Wavelet reservoir ID – calibration and application

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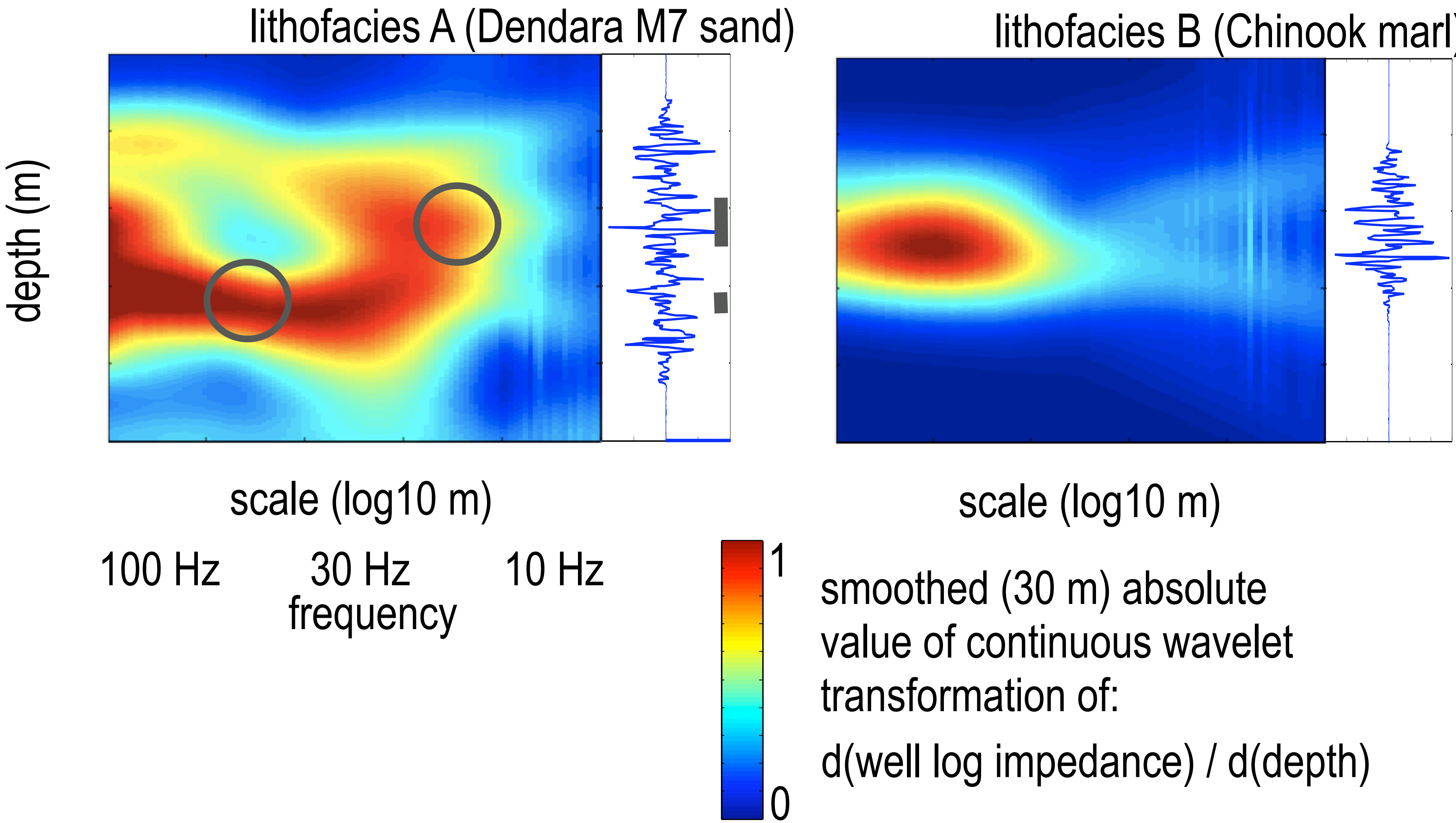
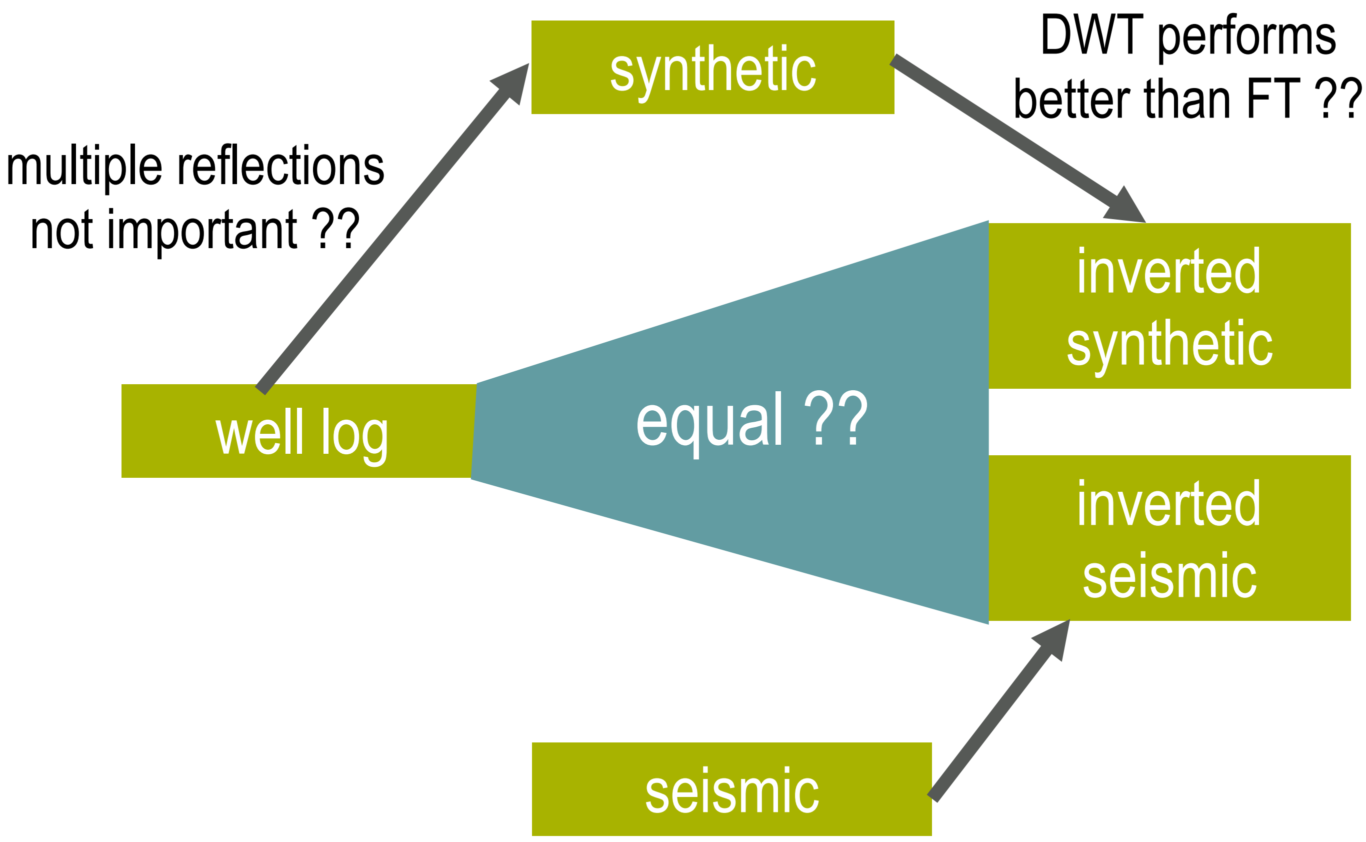
Questions for us to answer

- Is there more information in our seismic data?
  - Another constraint
- Can we find the science behind “attributes”?
  - Forward and inverse model
  - Quantitative
  - AVO analysis vs. amplitude attributes
- Does it work on real life cases?
  - Brunei (Vivaldi and Mozart)
  - GOM (Frampton, Cascade and Chinook)
  - Brazil (BMC-10)

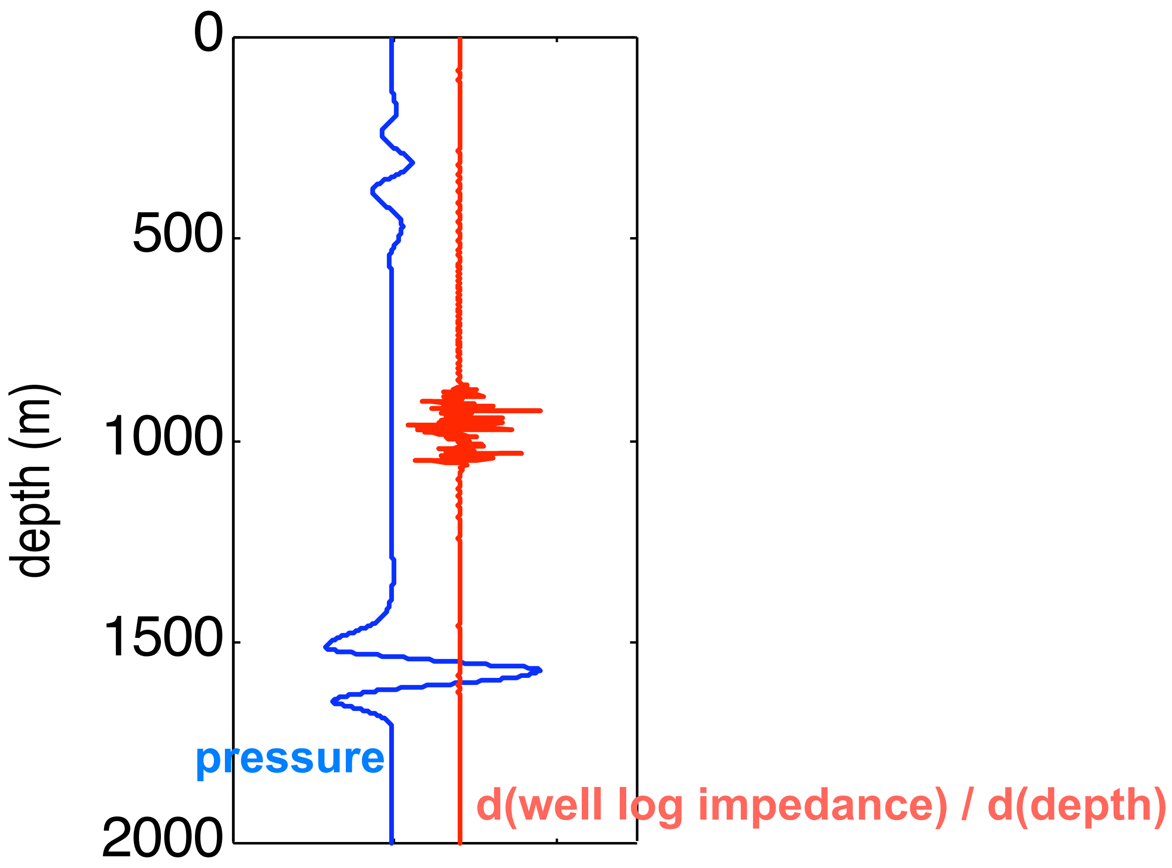
There is multiscale structure in seismic reflectors, can we detect it?



Development of a forward and inverse model



Forward acoustic model is used



Multiple reflections can be neglected enabling a linear inverse model

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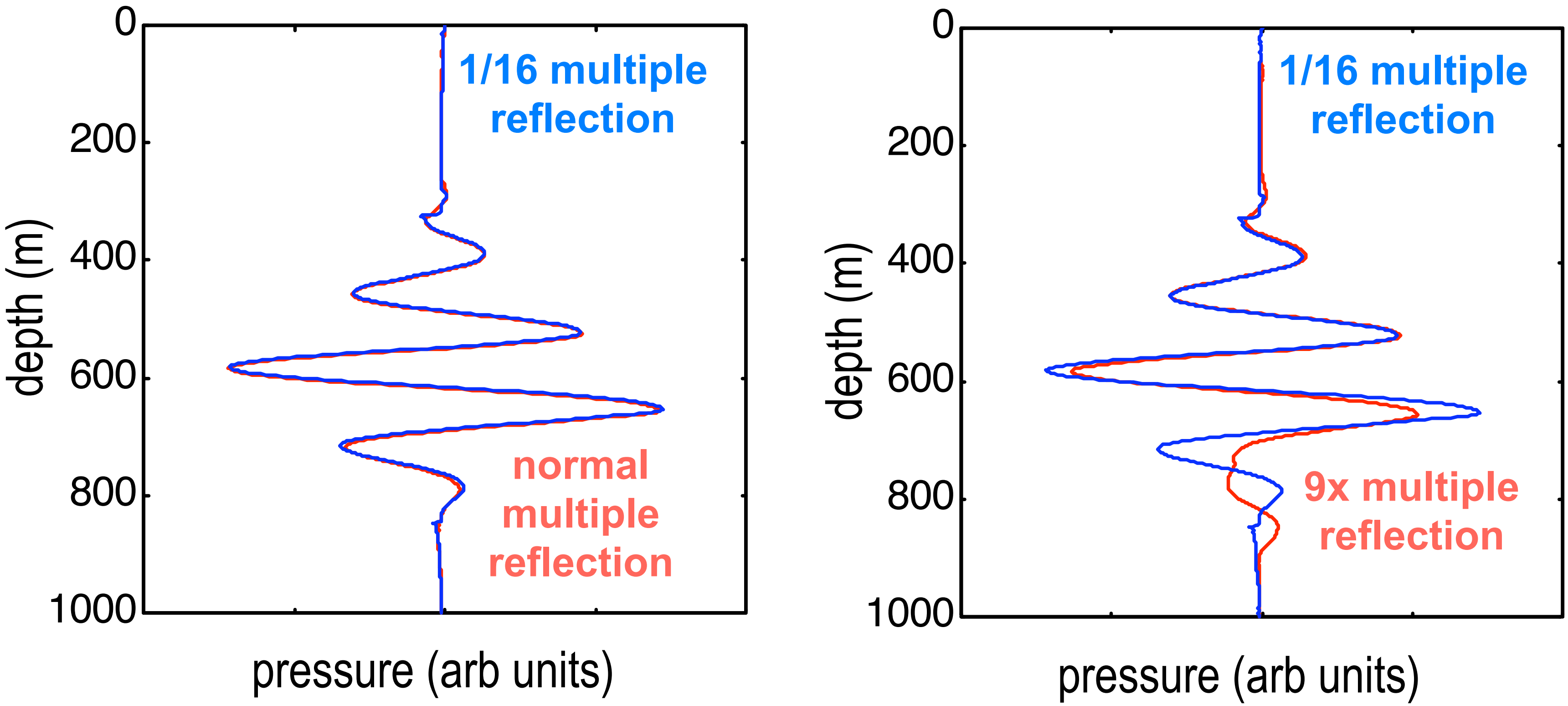

Discrete wavelet transform is a better implementation of inverse model than FT

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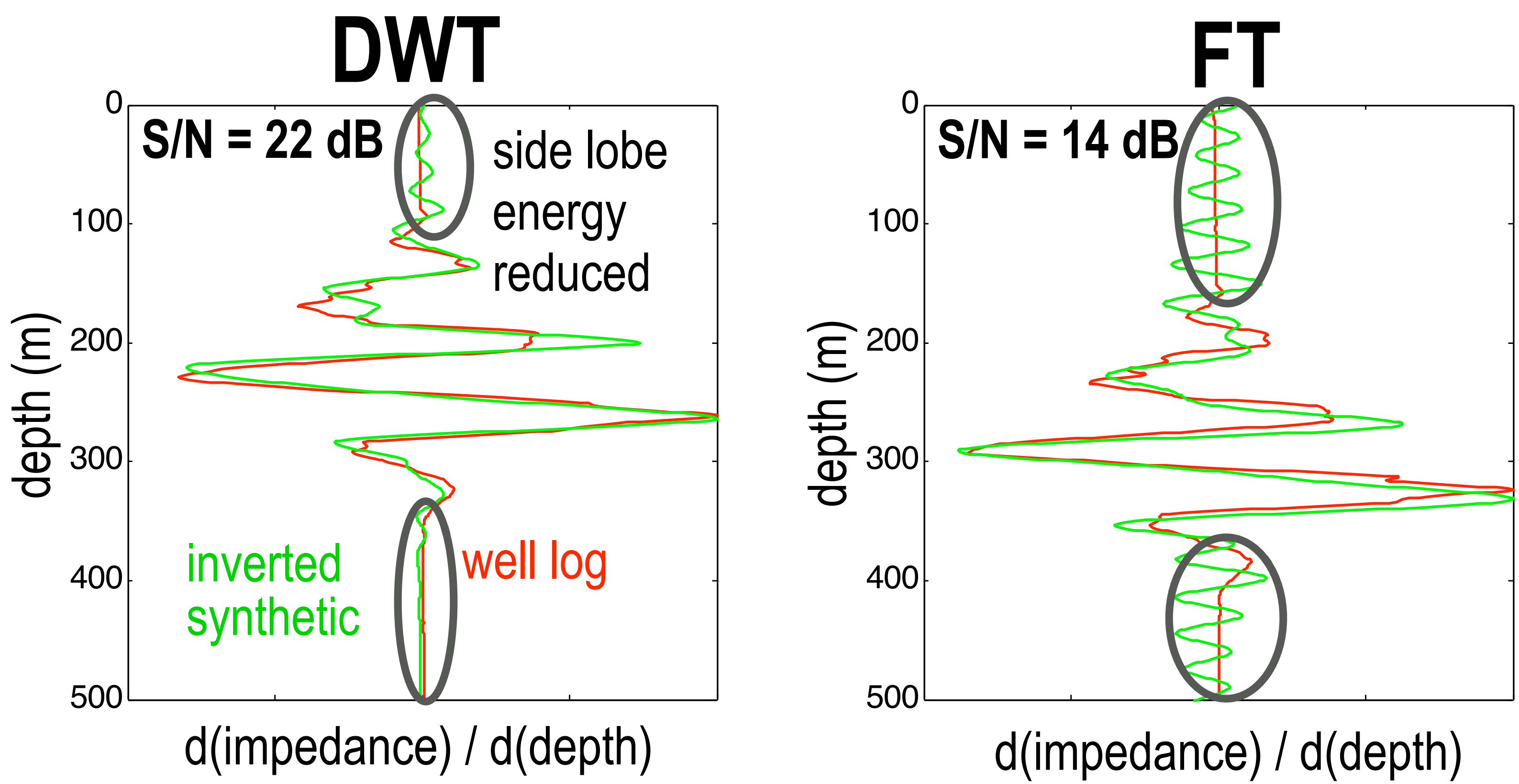
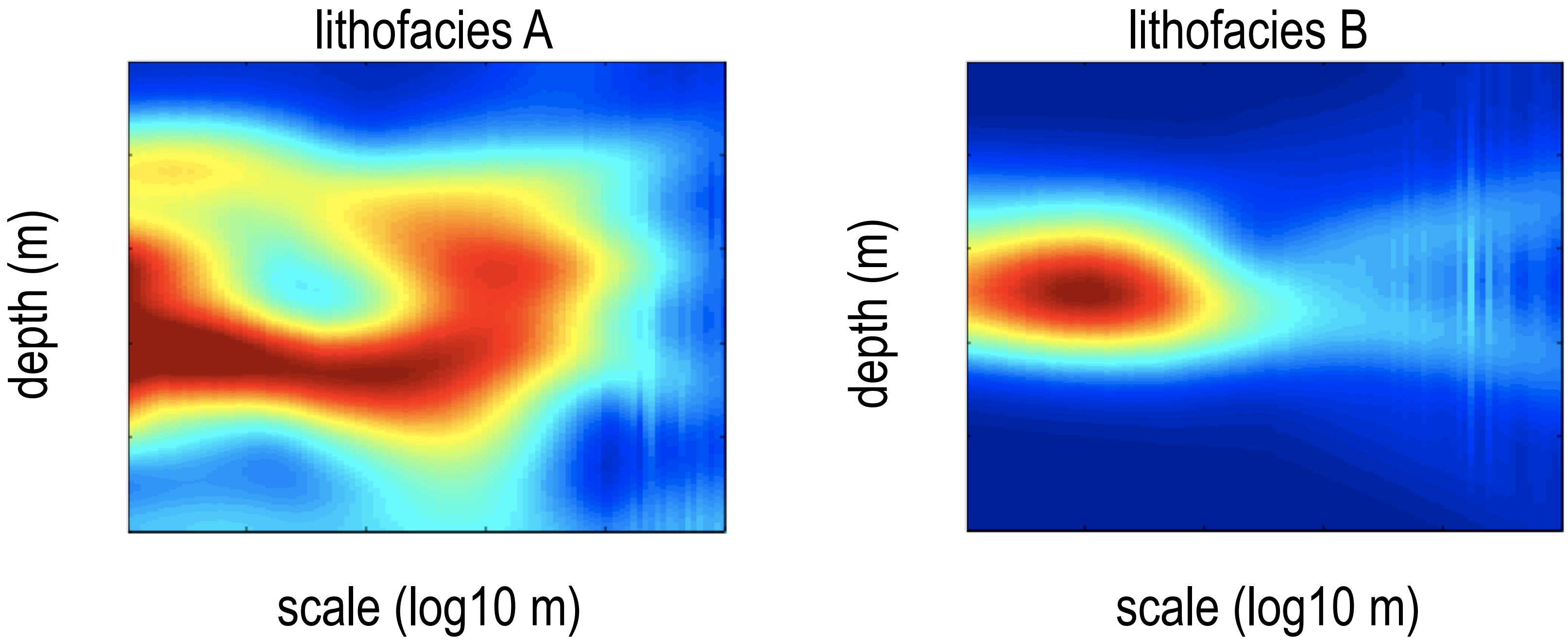
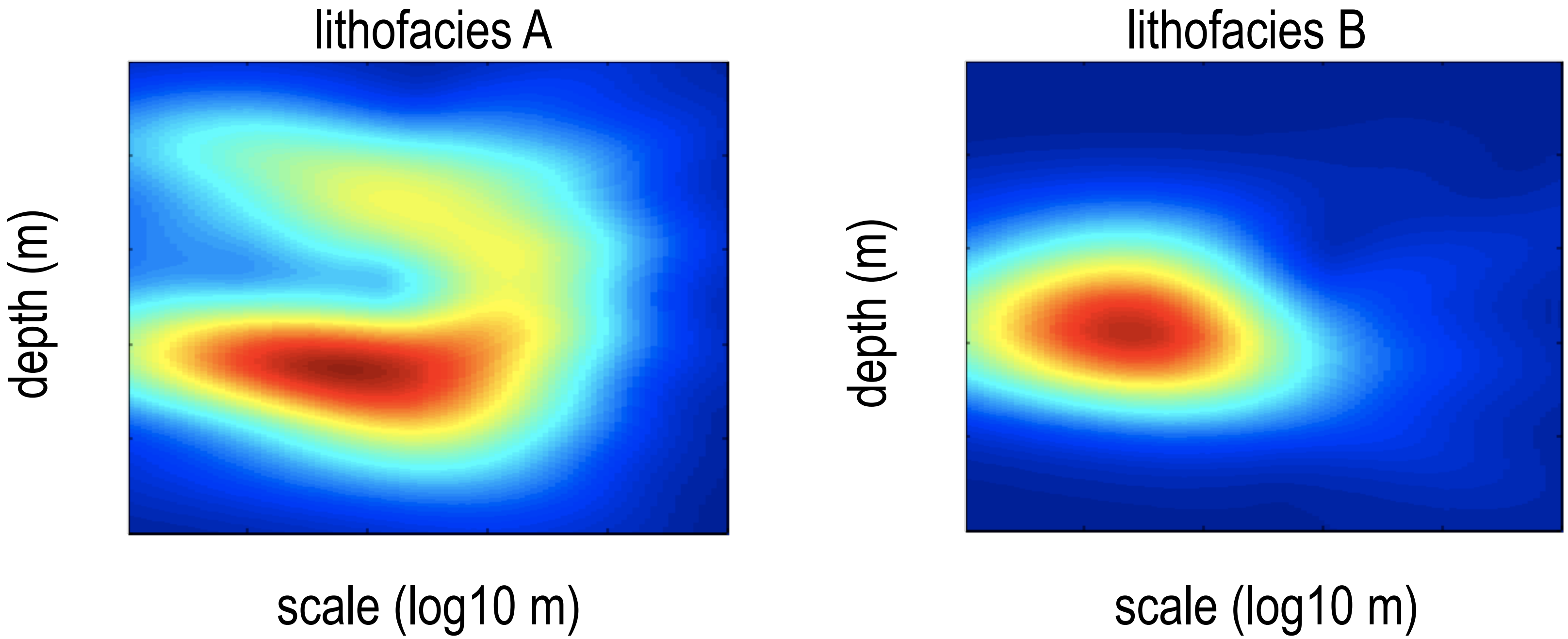


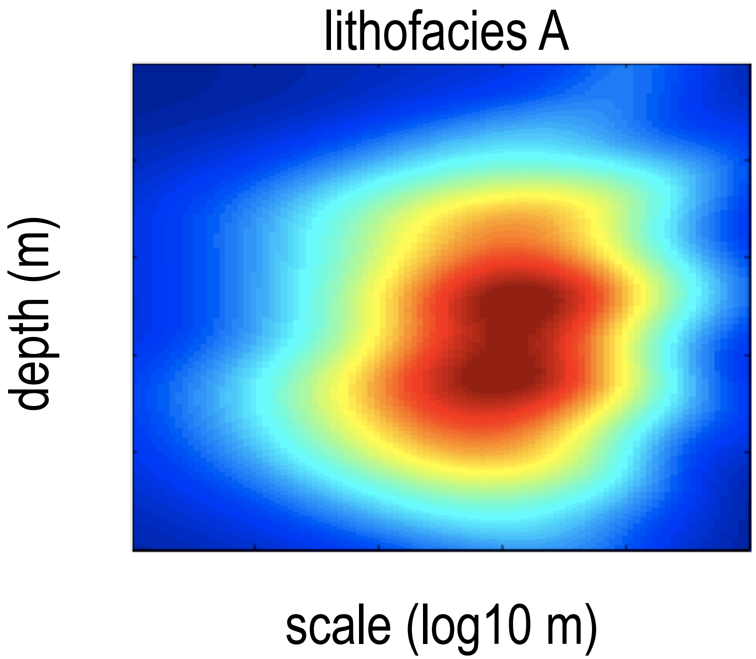
Start with the well log

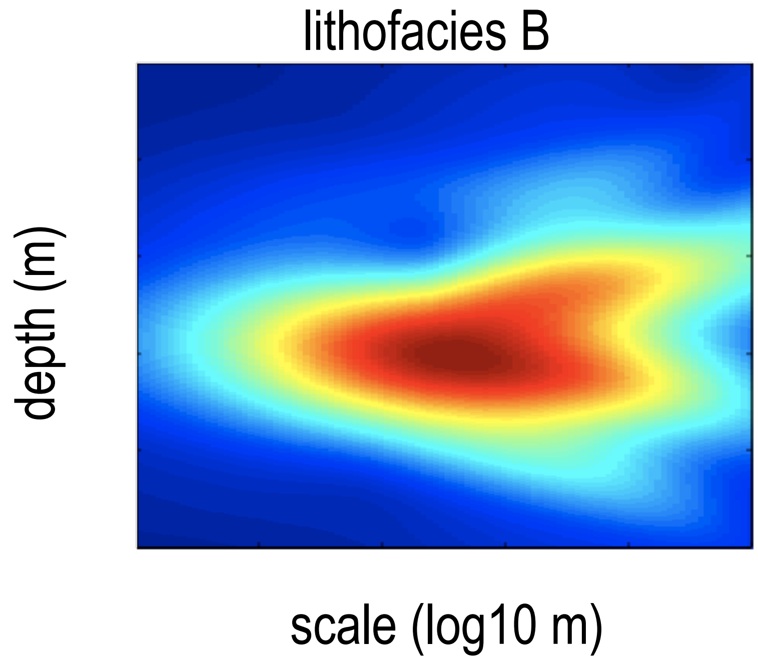


20 Hz synthetic shows differences

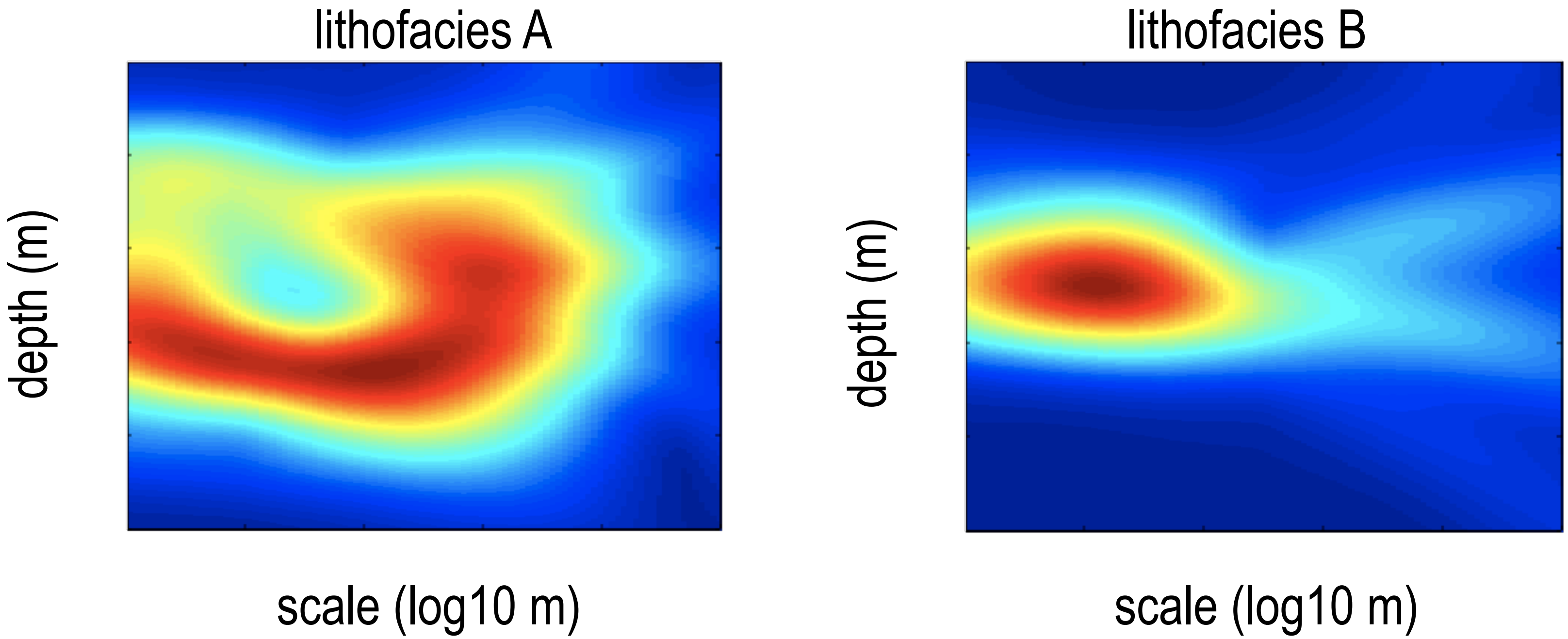


10 Hz synthetic also shows differences, even though geology is 60 Hz

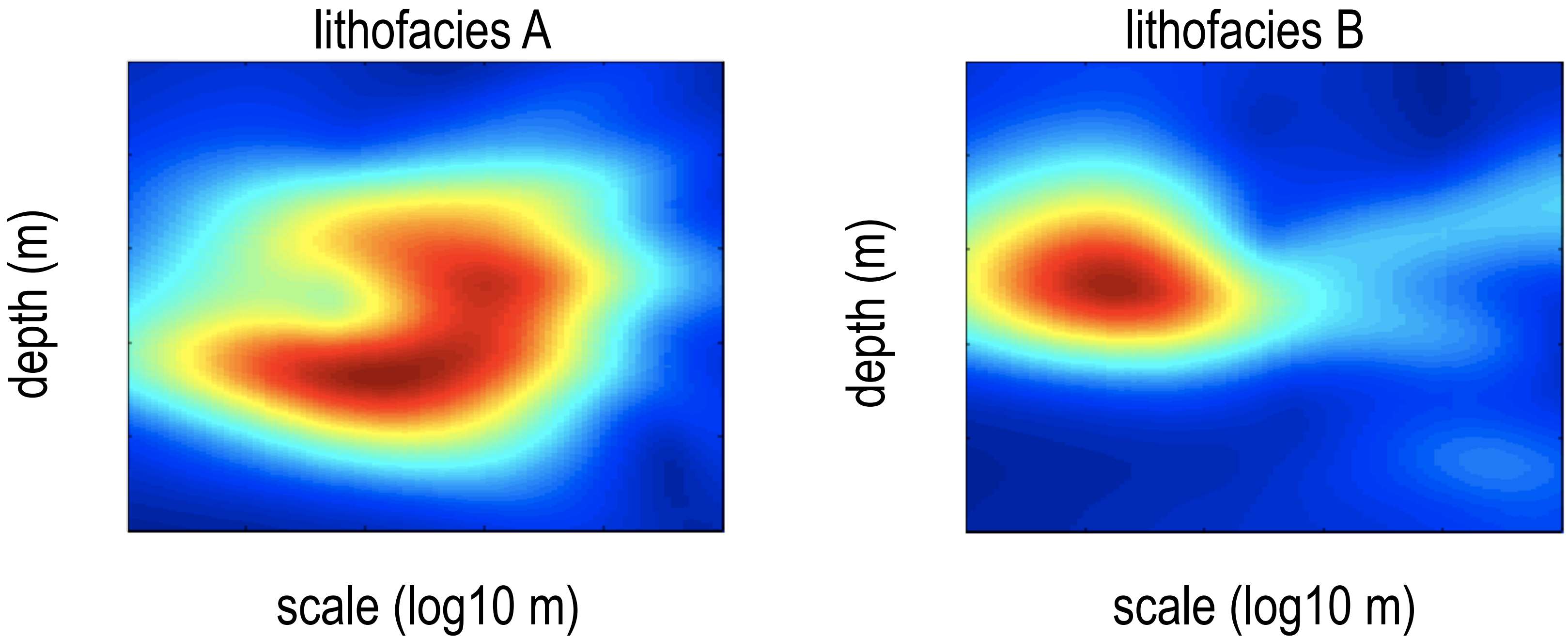




Linear inversion of 20 Hz synthetic recovers well log spectrum



Linear inversion of 10 Hz synthetic still recovers well log spectrum



Linear inversion of real seismic data also recovers well log spectrum

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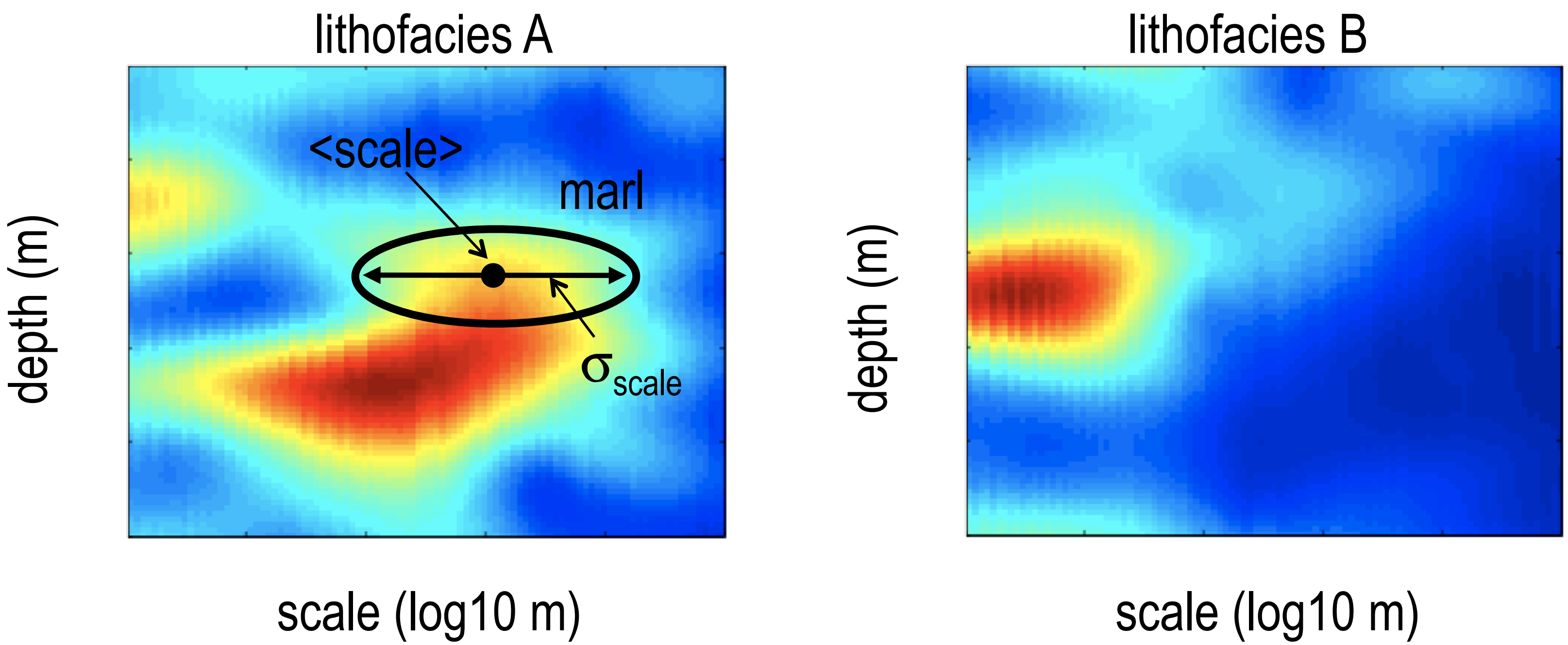
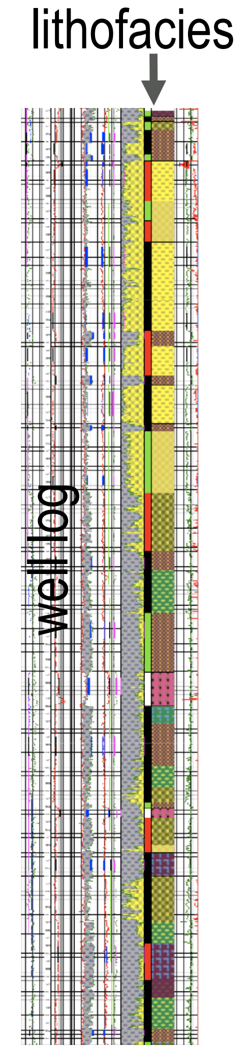


14 well logs were analyzed

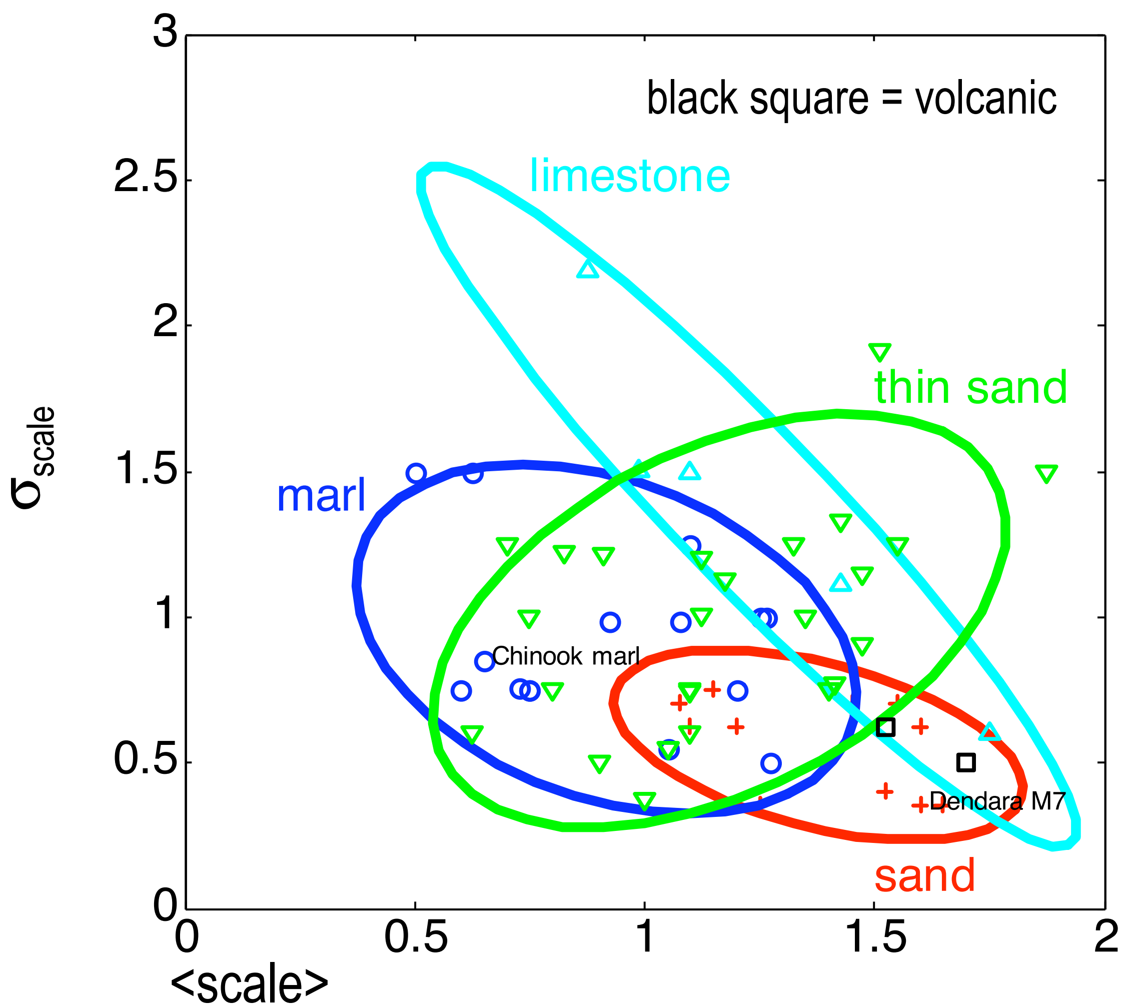
- Atlantis-1, Atlantis-2
- MadDog-1, MadDog-2, MadDog-3
- Neptune-1, Neptune-2
- Chinook
- Dendara
- Frampton
- Bass Lite
- Loyal
- Dana Point
- Blackjack

Intervals were classified on well logs according to seismic lithofacies

Principle Facies Curve	Range N:G SS%	Average N:G SS %	Bedding	Varieties Lithology		Upward thickness trend Bed Thickness or Degree of Amalgamation
A Blocky *Sandy*	A>70%		thick	A1 Sandy A2 Sandy, with thin shale breaks	a b c	increasing decreasing trendless
B Blocky *Limey*			thick	B1 Limey	a b c	increasing decreasing trendless
C Blocky *Muddy sand*	70%>C>45%		thick	C1 SS / mud C2 SS / carb C3 Carb / mud	a b c	increasing decreasing trendless
D Serrate *Interbedded sandy*	45%>D>25%		medium	D1 SS / mud D2 SS / carb D3 Carb / mud	a b c	increasing decreasing trendless
E Spikey *Heterolithics*	25%>E>10%		thin	E1 mud / SS E2 carb / SS E3 mud / Carb / siltst E4 SS/mud (70-45% N:G- thin bedded levees)	a b c	increasing decreasing trendless
F Smooth *Not sandy*	<100 API var	F<10%	thick	F1 mud F2 silty or sandy mud or thin beds F3 silty or carby mud or thin beds	a b c	increasing decreasing trendless
G Variable with high gamma, resistivity and velocity but low density *Pyroclastics*				G1 high gamma G2 lower gamma-reworked		



Good separation is found of lithofacies groups



lithofacies groups:

- sand
- thin sand
- marl
- limestone
- volcanic

note: ellipses are 2 standard deviations of fit probability function

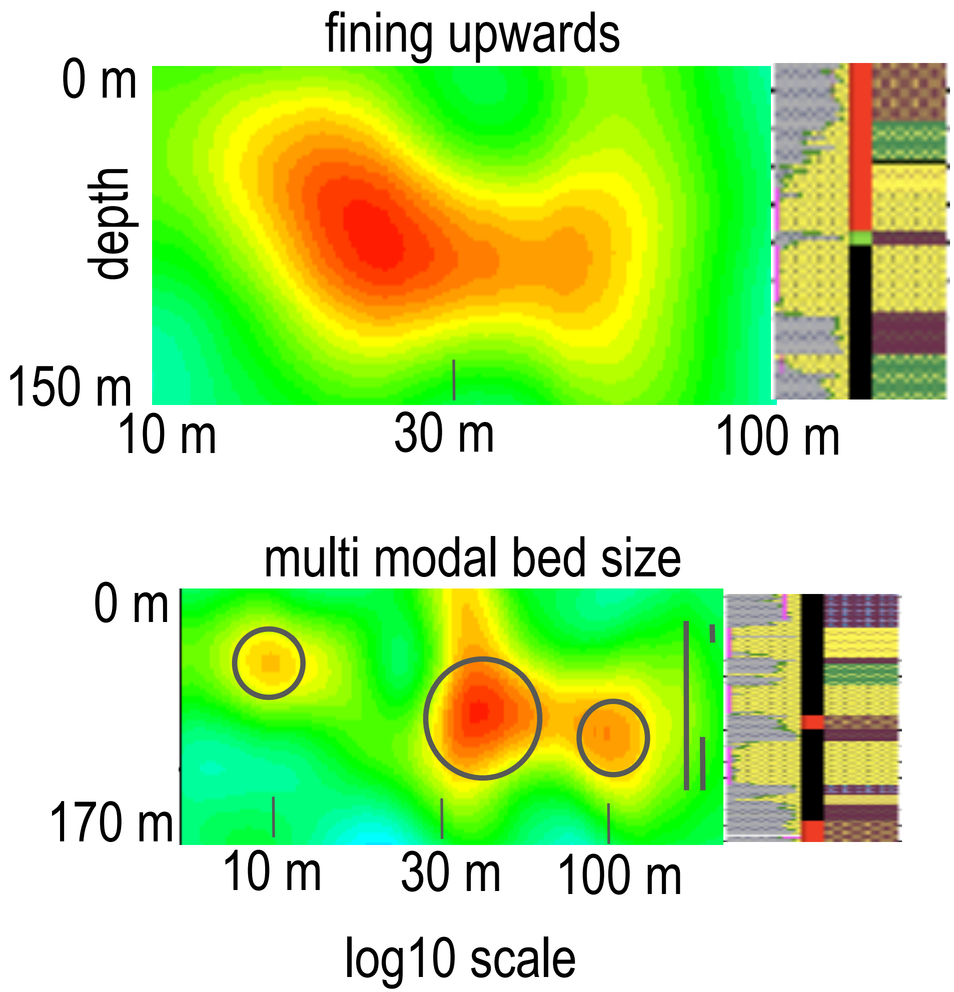
A quantitative estimate can be made of the probability of lithofacies group

Chinook marl	Dendara M7	
0.65	1.10	**average sigma**
1.35	0.35	**stddev sigma**
2.1%	97.7%	**P(blocky sand | average sigma, stddev sigma)**

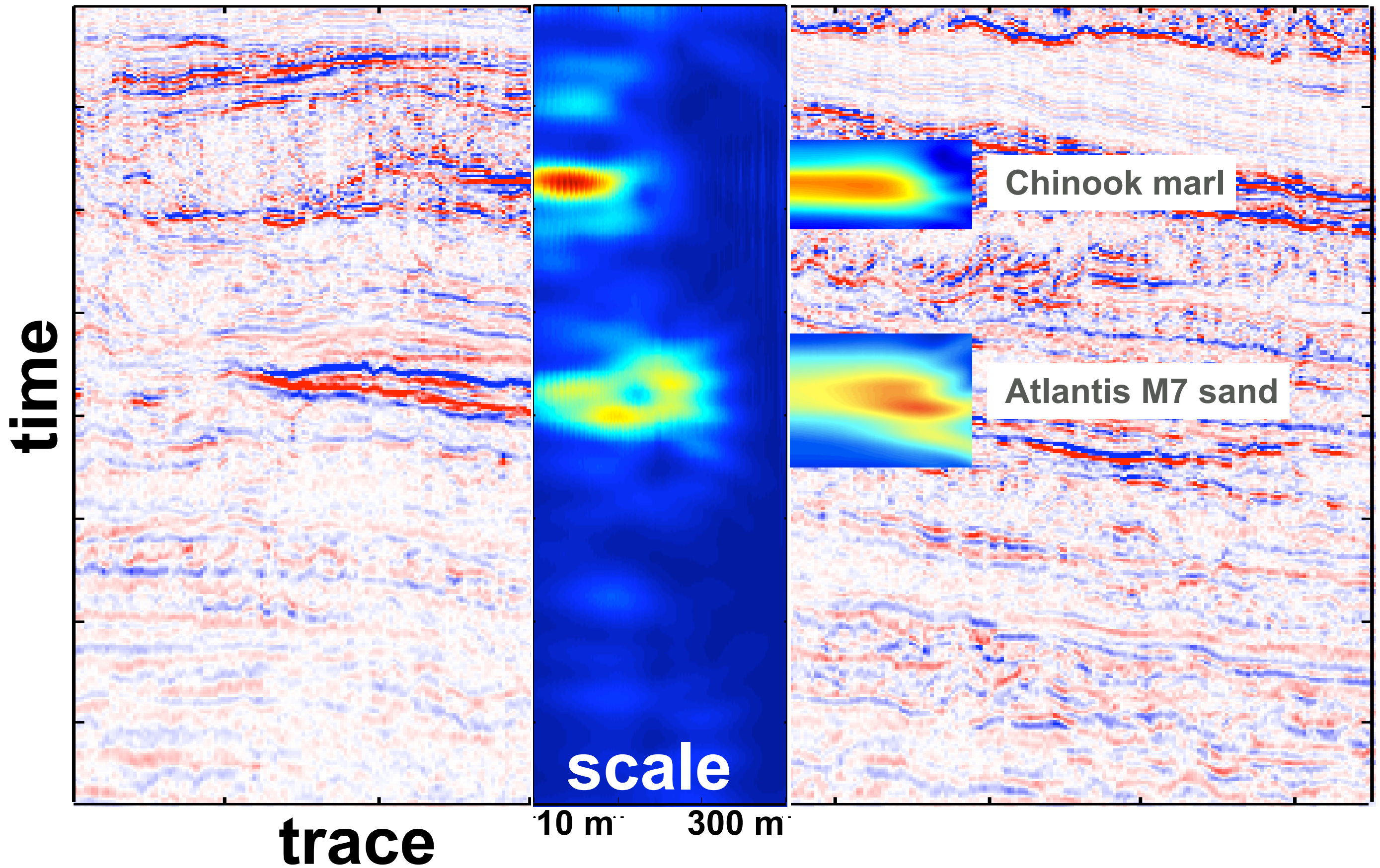
$$P(A \mid <\text{scale}>, \sigma_{\text{scale}}) = \frac{P(<\text{scale}>, \sigma_{\text{scale}} \mid A)}{P(<\text{scale}>, \sigma_{\text{scale}} \mid A) + P(<\text{scale}>, \sigma_{\text{scale}} \mid B)}$$

(Bayesian inversion)

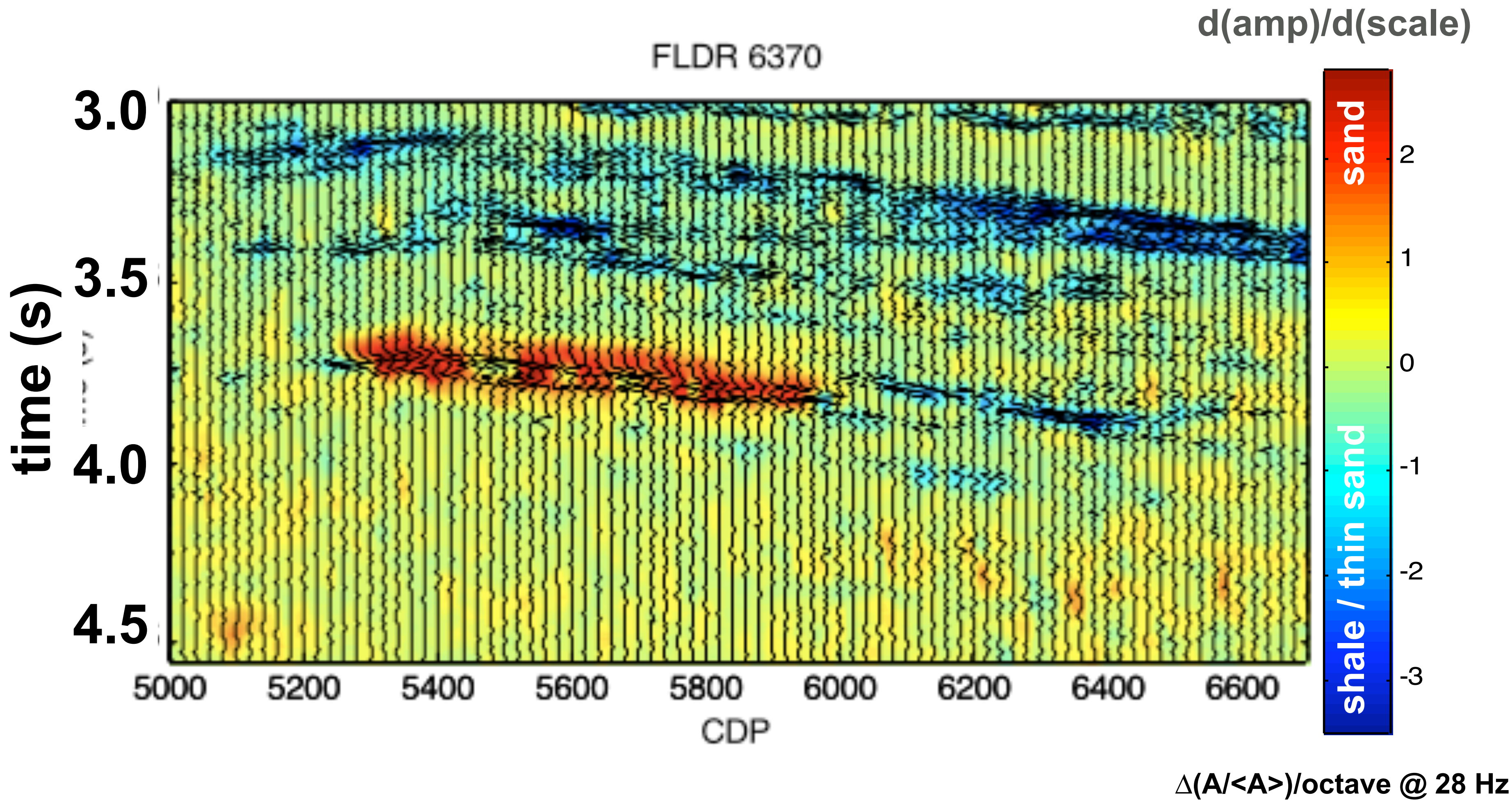
More detailed information can be extracted from the wavelet transform



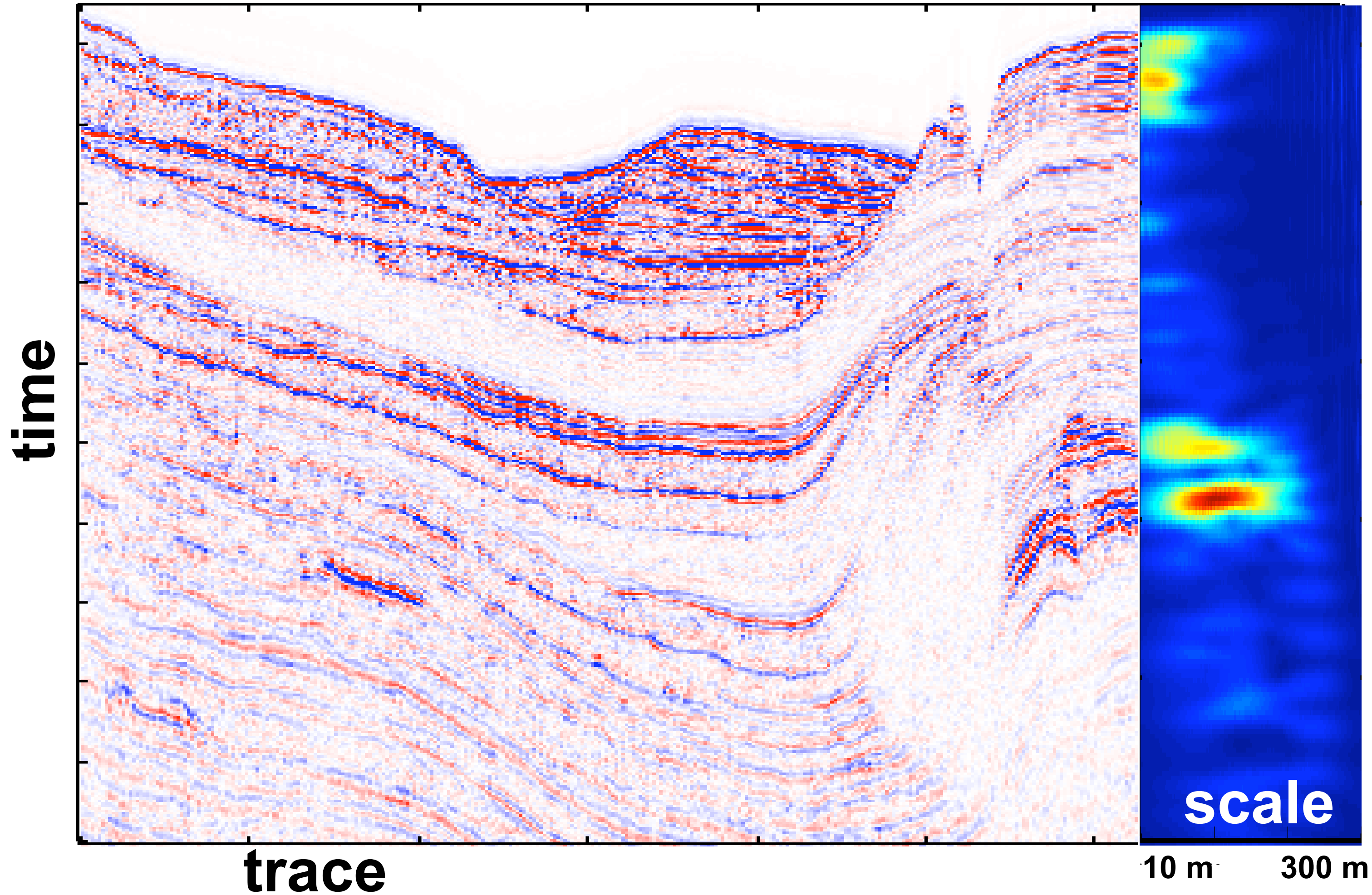
Brunei (Vivaldi prospect, line 6370) has a distinct hyperspectral image



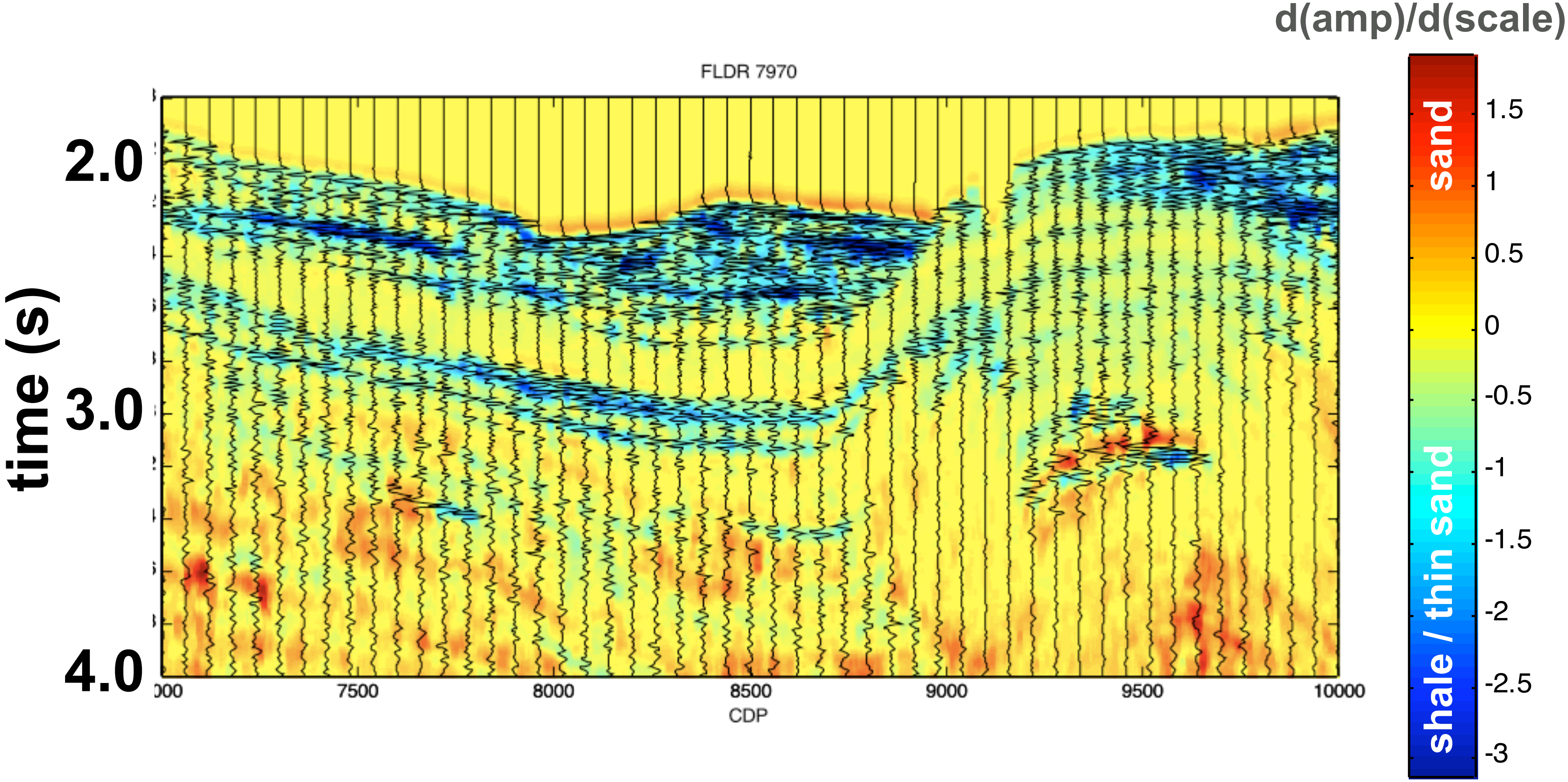
Large scale indicates well developed reservoir (Vivaldi prospect)



Mozart prospect (line 7970) hyperspectral image

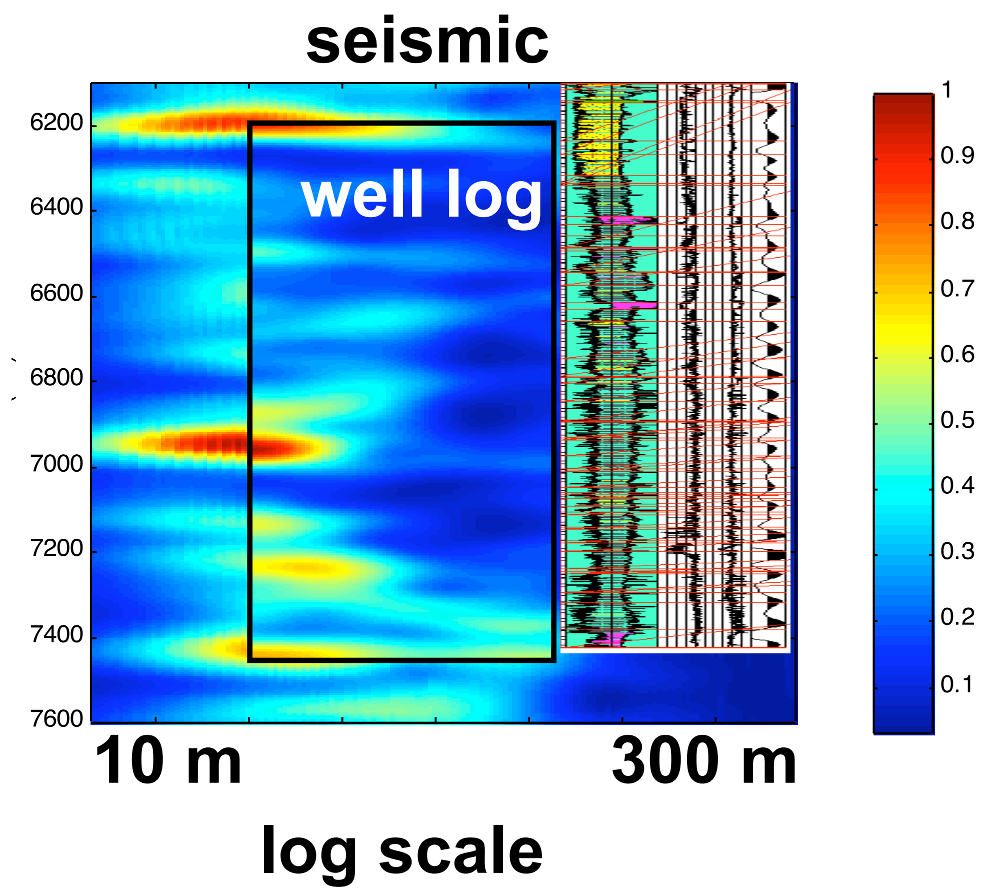


Large scale indicates well developed reservoir (Mozart prospect, level D)

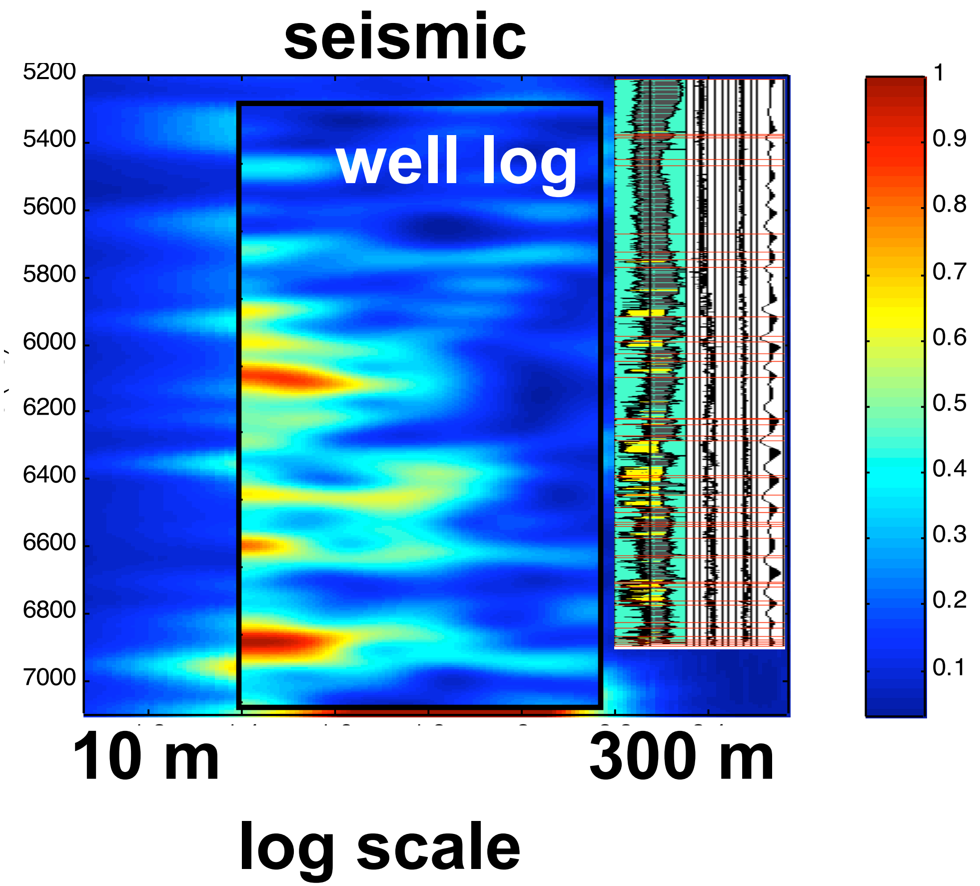


Δ(A/<A>)/octave @ 28 Hz

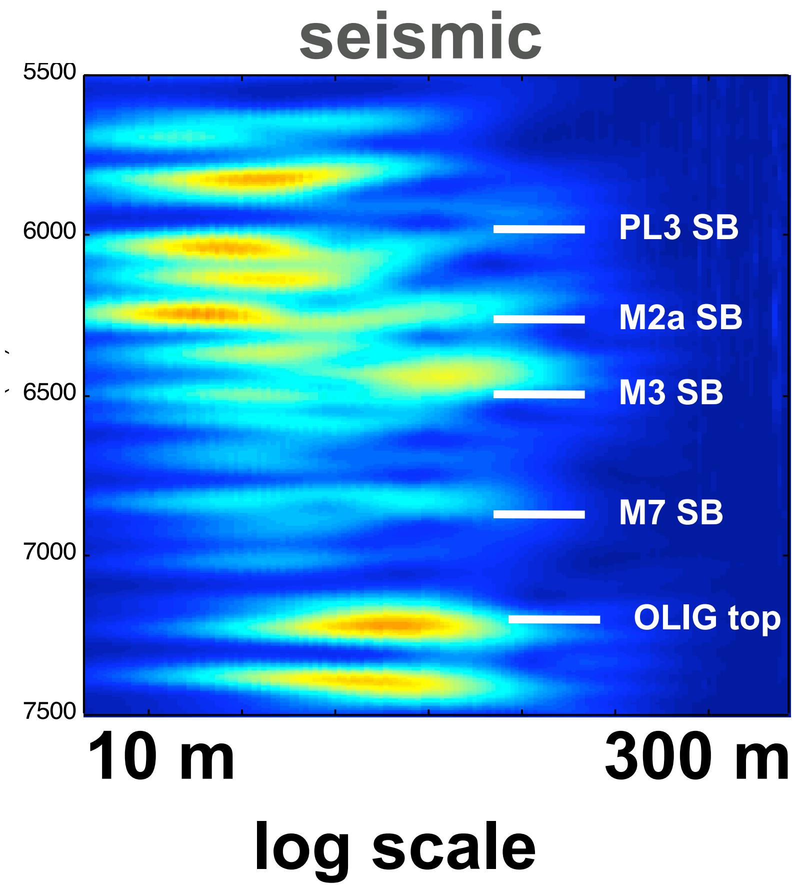
Chinook normalized wavelet spectrum



Dendara normalized wavelet spectrum



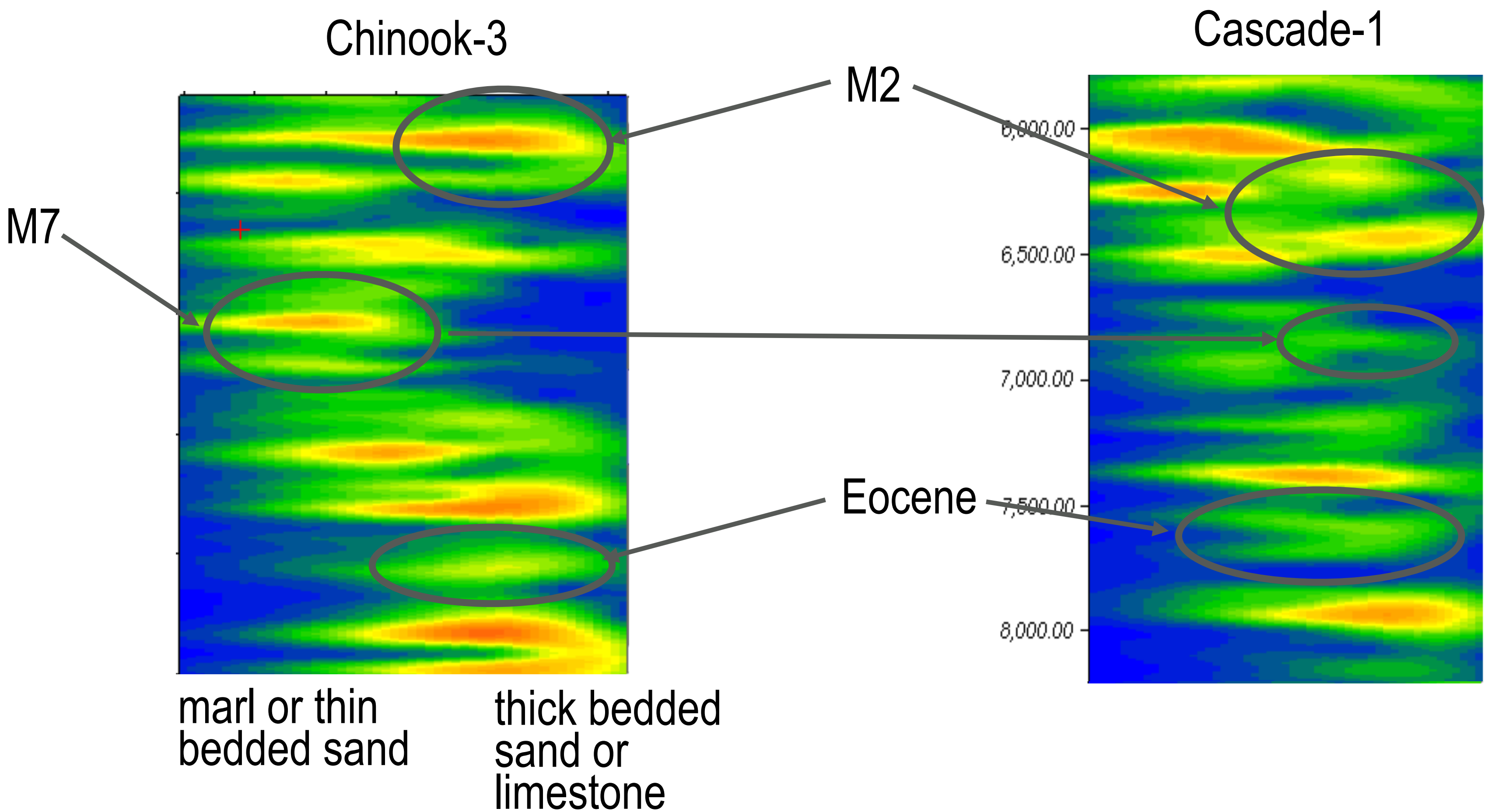
Cascade normalized wavelet spectrum



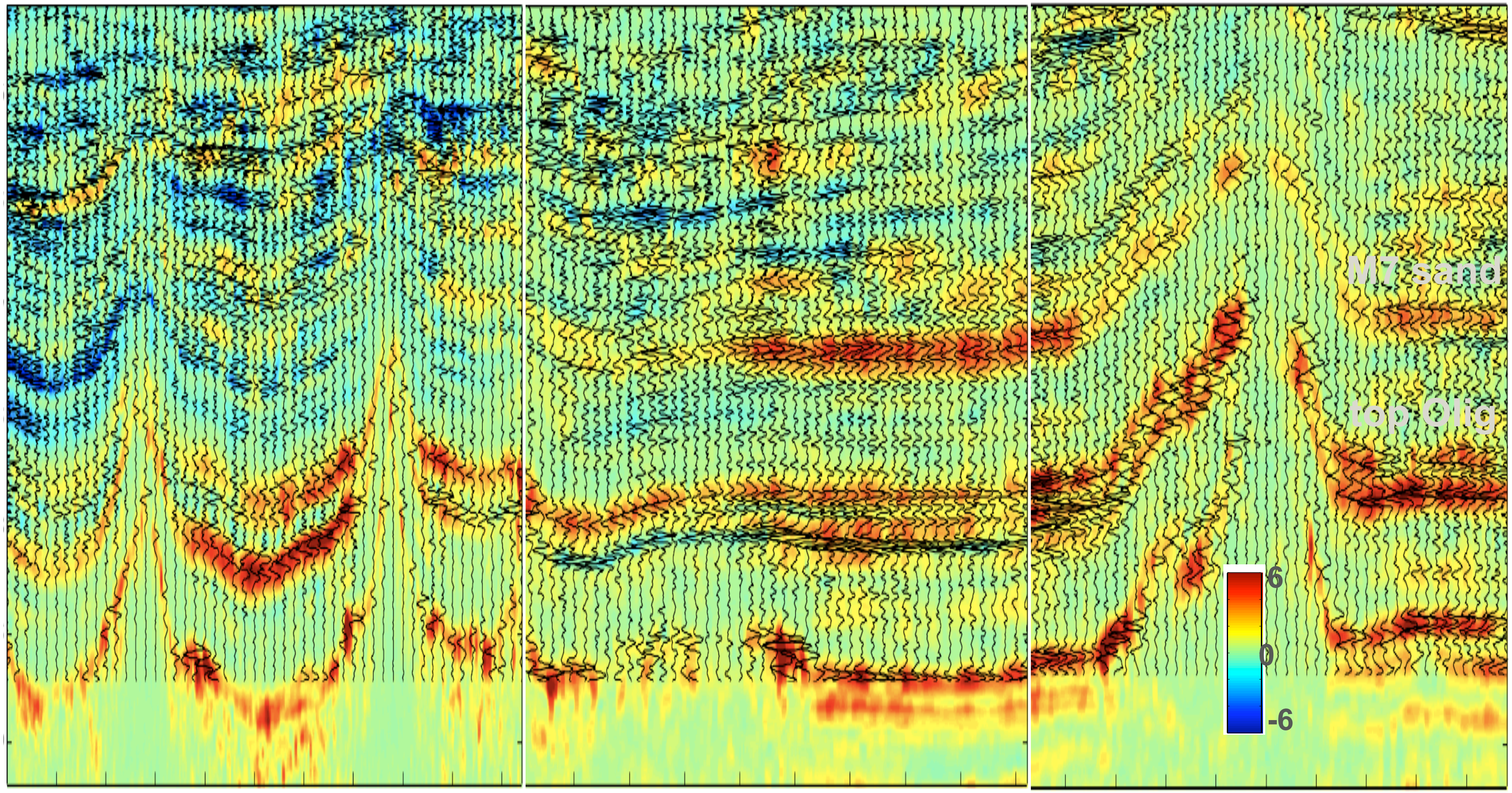
Add well log

????

Wavelet Reservoir ID for Chinook-3



Chinook-Cascade-Dendara cross section (all-in-one)



Chinook Cascade Dendara

Stratigraphic slice of wavelet transform

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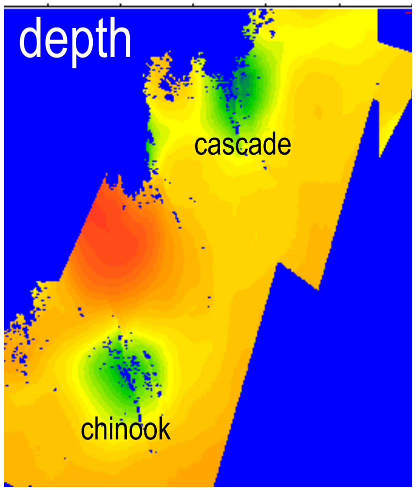
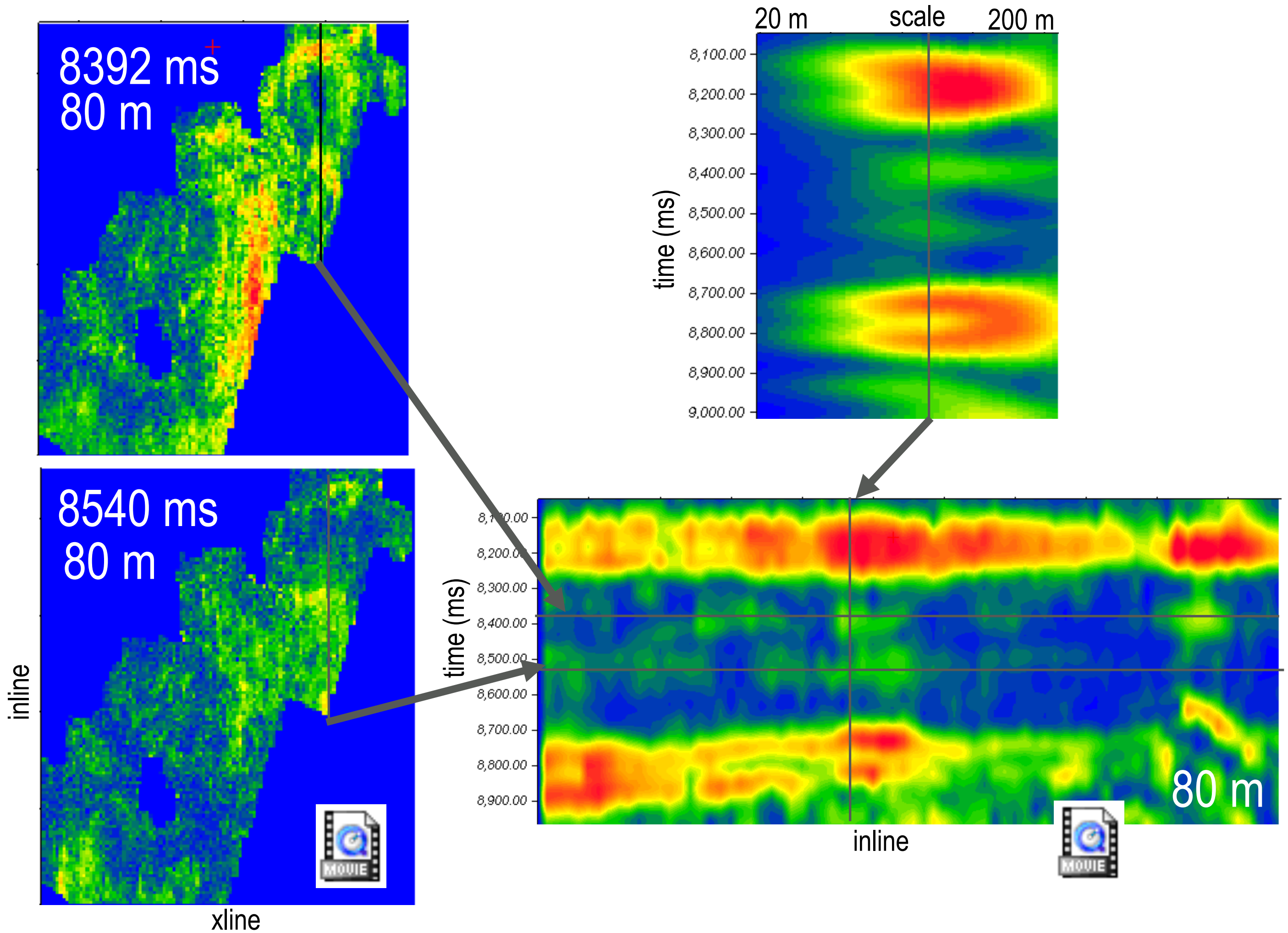
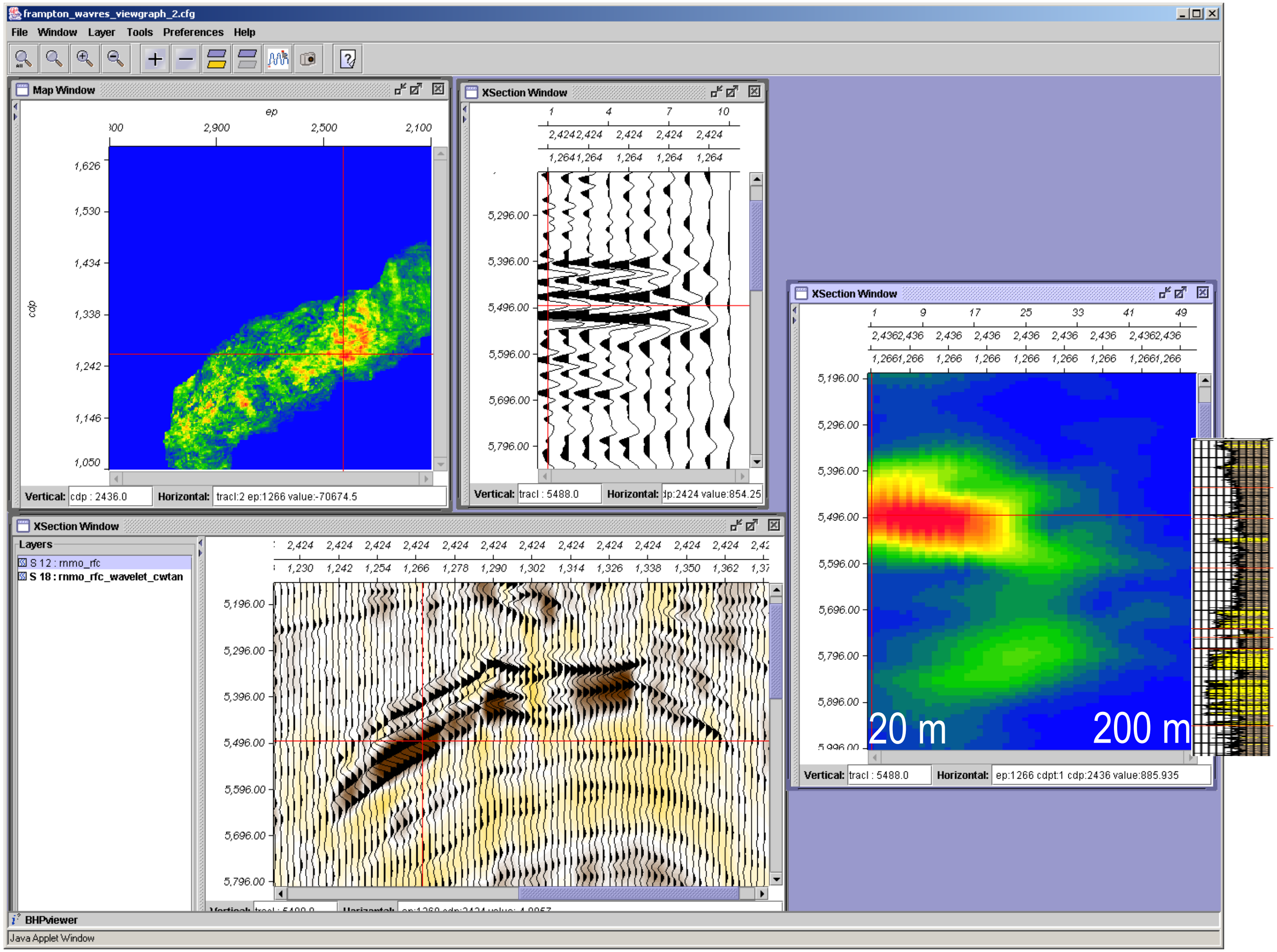




To browse live intviewer session goto:

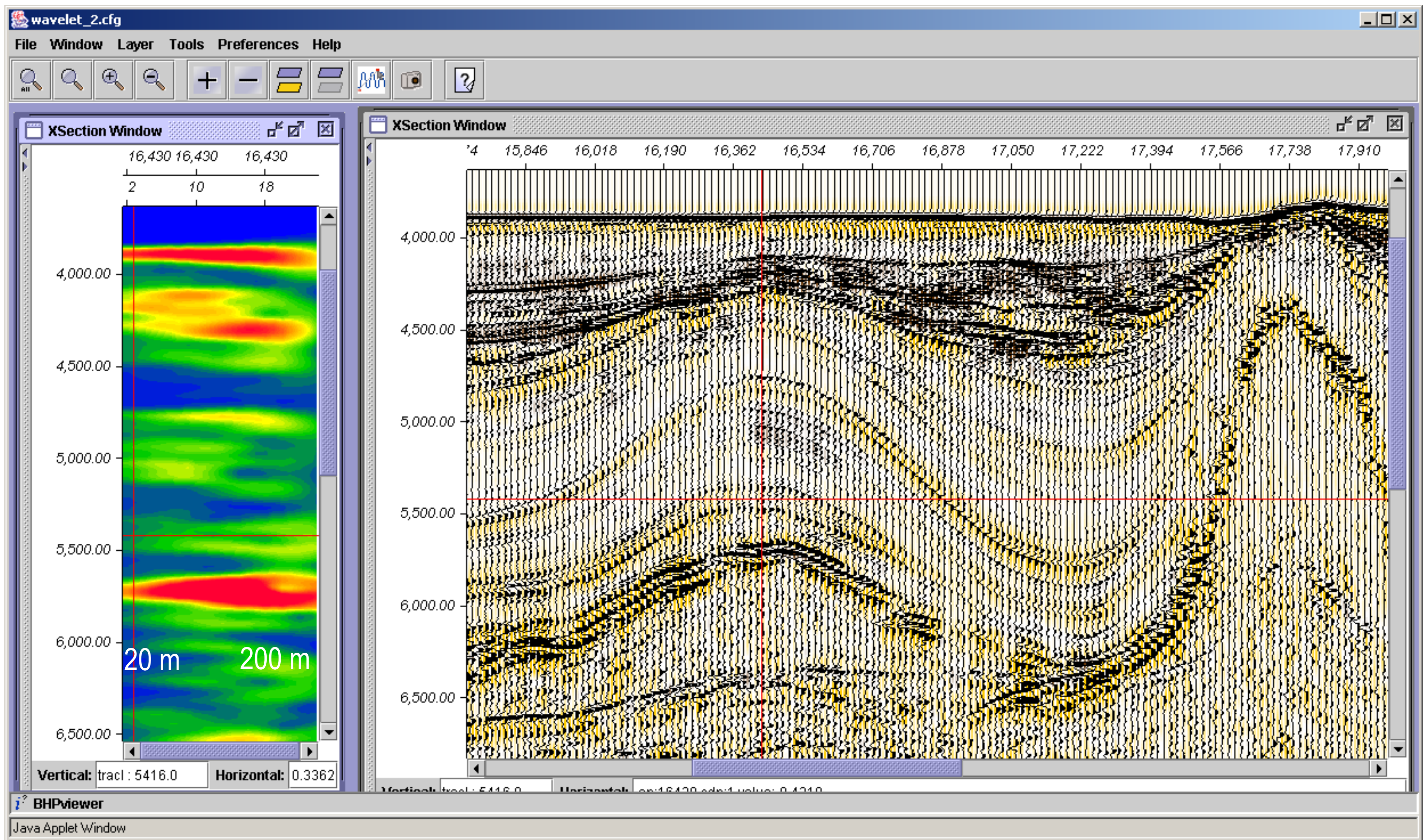
Frampton

To browse live intviewer session goto:



Brazil BMC-10

To browse live intviewer session goto:



Things to remember

- Geologic lithofacies can be quantitatively identified by the wavelet decomposition of the reflection
  - appears to be robust, works on data where standard quantitative interpretation does not work well
- 10 Hz data identifies 60 Hz geologic beds
- One does not need to consider multiple reflections in the inversion
- Discrete wavelet transform (DWT) performs better than Fourier transform (FT) for the inversion (deconvolution)

We would like to acknowledge for their help: Bruce Asher, Gillian Apps, Chris Lerch and Val Lincecum

THE END