

# **Quantifying Gas Hydrate Resources from Cumulative Seismic Attributes, Hydrate Ridge, Offshore Oregon\***

**Uwe Strecker<sup>1</sup>, Anyela Morcote<sup>1</sup>, Angel Zea<sup>1</sup> and Scott Singleton<sup>1</sup>**

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<sup>1</sup>Seismic Services Group, OHM Rock Solid Images, Houston, TX. ([uwe.strecker@ohmrsl.com](mailto:uwe.strecker@ohmrsl.com))

## **Abstract**

Application of an advanced type of seismic attribute (“cumulative seismic attribute = CATT”) detects gas hydrate saturations exceeding 20% beneath Hydrate Ridge, offshore Oregon. CATT is based on case-specific rock physics transforms that portray bulk properties of the gas hydrate stability zone. One such transform that links elastic wave velocities, porosity, fluid compressibility, mineralogy, and effective pressure of unconsolidated sediment is the “soft-sand model.” Moreover, this soft sand model populates part of the matrix with gas hydrate. The resultant porosity reduction with increasing gas hydrate saturation leads to higher impedances. However, geological scenarios may occasionally arise that result in high impedance contrasts from causes other than actual hydration (“false positives”). Nonetheless, where genuine, hydration generally affects the entire section occupied by sands, silts, and shales, most of which occurs within a narrow window no more than 30 to 50 milliseconds above the BSR. Hydration is highest in layers with low-VCLAY (30% to 40%). Interestingly, for a case study reservoir sand from the eastern flank of the dome, geobodies with impedances exceeding  $2,800 \text{ kgm}^2\text{s}^{-1}$  occur low on structure in a region characterized by en échelon normal fault escarpments. This observation suggests a genetic link between faulting and hydration. Since high gas hydrate saturations are not encountered toward the structural highs of the sand, this deficit may indicate a past gas supply problem or partially sealing faults, or a combination of both alternatives. Volumetric calculations of the CATT attribute give resource estimates of approximately 720 Bcf for a  $45 \text{ km}^2$  area. However, these volume calculations should be viewed with caution because of an incomplete data set from which impedance inversion was performed.

## References

Chevallier, J., 2004, Seismic sequence stratigraphy and tectonic evolution of southern Hydrate Ridge: Thesis M.S., Oregon State University, Corvallis, Oregon, 117 p.

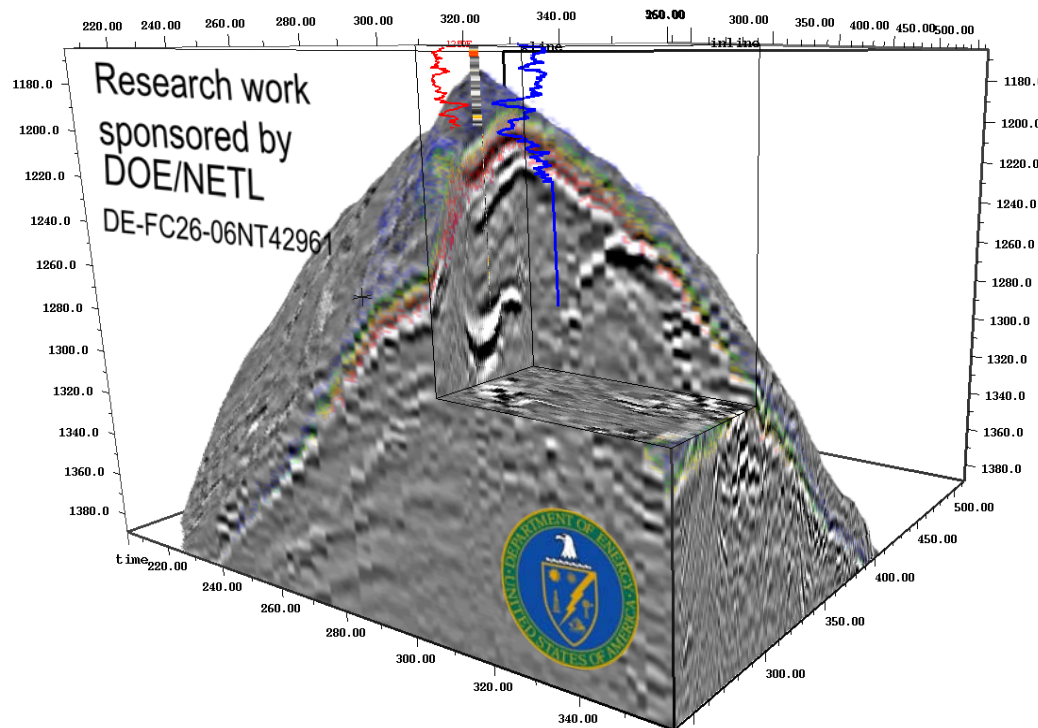
Cordon, I., J. Dvorkin, and G. Mavko, 2006, Seismic reflections of gas hydrate from perturbational forward modeling: *Geophysics*, v. 71/6, p. F165-F171.

Dvorkin, J., G. Mavko, A.M. Nur, 1999, Overpressure detection from compressional-and shear-wave data: *Geophysical Research Letters*, v. 26/22, p. 3417-3420.

Tréhu, A.M., PE. Long, M.E. Torres, et al, 2004, Three dimensional distribution of gas hydrate beneath southern Hydrate Ridge; constraints from ODP Leg 204: *Earth and Planetary Science Letters*, v. 222/3-4, p. 845-862.

Tréhu, A.M. and G. Bohrmann, 2003, Drilling gas hydrates on Hydrate Ridge, Oregon continental margin: *AAPG Annual Meeting Abstracts*, v. 12, p. 172.

# Quantifying Gas Hydrate Resources from Cumulative Seismic Attributes, Hydrate Ridge, Offshore Oregon



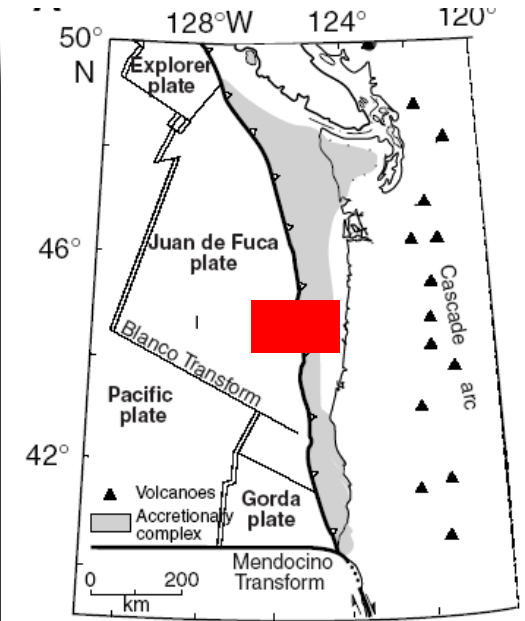
Uwe Strecker, Anyela Morcote, Angel Zea, Scott Singleton

# Agenda

1. Objectives
2. Workflow
3. Effective medium model design
4. Rock physics well log modeling
5. CATT theory & workflow
6. Interpretation
7. Resource estimates
8. Conclusions

# Project Objectives

- ❖ to design a case-specific effective medium model that accurately predicts the seismic response of gas hydrate
- ❖ to apply a new class of seismic attribute called Cumulative Attribute (CATT)
- ❖ to test CATT methodology contrasting well log and seismic data from Hydrate Ridge, offshore Oregon
- ❖ to quantify natural gas hydrate resources estimates



*Adapted and modified from Tréhu et al., 2003*

# Project Workflow

## Well log modeling

- 1.) establish basic petrophysical parameters ( $S_w$ ,  $\Phi$ ,  $V_{sh}$ )
- 2.) populate effective medium model
- 3.) condition original wireline log curves

Calculate  
CATT  
coefficients



emphasized today



not discussed today

Interpretation

Quantify Resource Estimates

## Seismic data conditioning

JTFA, EPS, PHASE

## Seismic-to-well tie

Determine best wavelet for inversion.

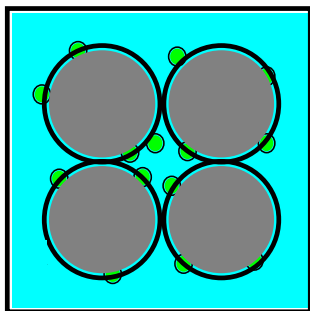
## Seismic inversion

Model-based (iterates from geologic model, creates best-fit with seismic data); calculates acoustic impedance

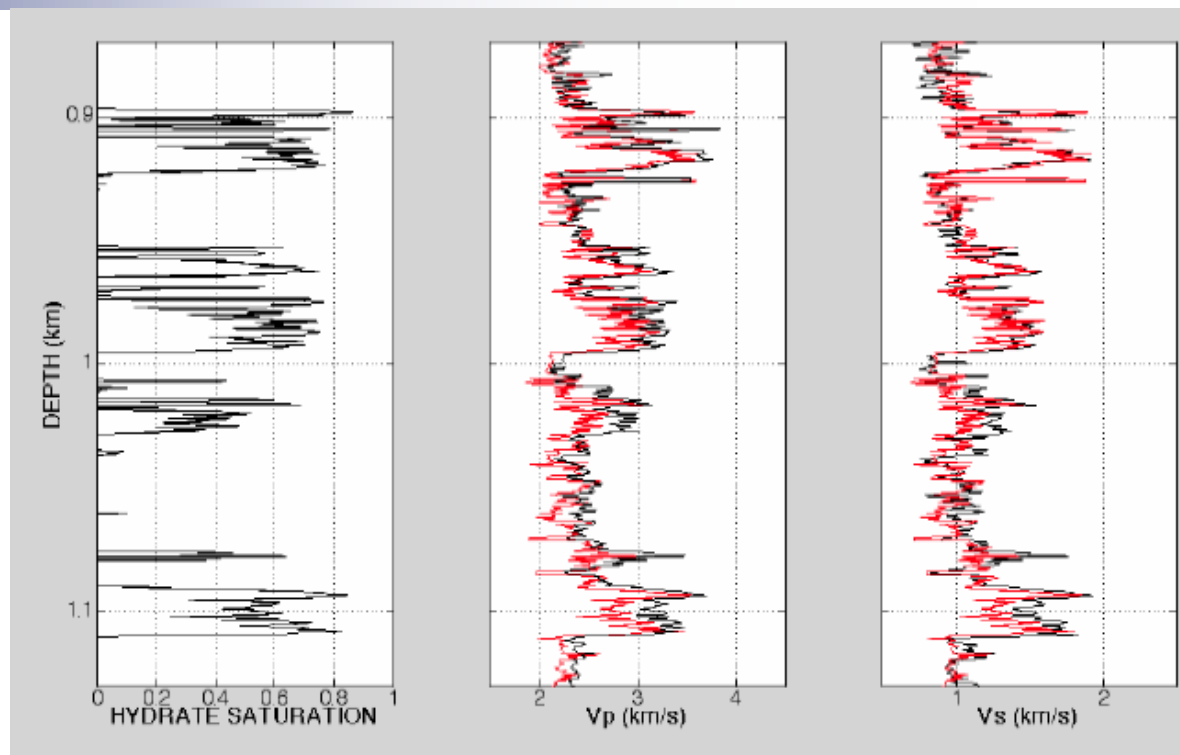
## Calculation of CATT attribute

Use coefficients determined from well logs; iterate if coefficients need optimization for seismic data

# “Soft Sand” Effective Medium Model



- quartz grains
- brine
- gas hydrate



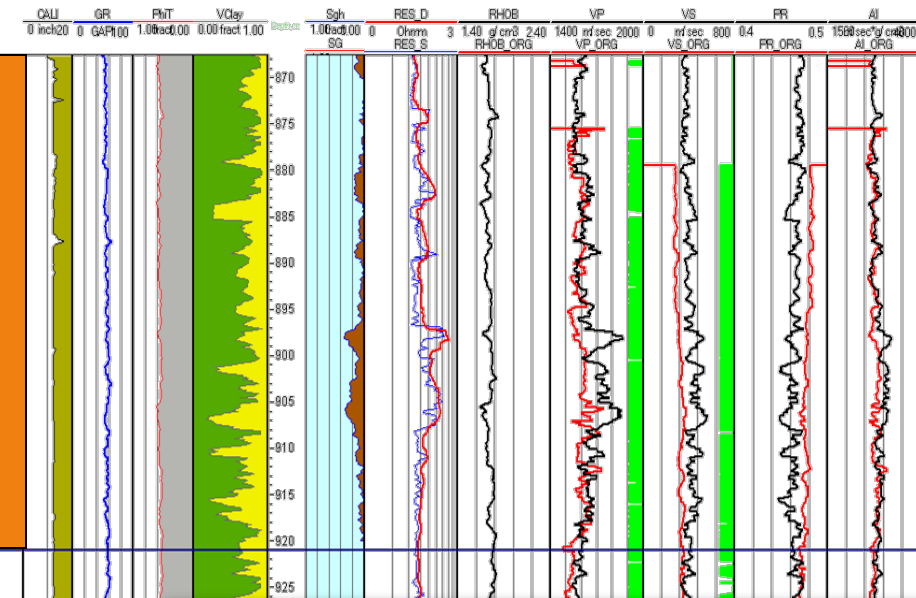
■ Modeled  $V_p$ ,  $V_s$

■ Measured  $V_p$ ,  $V_s$

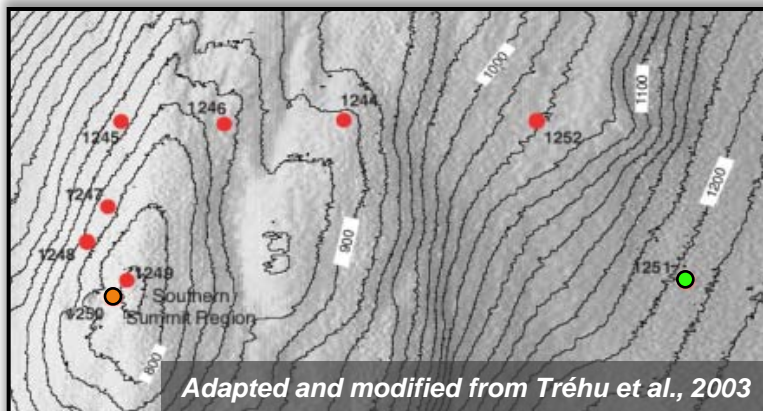
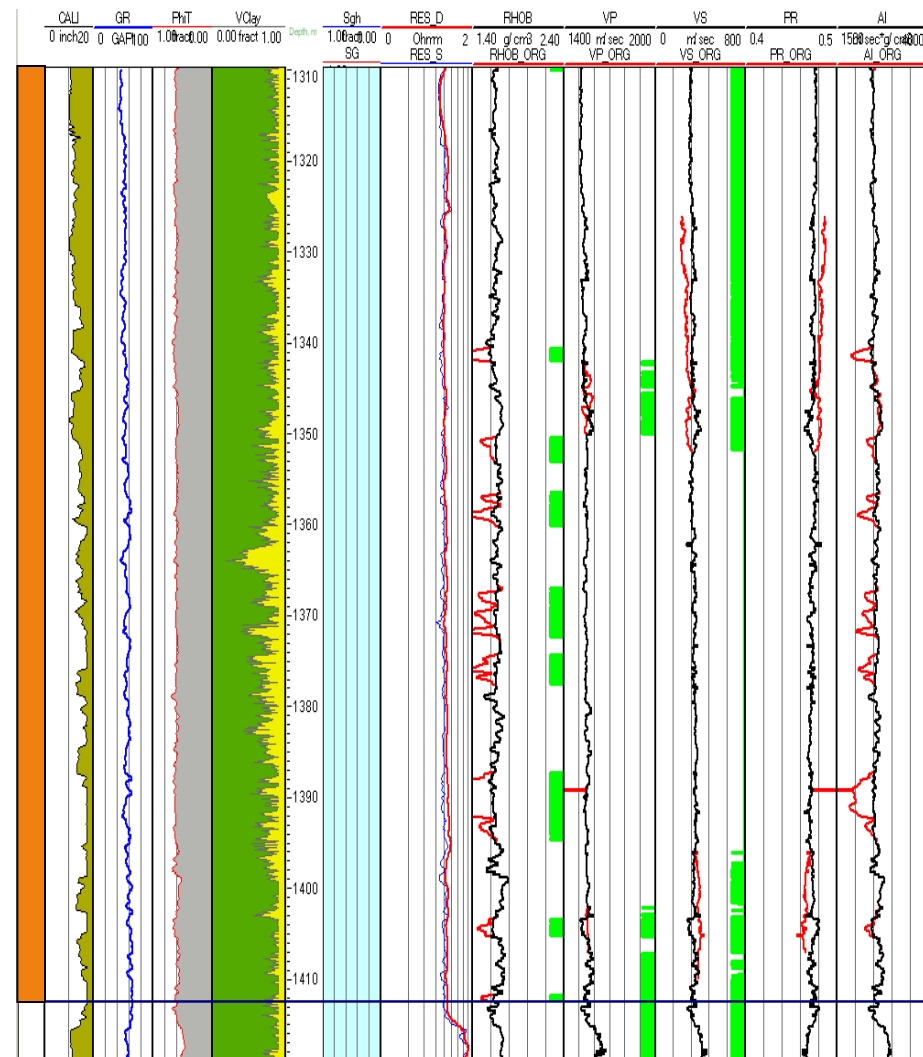
- ❖ incorporates gas hydrates as a solid mineral (Dvorkin et al., 1999; 2003)
- ❖ Porosity reduction causes elastic wave velocity increase
- ❖ reproduces measured well log data in unconsolidated sediment (Cordon, 2006)

# Log conditioning via effective medium model

Well 1250F



Well 1251H



2.5 km

GHSZ

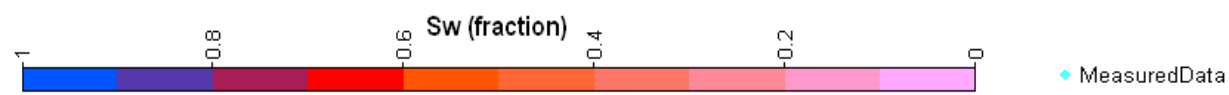
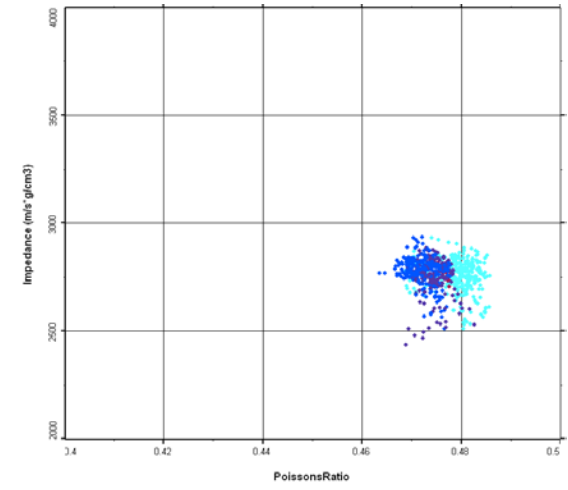
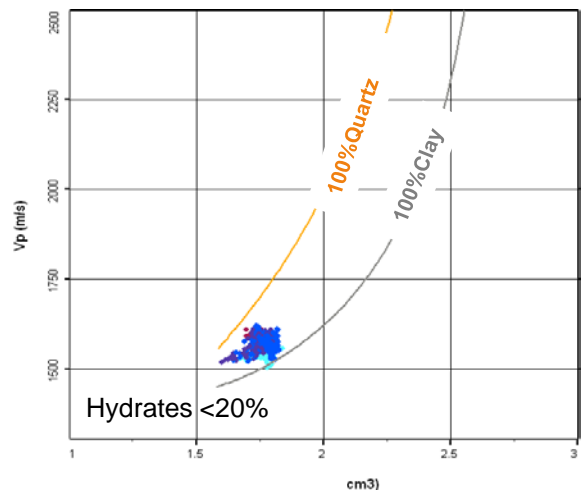
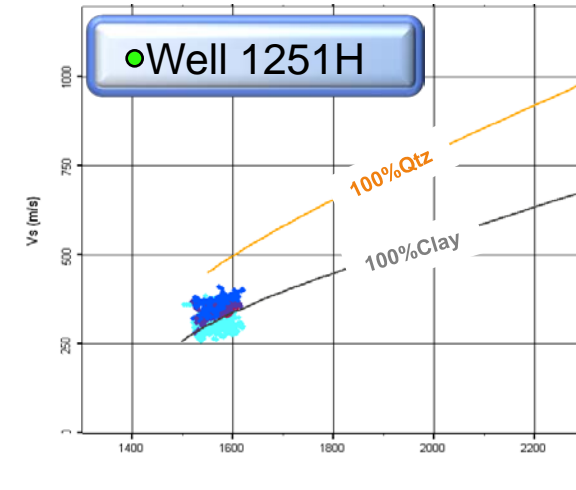
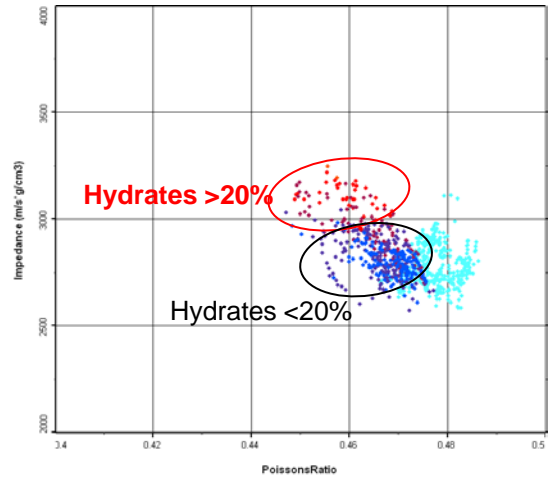
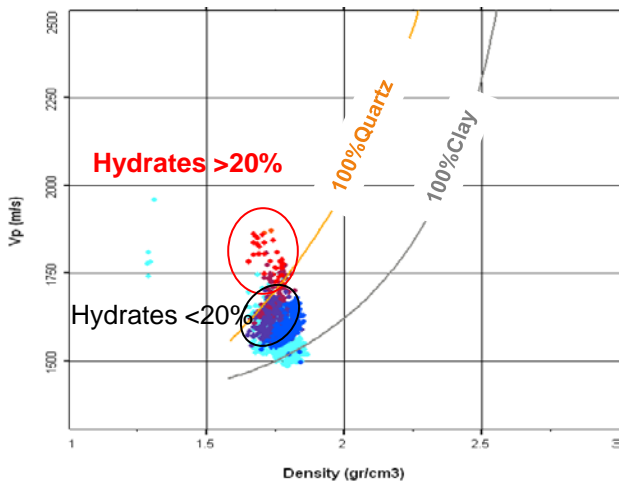
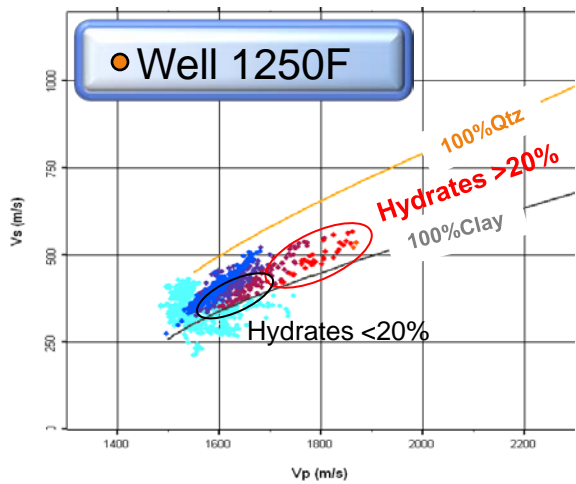
Measured logs

Conditioned logs using "soft sand" model

Edited wireline log intervals

BSR

# Rock Physics Diagnostics

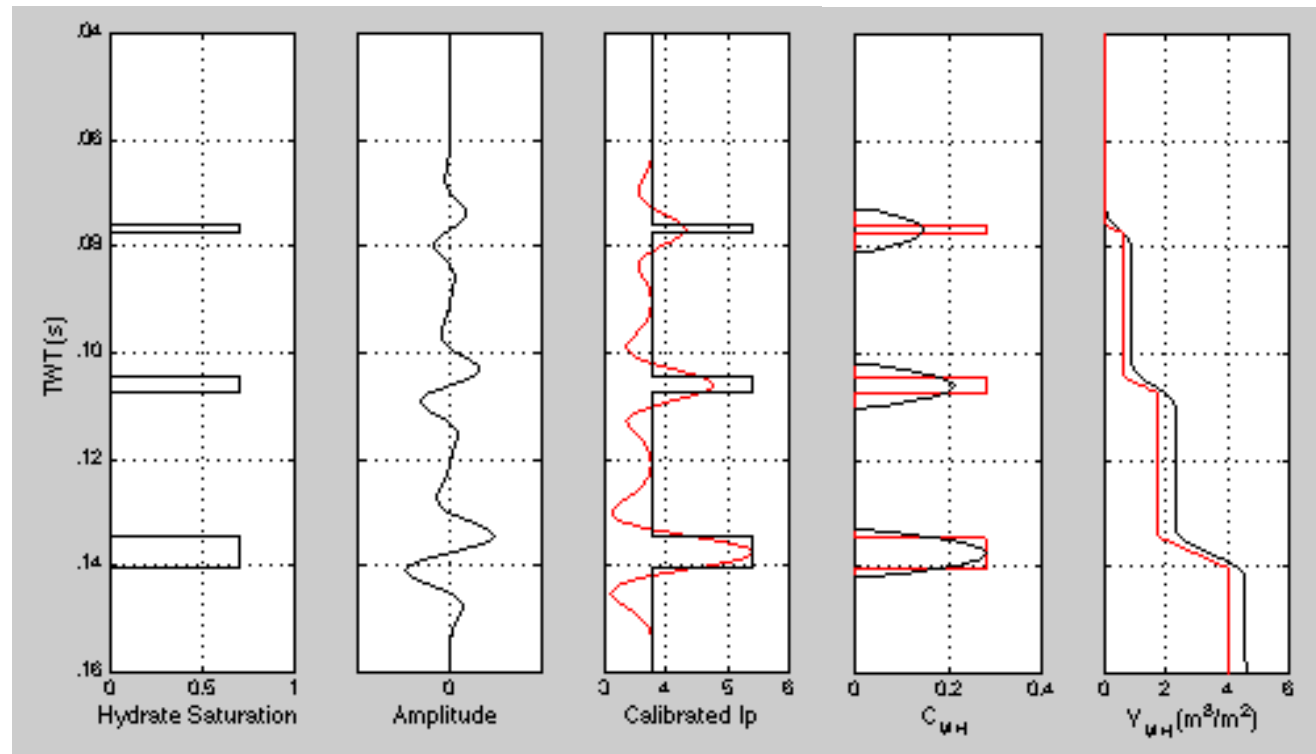
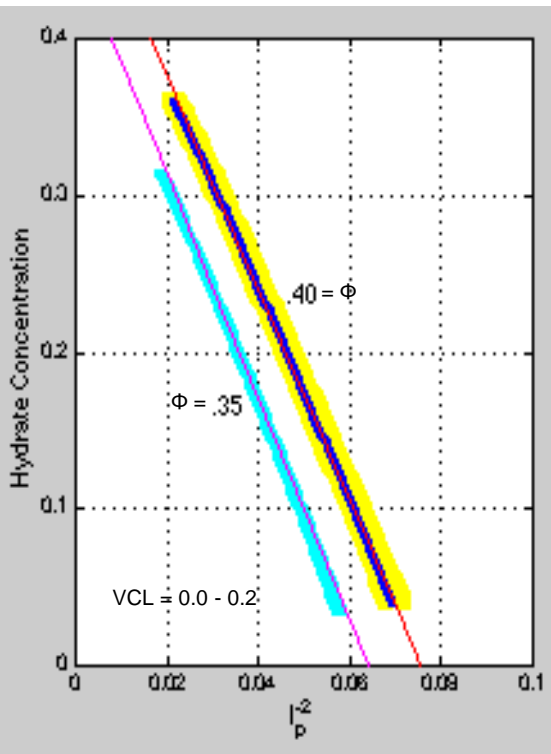


# CATTs Theory

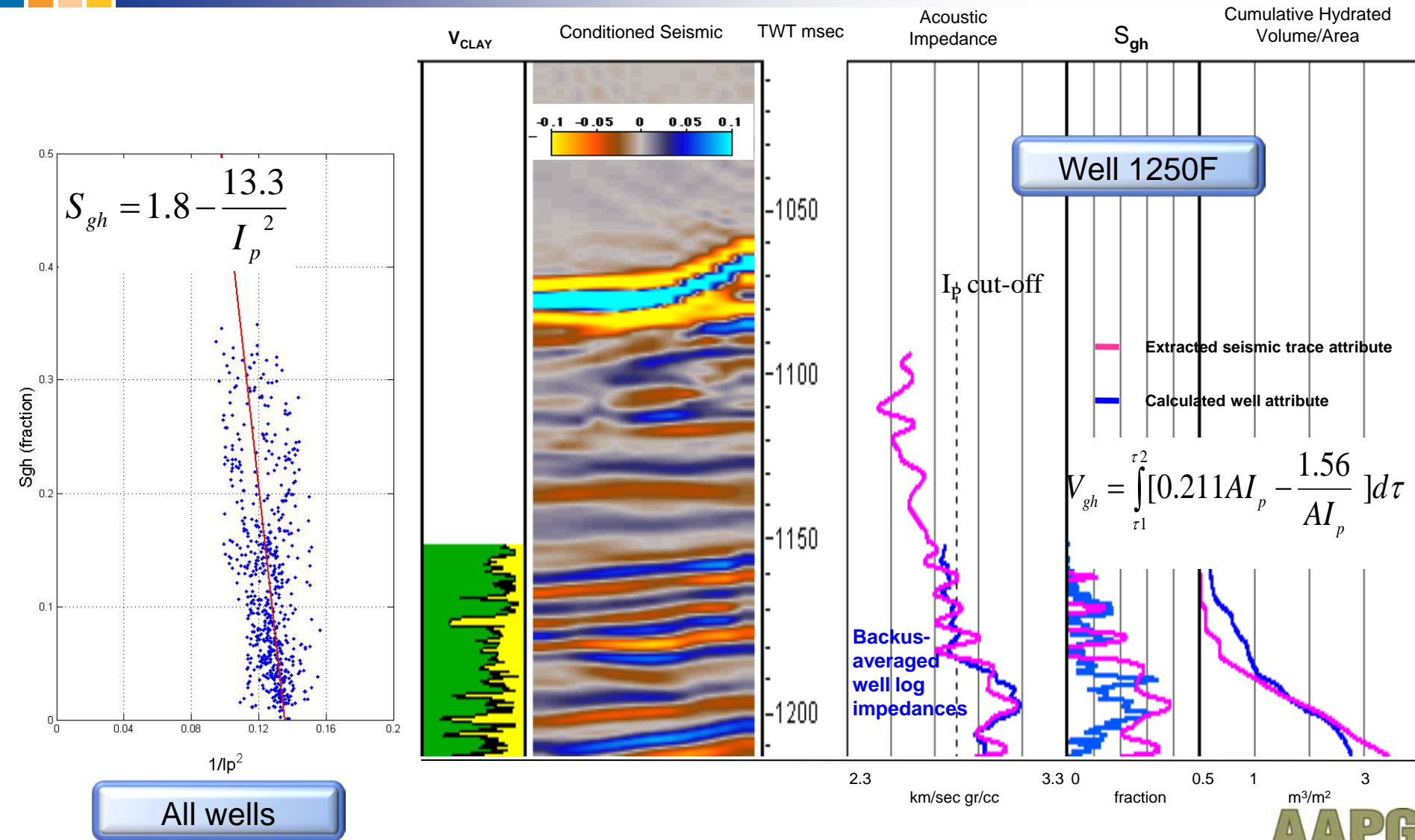
$$S_{gh} = a - \frac{b}{I_p^2}$$

$$V_{gh} = \int \phi(z) S_{gh}(z) dz$$

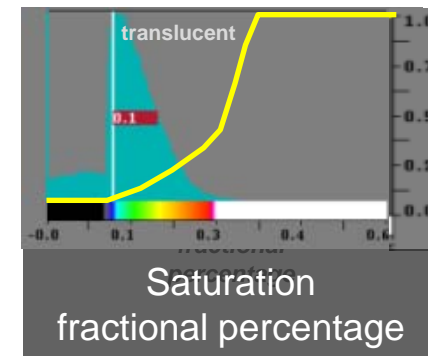
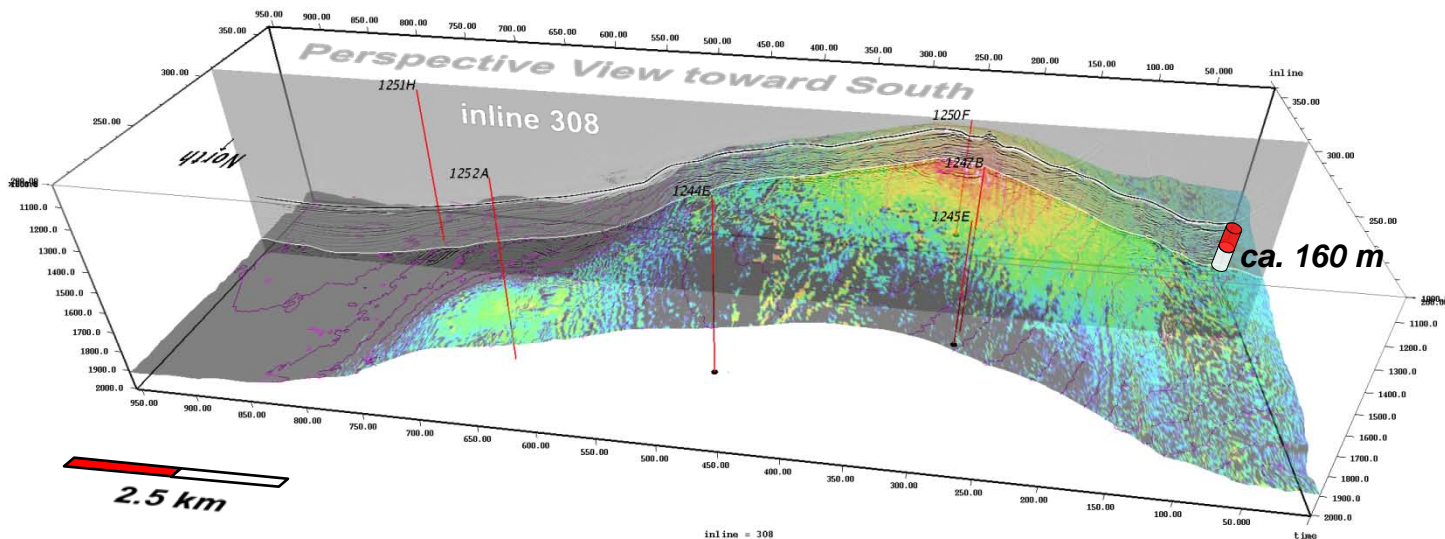
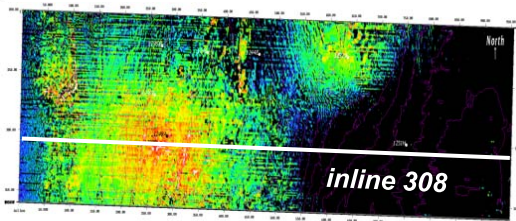
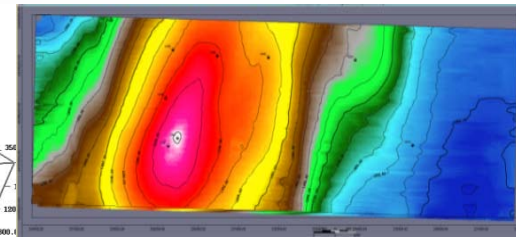
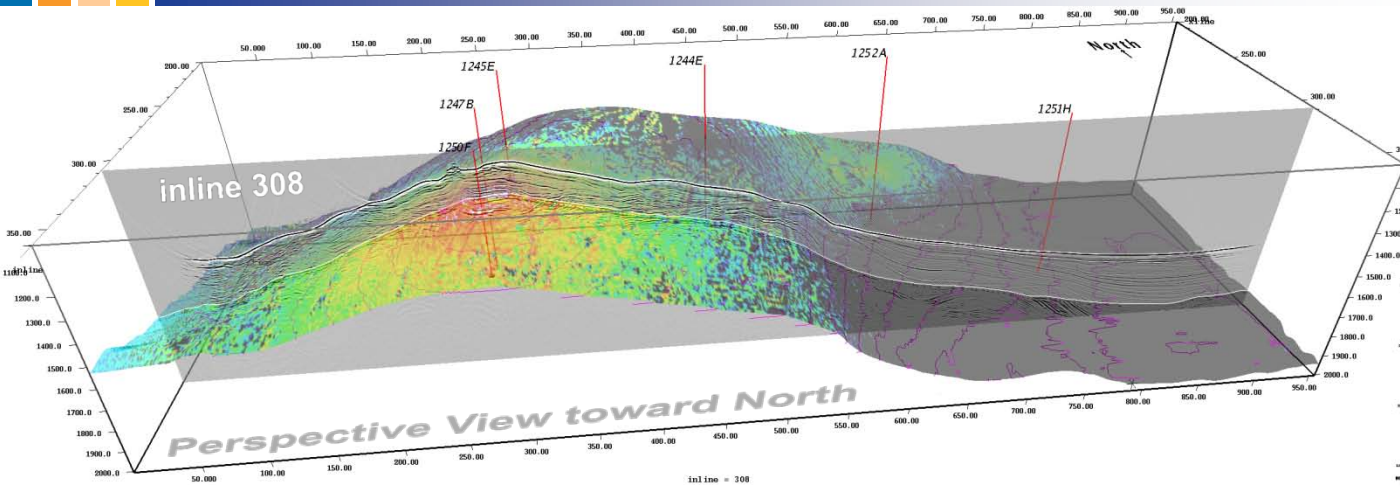
$$C_I = \int \left[ -\frac{u}{I_p} - w I_p \right] d\tau$$



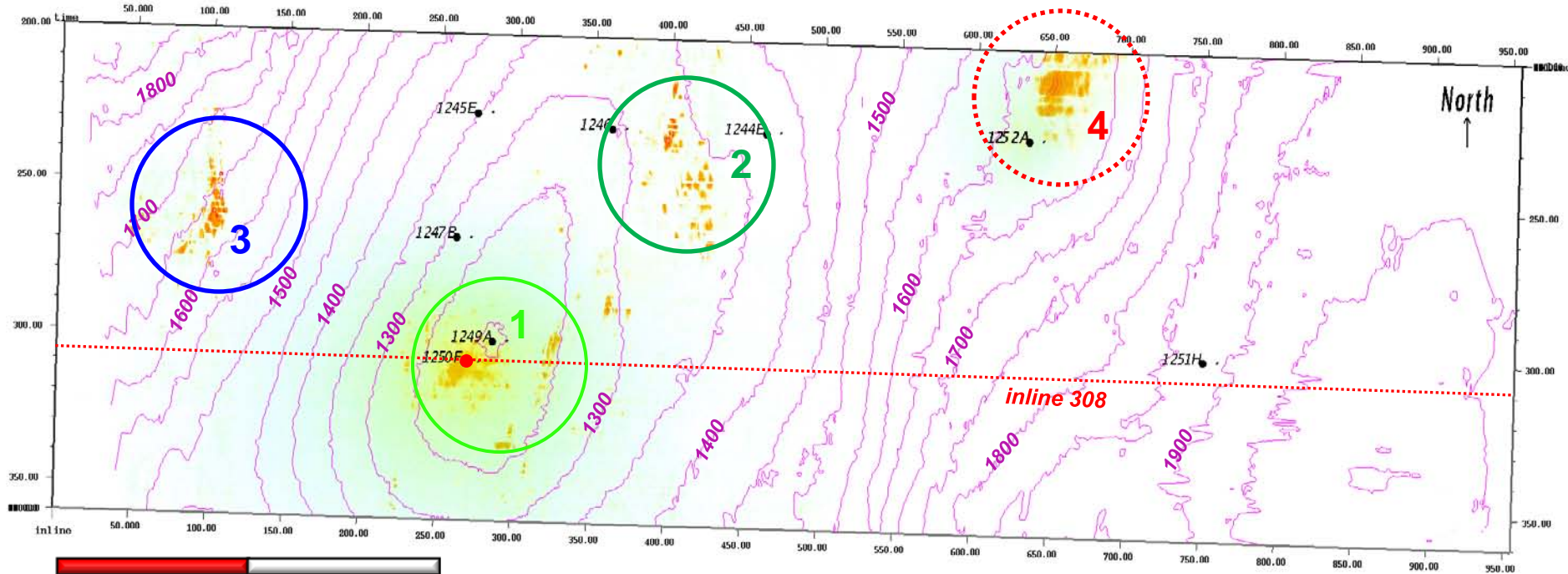
# CATT Workflow



# Saturation extraction (BSR – 0.013 s TWT)



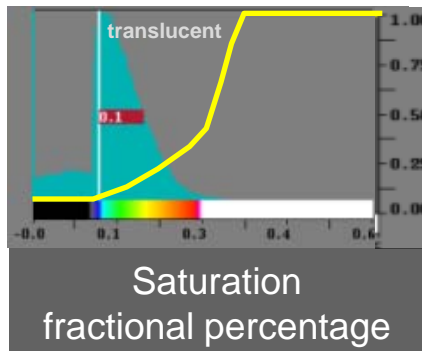
# Location Map for Hydrate Ridge, offshore Oregon



2.5 km

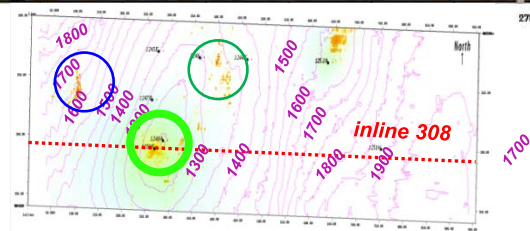
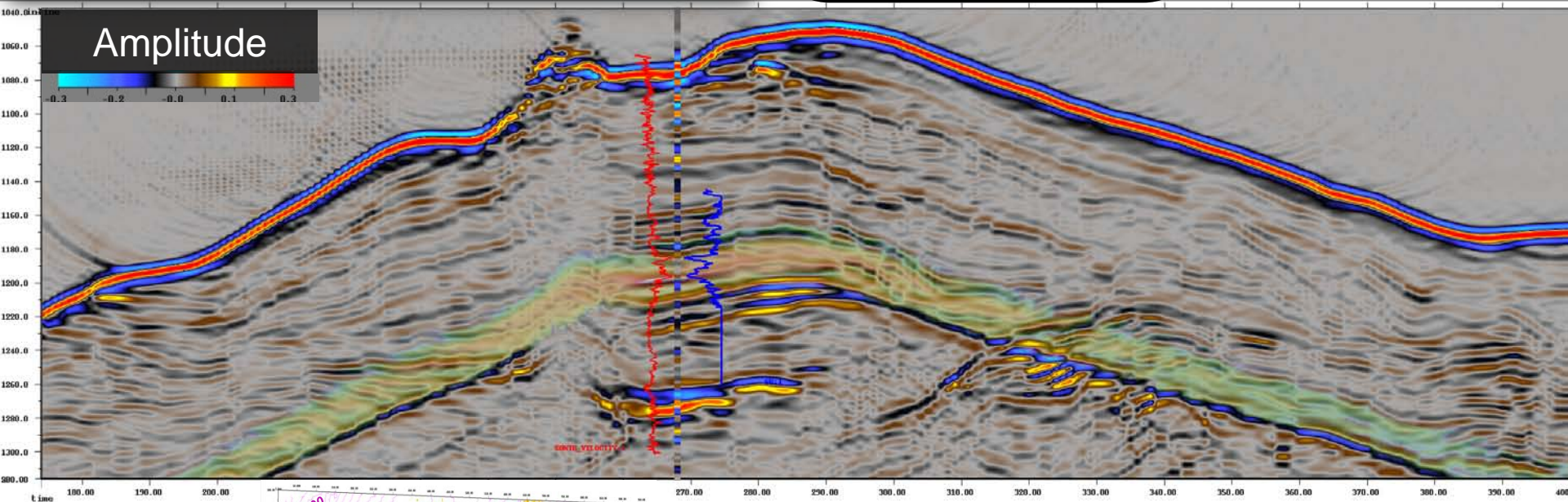
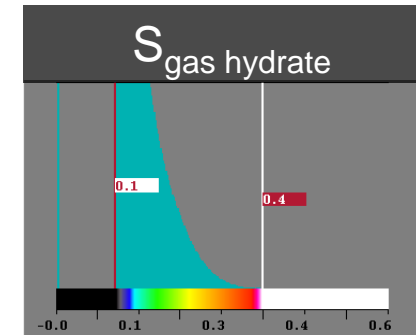
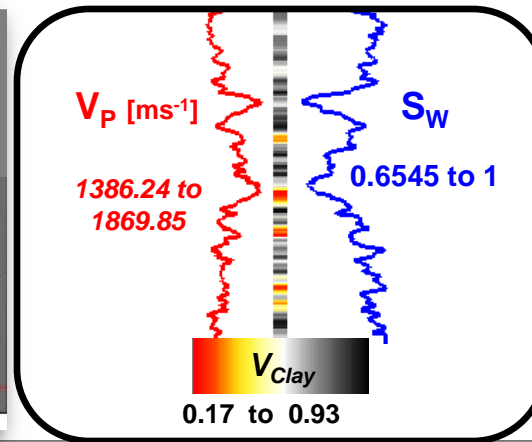
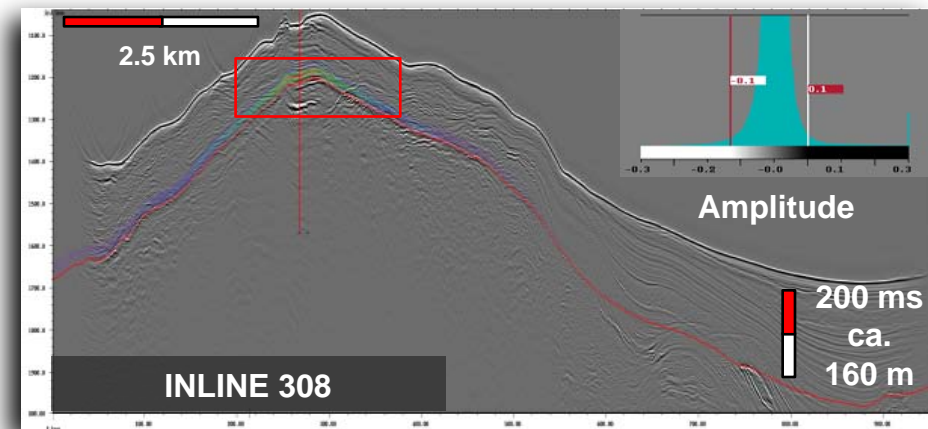
*C.I.  $\Delta t$  on BSR = 0.050 sec two-way travel time*

3 out of 4 *gas hydrate saturation anomalies* featured in presentation



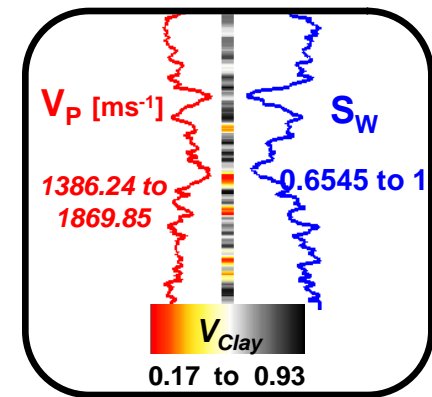
- Ridge crest
- Hydrated Sand "B" (Tréhu et al., 2004; Chevallier et al., 2004)
- West flank of dome
- 4<sup>th</sup> anomaly compromised by false positives

# Seismic section w/ saturation overlay

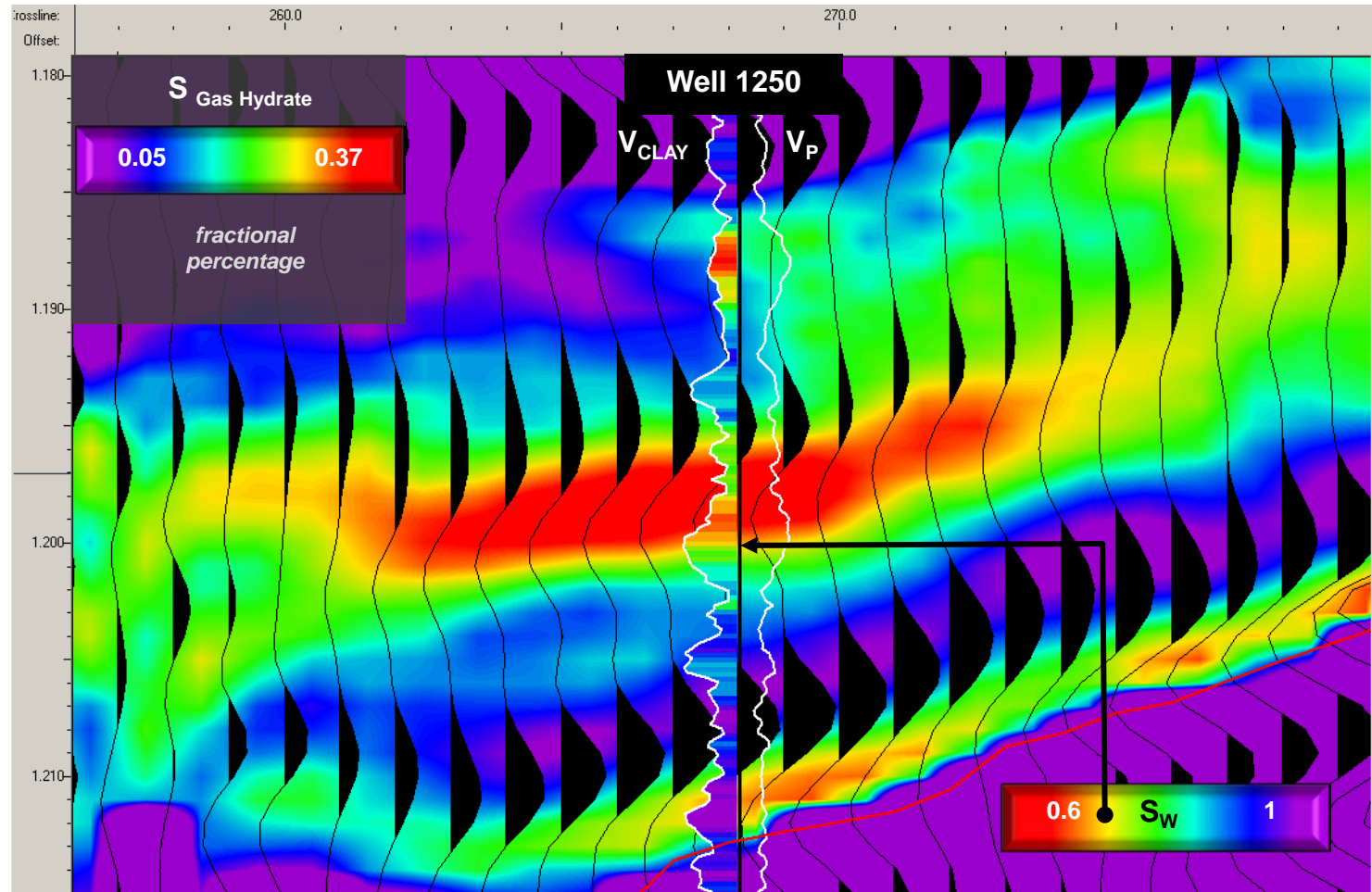


✓ Ridge crest

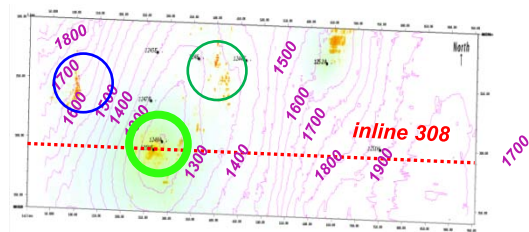
# Wiggle-trace amplitude w/saturation well tie



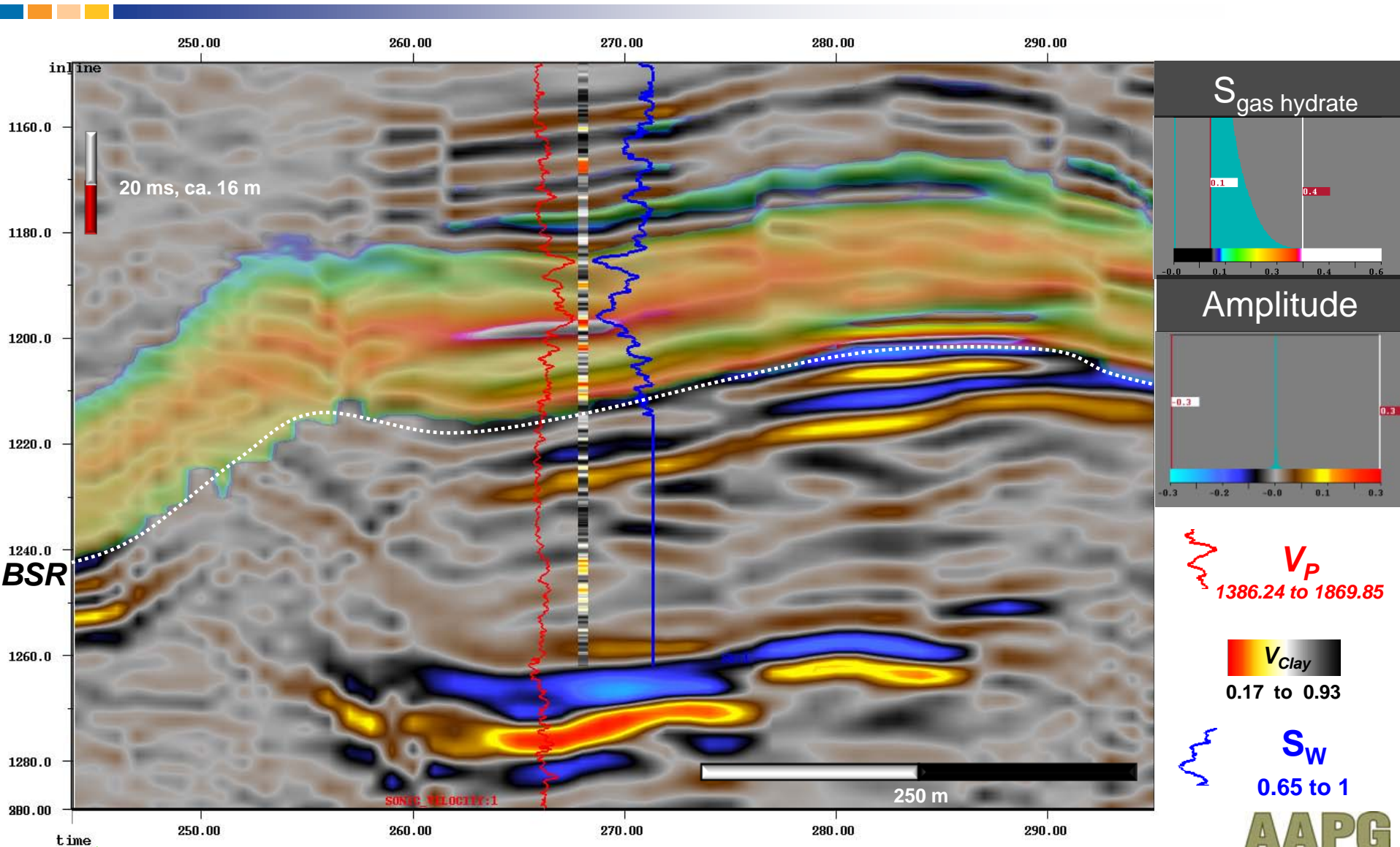
ca. 8 m



125 m

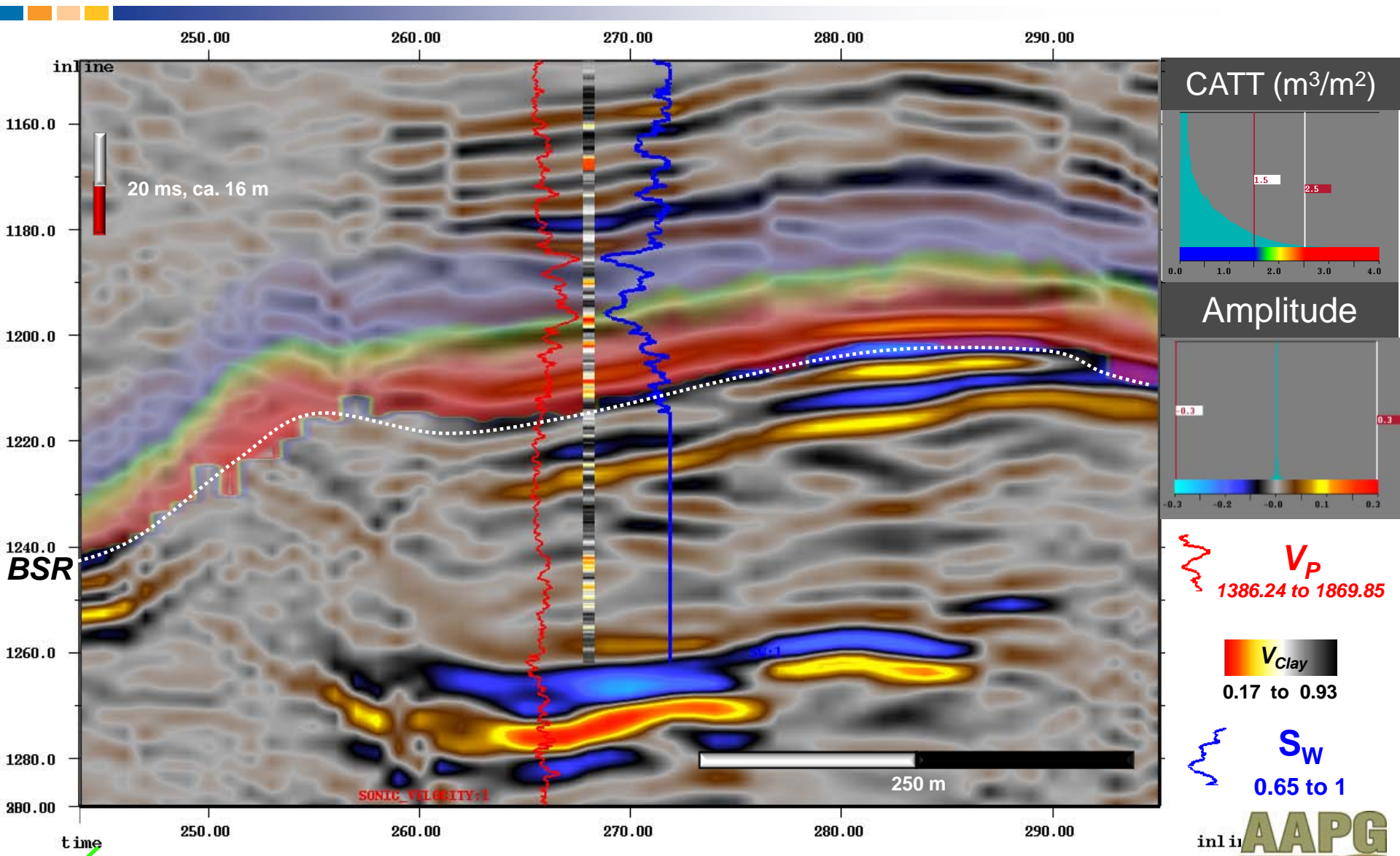


# Co-rendered saturation w/ amplitude



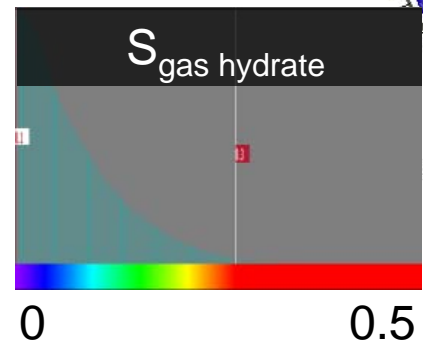
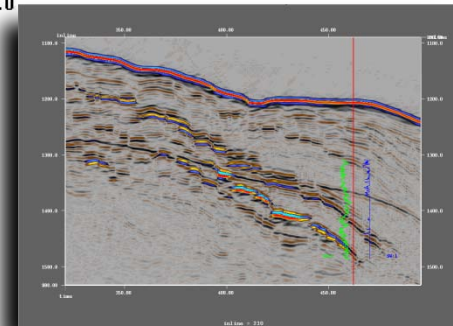
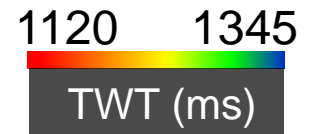
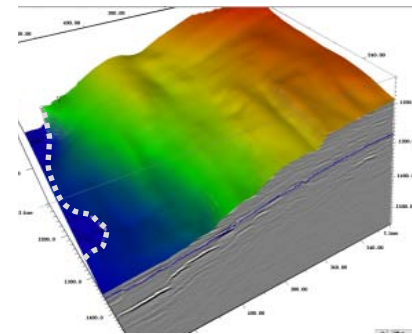
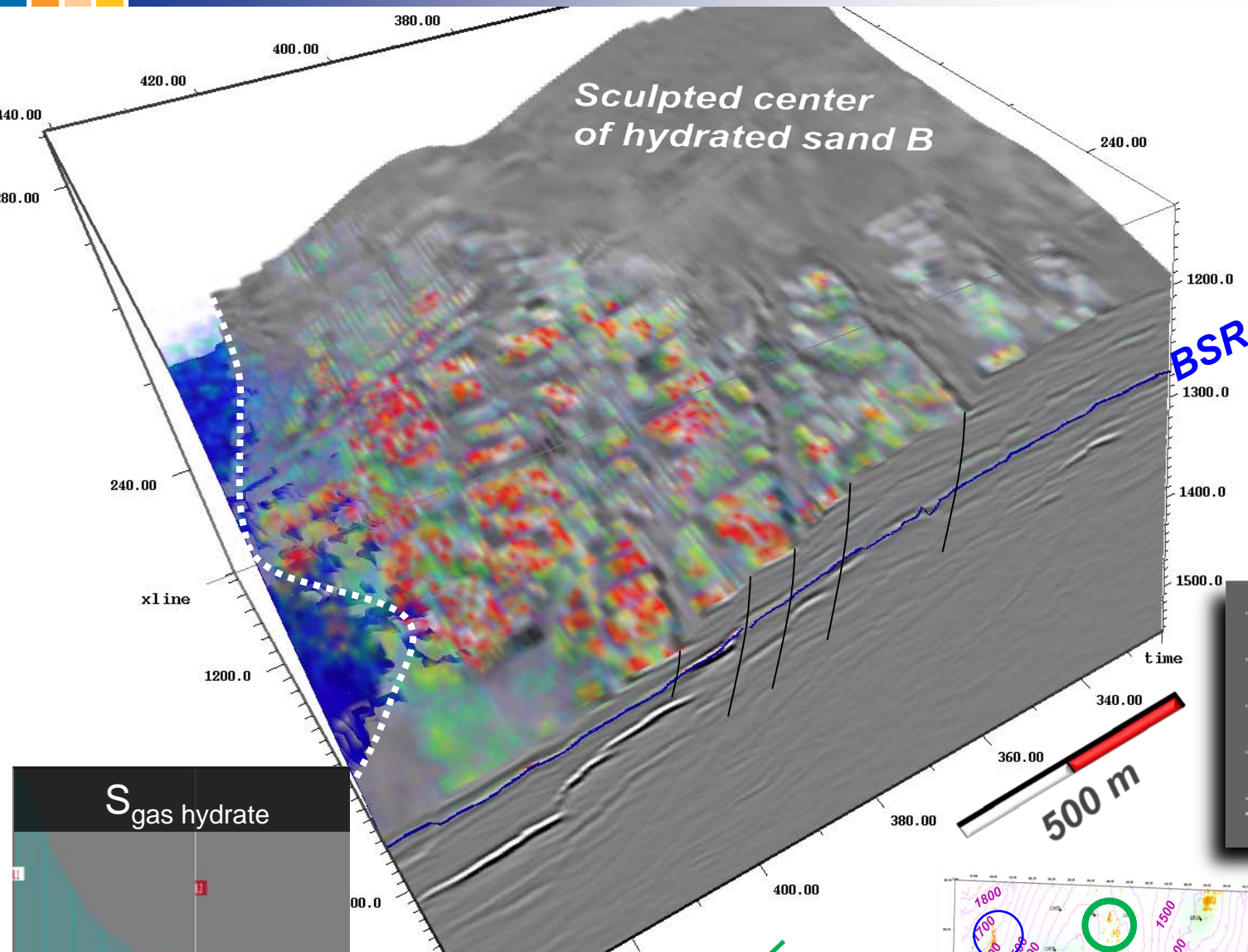
✓ Ridge crest

# Co-rendered CATT w/ amplitude

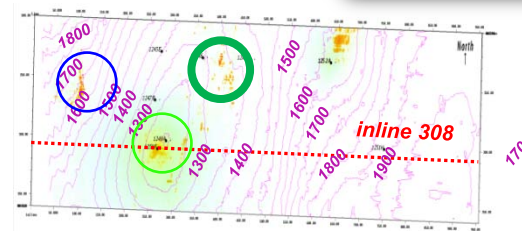


✓ Ridge crest

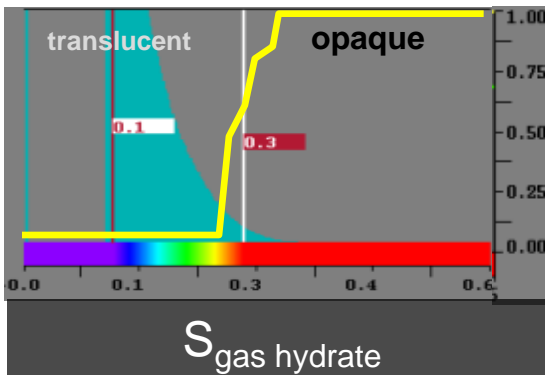
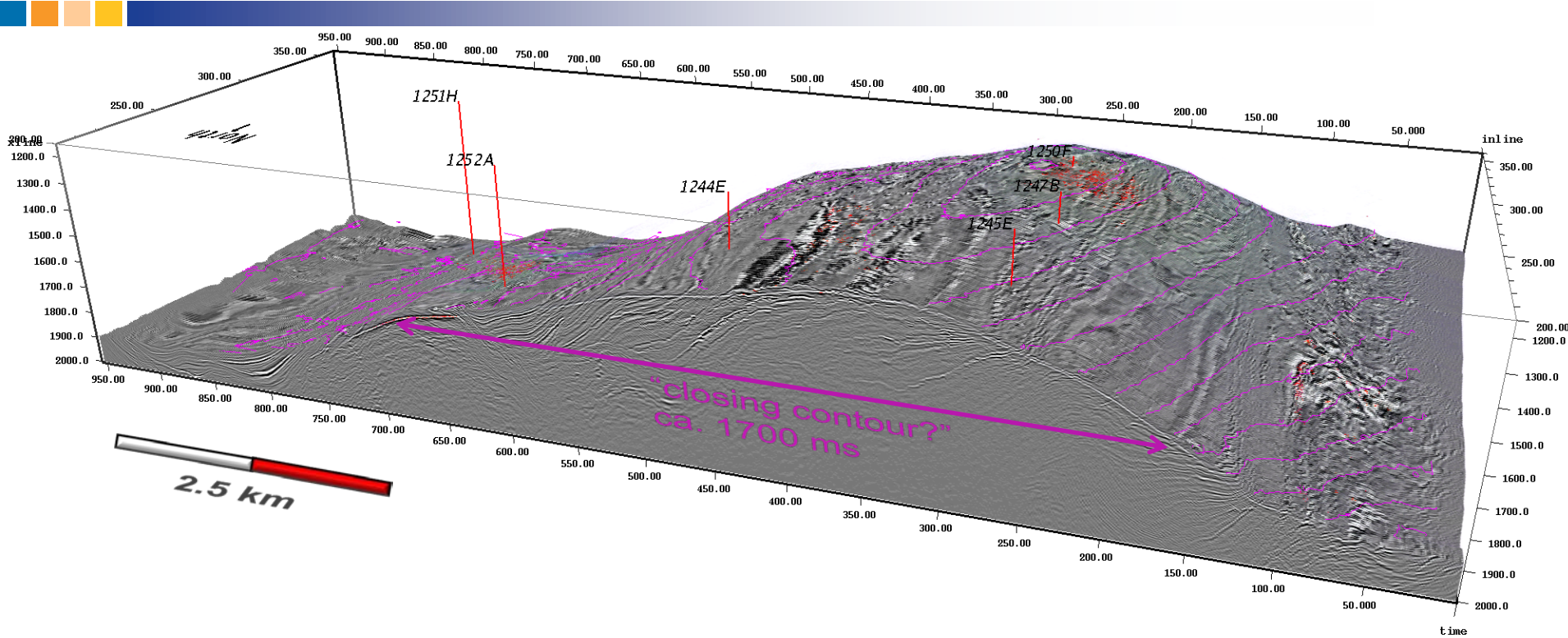
# Co-rendered saturation with amplitude



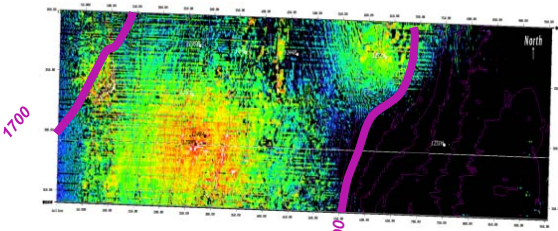
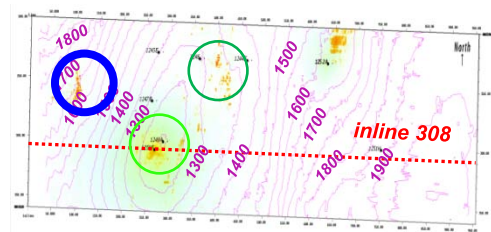
✓ "B" sand



# Seismic section w/ saturation >25% overlay



W Flank of dome



# Gas Hydrate Resource Estimates

Total number of samples (traces)	98,079
Minimum attribute value	0.03 m <sup>3</sup> /m <sup>2</sup>
Maximum attribute value	3.99 m <sup>3</sup> /m <sup>2</sup>
Average	1.26 m <sup>3</sup> /m <sup>2</sup>
Standard deviation	0.72 m <sup>3</sup> /m <sup>2</sup>
TOTAL Gas Hydrate Volume within 3D SURVEY AREA	123,291 m <sup>3</sup>
Conversion from m3 to scf (X 35.31)	4,353,405.21 scf
HYDRATE TO GAS EXPANSION FACTOR 166.7	7.26 × 10 <sup>8</sup> scf
<b>MINIMUM TOTAL GAS</b>	<b>ca. 730 BCF</b>

**(Areal extent = 44.95 km<sup>2</sup>)**

# Conclusions

Application of the cumulative seismic attribute ("CATT") detects gas hydrate resources for  $S_{\text{gas hydrate}} > 20\%$

Resource accumulations are subject to multiple controls:

- Elevation: Hydration is highest in a relatively narrow interval  $< 30$  ms ( $< 24$  m) immediately above BSR high on structure
- Lithology: hydration generally affects the entire section occupied by sands, silts, and shales, but hydration is highest in layers with low- $V_{\text{CLAY}}$
- En échelon normal faulting (migration conduit, sealing)

Resource estimates exceeding 700 Bcf for a 45 km<sup>2</sup> area must be viewed with discretion (data quality; seismic bandwidth; lack of velocity control; inversion bias; occasional false positives)

# Acknowledgements

