Deconvolution after migration

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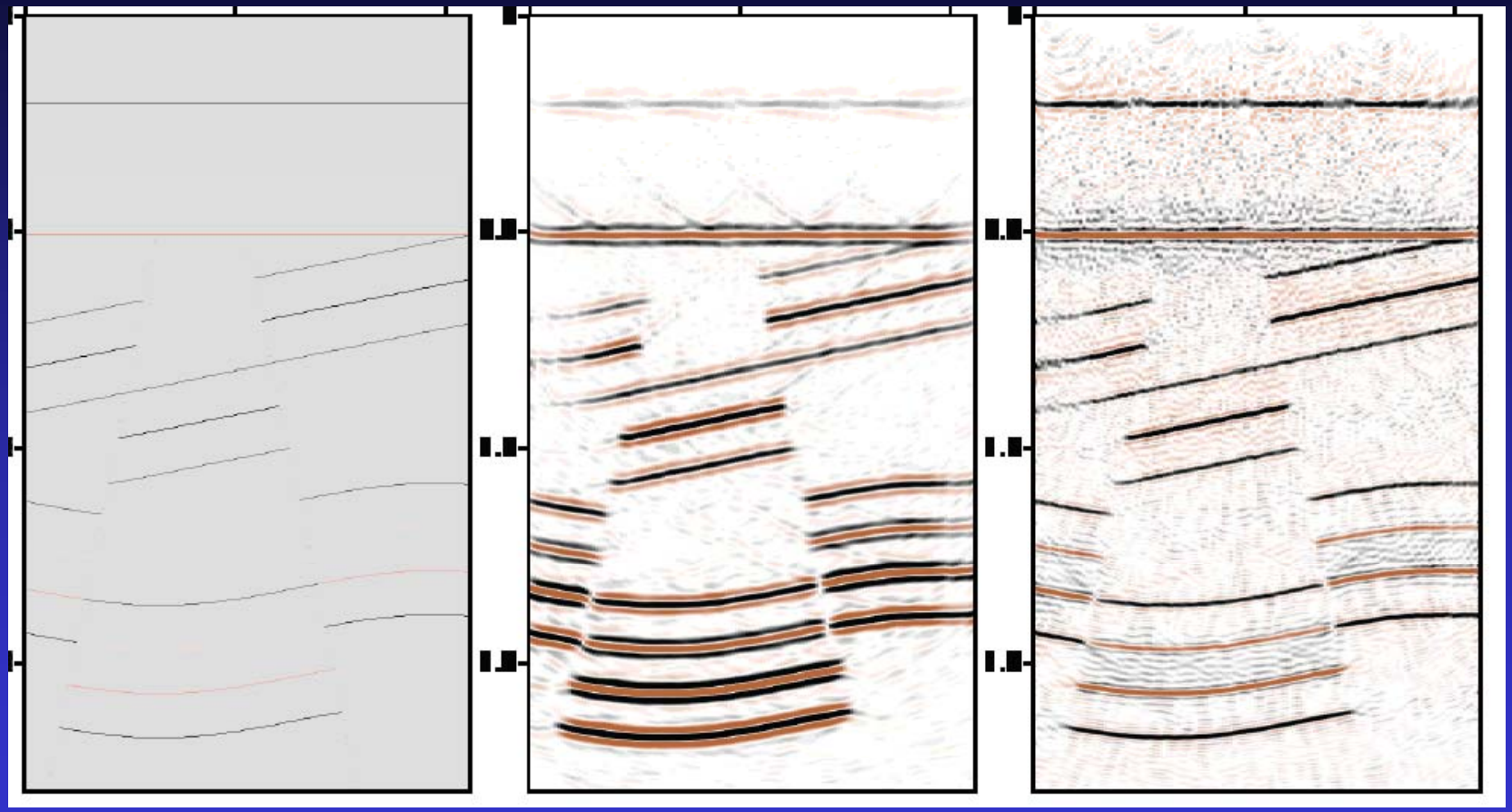
Motivation

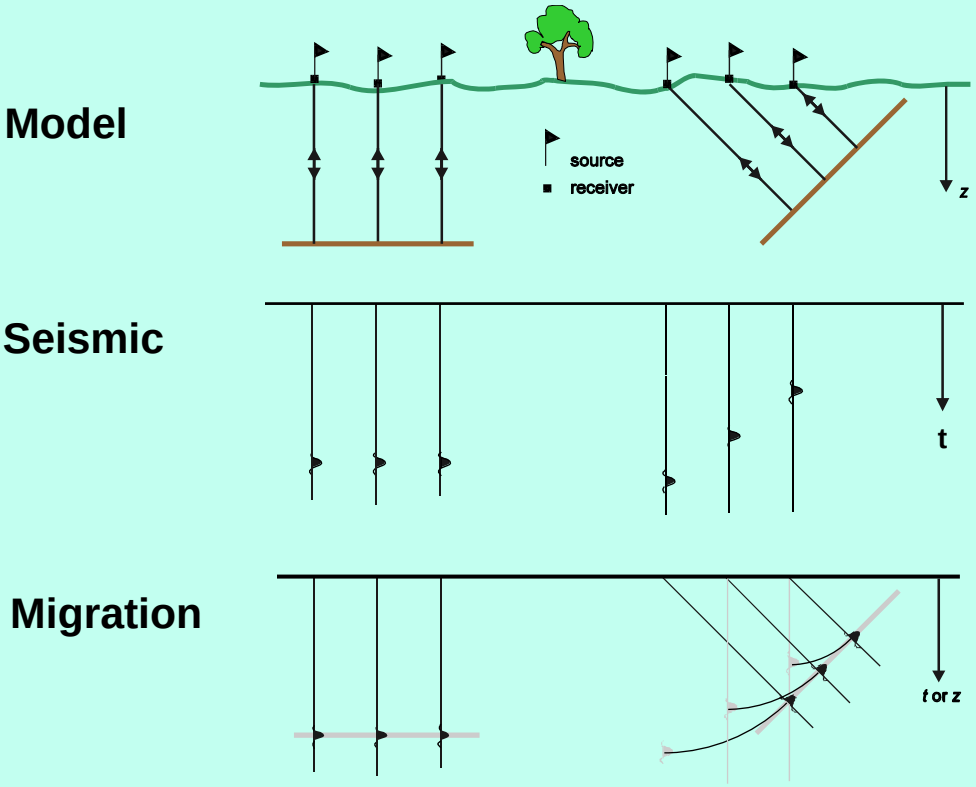


Reflectivity Migration ???

Outline:

- Migration basics
- Migration should attenuate noise
- Some migrations don’t attenuate noise
- Migration is a transpose process
- What is a diffraction?
- Least squares migration
- Noise reduction = greater bandwidth
- Hussar examples

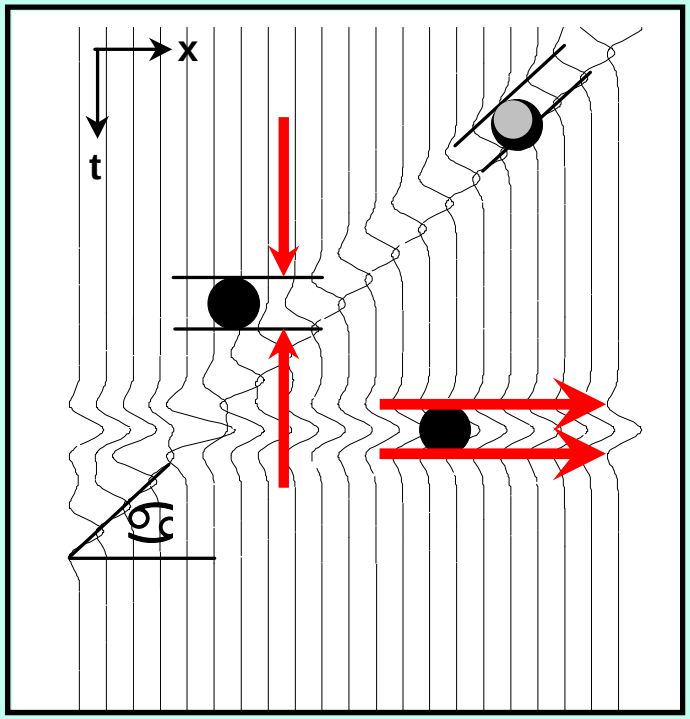
Migration concepts



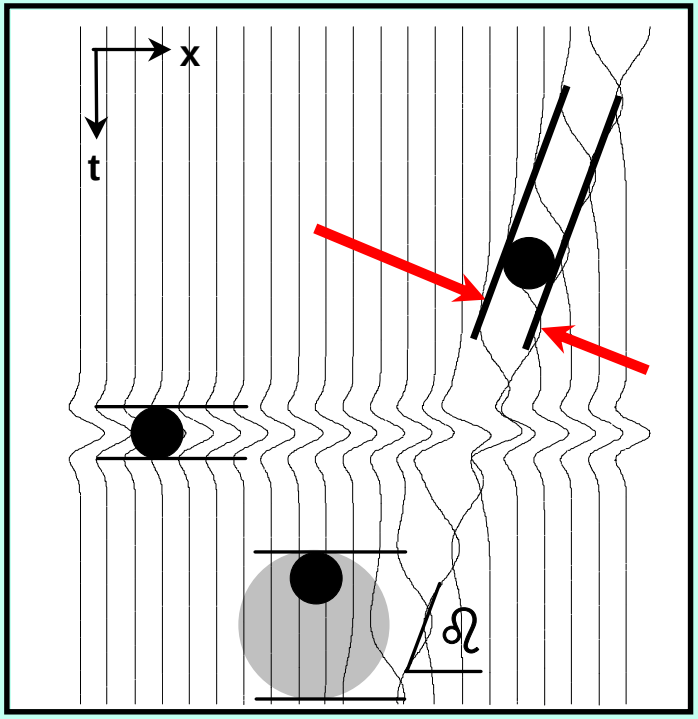
Migration concepts

Actual wavelet

Scaled wavelet



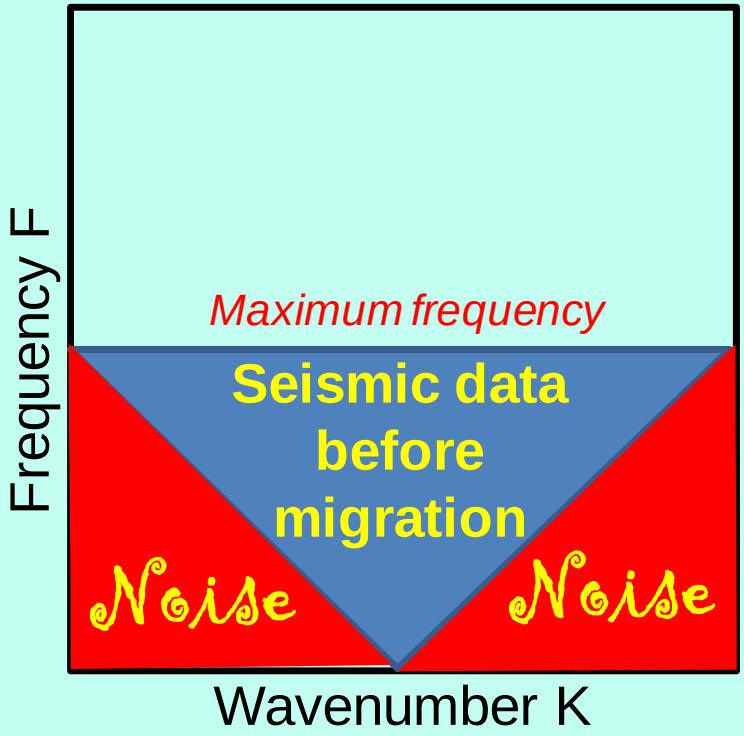
Before Migration

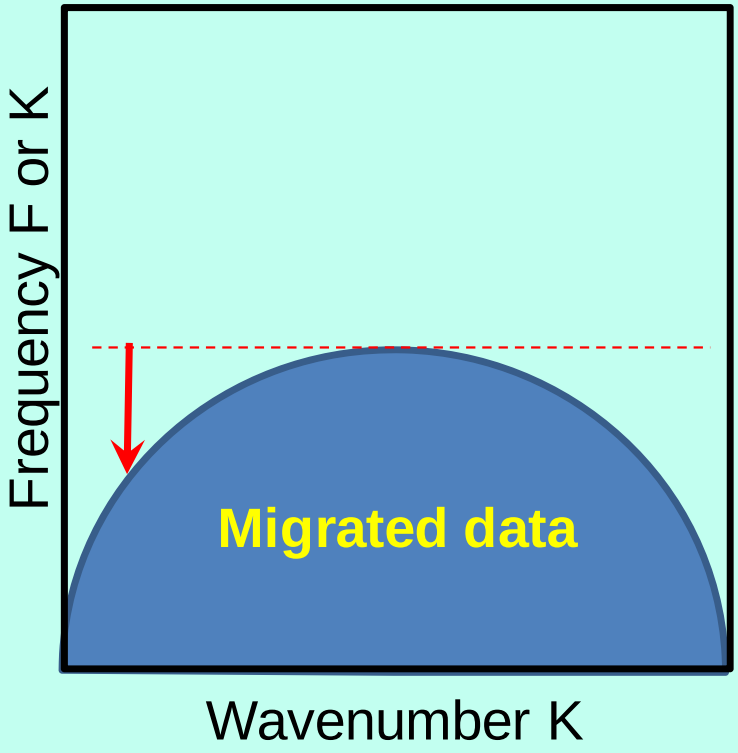


After migration

FK domain of seismic data

- Seismic energy is less than 45^{o} dip.
- Migration *should* attenuate noise.

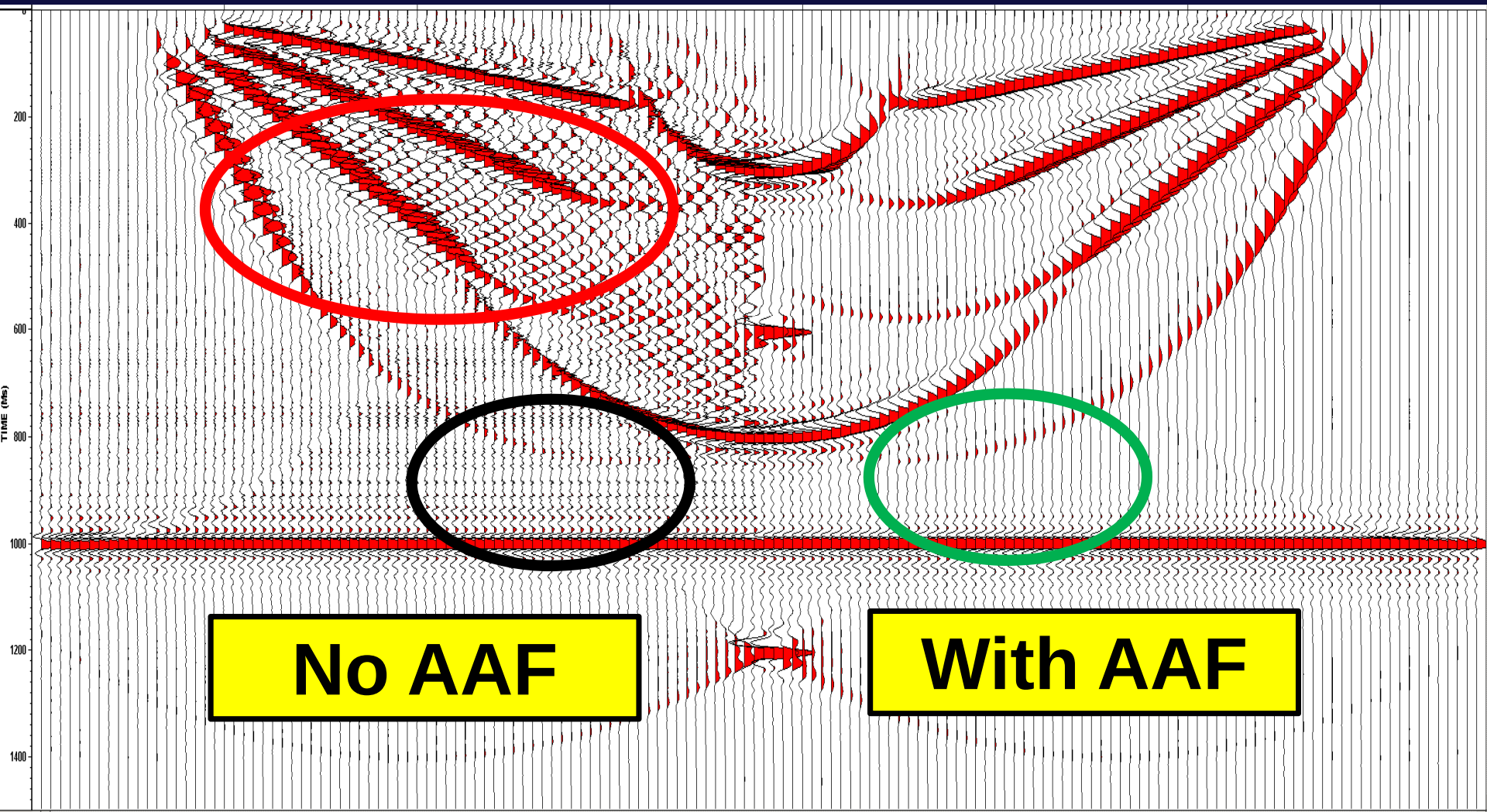




Reasons why migration does not attenuate noise

- Deliberate: appearance purposes
  - Add back some noise
- Algorithm wont allow it
  - Finite difference methods
- Antialiasing filter not used
  - Reduce run times (triangular filters???)
- Don’t need AAFs on flat data
    - Wrong!!!

Kirchhoff migration



Migration is a transpose process

Forward model

- **D** Diffraction matrix
- **r** Reflectivity
- **s** Seismic

$$\mathbf{Dr} = \mathbf{s}$$

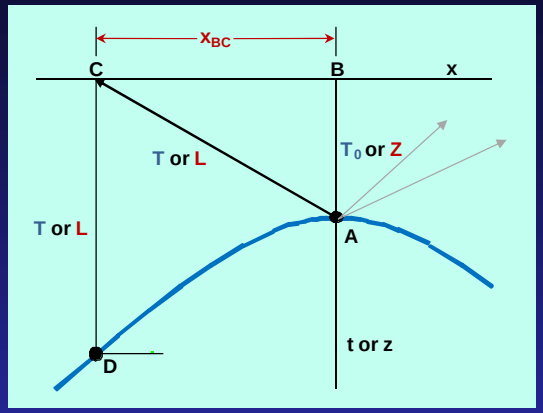
Migration $\mathbf{r} = \mathbf{D}^{T}\mathbf{s}$

Inversion model $\mathbf{r} = \mathbf{D}^{-1}\mathbf{s}$

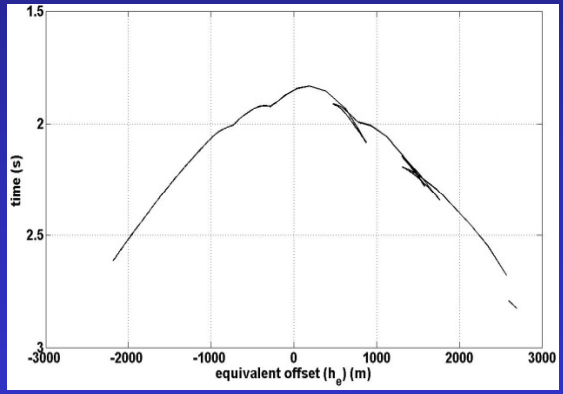
Least Sq. migration $\mathbf{r} = \left(\mathbf{D}^{T}\mathbf{D}\right)^{-1}\mathbf{D}^{T}\mathbf{s}$

Kirchhoff migration uses…

Migration $\mathbf{r} = \mathbf{D}^{\mathrm{T}}\mathbf{s}$



1. **Kirchhoff migration typically uses a single valued diffraction.**
2. **Sometimes 2 or 3 values.**
3. **May include an antialiasing wavelet.**



But that is not good enough…

- We should be including a wavelet matrix **W**

$$\mathbf{WDr} = \mathbf{s}$$

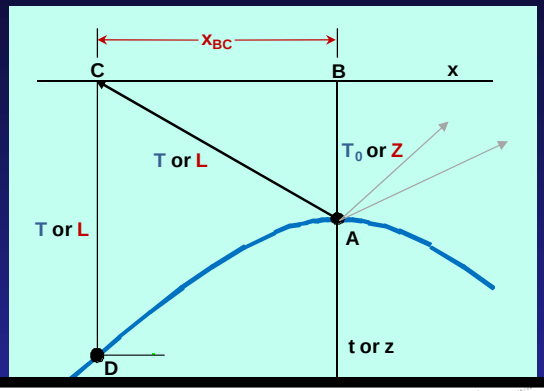
Migration $\mathbf{r} = \left(\mathbf{WD}\right)^{\mathbf{T}} \mathbf{s}$

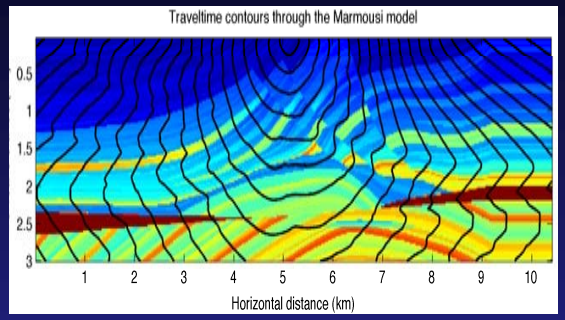
$$\mathbf{r} = \mathbf{D}^{\mathbf{T}}\mathbf{W}^{\mathbf{T}}\mathbf{s}$$

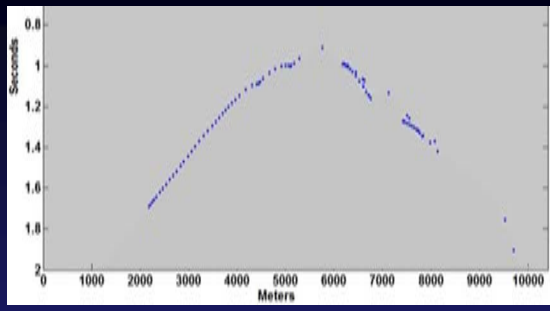
What is a diffraction?

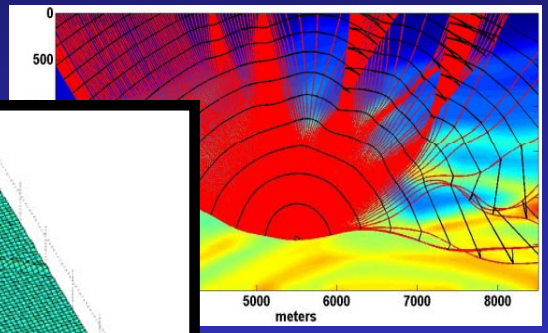
Backup

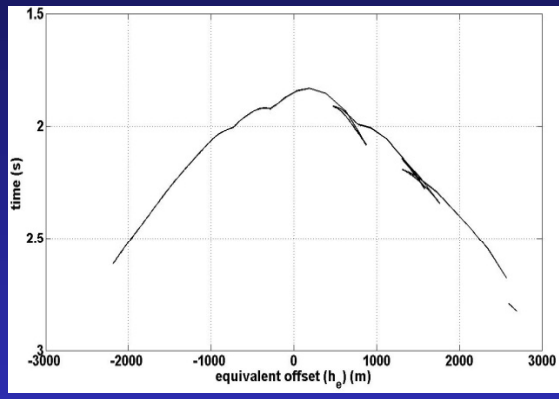
What is a diffraction ???

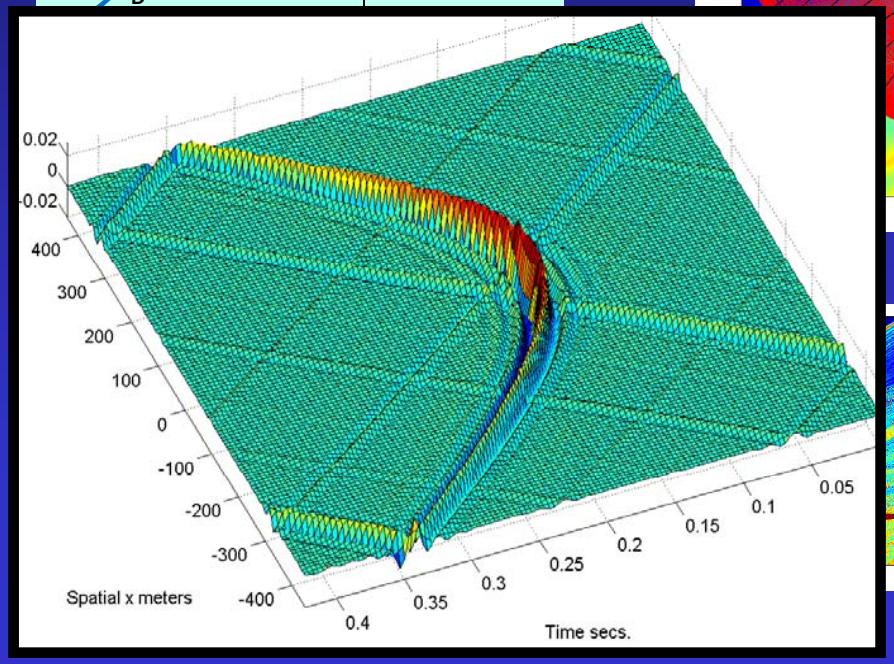


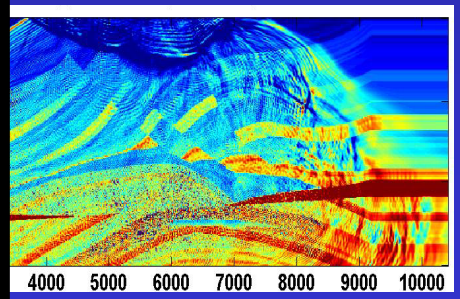


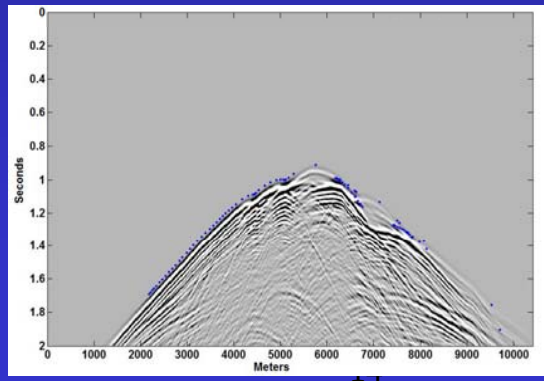








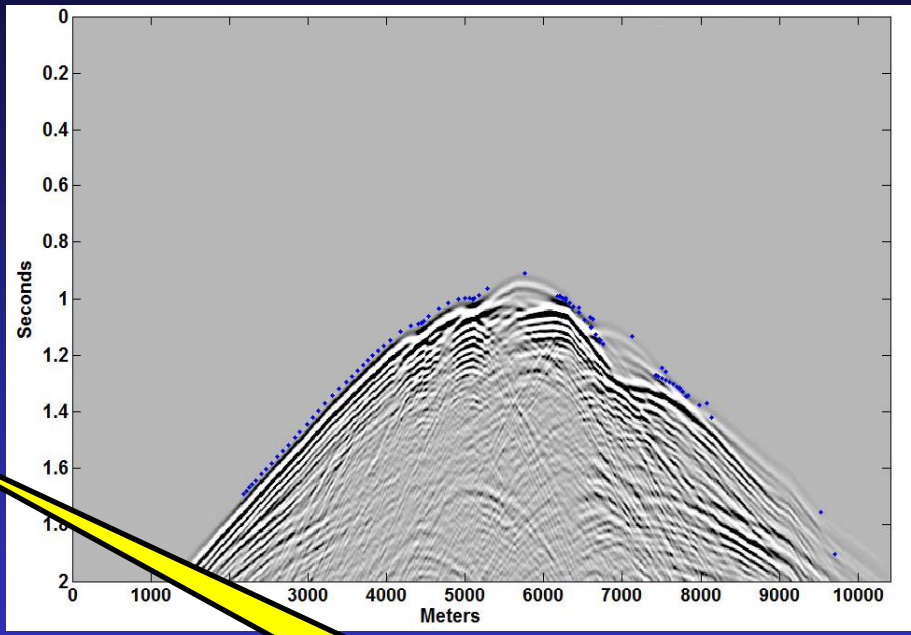




Kirchhoff migration uses…

Migration $\mathbf{r} = \mathbf{D}^T\mathbf{s}$

$\mathbf{r} = \mathbf{D}^T\mathbf{W}^T\mathbf{s}$

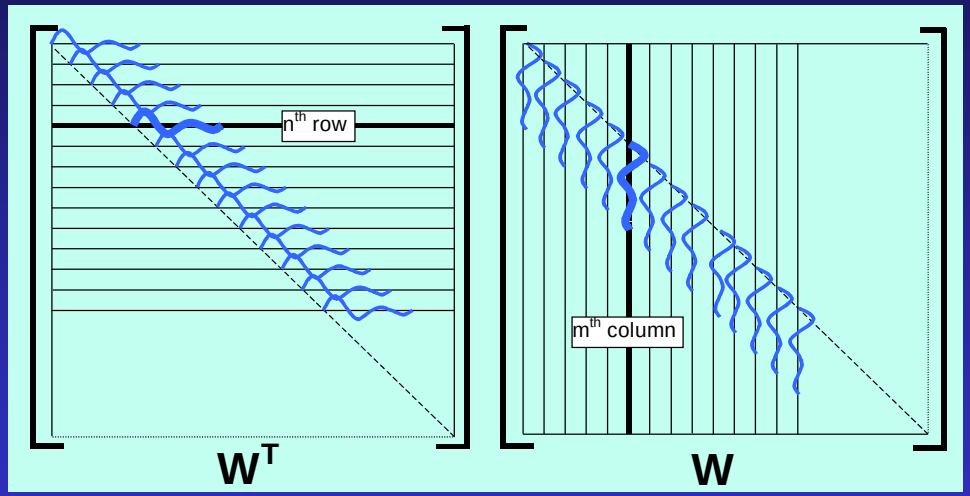


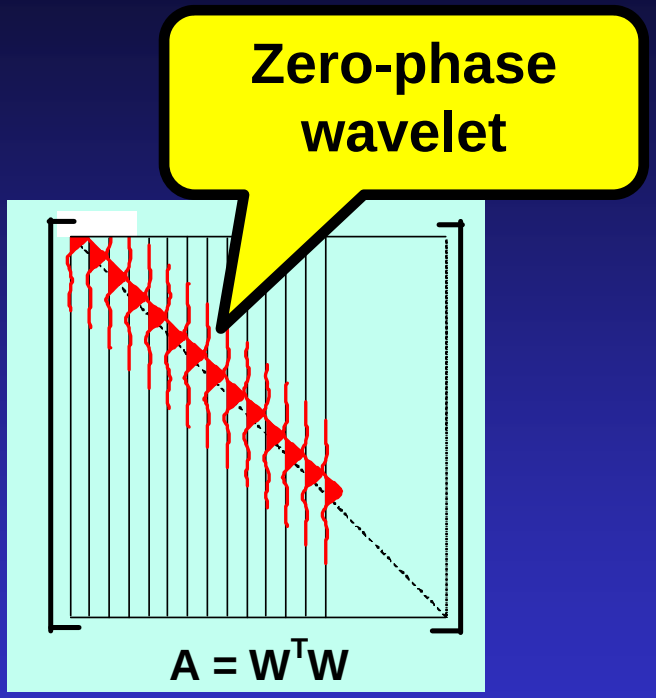
1. Lower signal bandwidth
2. Much lower noise
3. Better SNR …

Matched filter

Hold that ttouht

Matched filter ?





Autocorrelation

Reason 1

Least squares migration

Including the wavelet in LS mig

$$\mathbf{WDr} = \mathbf{s}$$

$$\left(\mathbf{WD}\right)^{T}\mathbf{WDr} = \left(\mathbf{WD}\right)^{T}\mathbf{s}$$

$$\mathbf{D}^{T}\mathbf{W}^{T}\mathbf{WDr} = \mathbf{D}^{T}\mathbf{W}^{T}\mathbf{s}$$

$$\mathbf{r} = \left(\mathbf{D}^{T}\mathbf{W}^{T}\mathbf{WD}\right)^{-1}\mathbf{D}^{T}\mathbf{W}^{T}\mathbf{s}$$

Including the wavelet

- What happens when we add a wavelet **W** to LS mig?

$$\mathbf{r} = \left(\mathbf{D}^T\mathbf{W}^T\mathbf{W}\mathbf{D}\right)^{-1}\underbrace{\mathbf{D}^T\mathbf{W}^T\mathbf{s}}$$

Conventional migration (with wavelet)

Including the wavelet

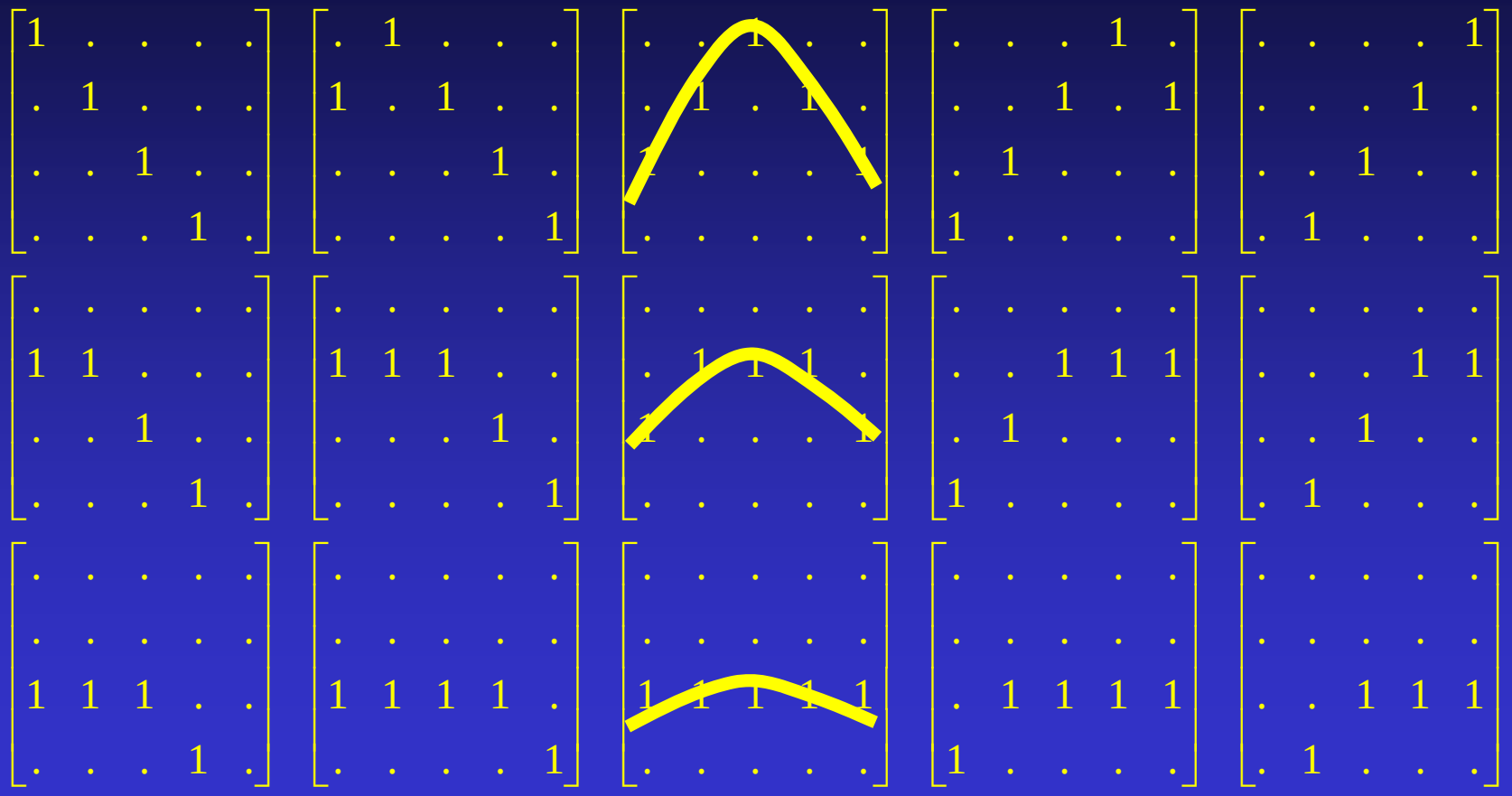
- What happens when we add a wavelet **W** to LS mig?

$$\mathbf{r} = \underbrace{\left(\mathbf{D}^T\mathbf{W}^T\mathbf{W}\mathbf{D}\right)^{-1}}\ \mathbf{D}^T\mathbf{W}^T\mathbf{s}$$

Ignored by conventional migration

This is the part that recovers the bandwidth

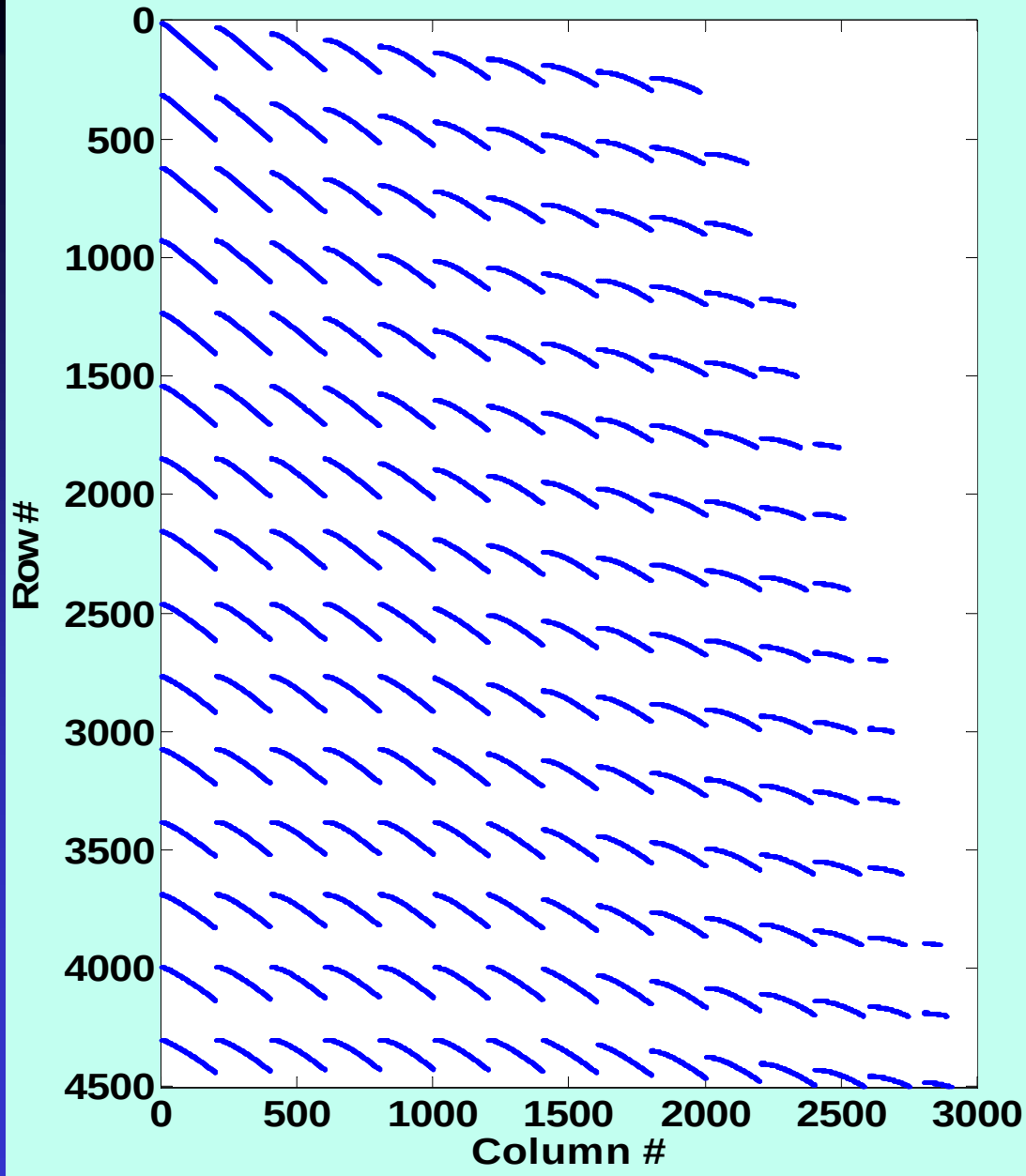
LS Diffraction Matrix 4x5x3x5



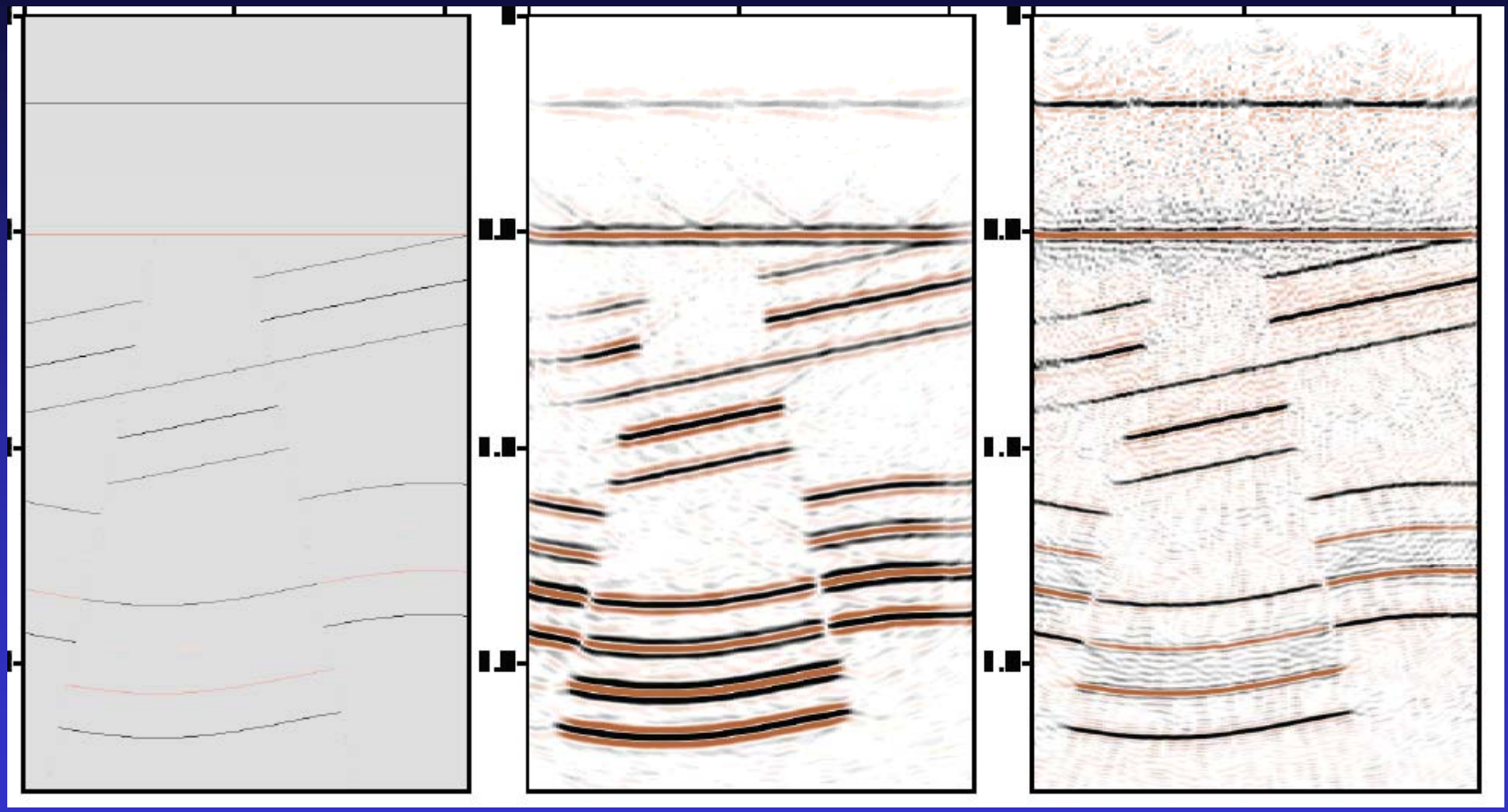
Diffraction matrix

- 1 source,
- 15 receivers,
- 15 CMPs,
- 200 depth samples
- 300 time samples

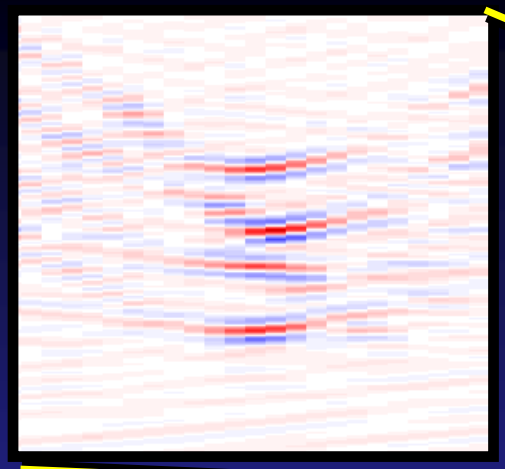
- Abdolnaser Yousefzadeh
  - (Naser)

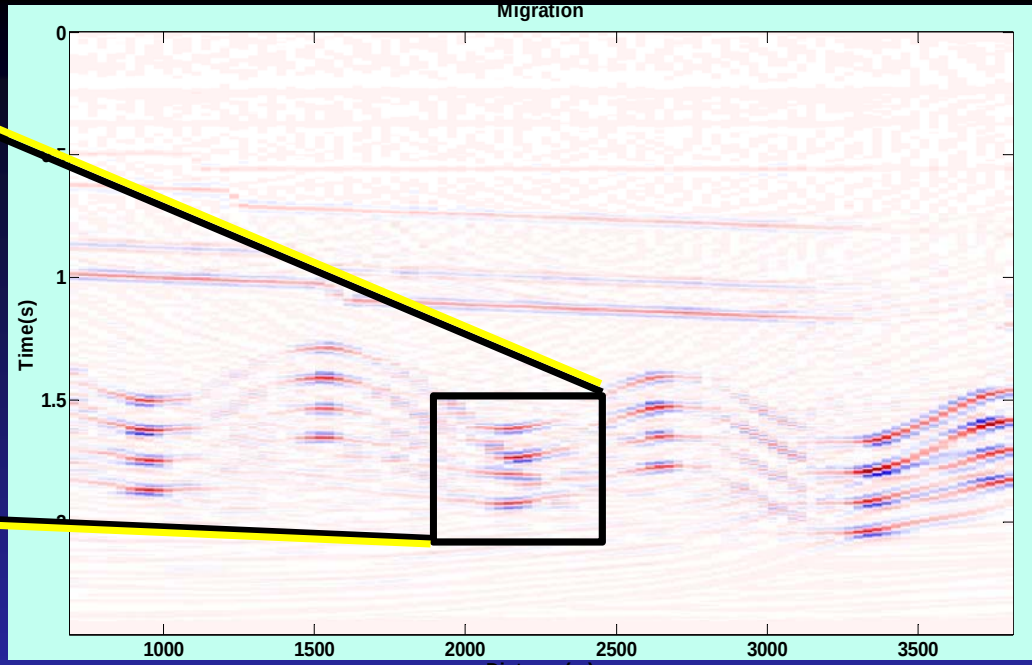


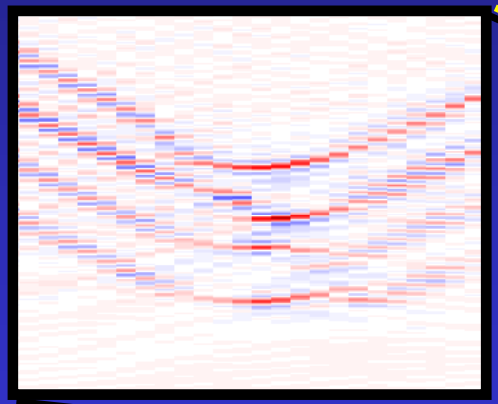
Approximate LSM with decon. ???

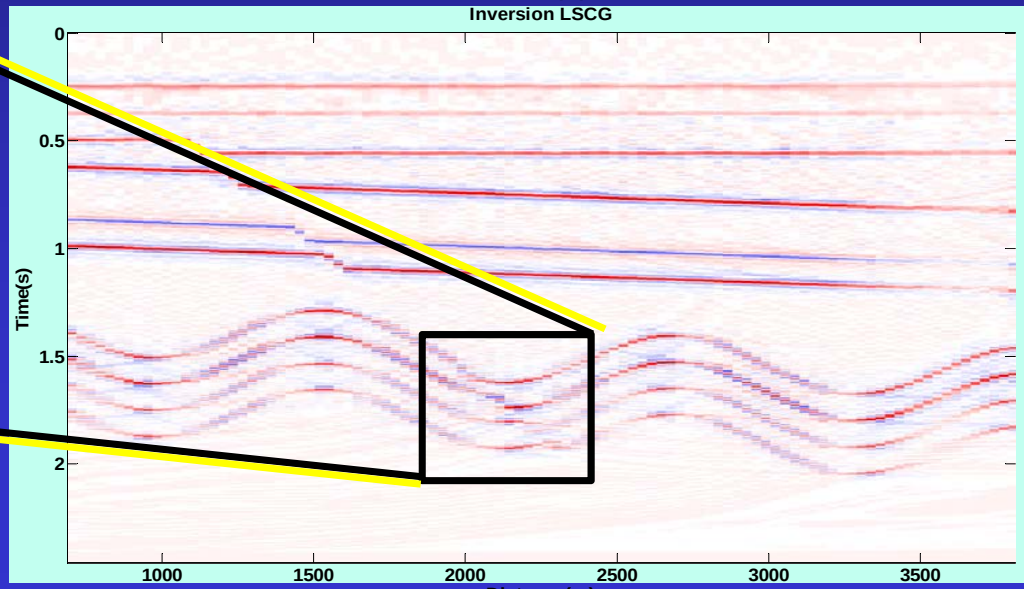


Reflectivity Migration LS migration




Migration
Time(s)
0
1
1.5
1000
1500
2000
2500
3000
3500
Distance(m)




Inversion LSCG
Time(s)
0
0.5
1
1.5
2
1000
1500
2000
2500
3000
3500
Distance(m)

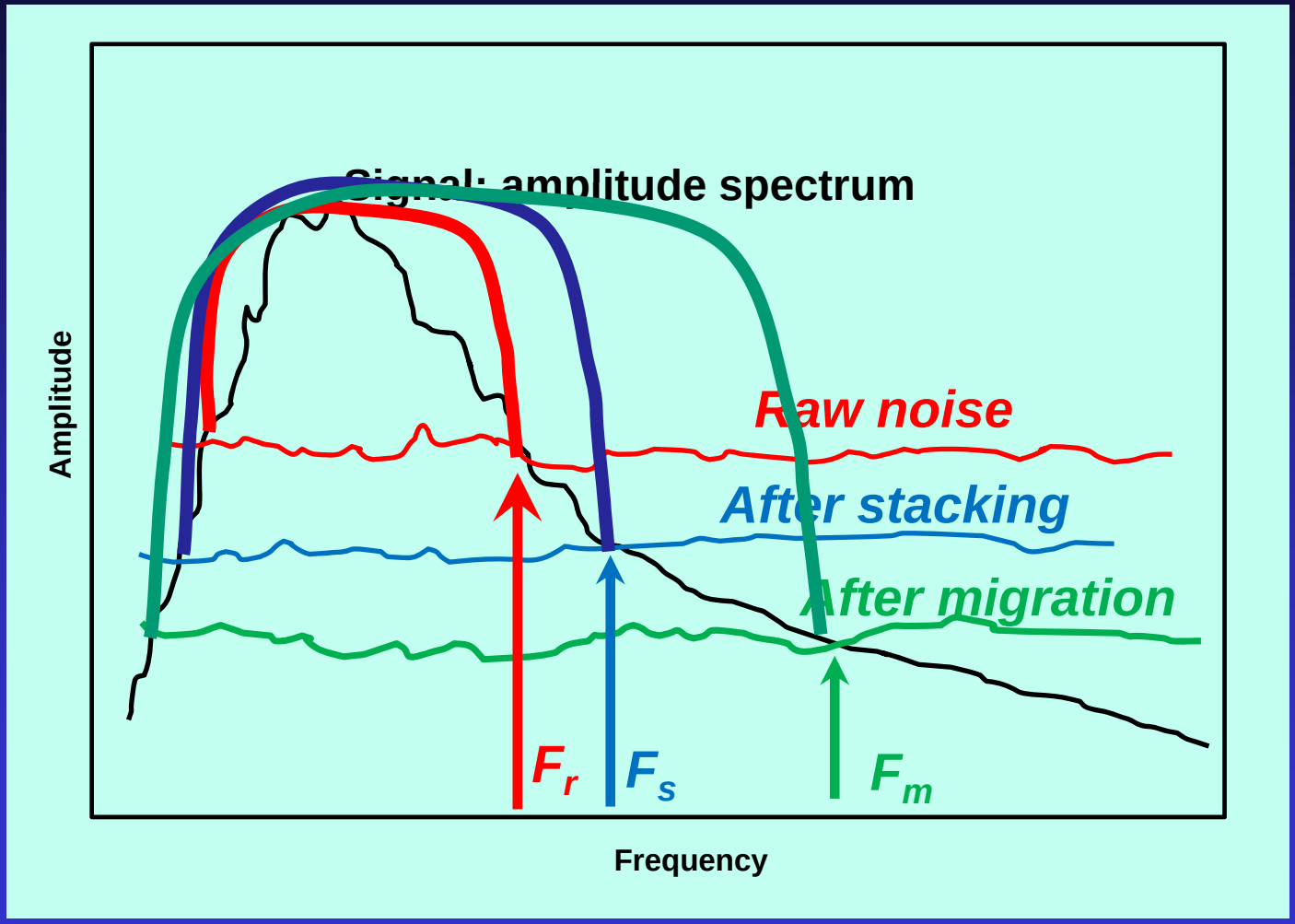
Reason 2

Improved SNR = greater bandwidth

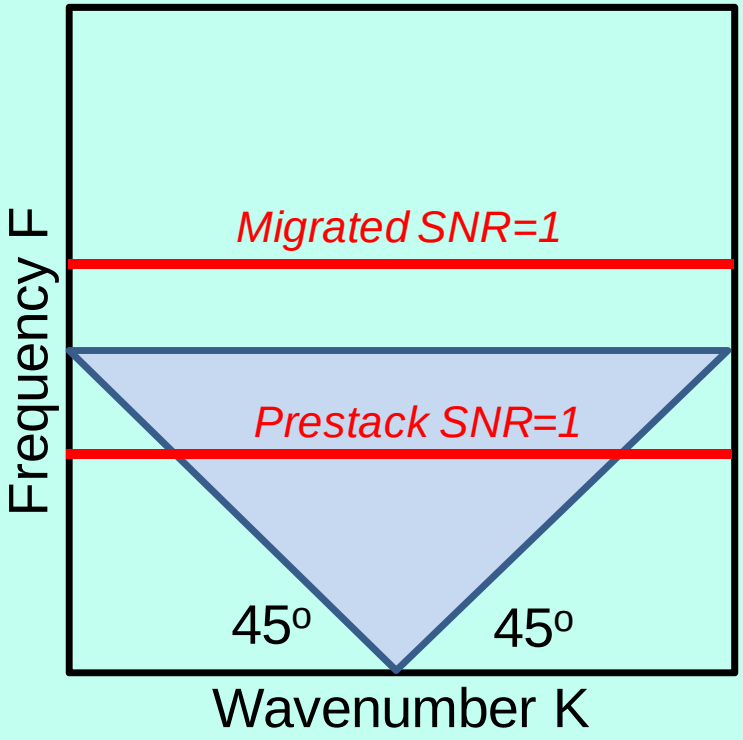
Noise

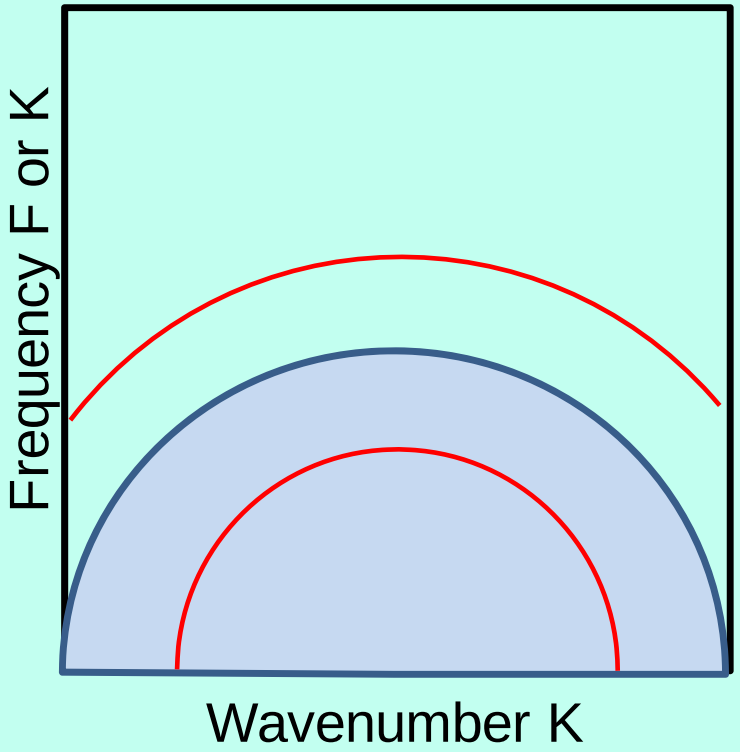
- Seismic energy is less than 45^{o} dip.
- Energy greater than 45^{o} is noise
- Migration should attenuate this noise
- Attenuated noise increases the bandwidth
- Increased bandwidth, better deconvolution
- Higher resolution

Improving the SNR with processing



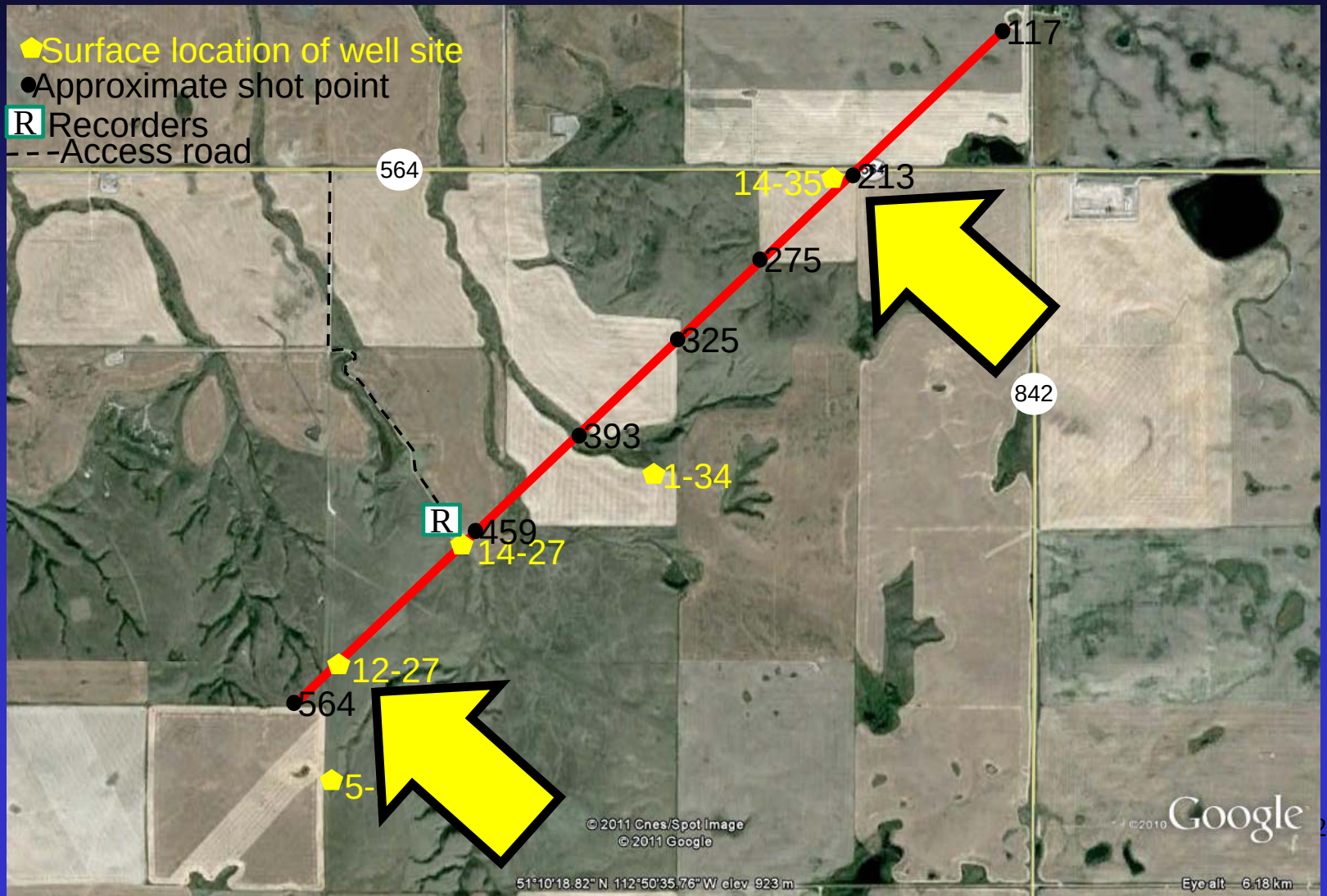
Fourier transform



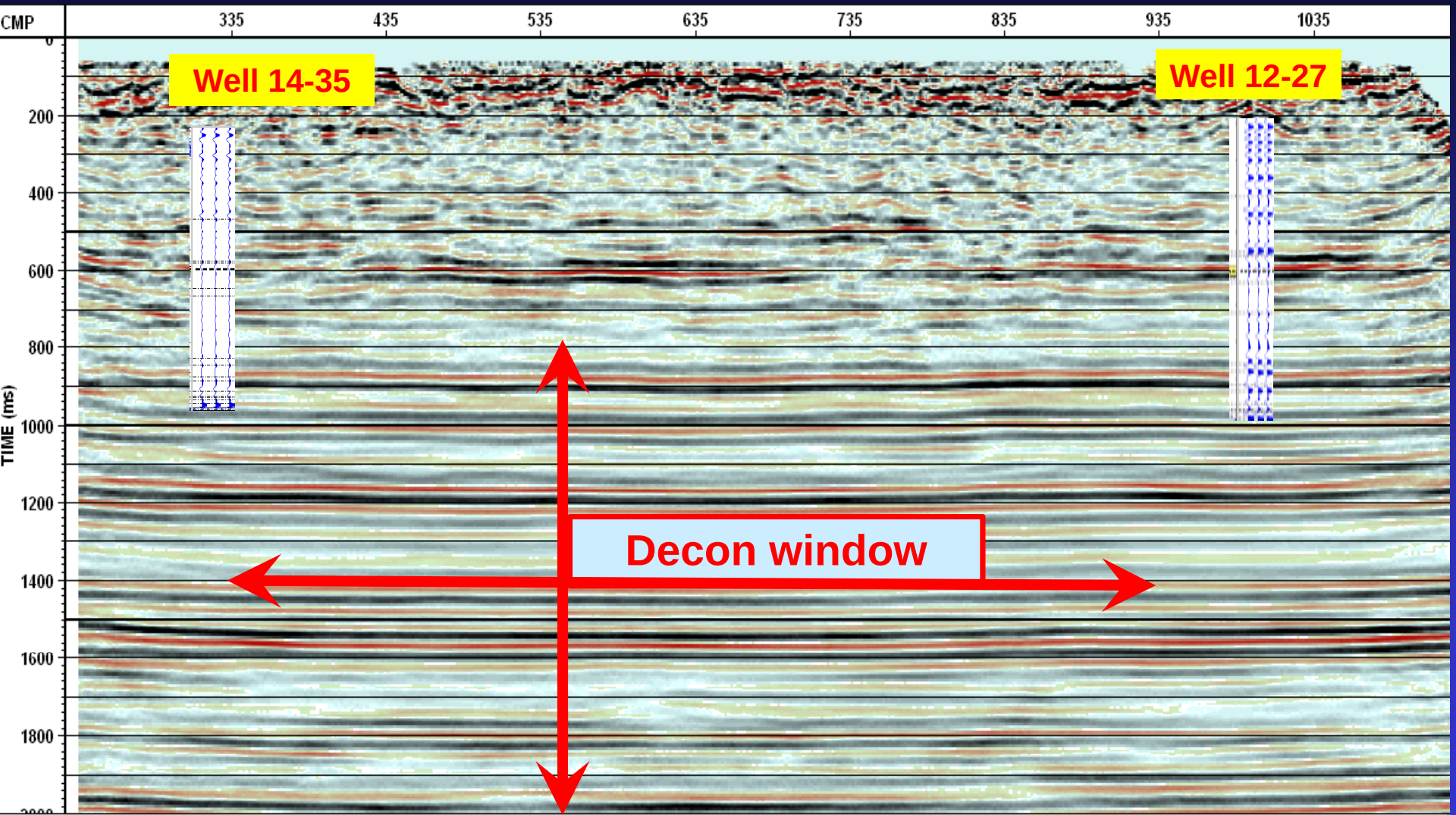


May need to re-think spatial sampling

Hussar Low-Frequency Shoot

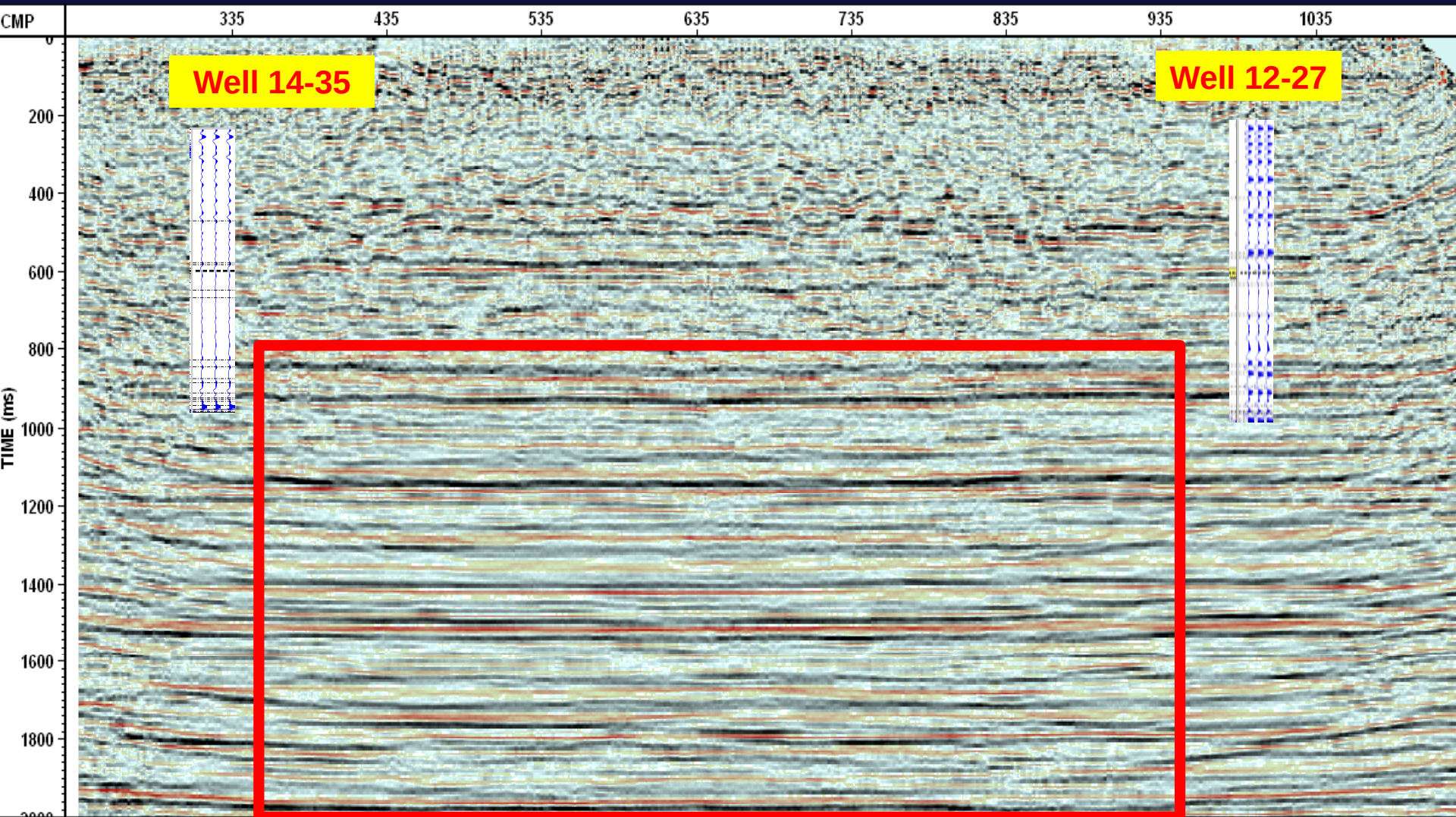


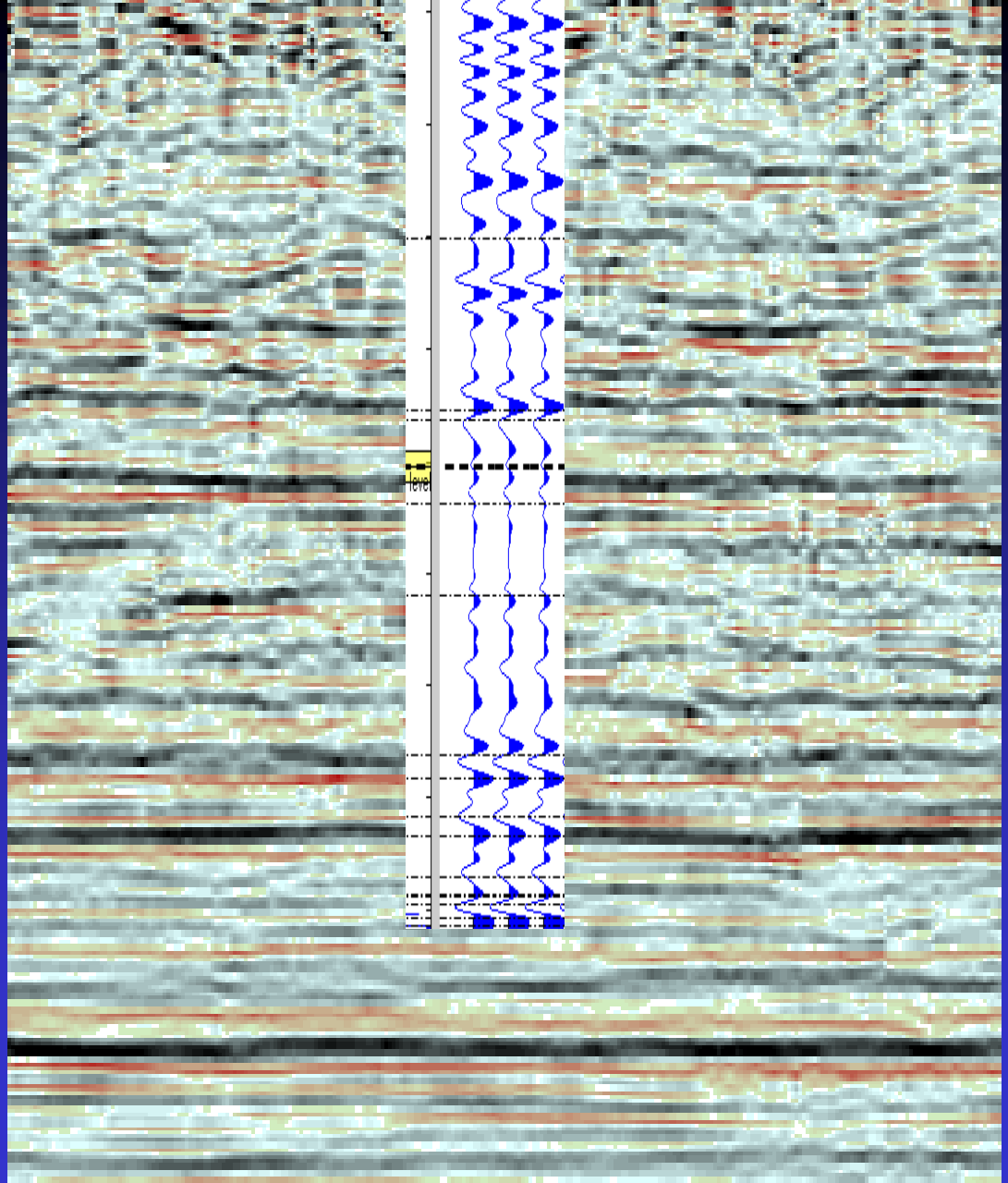
PSTM Low dwell line, noisy



PSTM + deconvolution

Wavelet 10-15-45-60



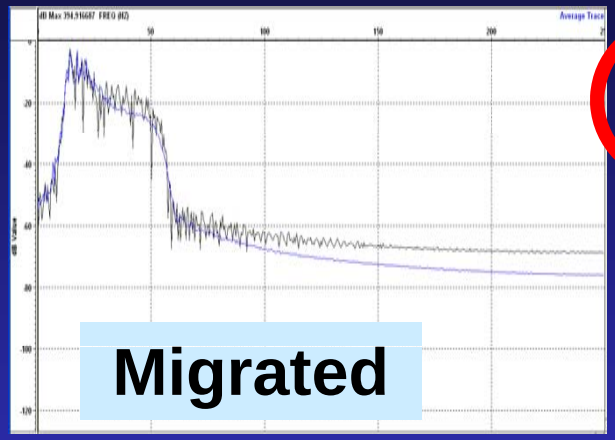


Deconvolution spectra

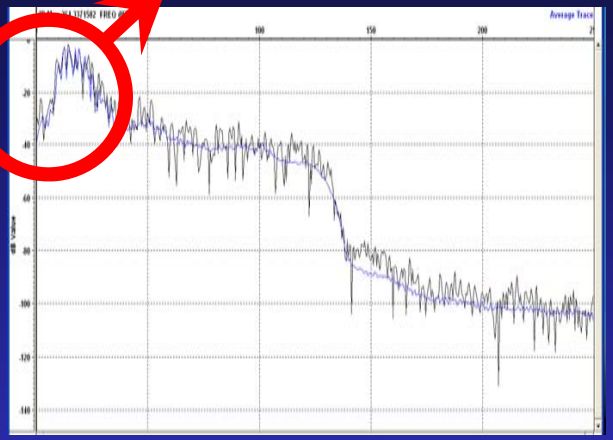
10-15-45-60

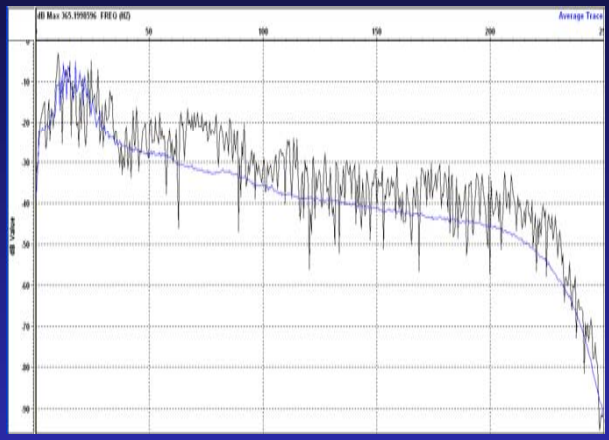
1-2-124-140

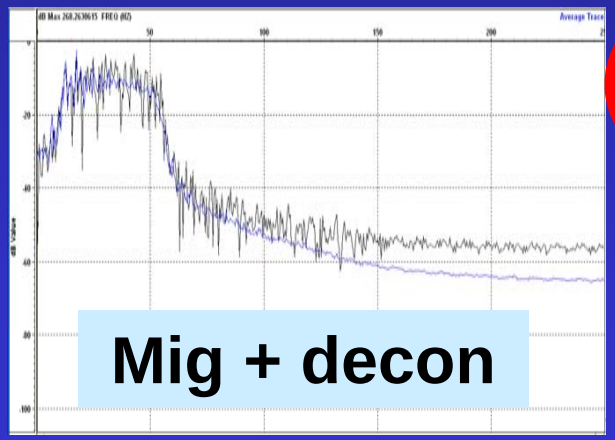
1-2-200-240



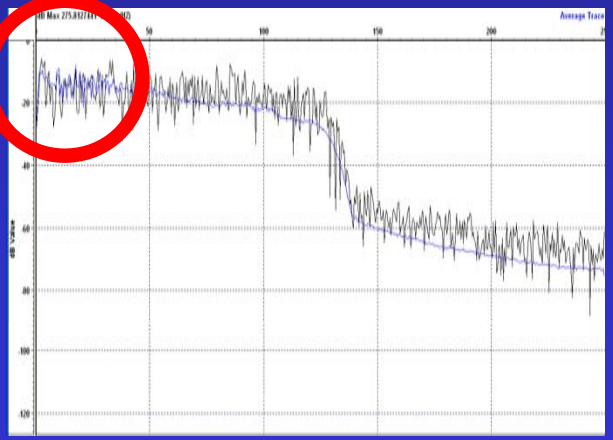
Migrated

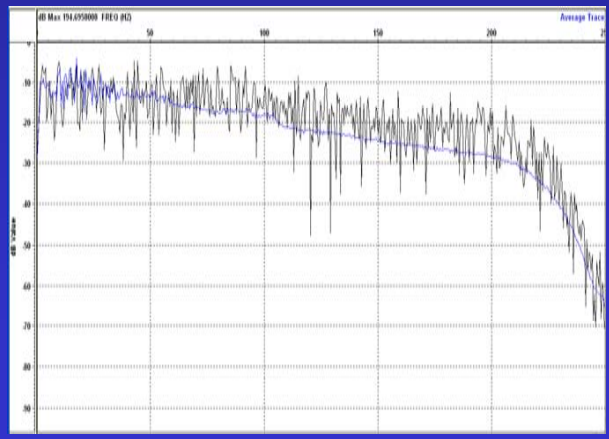




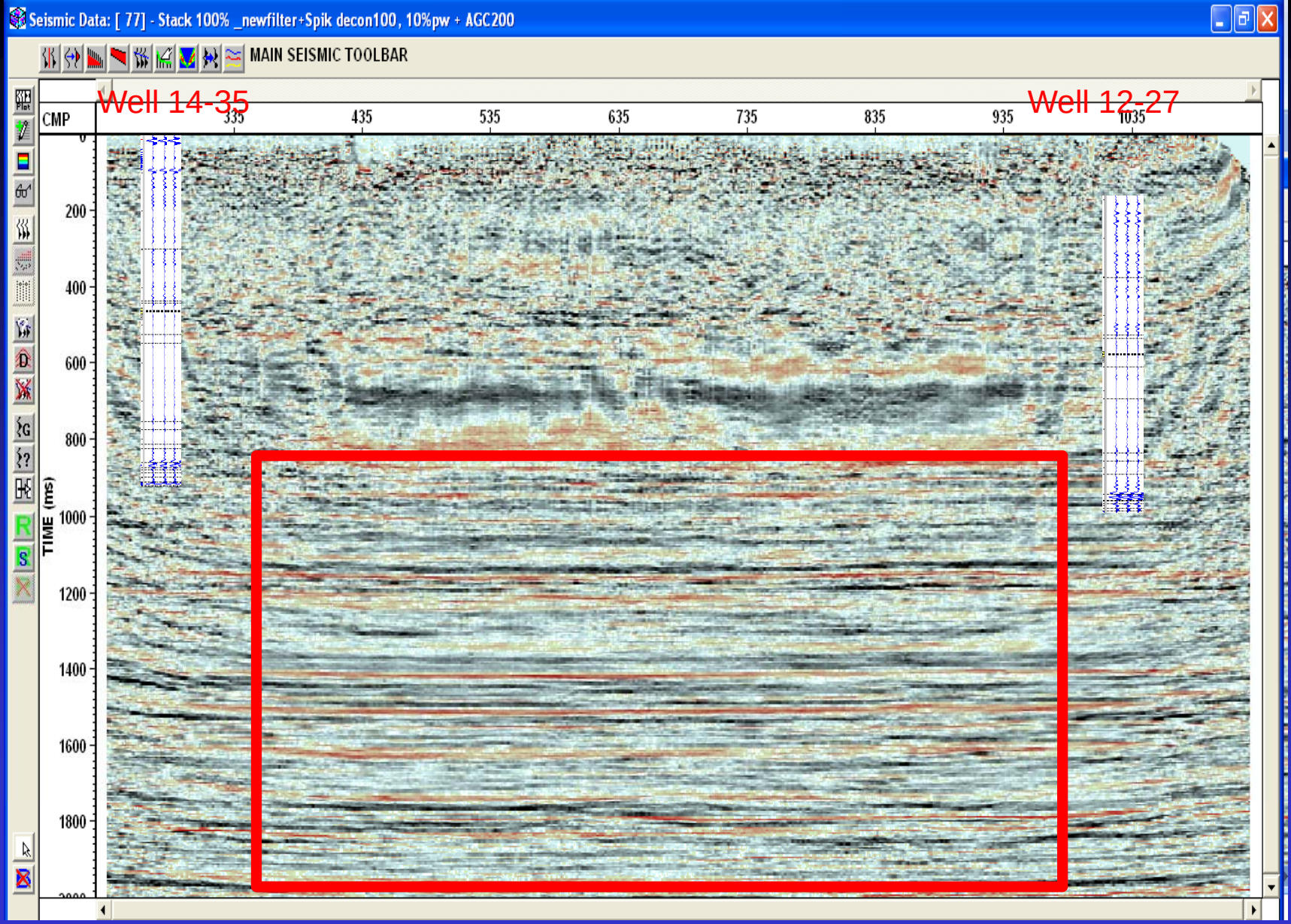


Mig + decon





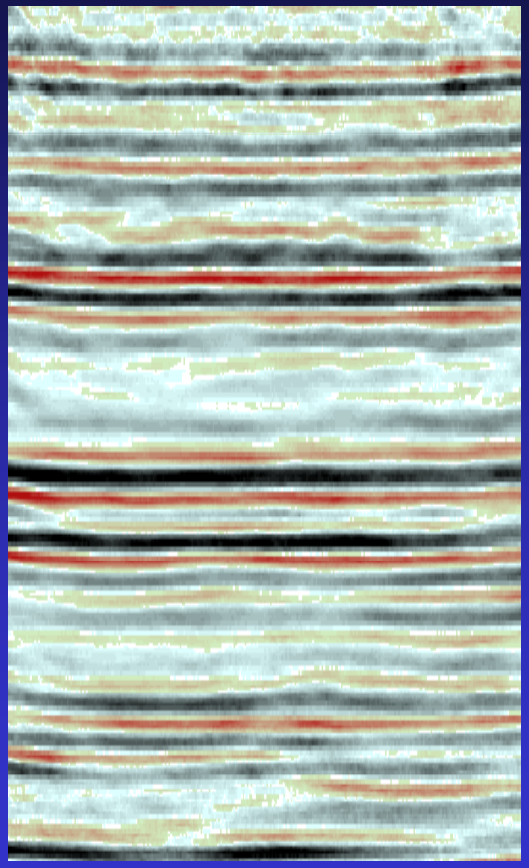
Fm = 250



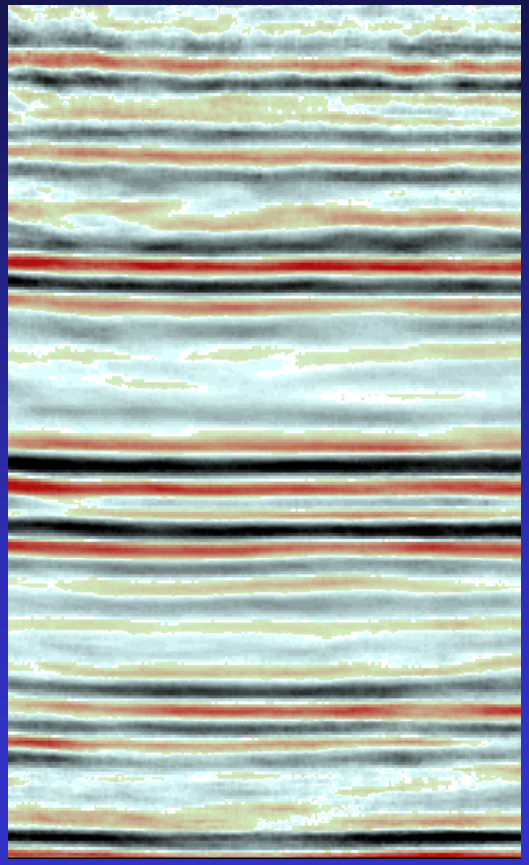
Wavelet 1-2-120-140

EOM data: decon window

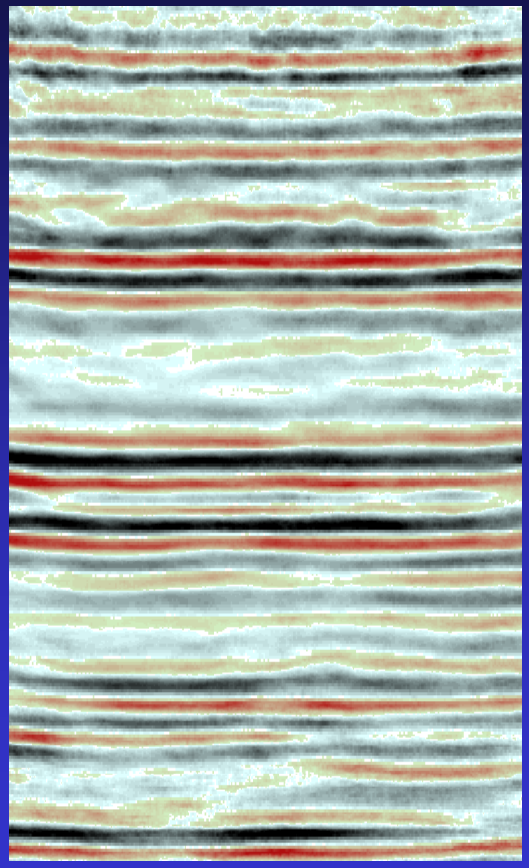
10-15-45-60



1-2-124-140



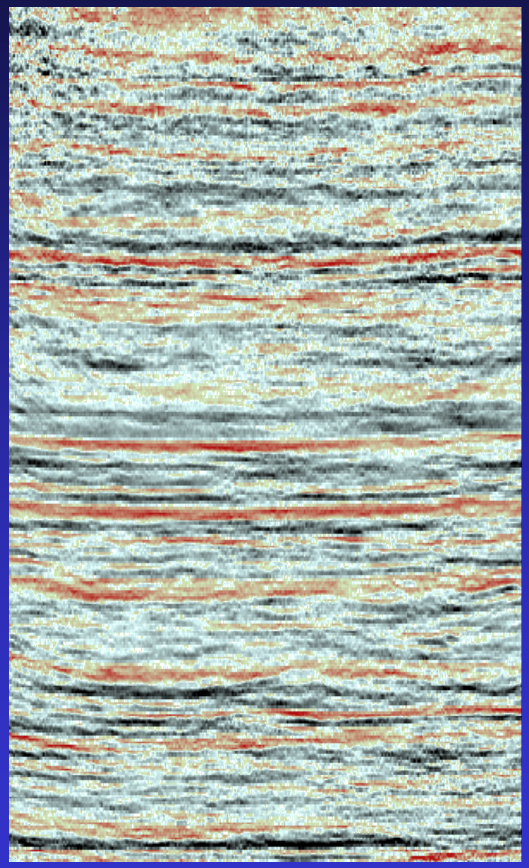
1-2-200-240



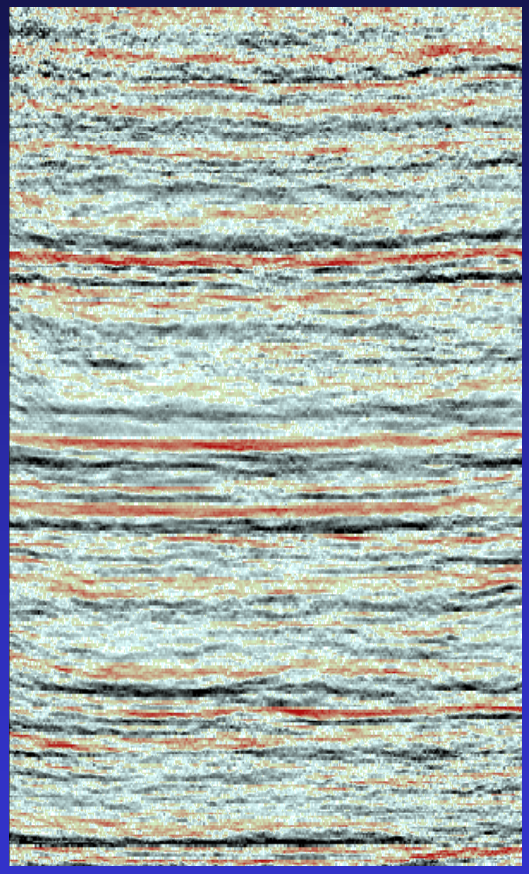
Spiking deconvolution

10-15-45-60

1-2-124-140



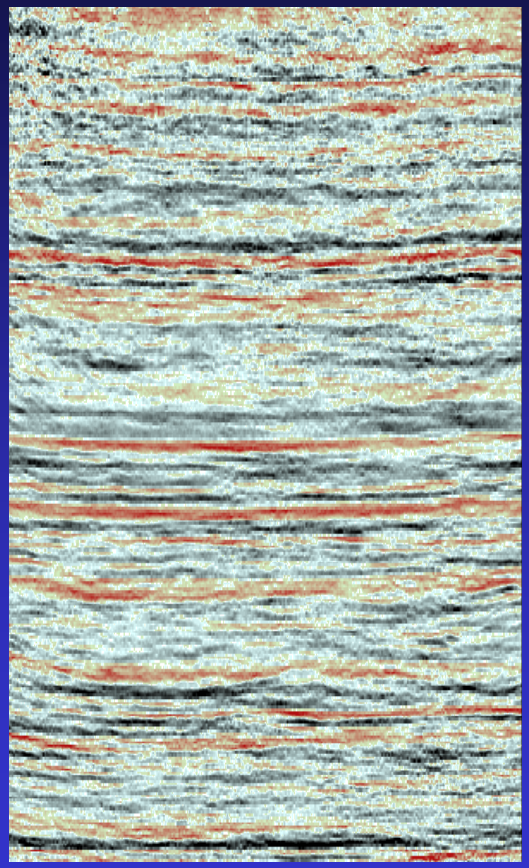
1-2-200-240



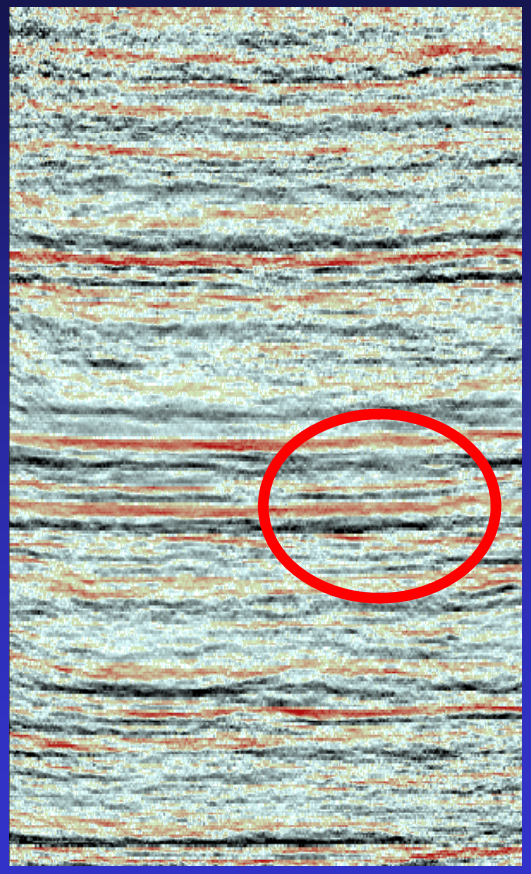
Spiking deconvolution

10-15-45-60

1-2-124-140



1-2-200-240



Comments and conclusions

- Migration should attenuate noise
- Should include the wavelet in Kirchhoff migration
- Deconvolution should be applied after migration
  - LSM
  - Lower noise threshold
- Decon after migration may simulate one property of LSM (interpolation)
- May need a dip dependent deconvolution


Thanks for your attention
The end

FK domain of seismic data

- Seismic energy is less than 45^{o} dip.
- Aliased noise