Understanding Seismic Detection and Resolution of High-Frequency Sequences and Systems Tracts*

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Abstract

Seismic mapping of stratigraphy can do better than the resolution limit (a quarter wavelength). For example, seismic geomorphology may resolve a feature normally detectable only in the vertical dimension. The vertical detection limit for horizontal resolution can be defined as an extension of Rayleigh's criterion for resolution limit, in which an event from a bed, not a surface, is visually separated from other events.

We can quantify detection limit by analyzing the configuration of seismic events that correspond to an acoustically converted stratigaphic profile through various frequency bands, or an Event versus Frequency (EVF). An EVF plot reveals seismic interference patterns, thickness tuning range, and what would be expected to see in seismic data of different frequency bands. Generally speaking, in the high-frequency range, the top and base of a unit are resolved, and amplitudes of an event are proportional to impedance contrast. In data of moderate frequency, the unit is detected but not resolved, and thickness tuning may dominate, with amplitudes varying with thickness. In the low-frequency range, the unit fails to be detected, its seismic responses merging with other events, and its identity becoming lost.

Each stratigraphic profile is different, and the detection limit may vary from one high-frequency sequence to another. By analyzing EVF's from field data at well sites, we can determine the detection range of field seismic data and how it compares with what is required for mapping high-frequency sequences and systems tracts. Proper data conditioning based on this analysis might significantly improve the study of high-frequency sequence stratigraphy.

Understanding Seismic Detection and Resolution of High-Frequency Sequences and Systems Tracts

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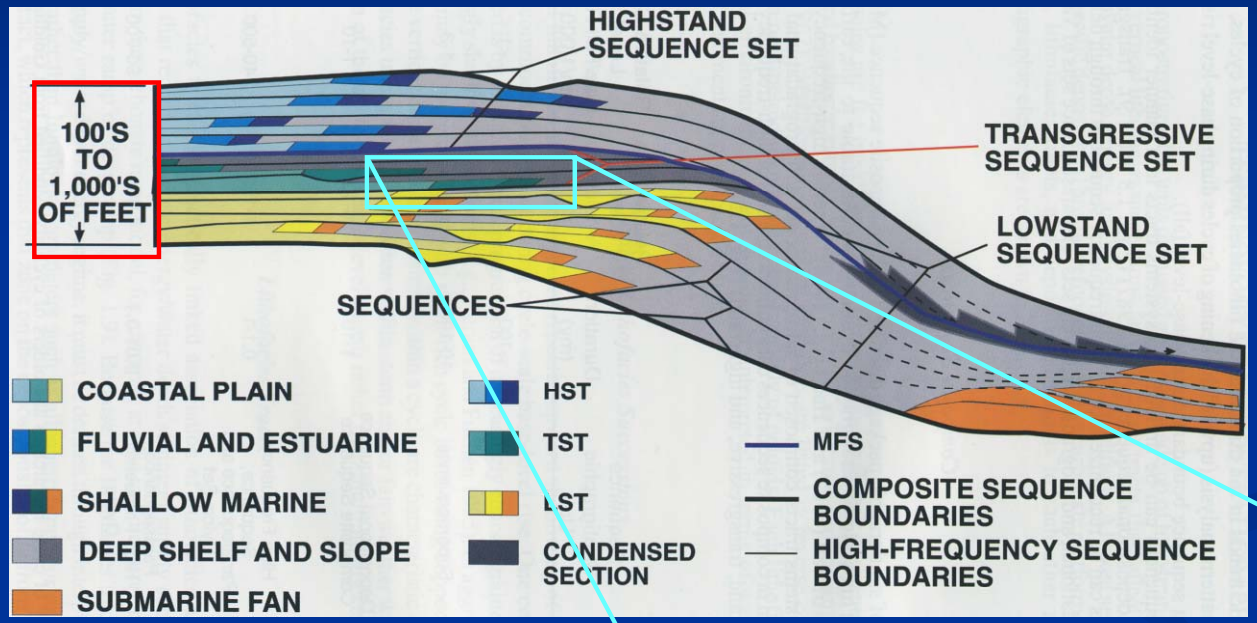
April 22, 2008

Outline

1. Challenges in high-frequency sequence stratigraphy
2. Two different concepts of seismic resolution
3. Amplitude-versus-frequency analysis
4. Case study

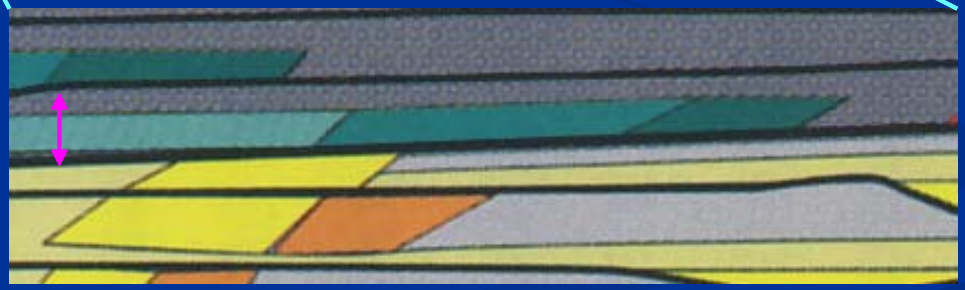
Scale of sequence stratigraphy (model)



Kerans and Tinker (1997)

3rd-order sequence

TENS TO HUNDREDS OF FEET

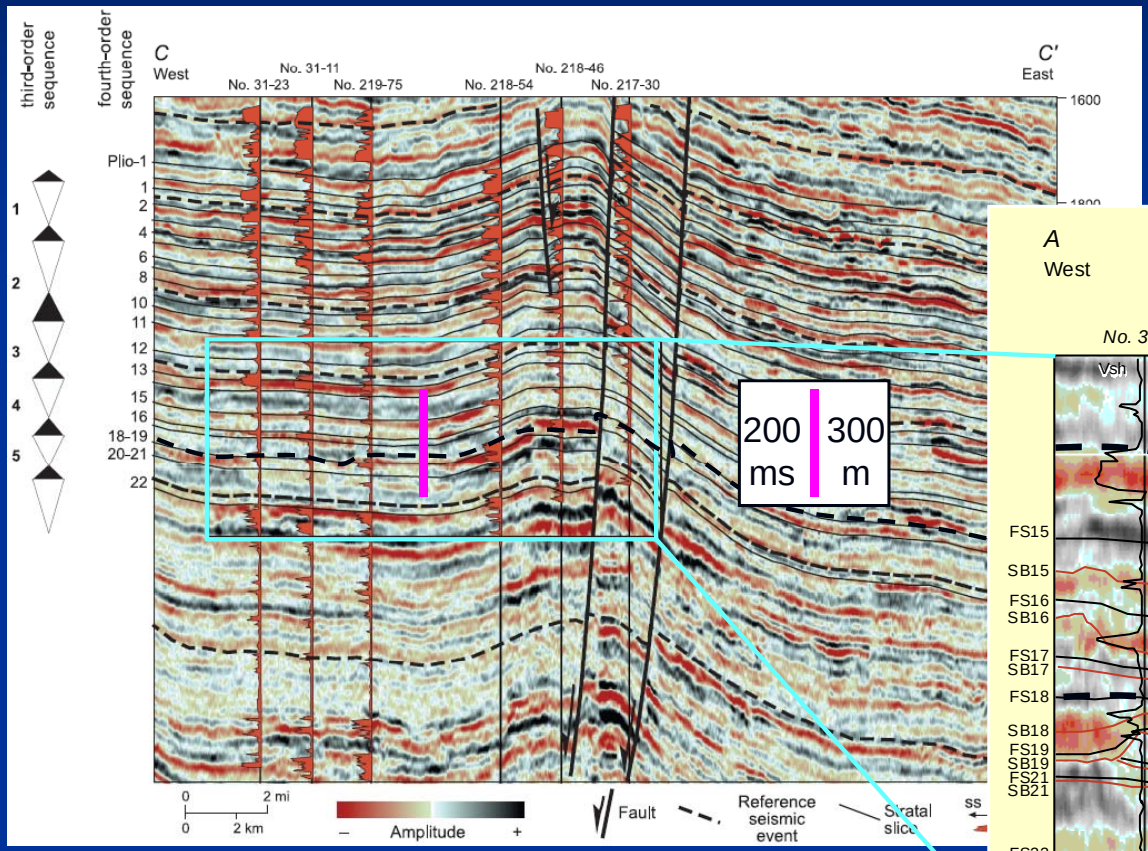


4th- and higher-order sequence

We have a resolution issue here!

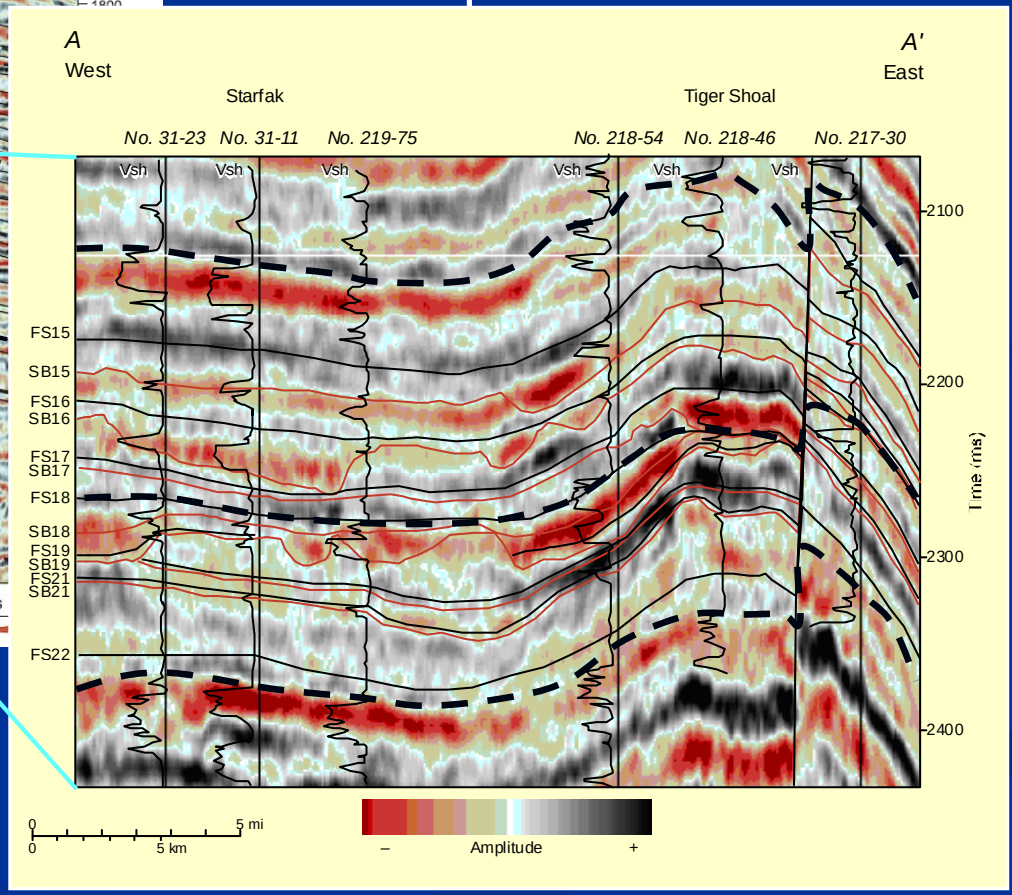
Scale of sequence stratigraphy (data)

Tiger Shoal, Offshore LA



7 fourth-order sequences

2 third-order sequences



From Zeng and Hentz (2004)

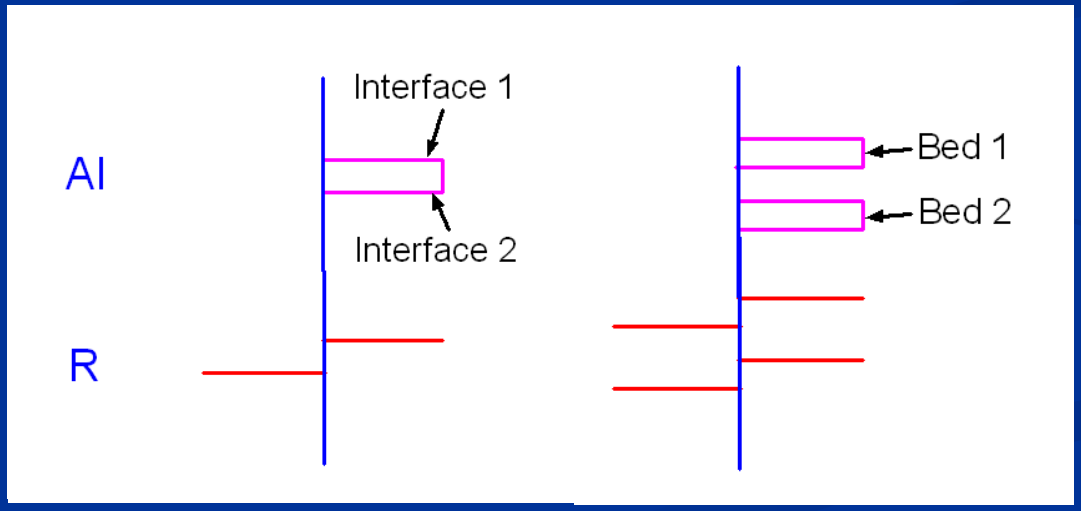
Challenges

1. What is the practical limit of seismic resolution?

2. How can seismic data be reconditioned for the best possible resolution?

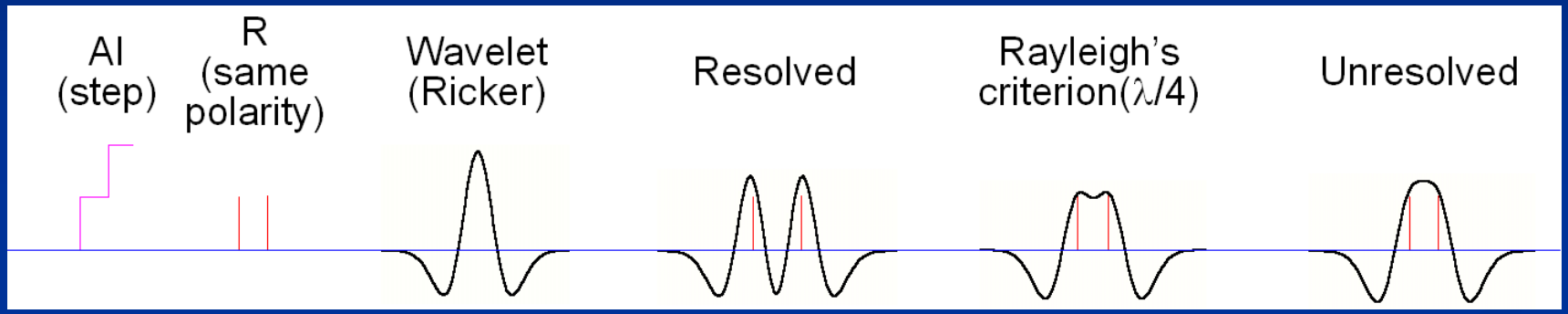
Two concepts of resolution

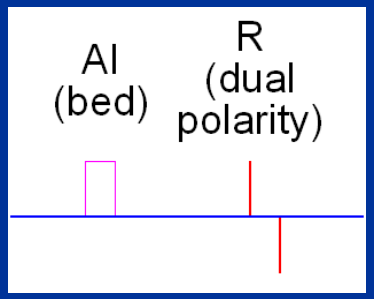
1. Interface resolution (IR)
2. Bed resolution (BR)

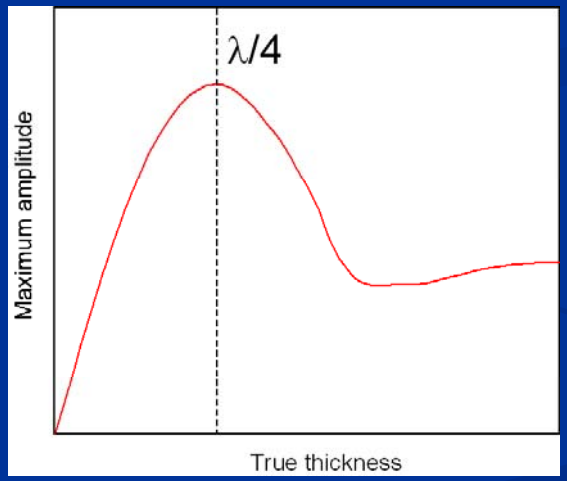


Interface resolution (industry standard)

Rayleigh's criterion (Kallweit and Wood, 1982)





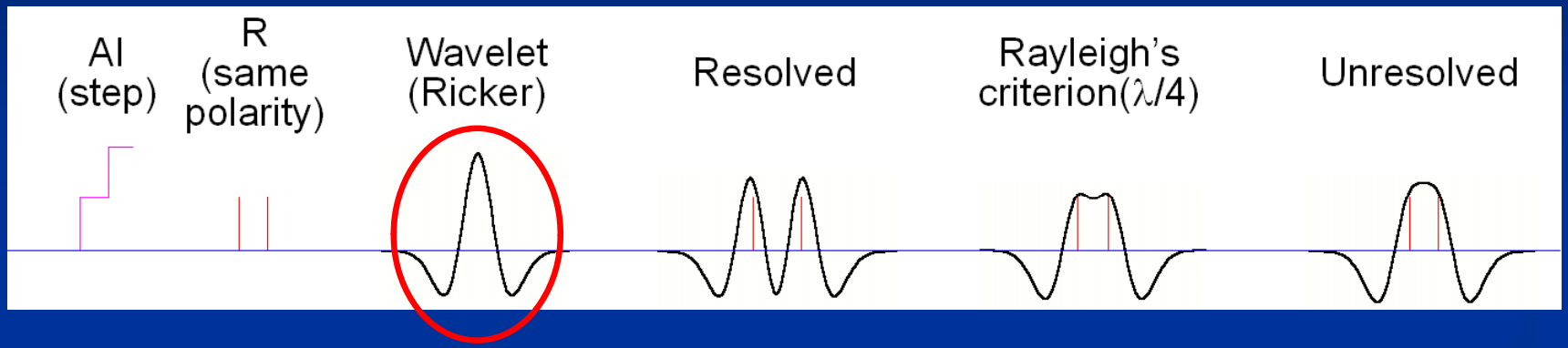


IR = λ/4

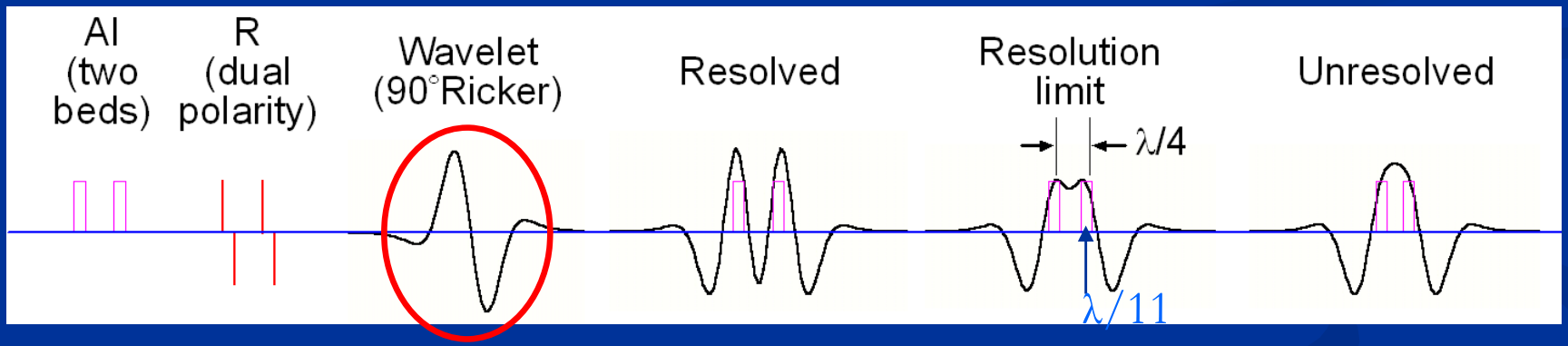
= 20 m (2-way, 25 Hz at 4000 m/s)

Bed resolution (this study)

Rayleigh's criterion (Kallweit and Wood, 1982)

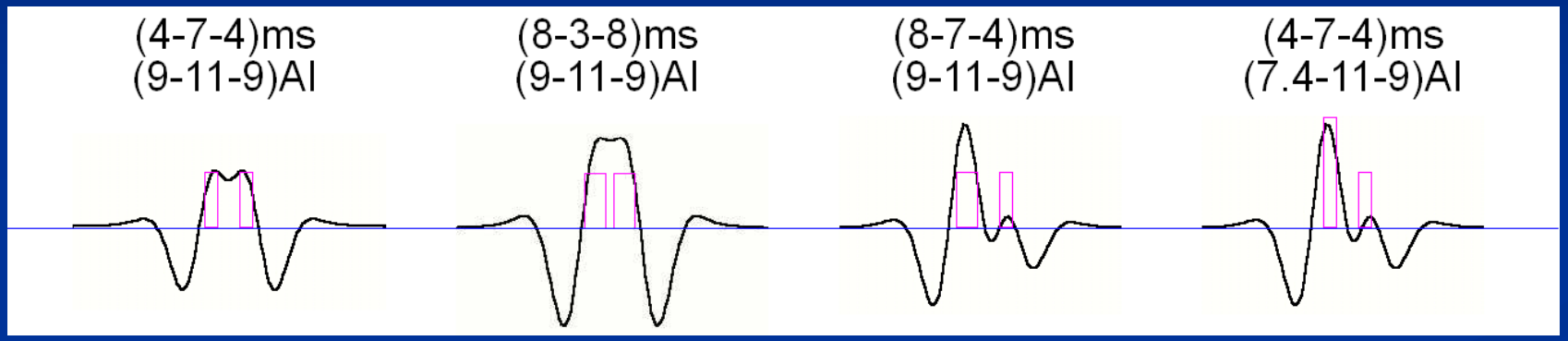


Expanding Rayleigh's criterion



Bed is better resolved than interface!

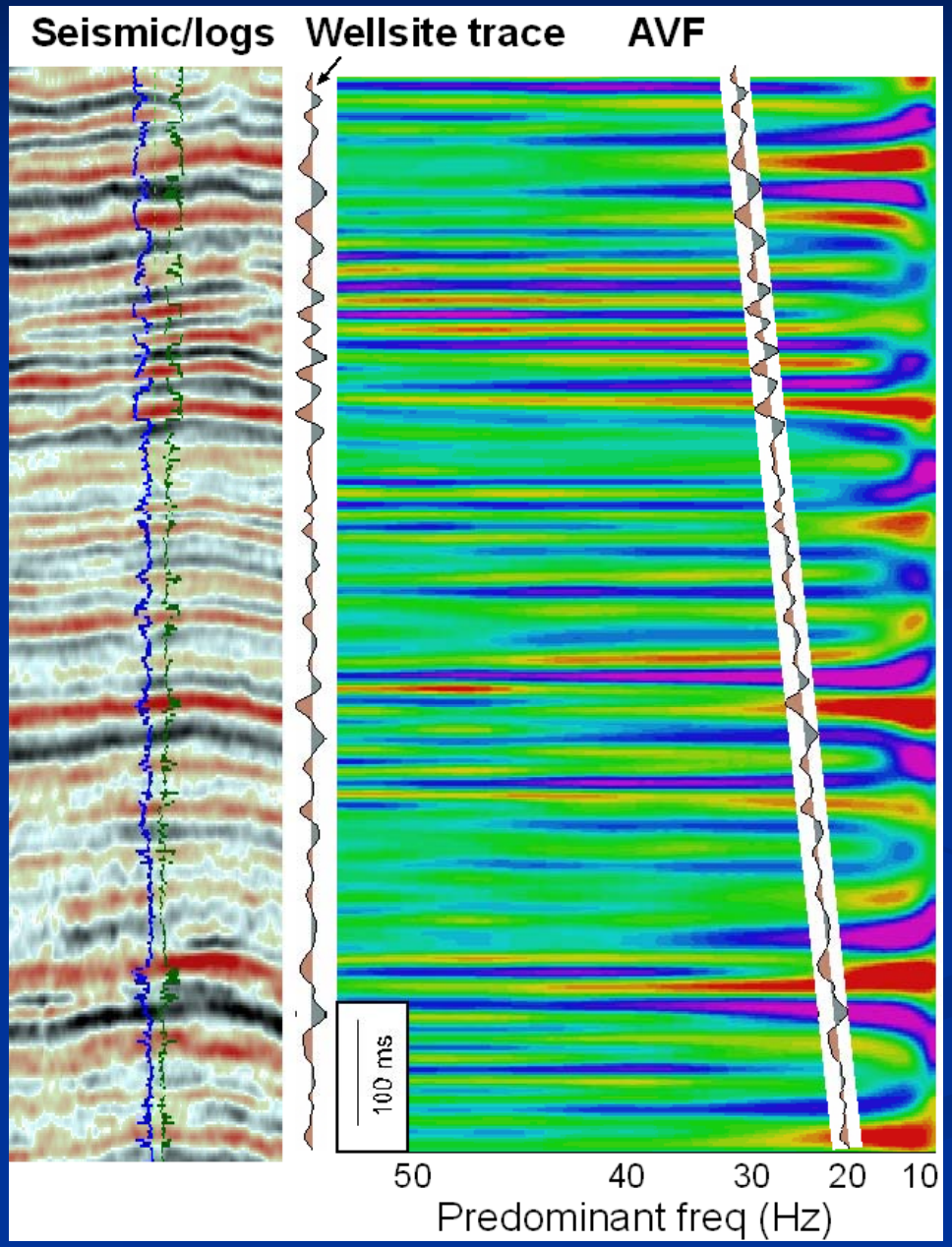
Factors that control BR (30 Hz, 90° Ricker)



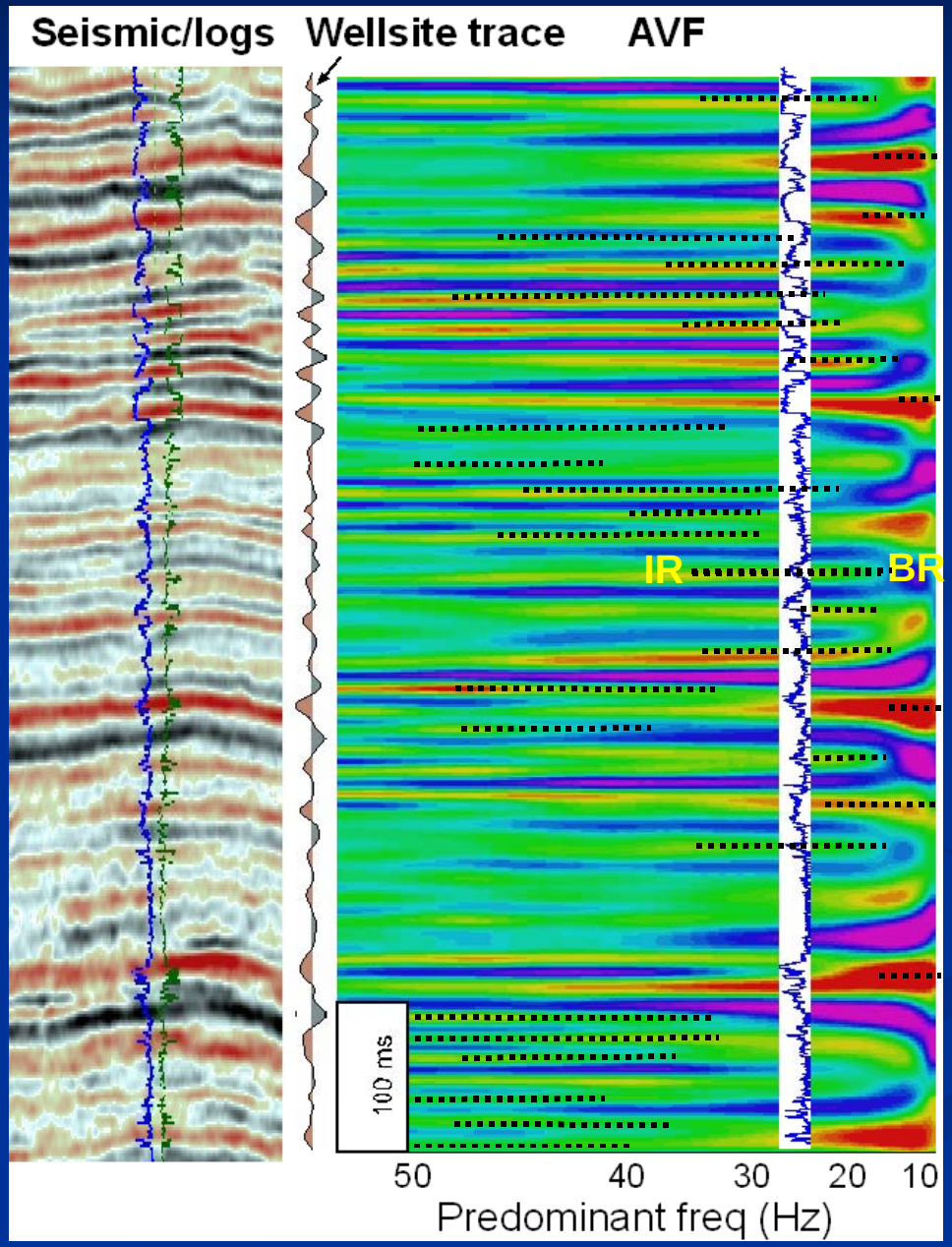
1. Bed-thickness ratio (sand-shale-sand)
2. Impedance (AI) profile (sand-shale-sand)

BR is -a variable
-a function of stratigraphy
-site specific

Tool: amplitude-versus-frequency (AVF)

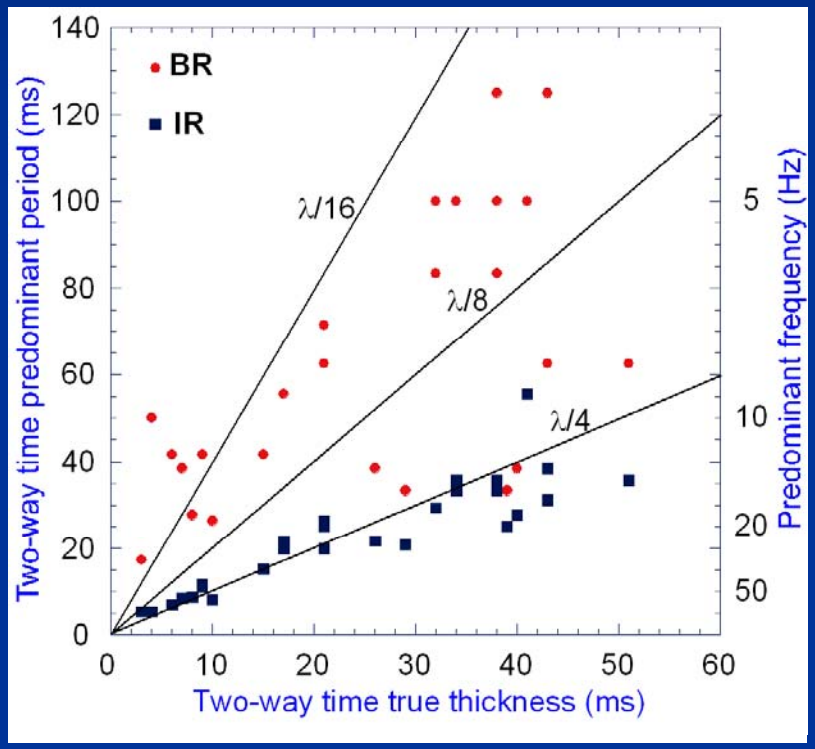


Defining BR and IR from AVF

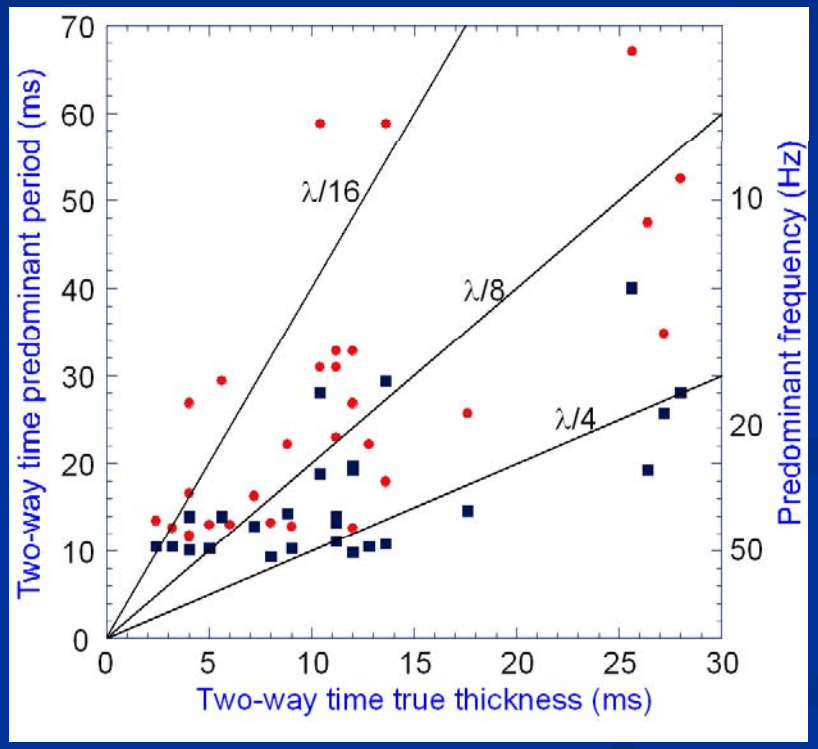


Improving seismic resolution

From model



From field data



IR = λ/4
= 20 m (2-way, 25 Hz at 4000 m/s)

BR = λ/16
= 5 m

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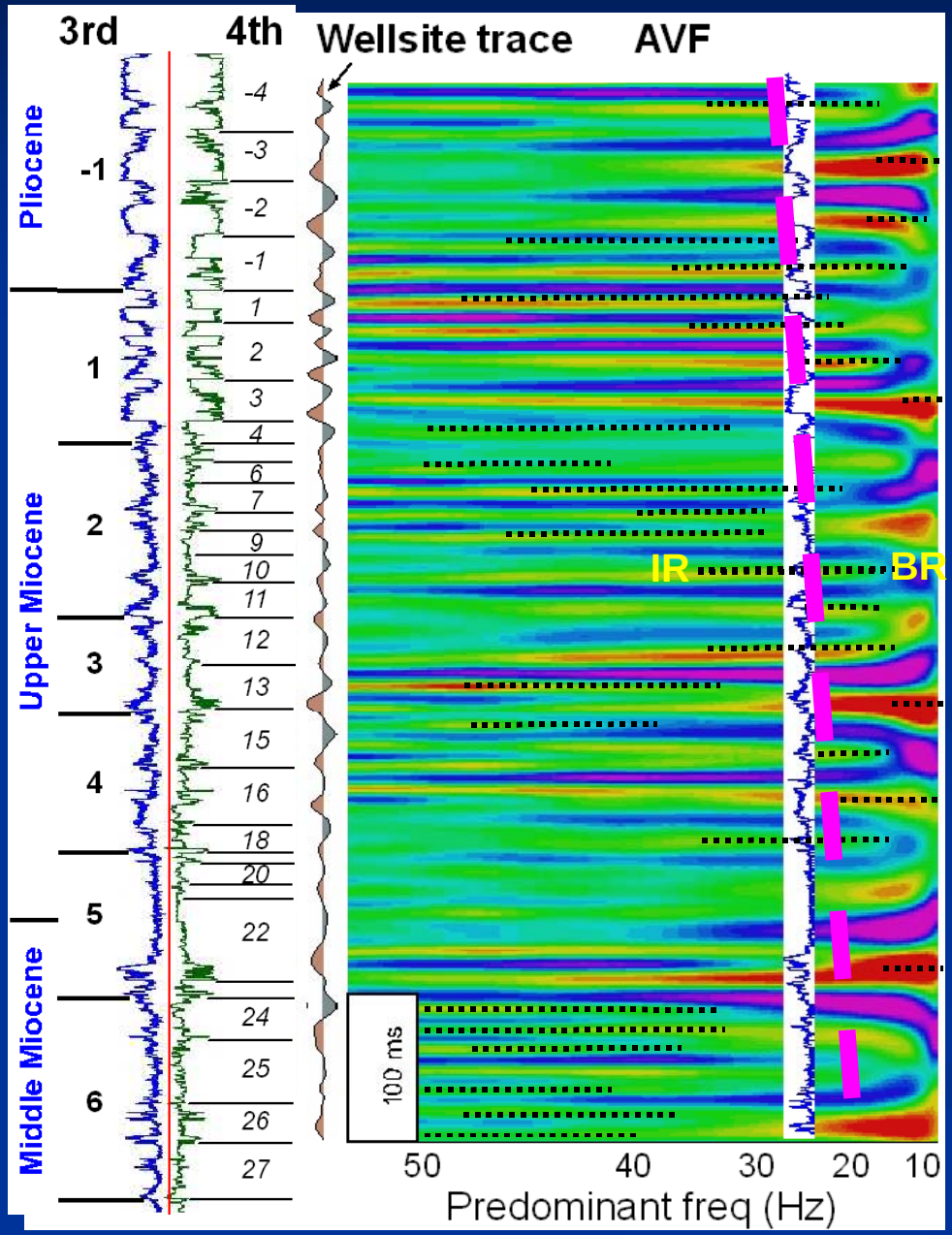
JACKSON SCHOOL OF GEOSCIENCES

Potential applications

1. Seismic correlation of high-frequency sequences
2. High-resolution imaging of systems tracts/facies
3. Prediction of thin-bed thickness
4. Attenuation/gas effect

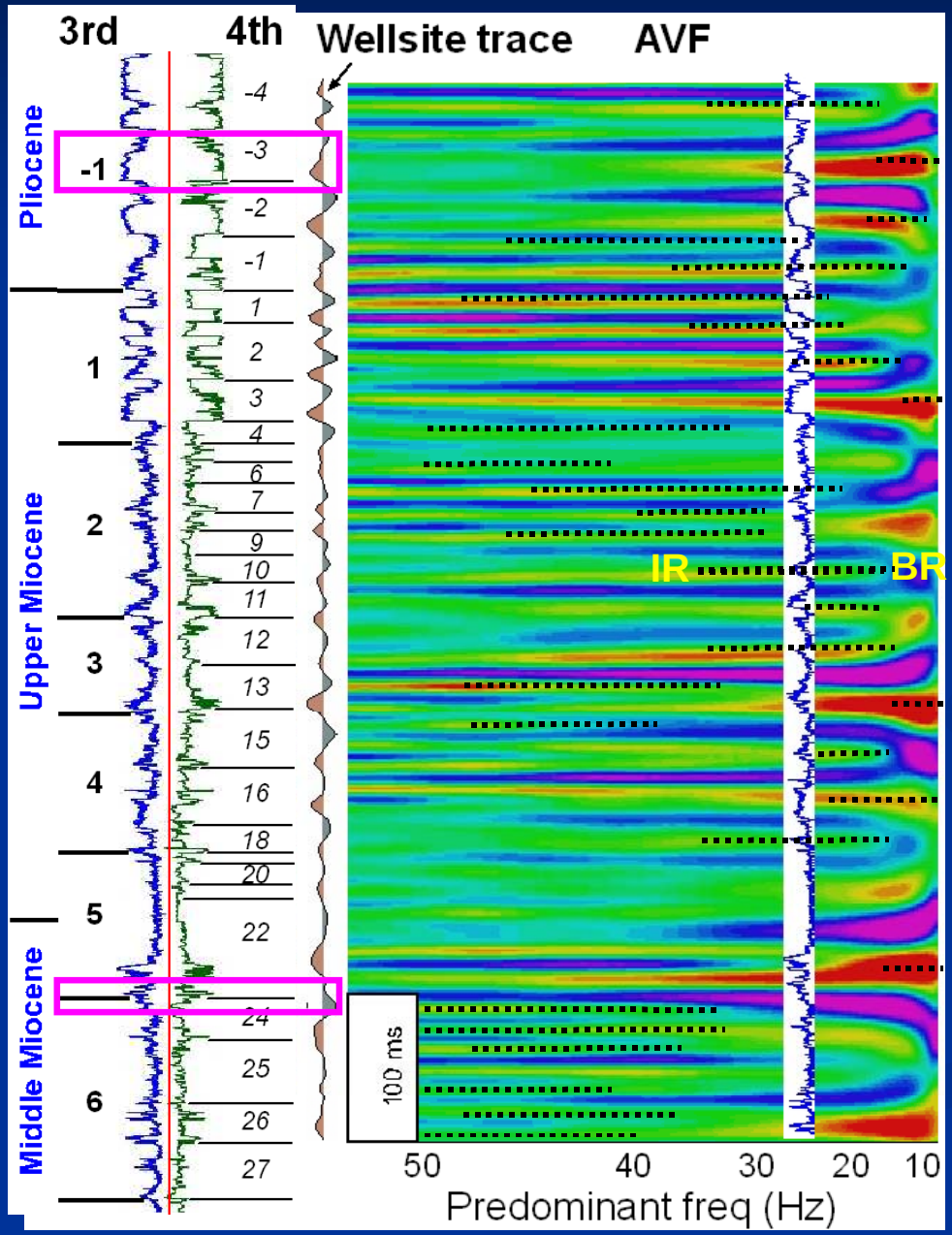
What does an AVF tell us?



- Resolution in BR and IR
- Limit of poststack data
- Increase of information with AVF processing
- How to improve interpretation?

Based on Hentz and Zeng (2003)

Improving sequence stratigraphic study



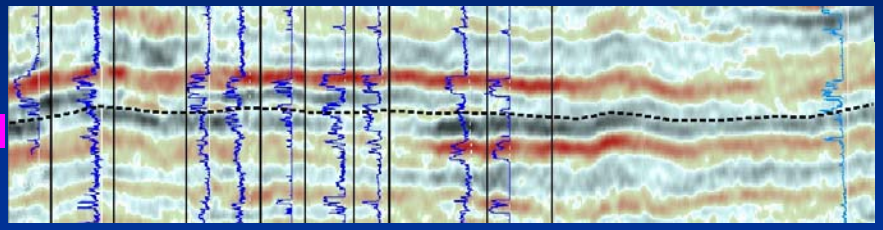
Lower frequency for facies imaging (thick unit)

Higher frequency for sequence correlation (thin unit)

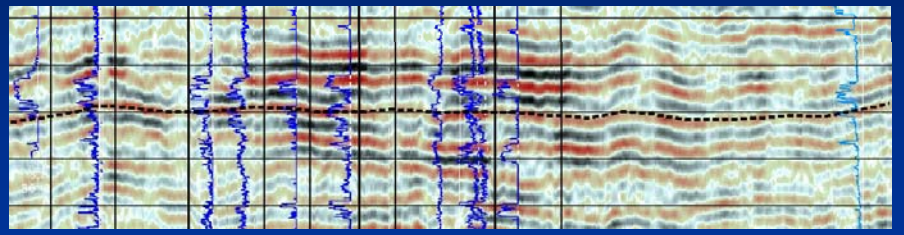
Based on Hentz and Zeng (2003)

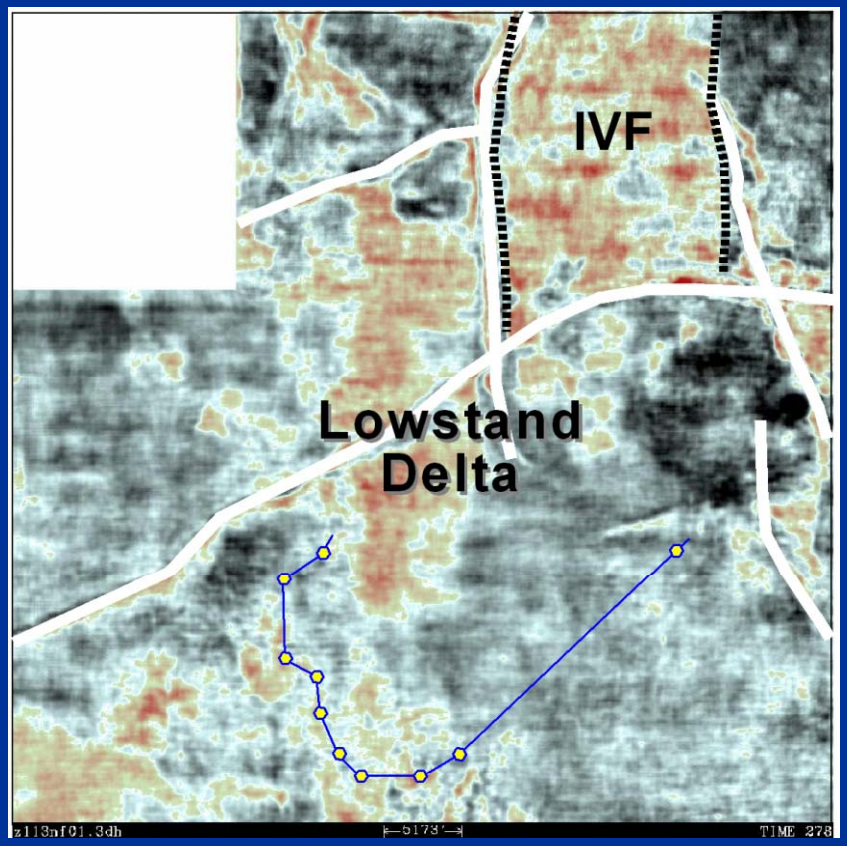
Improving sequence correlation by high-frequency extraction (Seq 23)

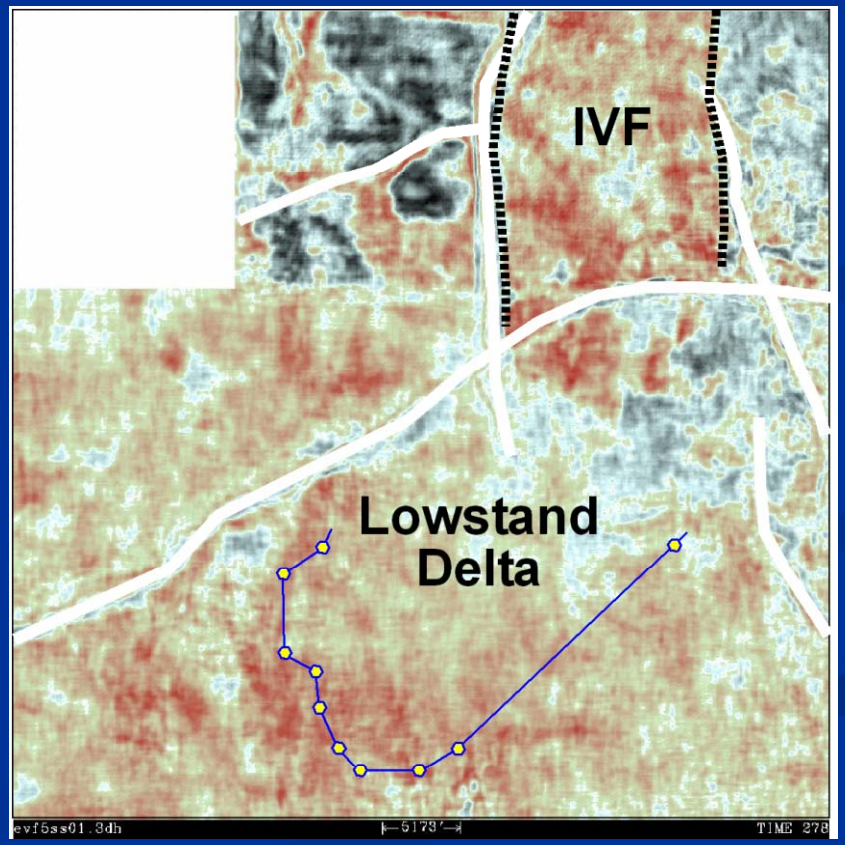
Original data (22 Hz)



High-frequency data (40 Hz)

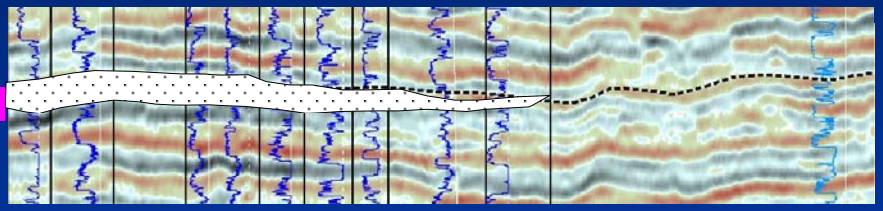




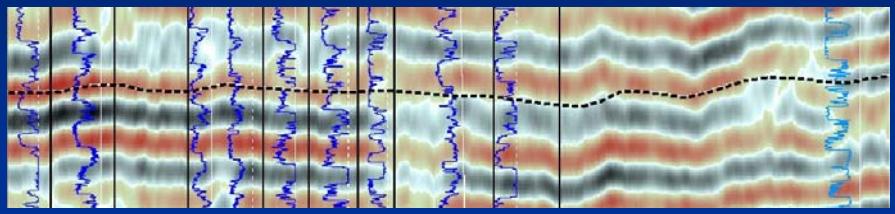


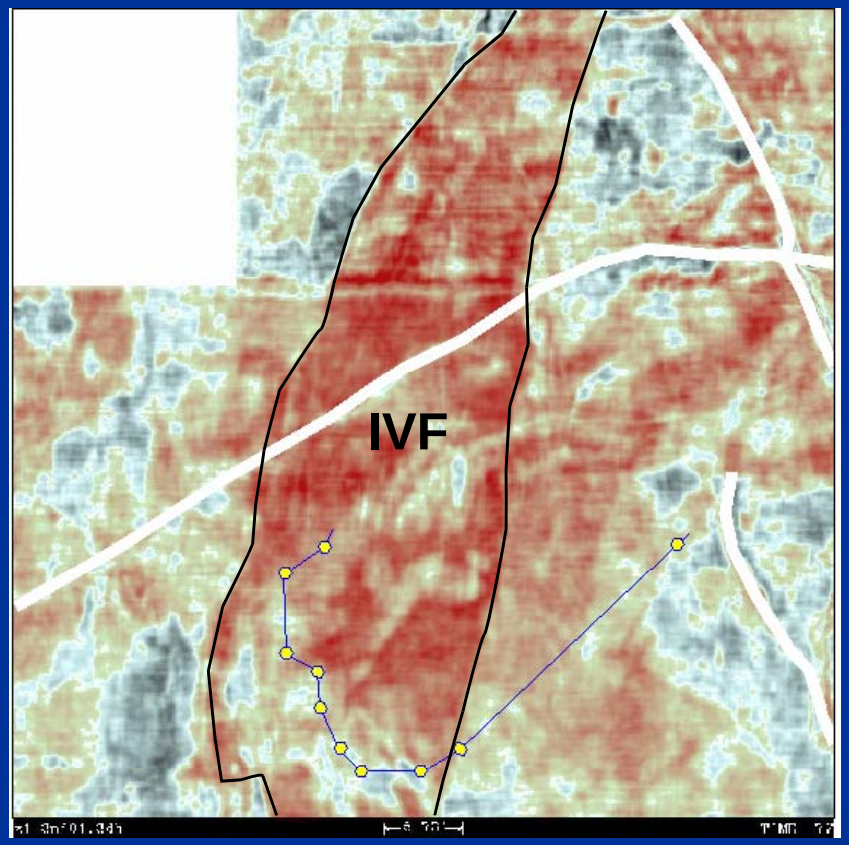
Improving imaging of systems tracts by low-frequency extraction (Seq 3)

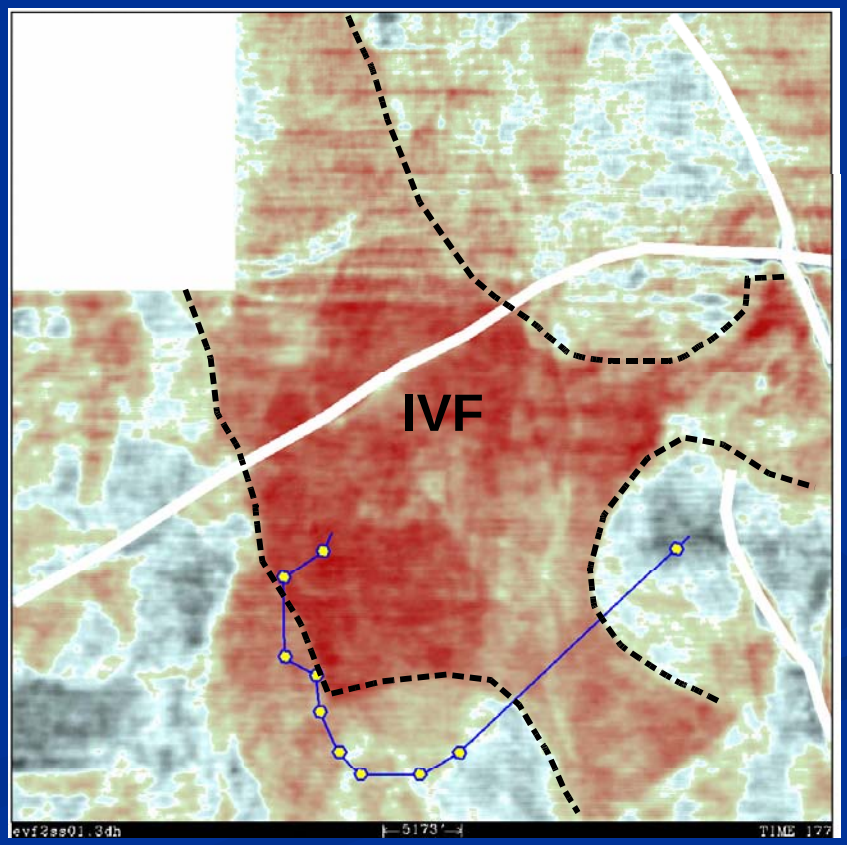
Original data (30 Hz)



Low-frequency data (15 Hz)

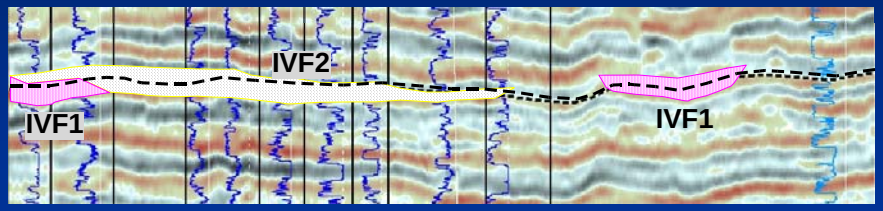


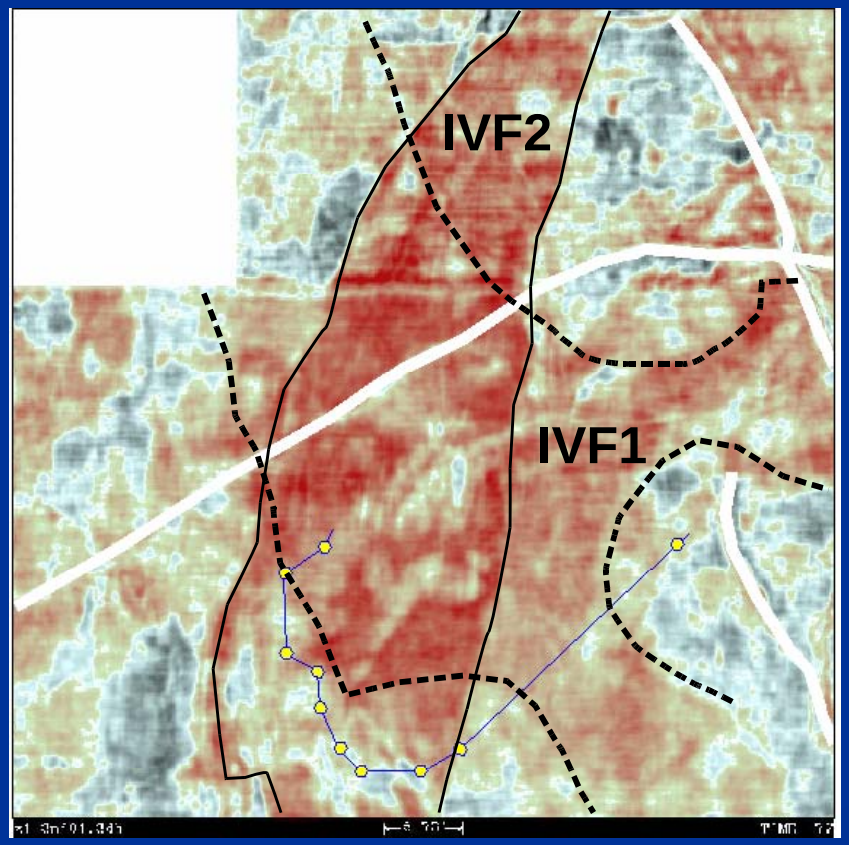




Improving imaging of systems tracts by low-frequency extraction (Seq 3)

Original data (30 Hz)





Conclusions

1. We can do better than $\lambda/4$!
2. We have to recondition seismic data for added resolution.
3. AVF and phase shift are practical tools.

Acknowledgments

1. Texaco Inc. (now Chevron) provided well/seismic data

2. Landmark Graphics provided seismic interpretation software

3. Publication authorized by the Director of BEG.

Selected References

Hentz, Tucker F., and Hongliu Zeng, 2003, High-frequency Miocene sequence stratigraphy, offshore Louisiana: Cycle framework and influence on production distribution in a mature shelf province: AAPG Bulletin, v. 87, p. 197-230.

Kallweit, R.S. and L.C. Wood, 1982, The limits of resolution of zero-phase wavelets, Geophysics, v. 47, p. 1035.

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