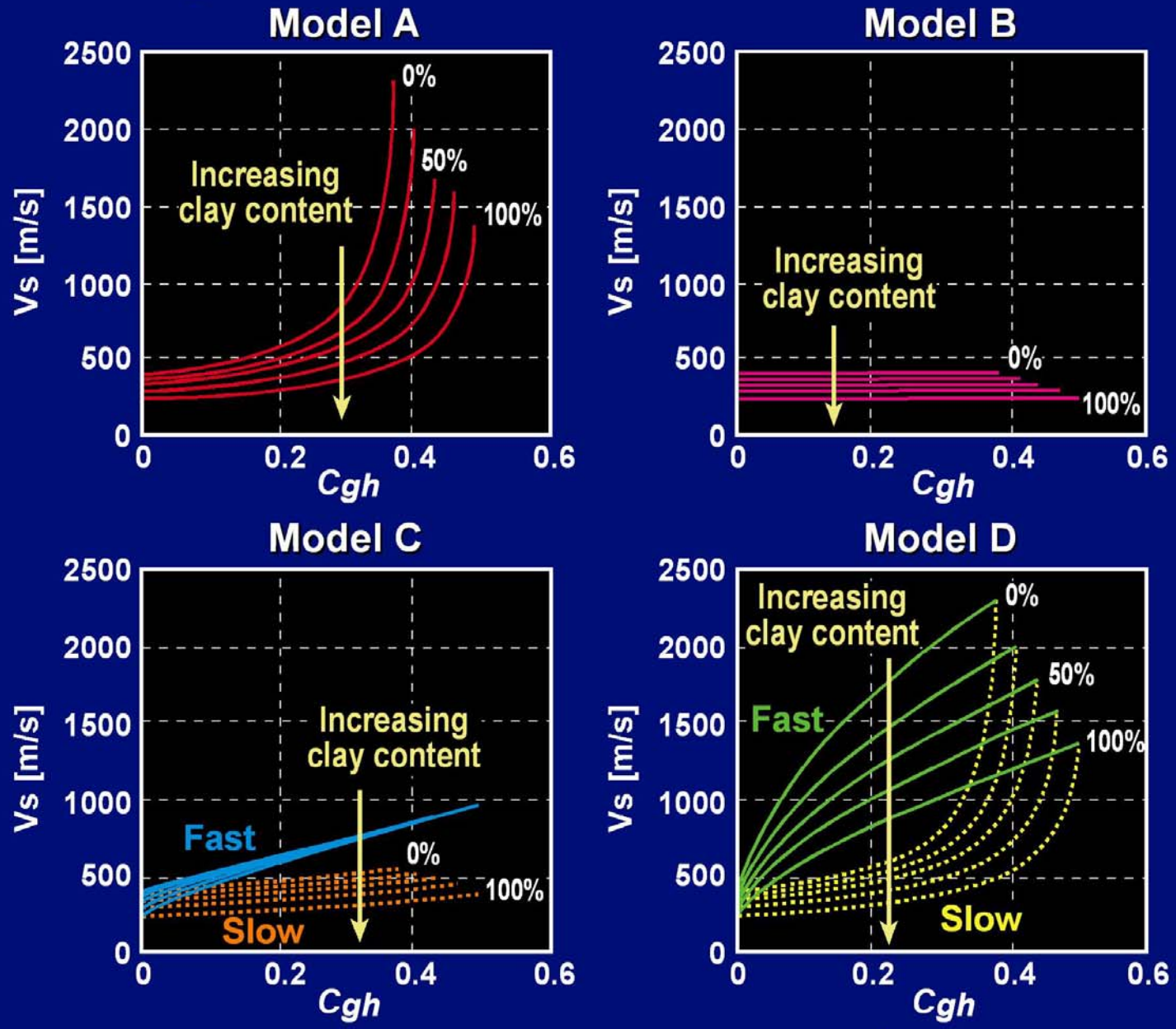
V_S AND HYDRATE CONCENTRATION



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ϕ_{crit} = 0.37, 0.445, 0.52, 0.595, 0.67 C = 8, 7, 6, 5, 4 P_{eff} = 0.5 MPa ϕ = 0.37, 0.41, 0.44, 0.47, 0.50

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KEY TASKS: PHASE II

1. Interpret P and S images
2. Create V_p and V_s layering
3. Predict hydrate concentration

$(V_p, V_s) \longrightarrow (C_{gh})$

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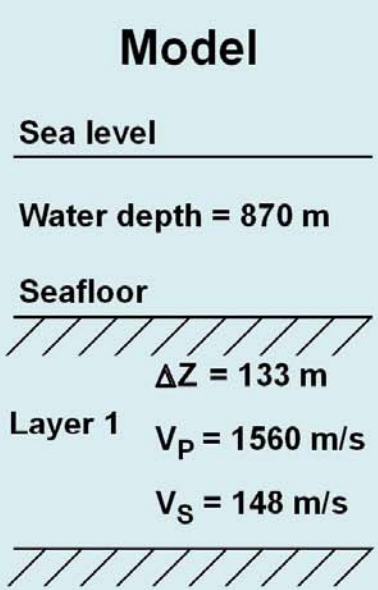
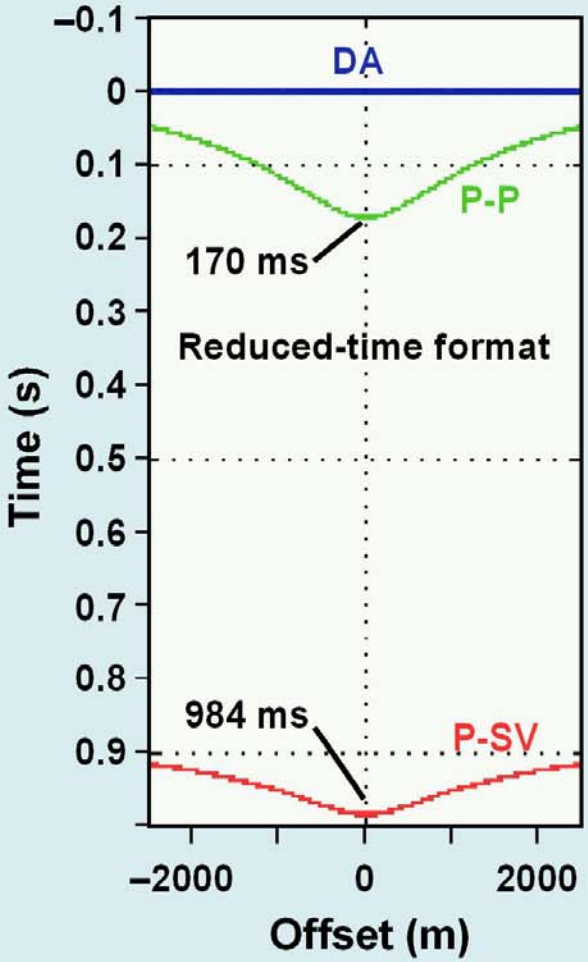
NEAR-SEAFLOOR INTERPRETIVE MODELING: TRIAL 1, SINGLE-LAYER EARTH

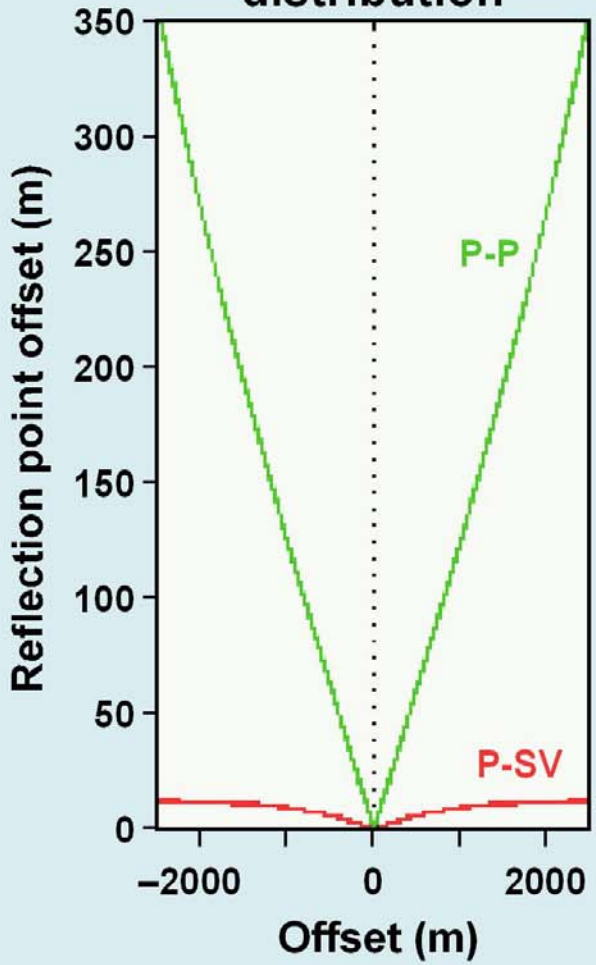
Model



DA, P-P, P-SV events



Reflection point distribution



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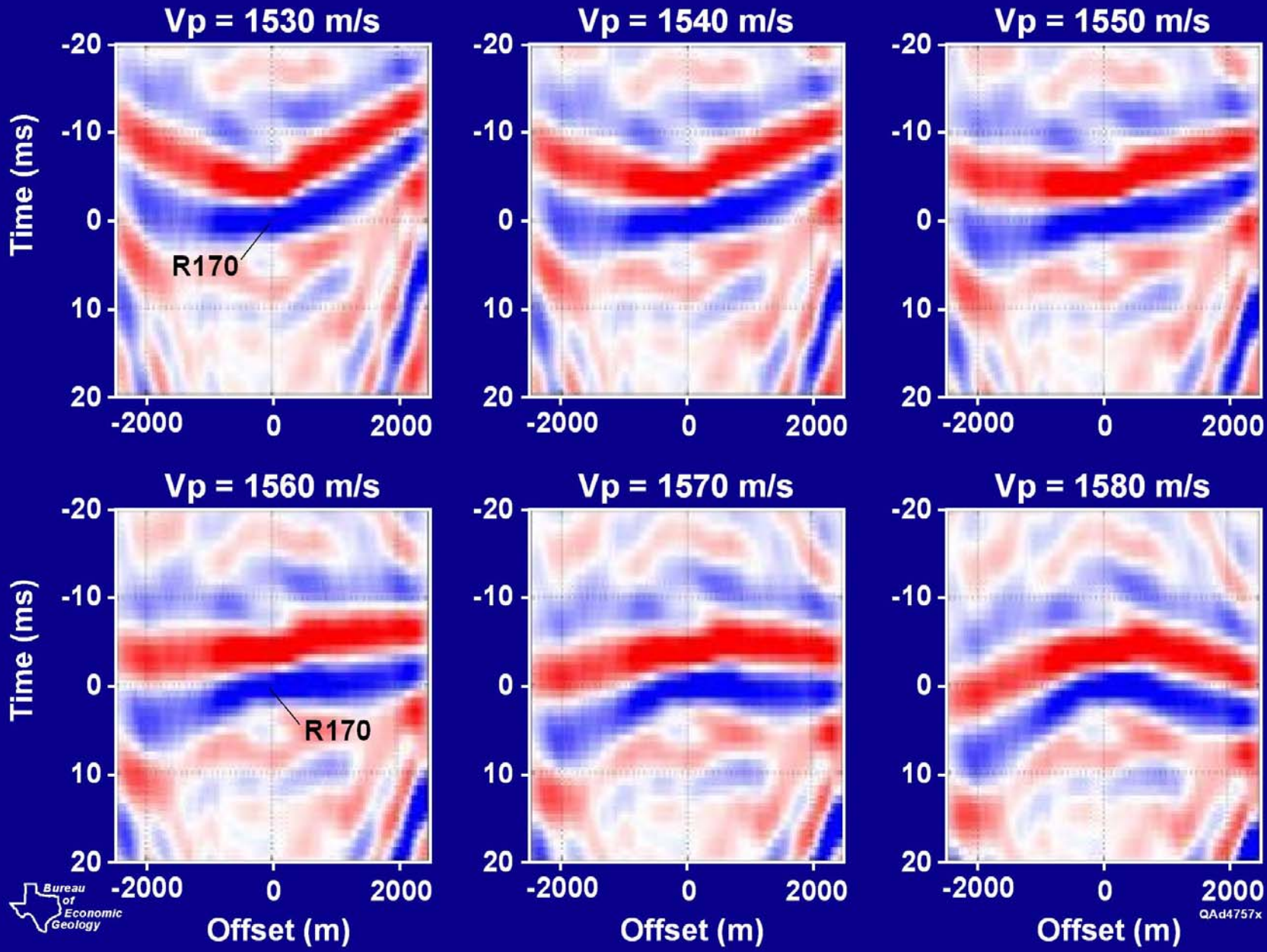
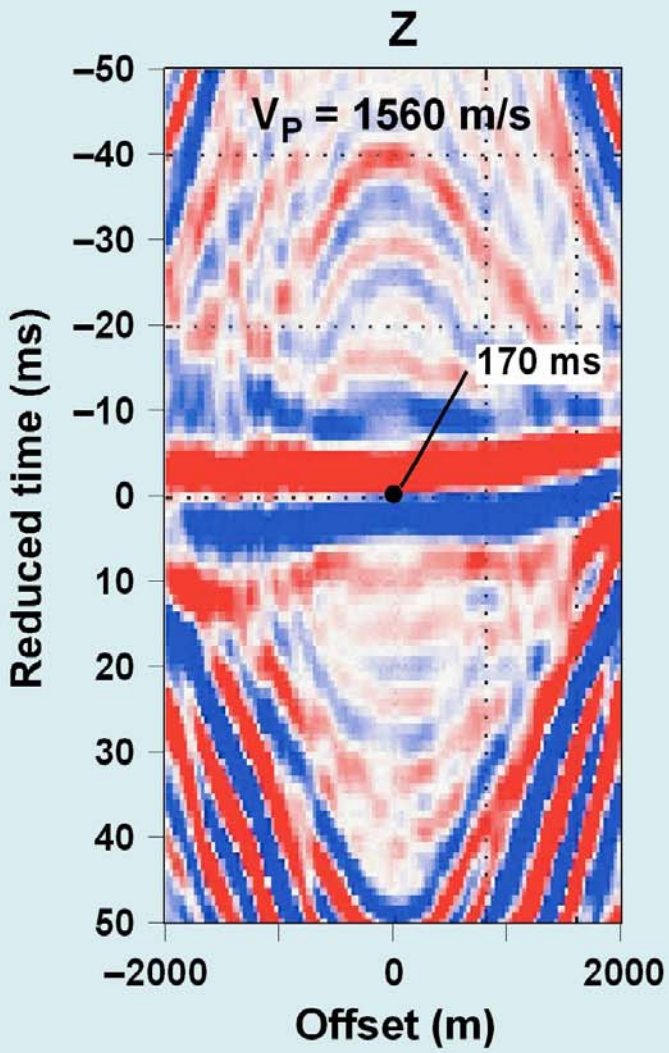
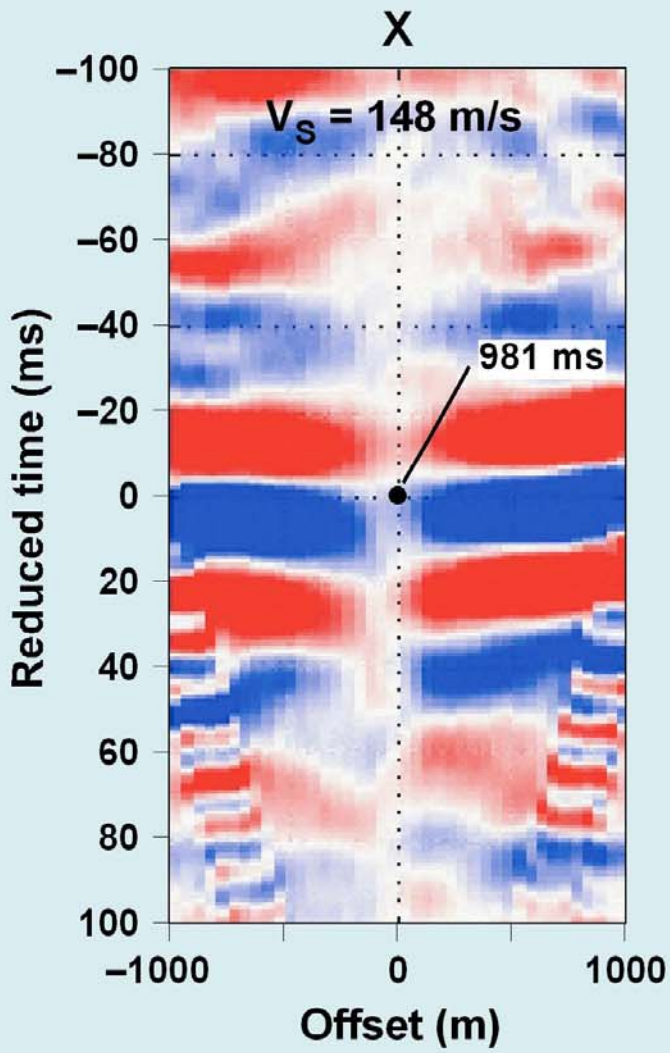
P-WAVE VELOCITY SCANS: RAY TRACE BASED



4-C OBC FIELD RECORD, LINE 549, CDP 13949: SINGLE-LAYER MODEL





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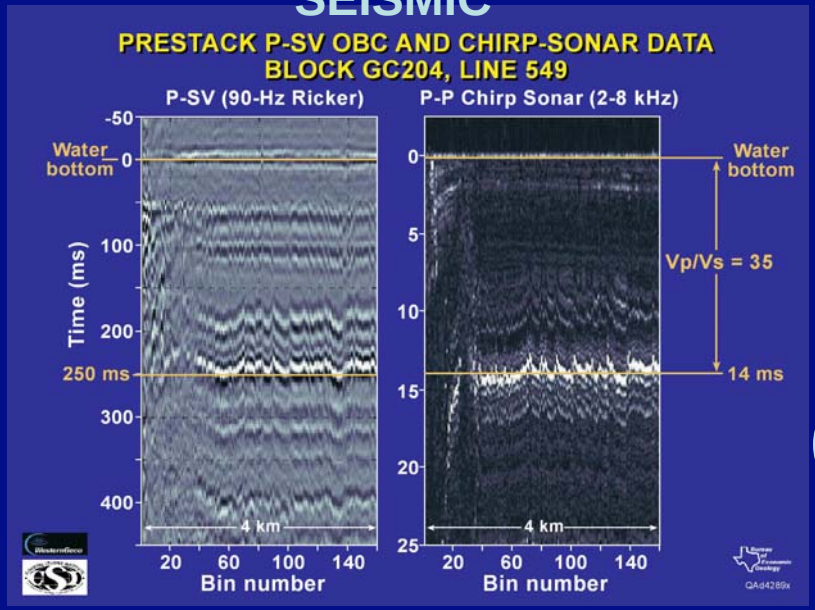
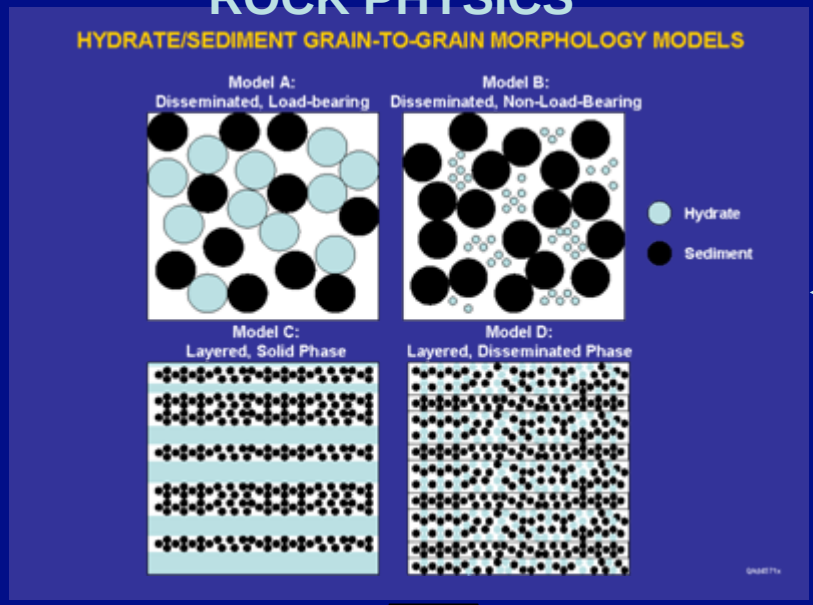
MEASURING THE RESOURCE

SEISMIC



(V_p, V_s)

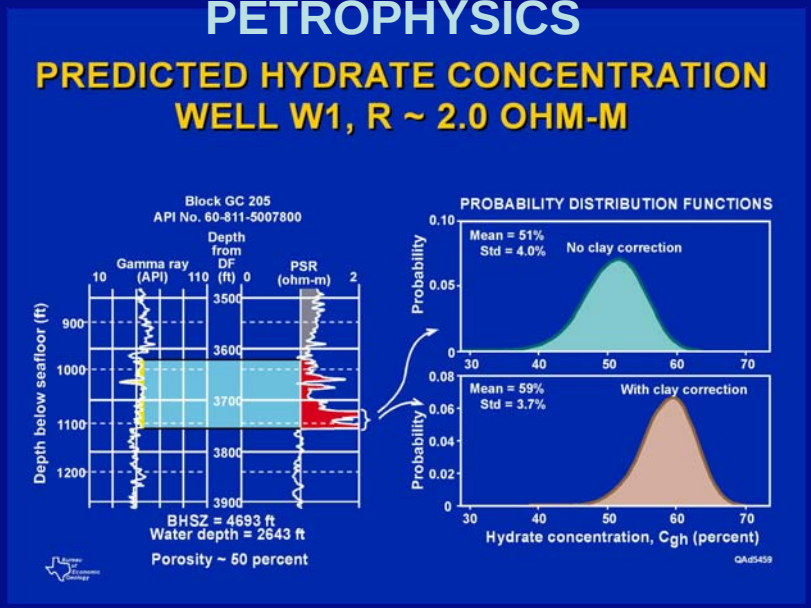
ROCK PHYSICS



CALIBRATION

C_{gh} (seismic)

PETROPHYSICS



C_{gh} (log)

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

C_{gh} = Hydrate Concentration

Iterate

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