Surface-consistent Gabor deconvolution

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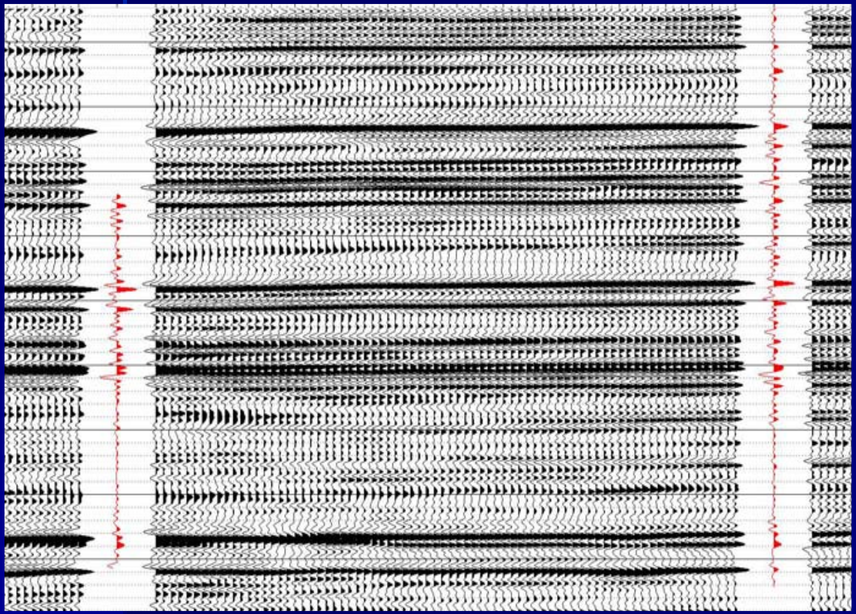
Elastic Wave Exploration Seismology

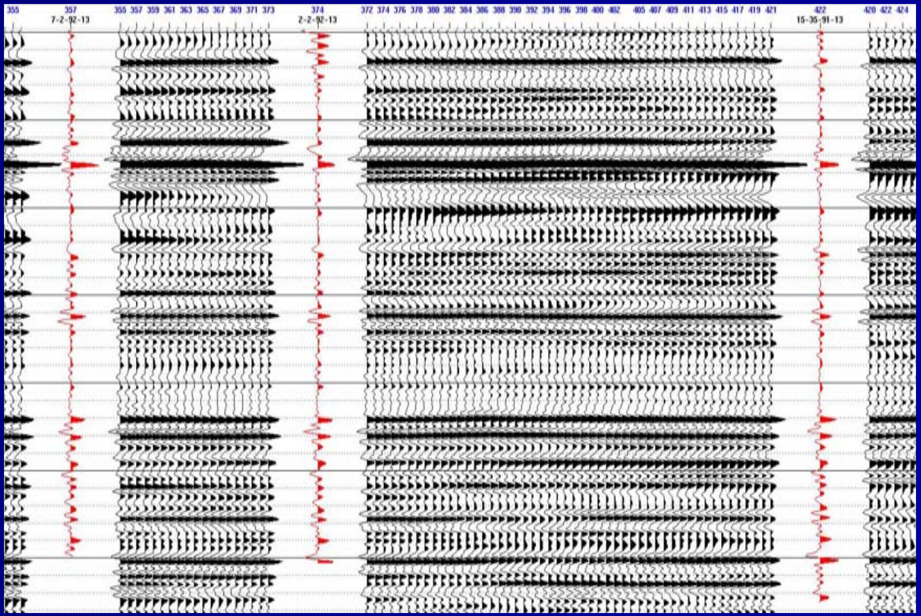
Outline

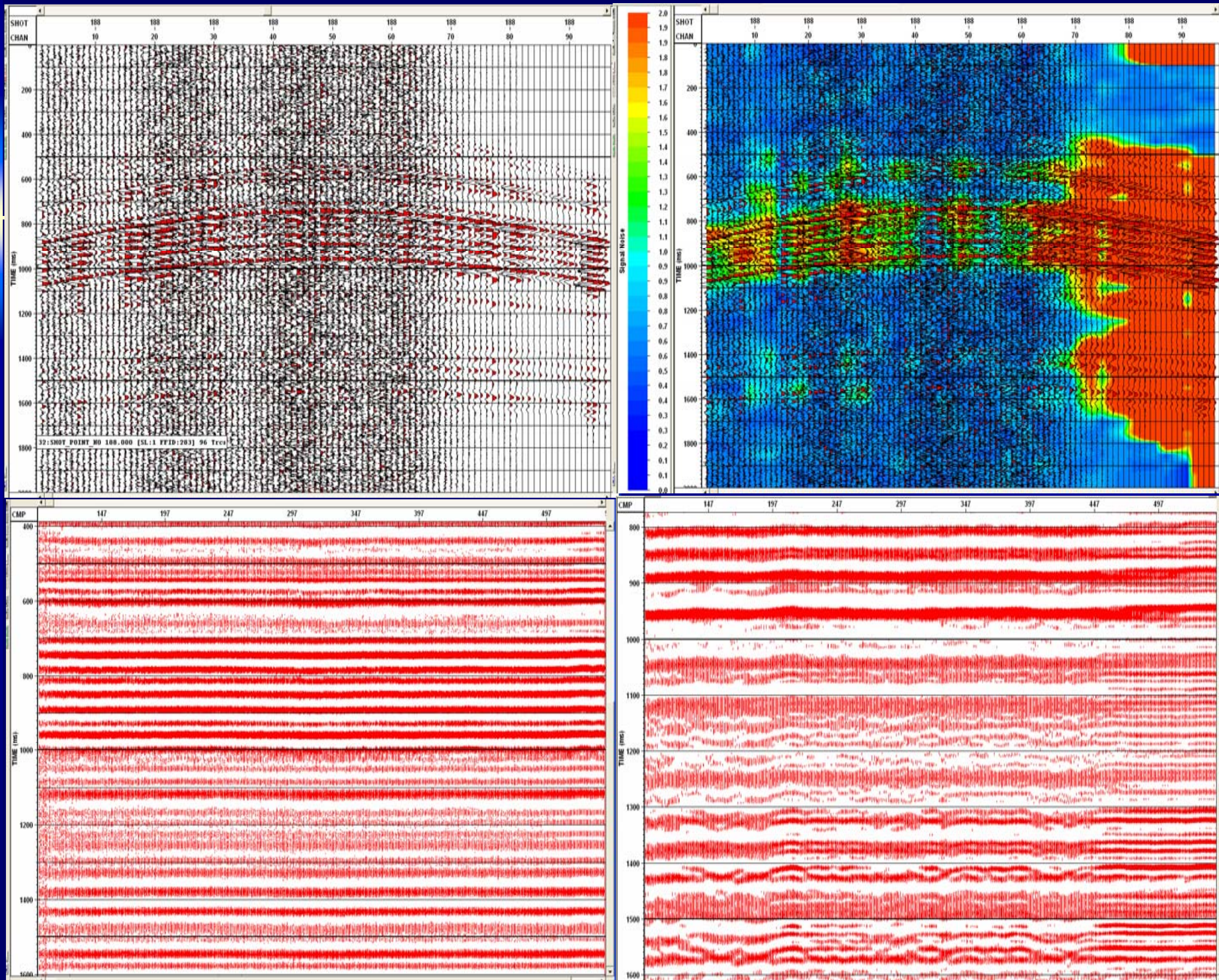
- Why could we need SCGABOR?
- Overview of Gabor deconvolution
- A surface consistent Gabor algorithm
- Example
- Conclusions

DIVETSCO TESTS

(From Perz et al., 2005, CSEG meeting)







SHOT
CHAN
TIME (ms)
Signal Noise
CMP

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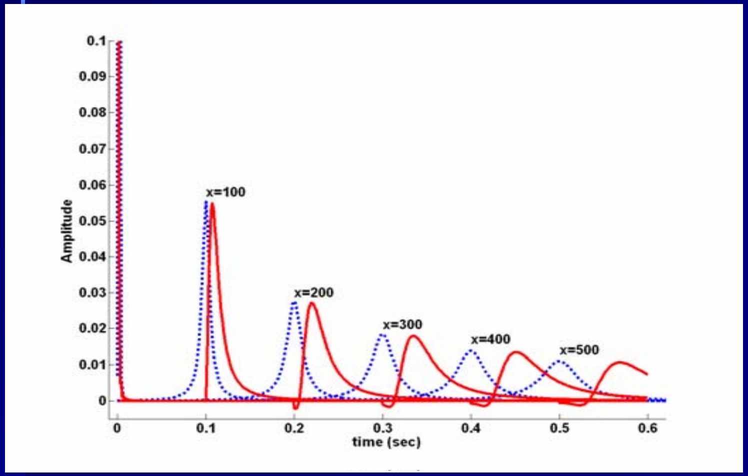
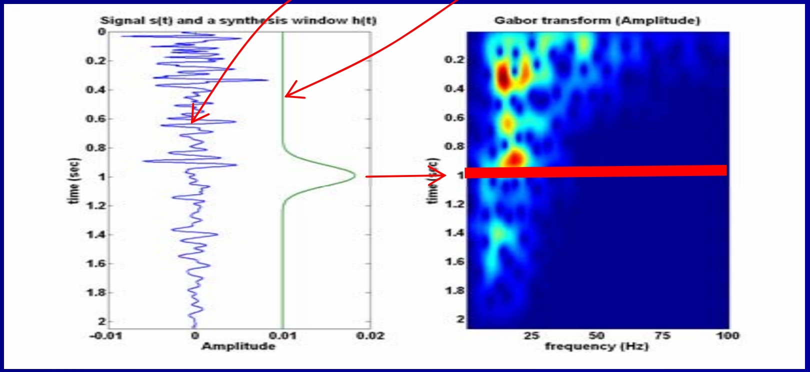
From Wiener to Gabor

- 1. Constant Q theory

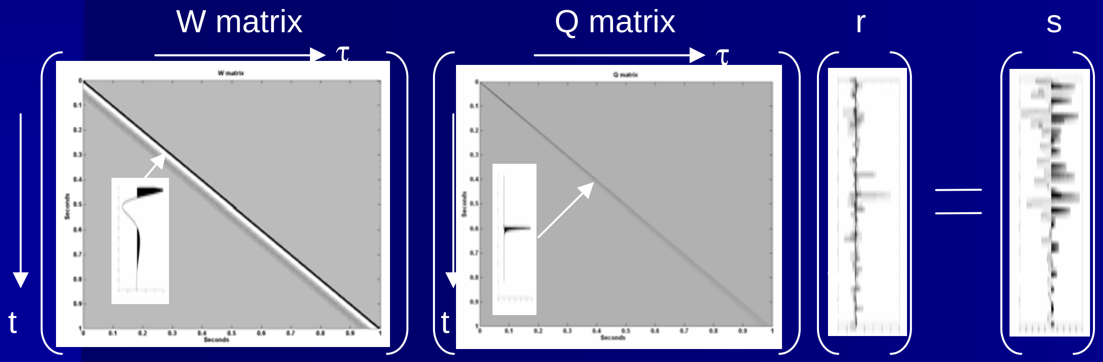


- 3. Gabor transform

$$G[s](\tau, f) = \int_{-\infty}^{\infty} s(t)\, g(t-\tau)\, e^{-2\pi i f t}\, dt$$



2. Nonstationary convolutional model



$$\hat{s}(f) = \hat{w}(f) \int_{-\infty}^{\infty} \alpha_Q(f,\tau)\, r(\tau)\, e^{-2\pi i f \tau}\, d\tau$$

Nonstationary conv. Model in the Gabor domain

- Factorization of the nonstationary convolutional model

$$\hat{s}(f) = \hat{w}(f)\int_{-\infty}^{\infty} \alpha_Q(f,\tau) r(\tau) e^{-2\pi i f \tau} d\tau$$

Approximated factorization

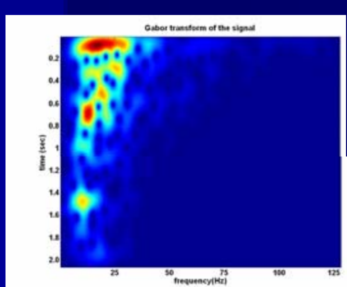
$$G[s](\tau, f) \approx \hat{w}(f)\alpha_Q(\tau, f) G[r](\tau, f)$$

Fourier of the wavelet

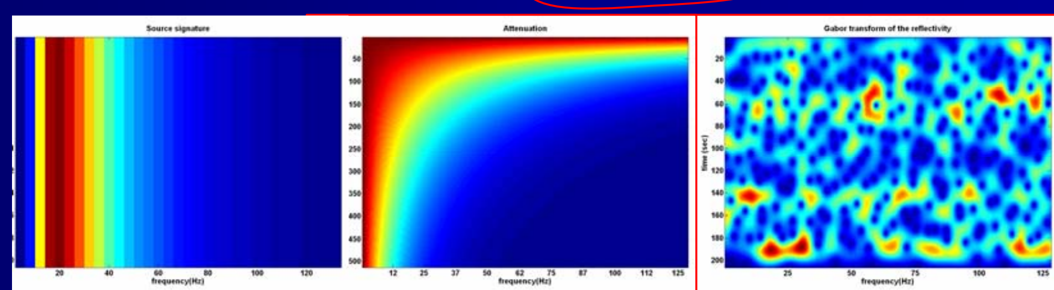
Gabor of the trace

Attenuation function

Gabor of the reflectivity

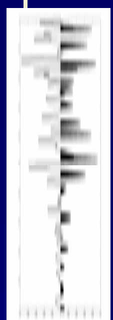


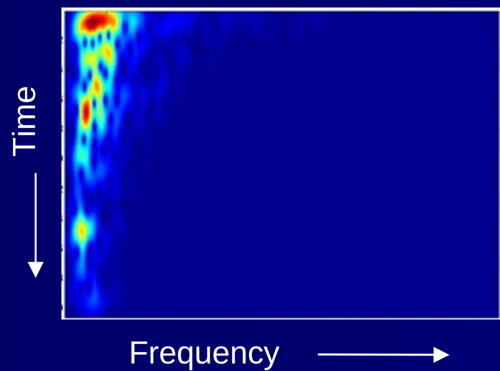
$\approx$



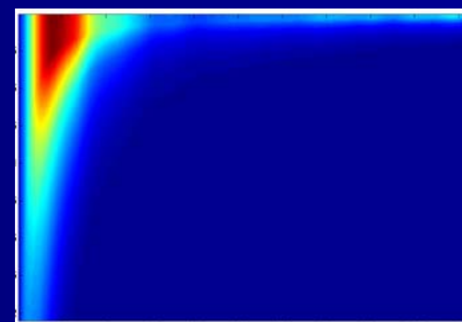
Gabor deconvolution

Gabor transform of the trace

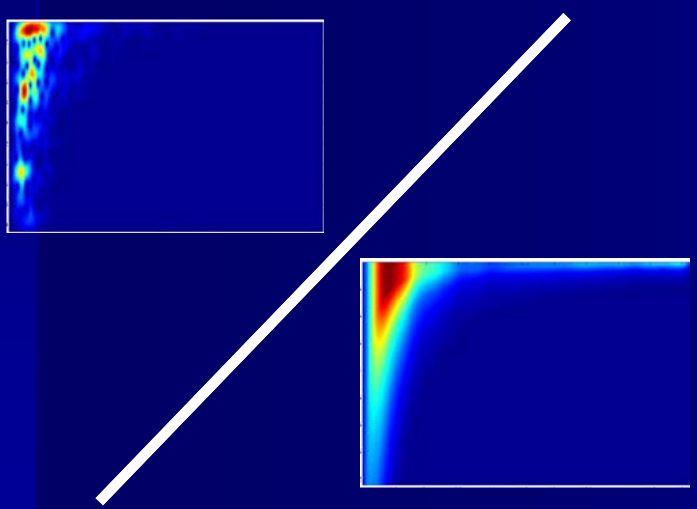


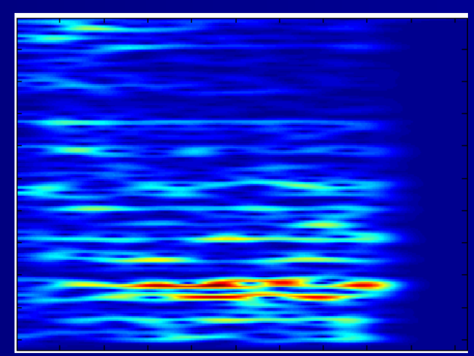


Deconvolutional operator:

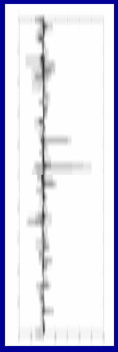


- smoothing
- phase:
  using Hilbert
  transform





Estimate of the
Gabor reflectivity

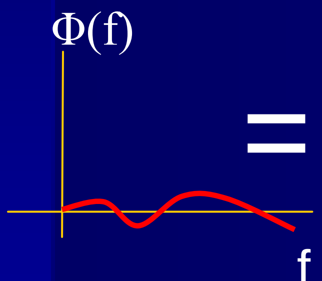


Wavelet removal and compensation for attenuation are simultaneous

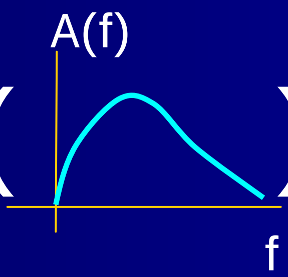
Minimum phase, linearity, causality and Hilbert transform.

- Minimum phase
  - Explosive sources are also minimum phase.

Futterman (1962) showed that wave attenuation in a causal, linear theory is always minimum phase.



=H(log(



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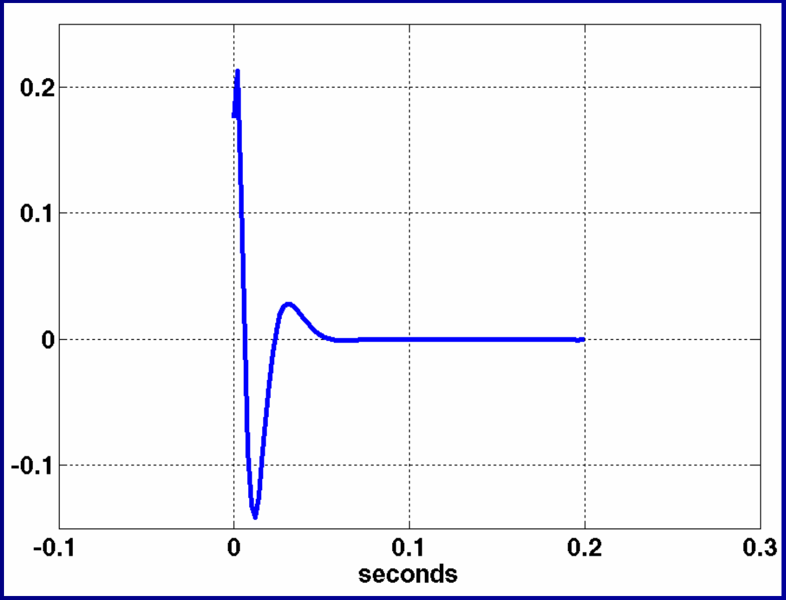

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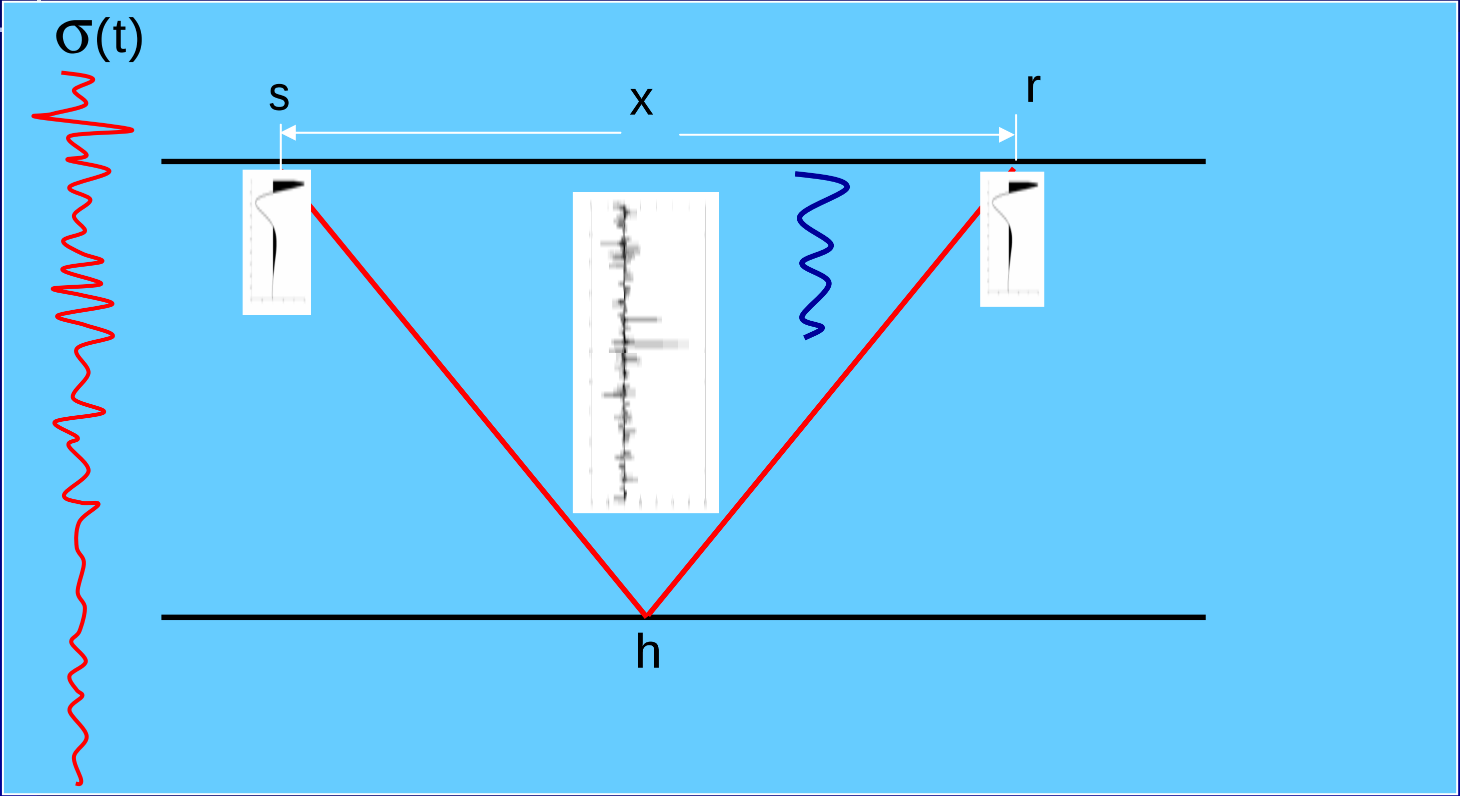
Surface Consistency

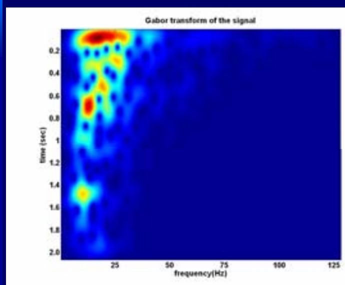


$$\sigma(s,r,x,h,t) = a(s,t) \otimes b(r,t) \otimes c(x,t) \otimes d(h,t)$$

$$\hat{\sigma}(s,r,x,h,\omega) = A(s,\omega)B(r,\omega)C(x,\omega)D(h,\omega)$$

Surface-consistent Gabor deconvolution

$$G[\sigma](\tau, f) \approx \hat{w}(f)\alpha_Q(\tau, f)G[\rho](\tau, f)$$



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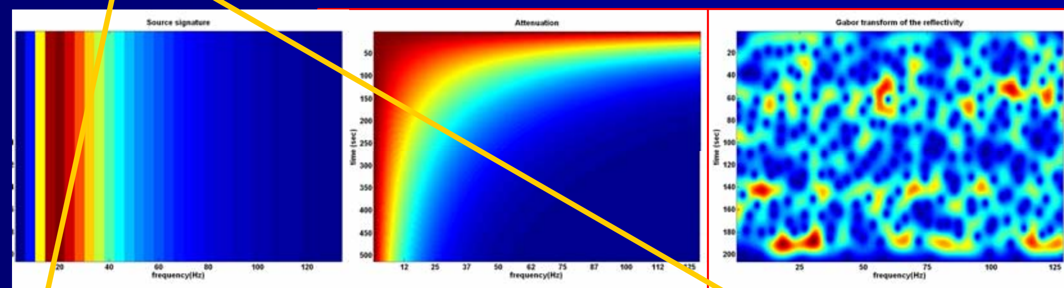
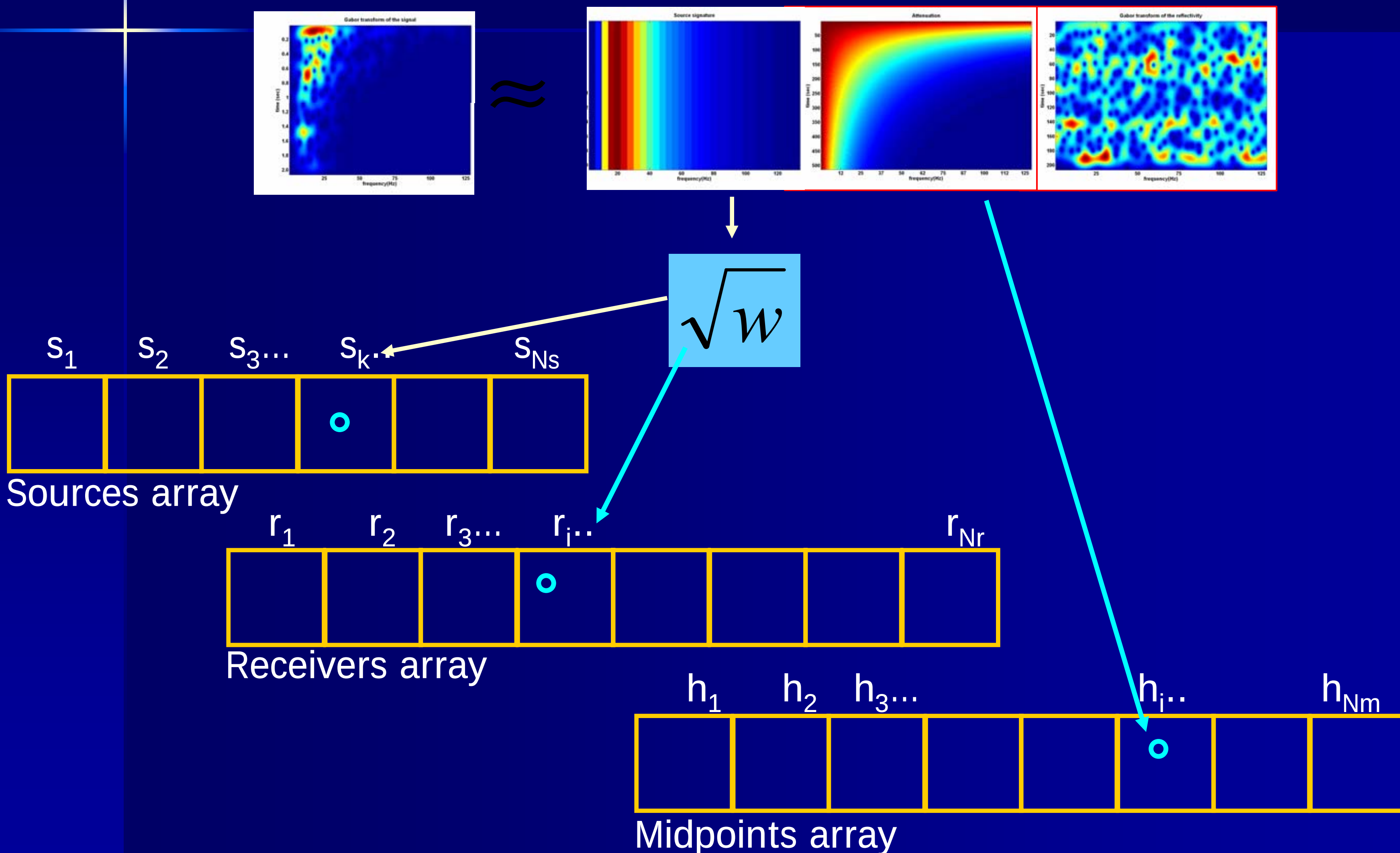


$$G\sigma(f,\tau,h,r,s) = [w_s(f,s)][\alpha_Q(f,\tau,h)][G\rho(f,\tau,h)][w_r(f,r)]$$

h, r, s: midpoint, receiver and source coordinates respectively

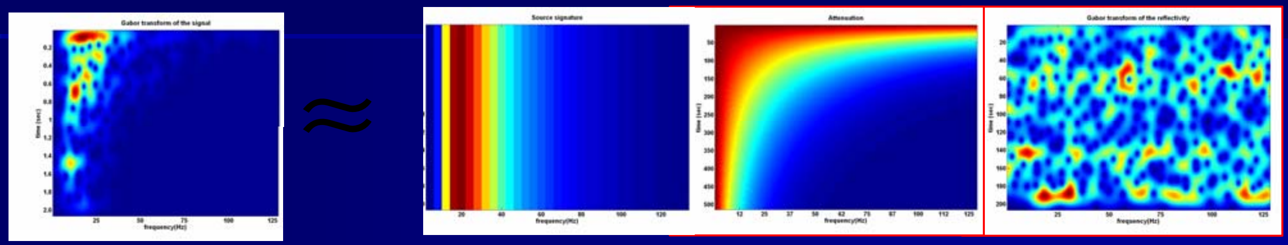
Surface-consistent Gabor algorithm

For the i, j, k trace: ith midpoint, jth receiver and kth source indexes



Surface-consistent Gabor algorithm

For the i, j, k trace: ith midpoint, jth receiver and kth source indexes

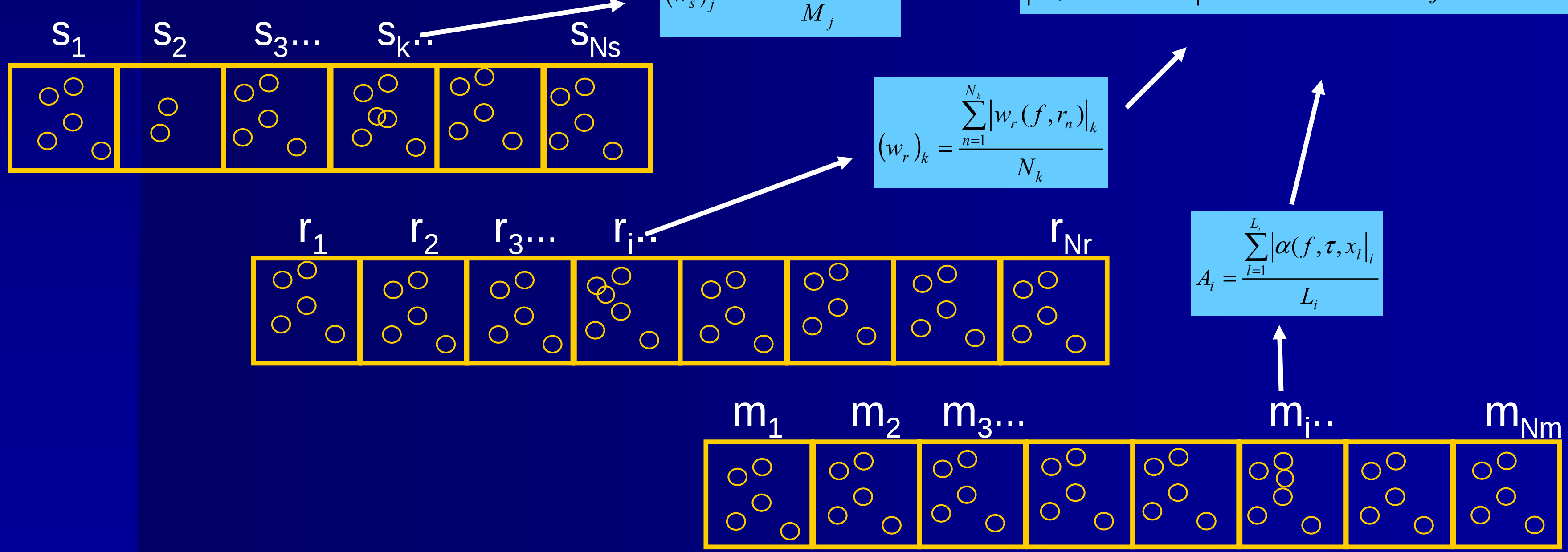


$$(w_s)_j = \frac{\sum_{m=1}^{M_j} |w_s(f,s_m)|_j}{M_j}$$

$$|\theta_{ijk}(f,\tau)| = A_i ** [(w_s)_j] * [(w_r)_k]$$

$$(w_r)_k = \frac{\sum_{n=1}^{N_k} |w_r(f,r_n)|_k}{N_k}$$

$$A_i = \frac{\sum_{l=1}^{L_i} |\alpha(f,\tau,x_l)|_i}{L_i}$$



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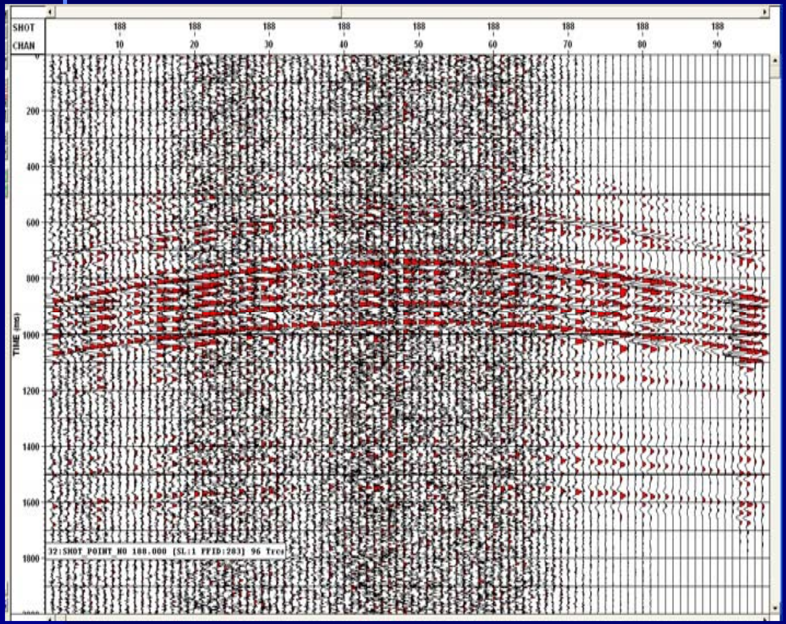
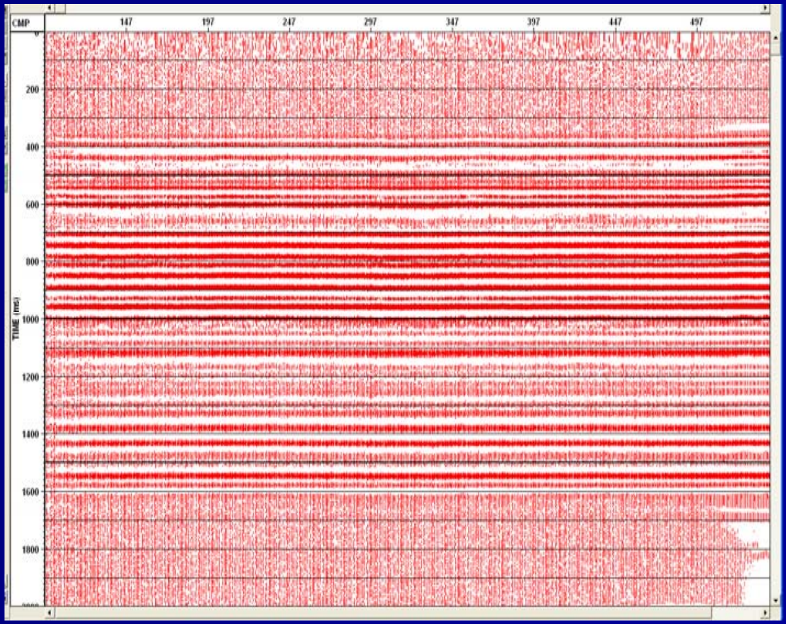
Synthetic raw data

(Courtesy DIVESTCO)



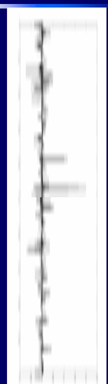
The dataset is made up of 78 shots,
96 channels per shot
Q=40, sample rate=2ms, length=2 sec.
Station interval=34 m.

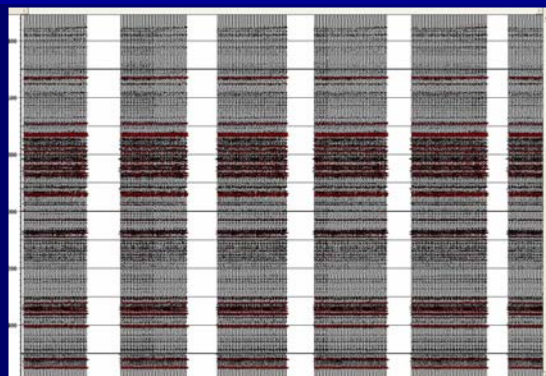


Brute stack

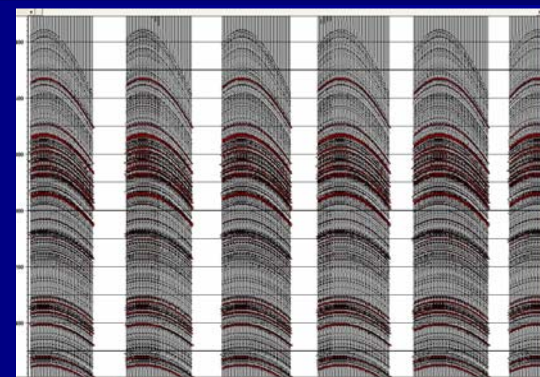
Synthetic raw data

(Courtesy DIVESTCO)

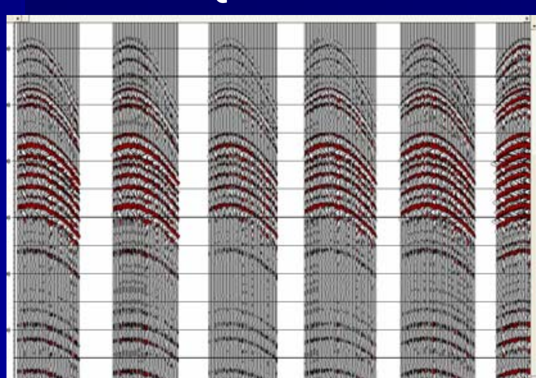




V=3500



Q=40



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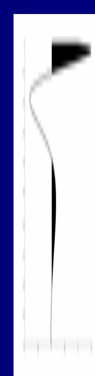

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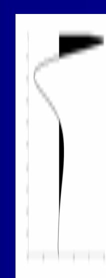
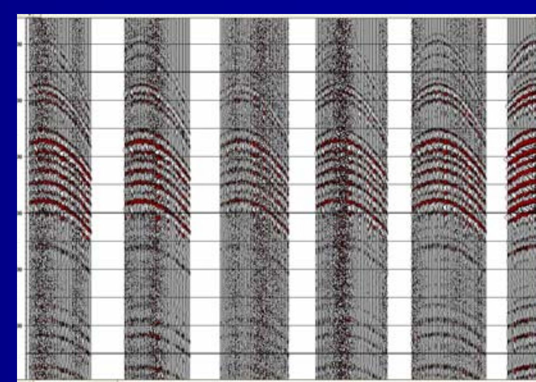


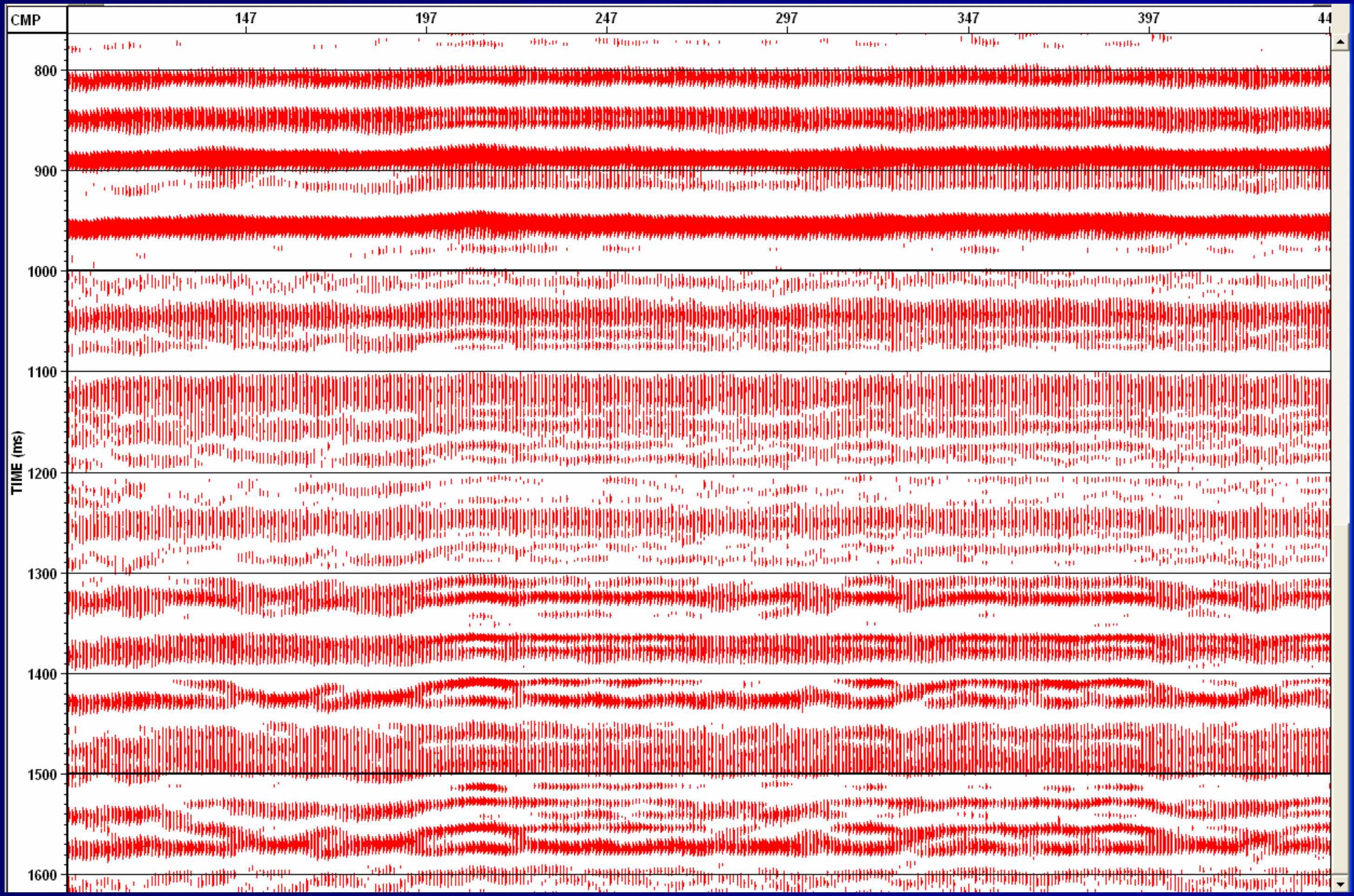


Strong attenuation

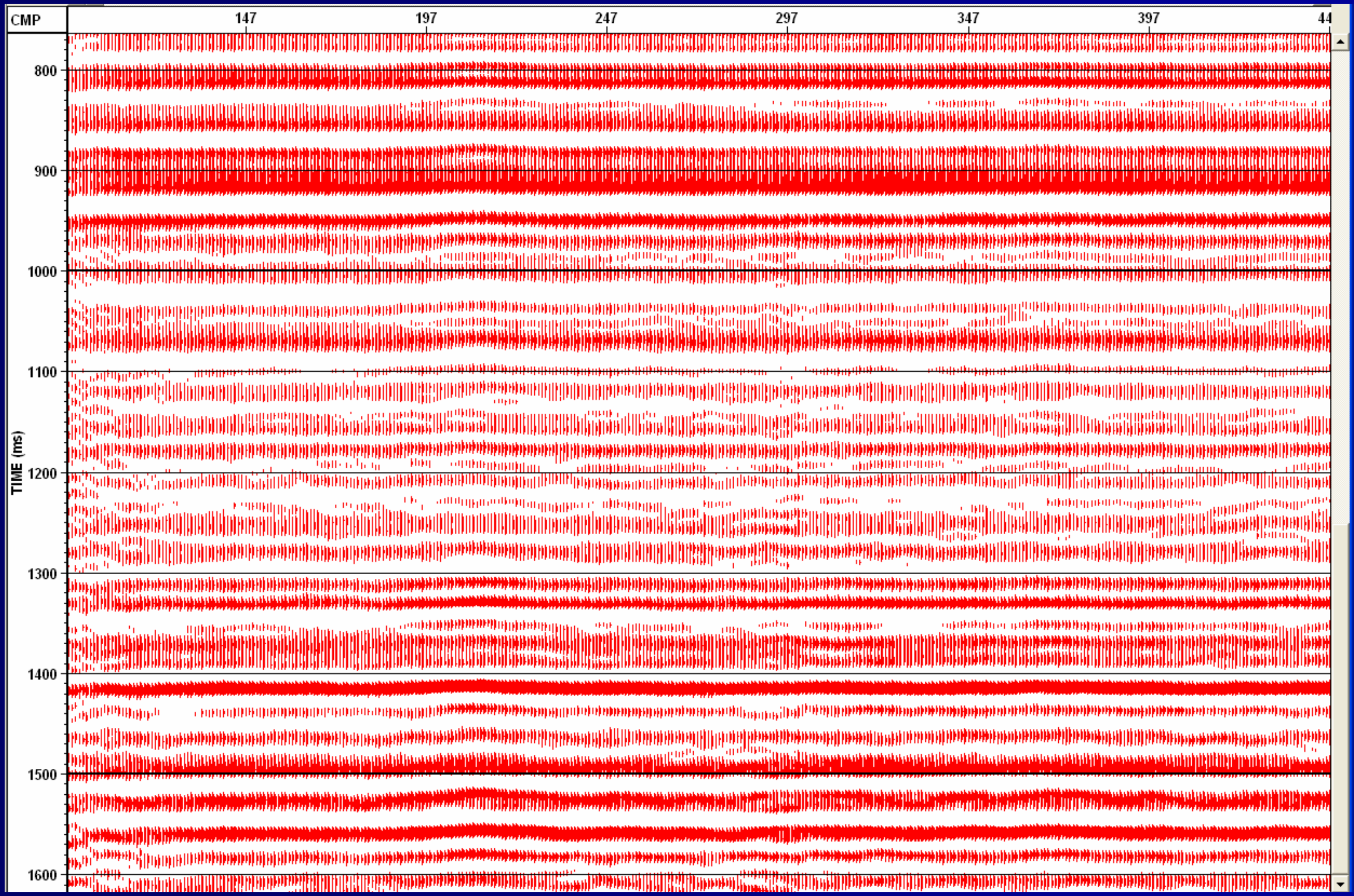
Surf. Consist. wavelets

Strong random noise

After single channel Gabor



After Surf. Cons. Gabor



Conclusions

- A poor S/N could harm the estimation of the minimum phase Gabor deconvolution operator, introducing undesirables artefacts
- The Surface-Consistent implementation of Gabor deconvolution allows a robust estimation of the minimum phase deconvolution operator in the presence of
  - Strong random noise
  - Strong variations of the near-surface features

Acknowledgements

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- Mike Perz