Spectral Decomposition and Other Seismic Attributes for Gas Hydrate Prospecting

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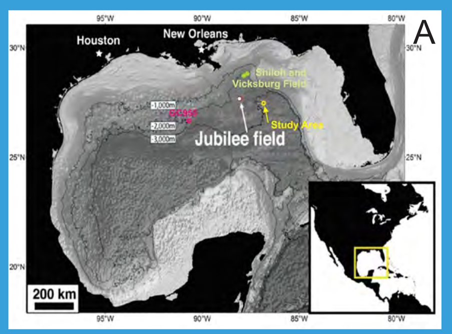
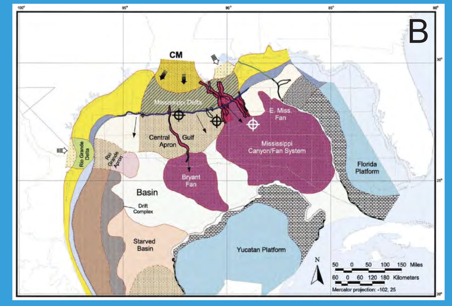
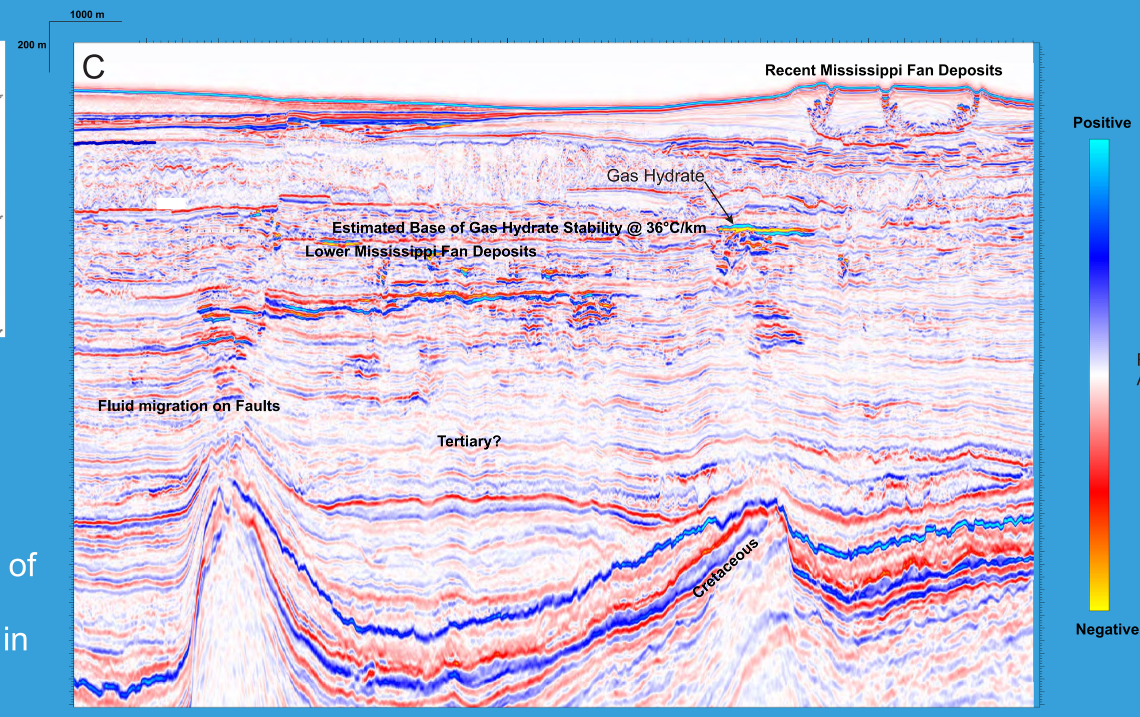
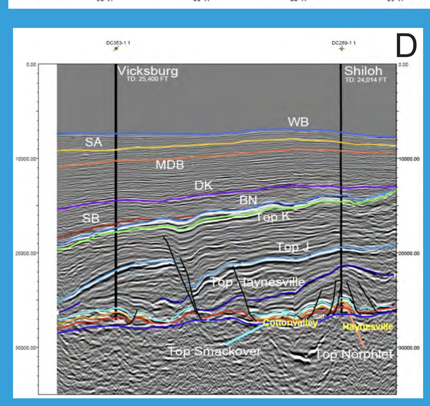
Studying the sediments at the base of gas hydrate stability is ideal for determining the seismic response to gas hydrate saturation. First, assuming gas migration to the shallow section, this area is more likely to have concentrated gas hydrate because it encompasses the zone in which upward moving buoyant gas transitions to form immobile gas hydrate deposits. Second, this zone is interesting because these areas have the potential to show a hydrate filled zone and a gas filled zone within the same sediments. Third, the fundamental measurement within seismic data is impedance contrasts between velocity*density layers. High saturation gas hydrates and free gas inhabit opposite ends of these measurements making the study of this zone ideal for investigating the seismic characteristics of gas hydrate and, hence, the investigation of other seismic attributes that may indicate gas hydrate fill.





Galloway, et al., 2000





Chowdhury, 2009

Study Area in Eastern Gulf of Mexico
A) Location map
B) PlioPleistocene abyssal fan
C) Migration and accumulation of gas hydrate
D) Petroleum system example in Eastern GoM

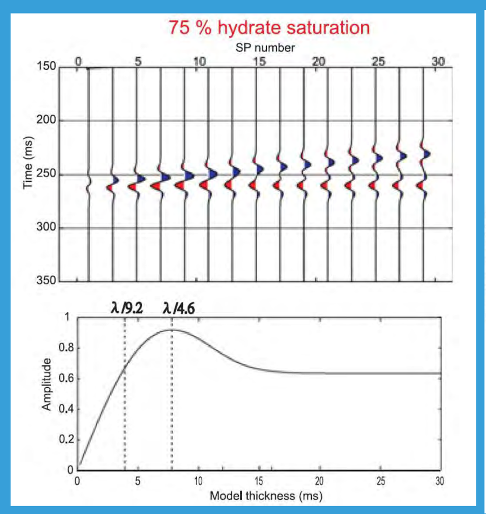
Most Gas Hydrate Deposits are Seismic Thin Beds

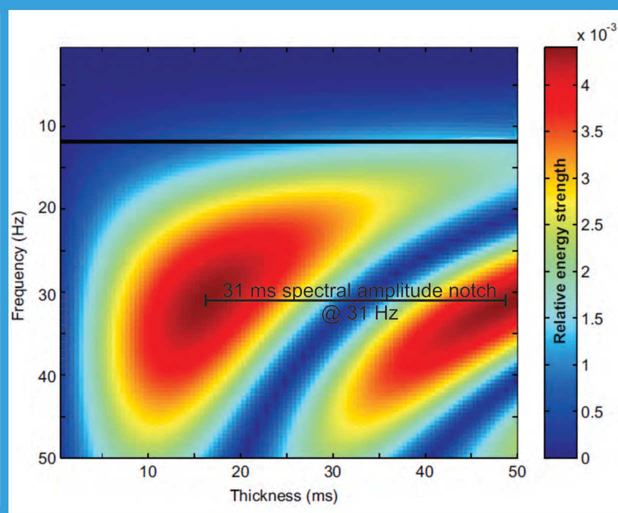
The "leading peak" anomaly at GC955 (seismic not shown here) is a thin bed response... as are most typical gas signatures near the BGHS

Two approaches using spectral decomposition for thin bed time-frequency analysis
a) Wedge model to find frequency notches (constructive-destructive interference curves) to determine thin bed thickness
b) Substitute first peak spectral frequency band with most constructive energy to approximate tuning frequency

Is the Thickness of GC955 H Gas Hydrate Deposit Predicted by Thin Bed Analysis?

Example Using the Wedge Model:



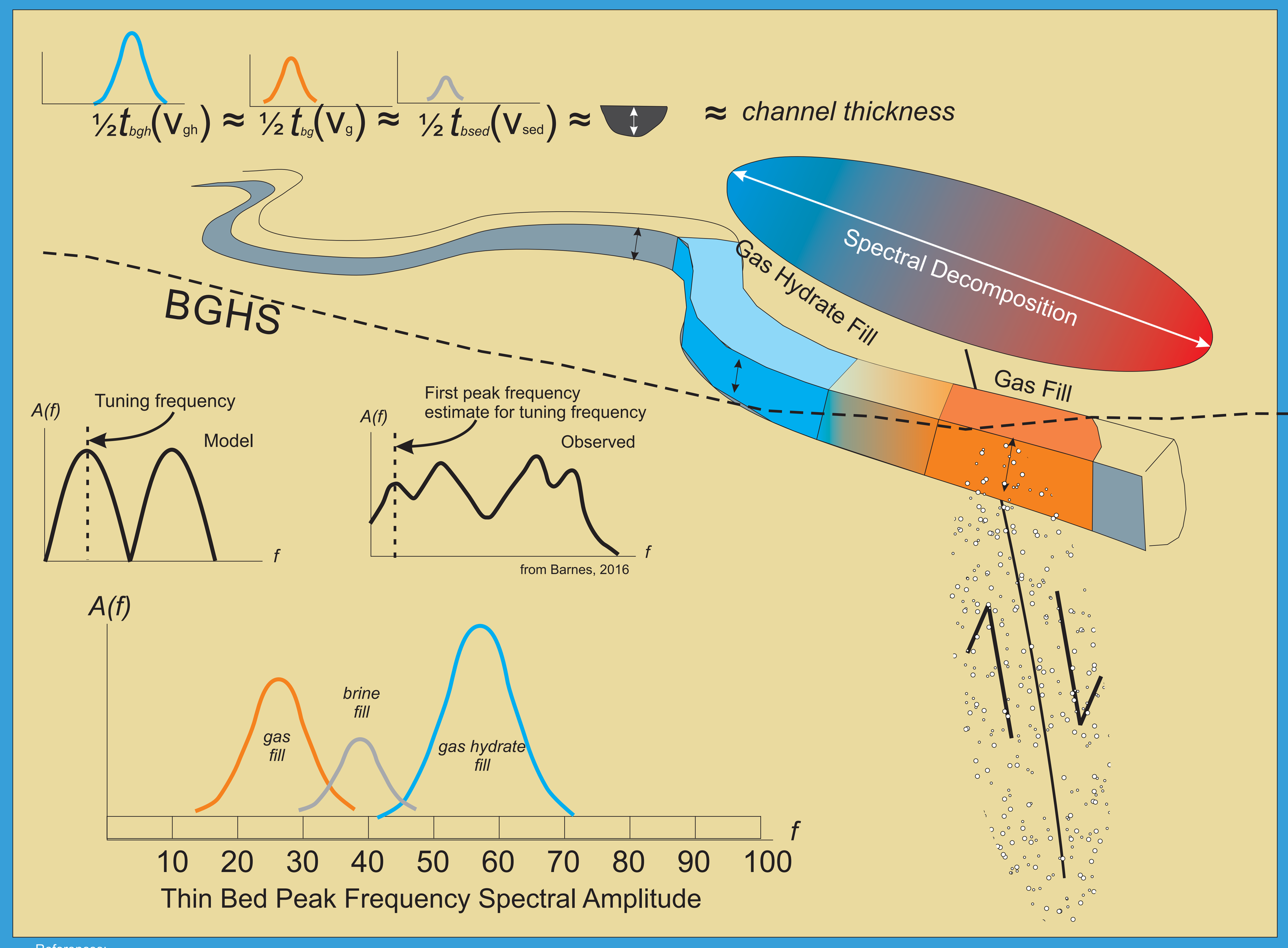


Modified from Zhang et al., 2012

Amplitude spectra for the 75% gas hydrate saturation model derived from the wedge model at GC 955 H.
Given Partyka (1999) that Pf = 1/t in which Pf is the period of frequency notching and t equals thin bed thickness in two-way travel time, then t= 1/0.031 = 32 ms TWT . The velocity within gas hydrate saturated sands at GC955 H is approximately 2600 m/s but the velocity of the non-gas hydrate bearing portions of the sand is 1600 m/s. A mean velocity through the entire 350 m sand, both the gas hydrate saturated portion of the sand and the brine portion of the sand is ~1800 m/s The resulting thin bed thickness from the spectral frequency model wedge is approximately 29 m which is consistent with the 30 m of ~75% saturation gas hydrate sand that was logged at the well (McConnell et al, 2009).

Can Frequency-Derived Thin Bed Thickness Suggest Hydrocarbon Fill?

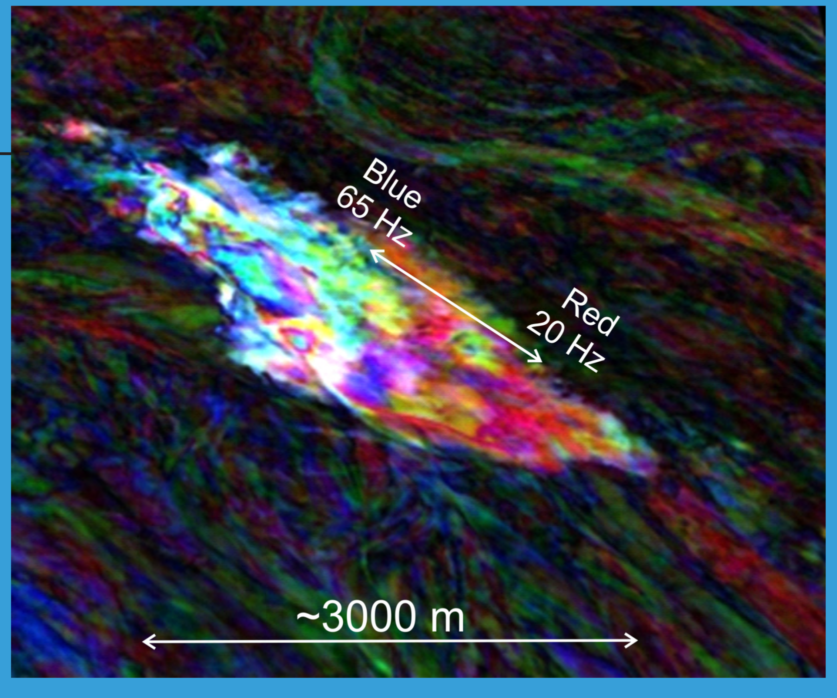
Example Using the Observed Model:



Spectral decomposition is primarily a tool to determine thin bed thickness. Using it in that strict way, the channel with gas hydrate is thinner in time than the channel with no hydrocarbon charge and the channel is thickest in time where is it gas filled.

One explanation is that gas hydrate deposition creates thin layers that are detected in spectral decomposition. Gas, on the other hand, will fill pore space more uniformly than gas hydrate and will be detected as a thicker layer in spectral decomposition.

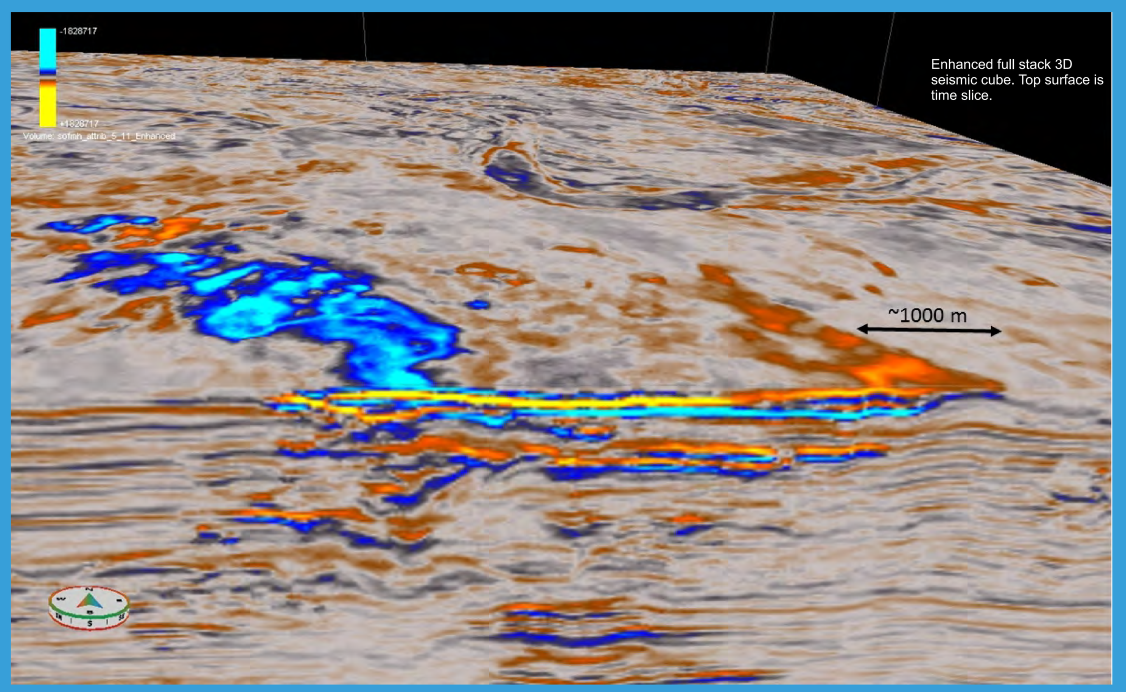
The substitution of velocities to the thin layer times for gas hydrate, brine, and gas, however, result in a channel of uniform thickness which is more likely.

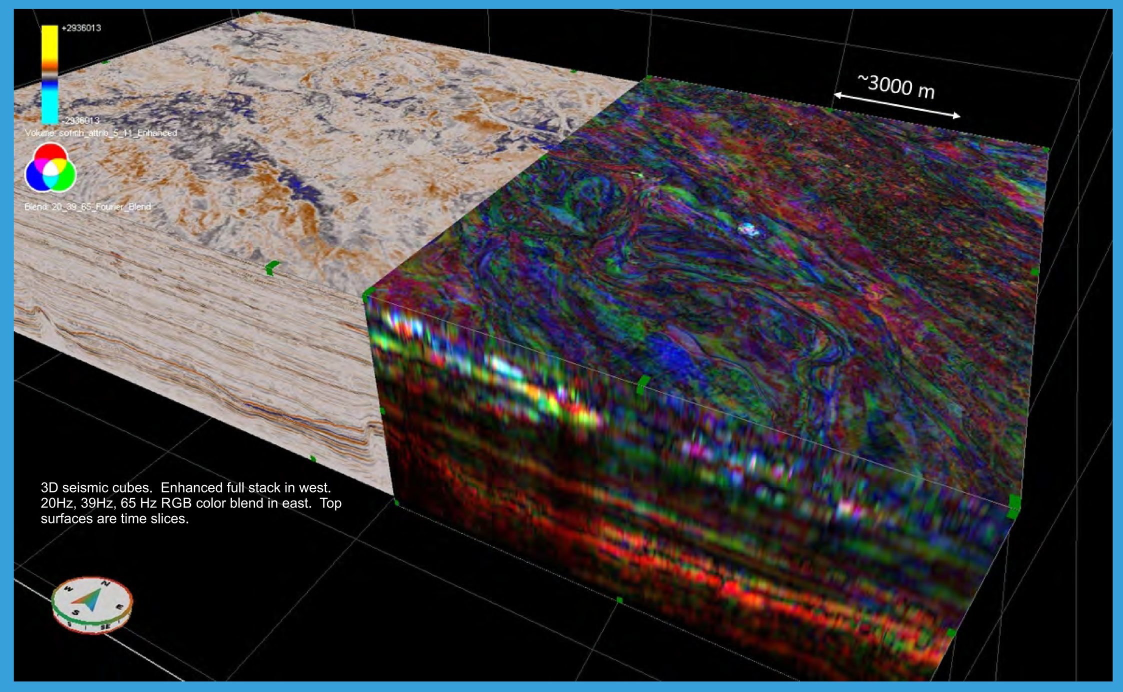


Amplitude Interpretation and Spectral Decomposition in Eastern GoM

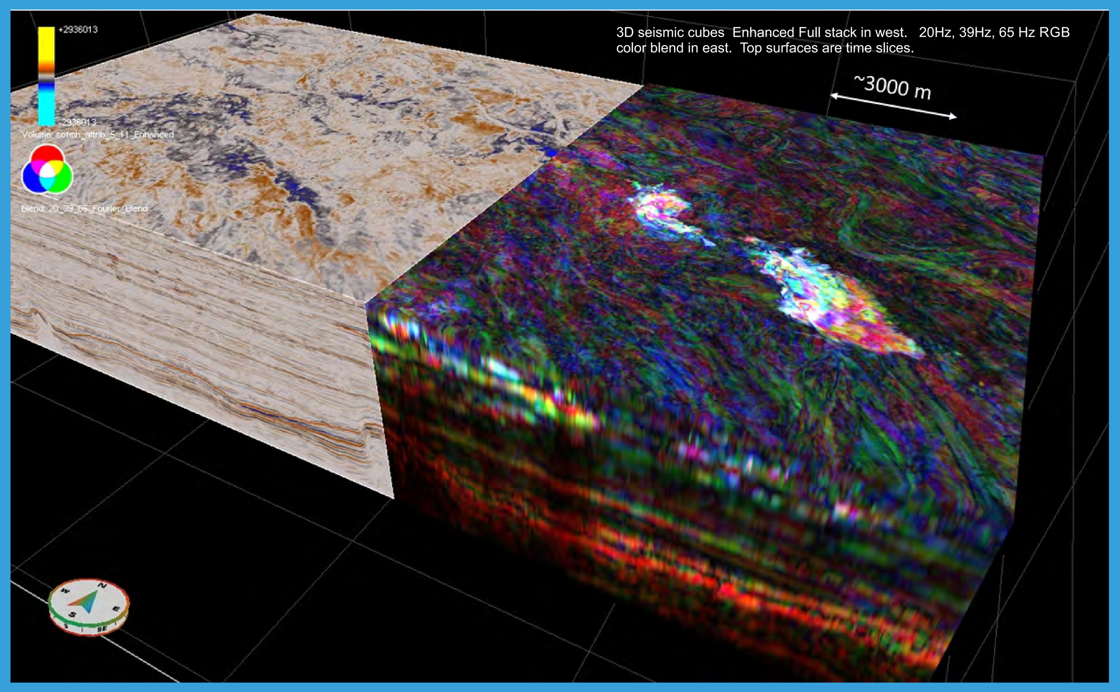
The gas hydrate seismic response is a "leading peak" thin bed similar to GC955 H. Essentially a phase reversal of a thin bed gas response.

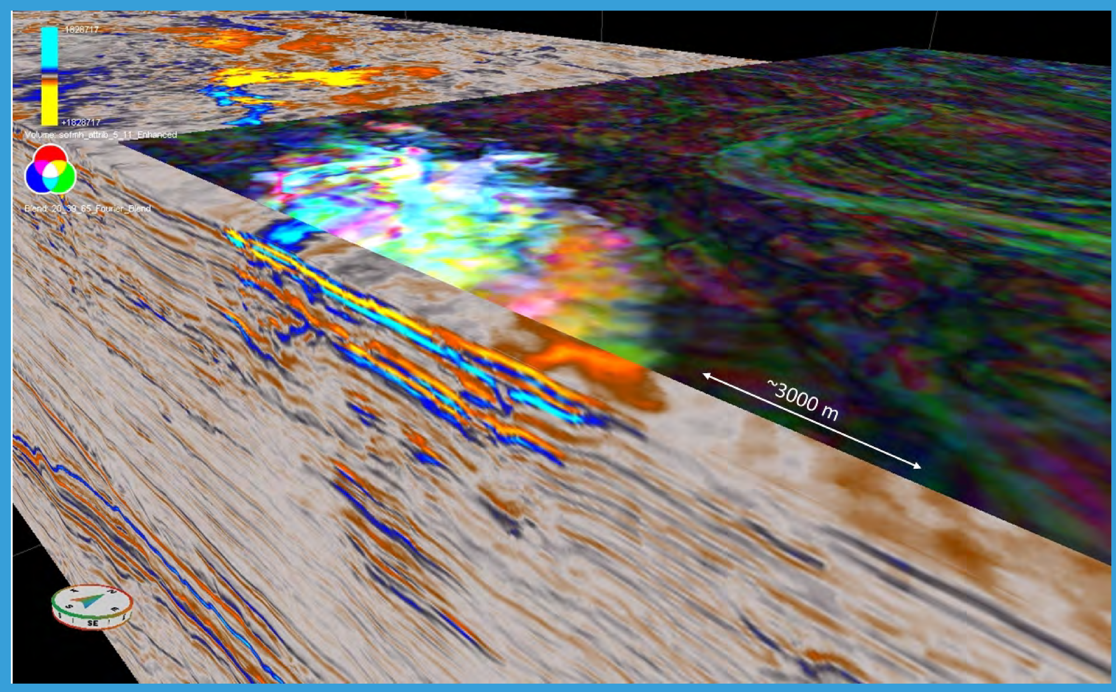
The "leading peak" anomaly transitions to a "leading trough" across the zone of hydrocarbon accumulation at the BGHS. RGB blend of 20 Hz, 39 Hz, and 65 Hz narrow band frequencies from Fourier transform shows abyssal channel fan deposits of consistent widths and thicknesses.





RGB blend of 20 Hz, 39 Hz, and 65 Hz narrow band frequencies from Fourier transform shows high frequency dominance in the interpreted gas hydrate deposit and low frequency dominance in the gas leg.

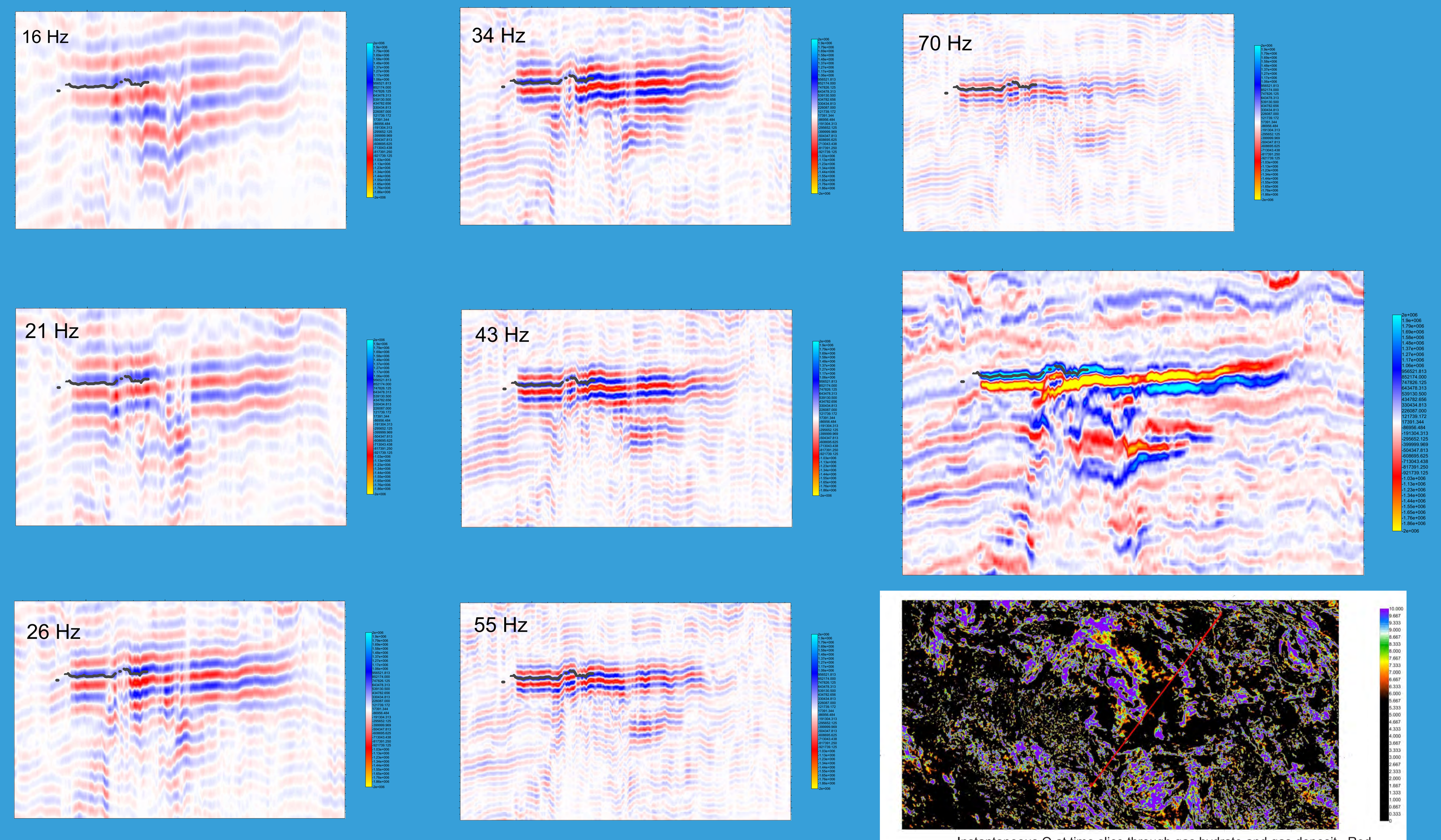




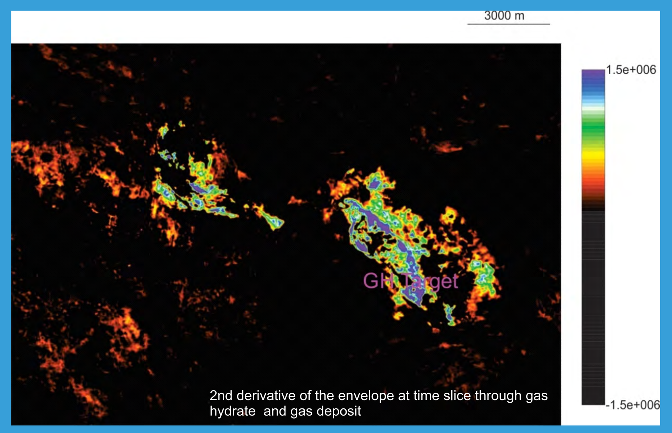
What Other Seismic Attributes Help Detect High Saturation Gas Hydrate in Sands?

Second derivative of the envelope shows the rate of the rate of change of total instantaneous energy. It will show high energy thin layers within the seismic bandwidth.
Instantaneous Q is a post-stack frequency attribute that can show the decay of frequency that can be an indicator of attenuation.
Instantaneous Q shows contiguous low values (attenuation) beneath both the gas hydrate and gas deposits.

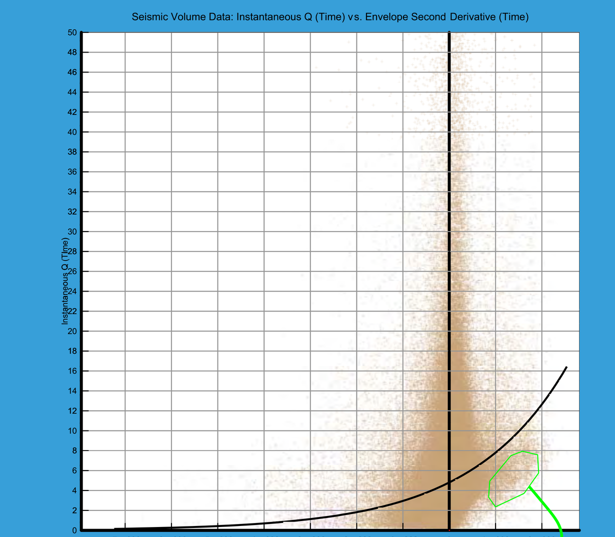
Crossplots of high positive values of 2nd derivative of envelope and low values of Instantaneous Q correlate to the gas hydrate deposits.

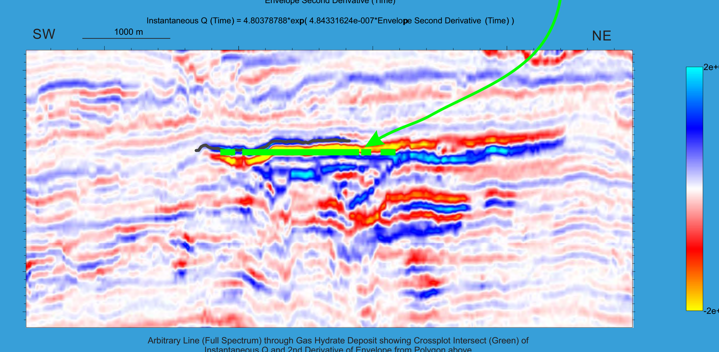


Instantaneous Q at time slice through gas hydrate and gas deposit. Red line is location of arbitrary lines through full stack and spectral reflectivity



2nd derivative of the envelope at time slice through gas hydrate and gas deposit





References:
Barnes, A. E., 2016, Handbook of poststack seismic attributes. Geophysical References Series No. 21, Harvey, E. L., and R, Latimer eds., Society of Exploration Geophysicists, Tulsa, OK, 254 p.
Chowdhury, A., 2009, Salt geology and hydrocarbon plays in the northeastern Gulf of Mexico: American Association of Petroleum Geologists Search and Discovery Article 10215, 9 p., www.searchanddiscovery.net/documents/2009/10215chowdhury/images/chowdhury.pdf.
Galloway, W. E., P. E. Ganey-Curry, X. Li, and R. T. Buffler, 2000, Cenozoic depositional history of the Gulf of Mexico basin: AAPG Bulletin, v. 84, no. 11, p. 1743-1774
McConnell, D., R. Boswell, T. Collett, M. Frye, W. Shedd, G. Guerin, A. Cook, S. Mrozewski, R. Dufrene, and P. Godfriaux, 2009, Proceedings of the Drilling and Scientific Results of the Gulf of Mexico Gas Hydrate Joint Industry Project Leg II: Green Canyon 955 Site Summary: https://www.netl.doe.gov/File%20Library/Research/Oil-Gas/Methane%20Hydrates/JIPLegII_GC955SiteSum.pdf
Partyka, G., J. Gridley, and J. Lopez, 1999, Interpretational implications of spectral decomposition for reservoir characterization, The Leading Edge, v. 18, I. 3, p. 353-360
Taner, T., 2003, Attributes revisited, http://www.rocksolidimages.com/attributes-revisited/
Zhang, Z., D. McConnell, and D. Han, 2012. Rock physics based seismic trace analysis of unconsolidated sediments containing gas hydrate and free gas in Green Canyon 955, Gulf of Mexico. J. Marine and Petroleum Geology 34 (1), p.119-133.

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