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Radon transforms and multiple attenuation of White Rose data

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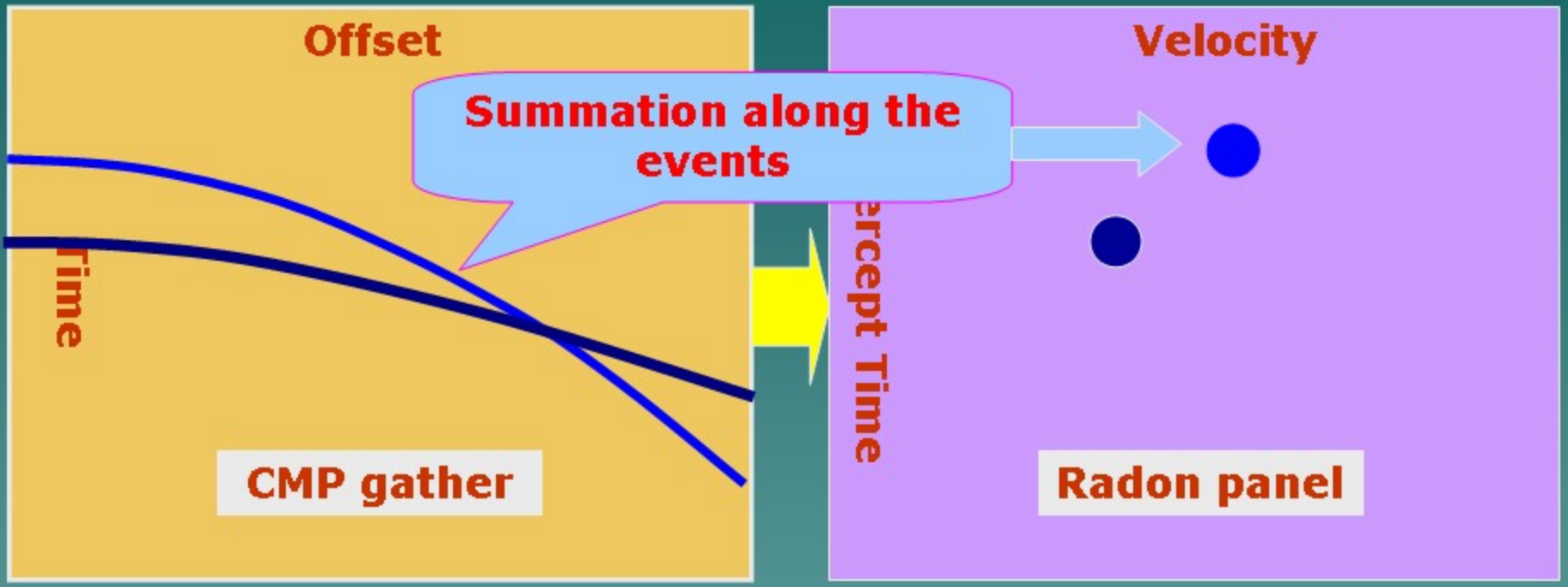
CREWES

Outlines

- Introduction to the Radon transform
  - Definition
  - Problems of the transform
- The semblance-weighted Radon method
- Data examples
  - Synthetic data
  - Real data
- Conclusions
- Acknowledgements

Introduction: Definition



-The Radon transform is defined as an integration of data along certain paths: such as hyperbola or parabola

-Basically, a point in the Radon domain stands for an event in the CMP domain

-Events with different velocities, such as primaries and multiples, map to different points in the Radon domain

Introduction: Definition

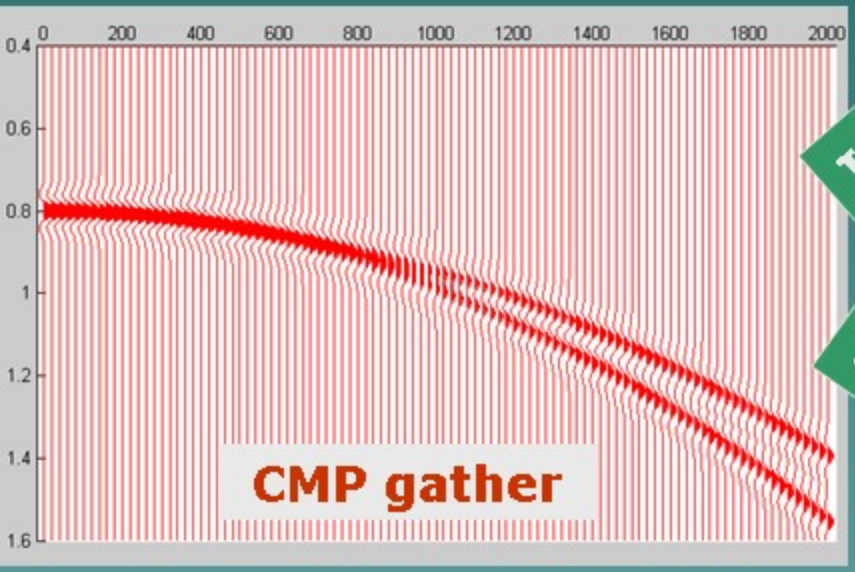
- Parabolic Radon transform in equations:
  - Forward transform

$$u(q,\tau)=\sum_h d(t=\tau+qh^2,h) \qquad \mathbf{u}=\mathbf{L}^{\mathrm{T}}\mathbf{d}$$

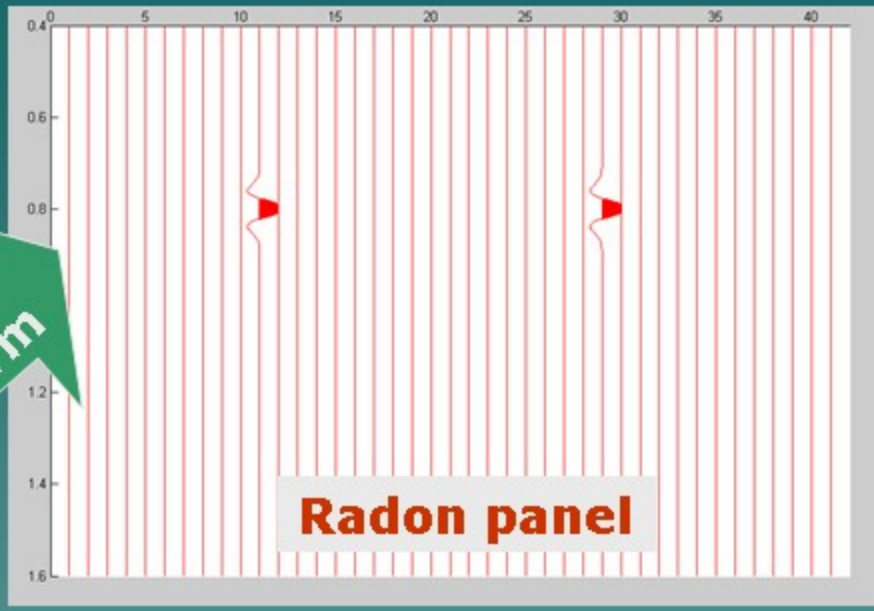
  - Inverse transform

$$d(t,h)=\sum_q u(\tau=t-qh^2,q) \qquad \mathbf{d}=\mathbf{L}\mathbf{u}$$

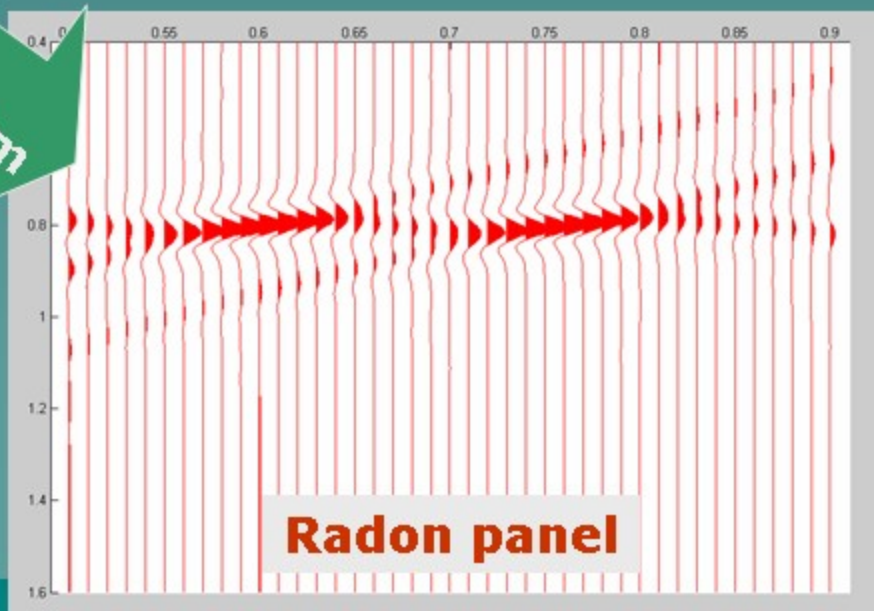
Problem 1: Smearing



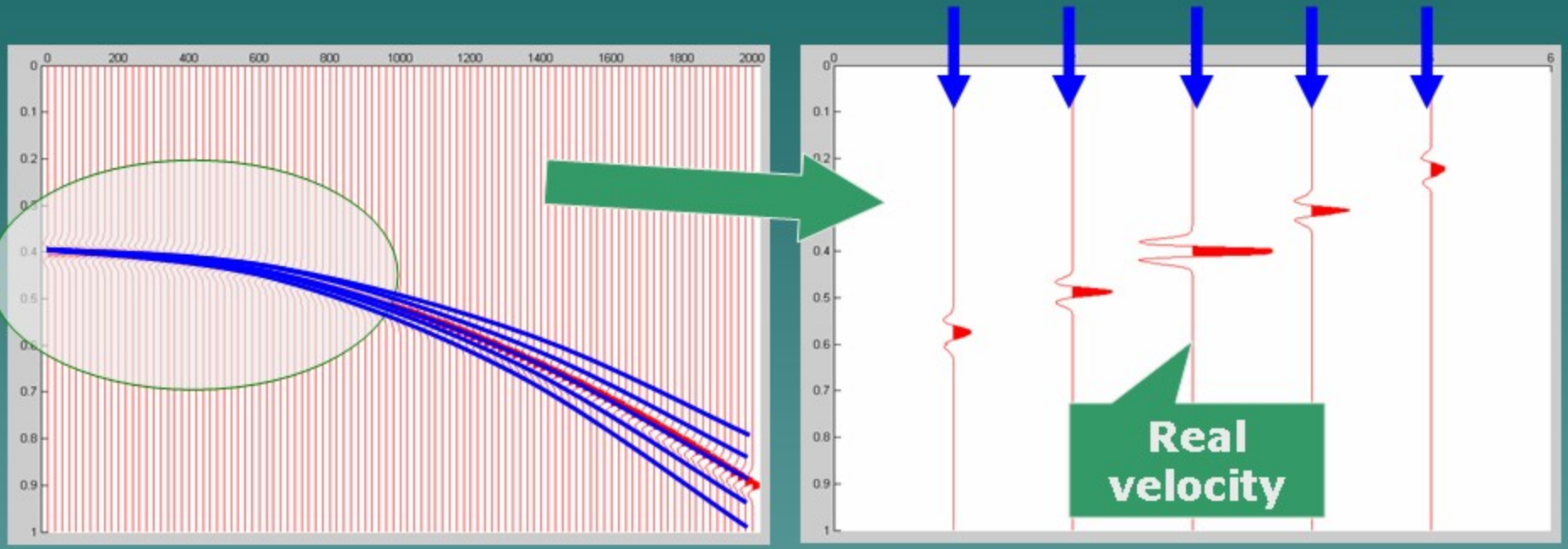
Ideal transform



Real transform



Why smearing



CMP gather

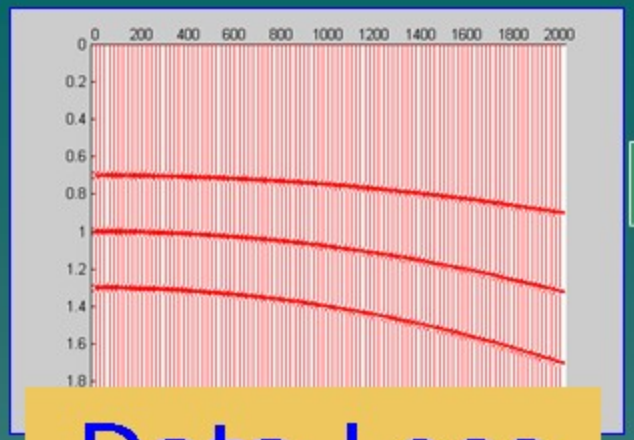
Radon panel

-Near offsets data are repeatedly transformed into the Radon domain;

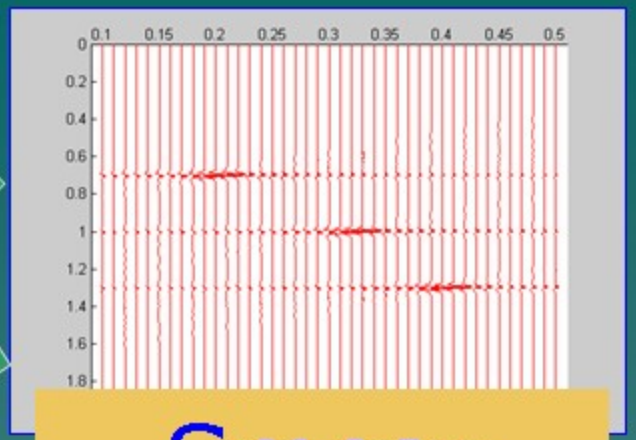
-Near offsets energy sharing causes smearing problem.

Problem 2: data loss

- Radon transform is not an orthogonal algorithm, which means we lose data when we perform the Radon transform.



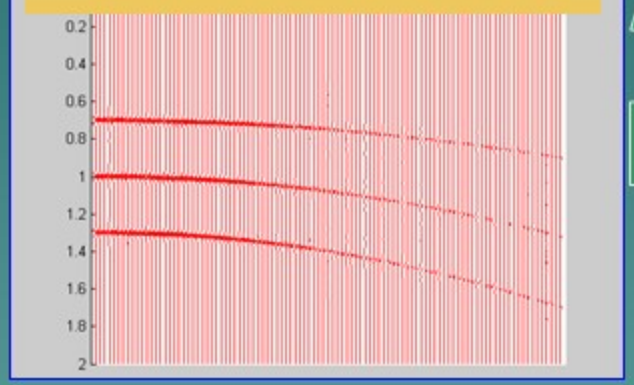
Forward



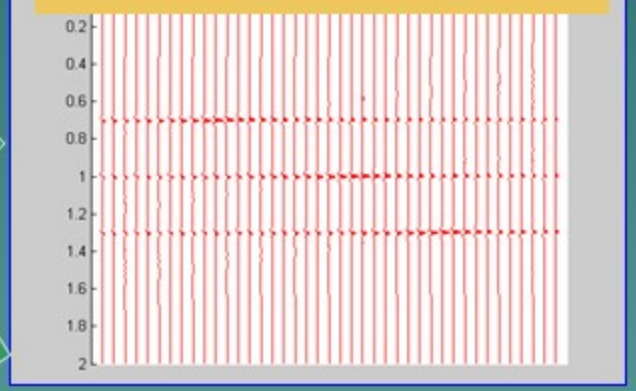
Data Loss

Inverse

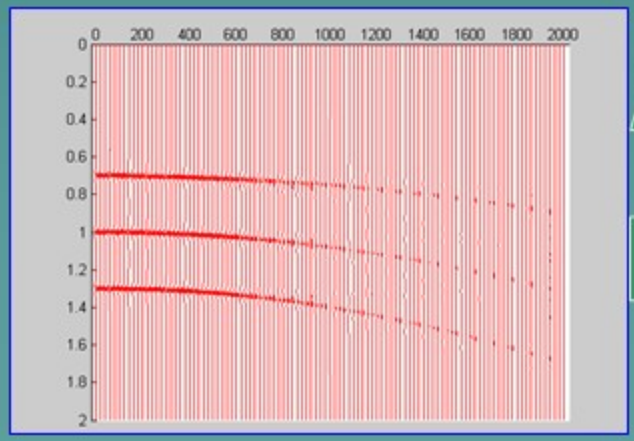
Smear



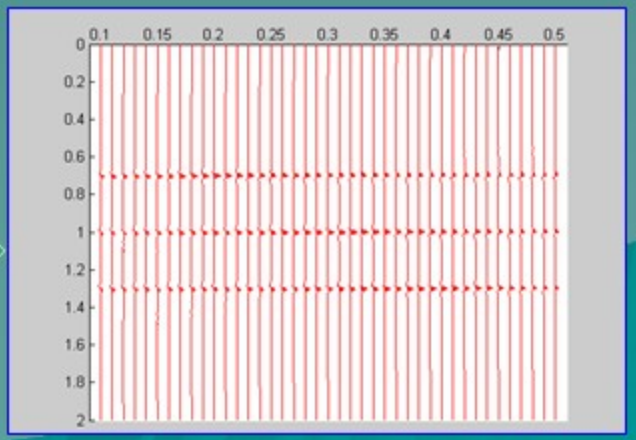
Forward



Inverse



Forward



Semblance-weighted Radon transform

- Objectives:
  - Reduce the smearing problem in the Radon domain and improve the resolution
  - Prevent data loss

Semblance-weighted Radon transform

- Step 1 - weighting
  - Weighting the transform with the semblance of the input gather;
  - Semblance is defined in a similar way with the Radon Transform. The only difference is that semblance is independent of amplitudes of events and it ranges from 0-to-1;
- Step 2 - sorting
  - Find out the most important traces in the Radon domain;
  - First transform data along these important traces and remove the corresponding data from the input gather.

Semblance-weighted Radon transform

- Forward Radon transform:

$$u(q,\tau)=\sum_{h} d\left(t=\tau+qh^2,h\right)$$

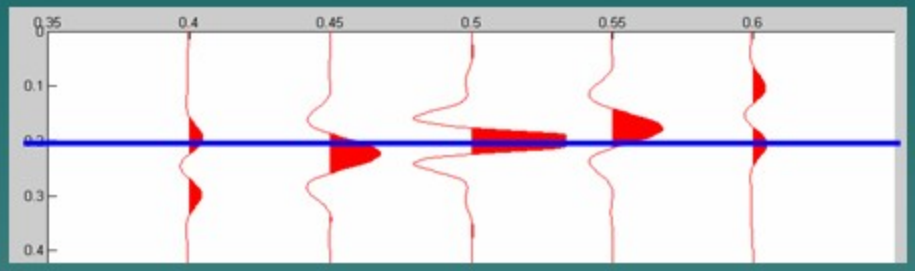
- Semblance:

$$S(q,\tau)=\frac{\sum_{l}\sum_{h}\left(d\left(t=\tau+qh^2,h\right)\right)^2}{N_h\sum_{l}\sum_{h}d^2\left(t=\tau+qh^2,h\right)}$$

  - Same integration paths with the Radon transform;
  - Values are normalized to 0-to-1, dependent of amplitudes;
  - Offers coherency measurement of events;
  - Weight the Radon transform with semblance will improve the Radon resolution.

Semblance-weighted Radon transform

Radon panel

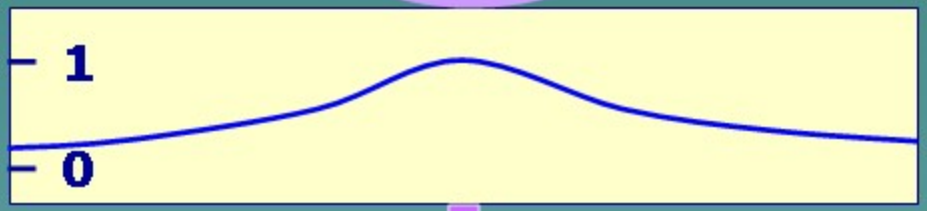


Step 1:

Weighting

Amplitudes of Radon

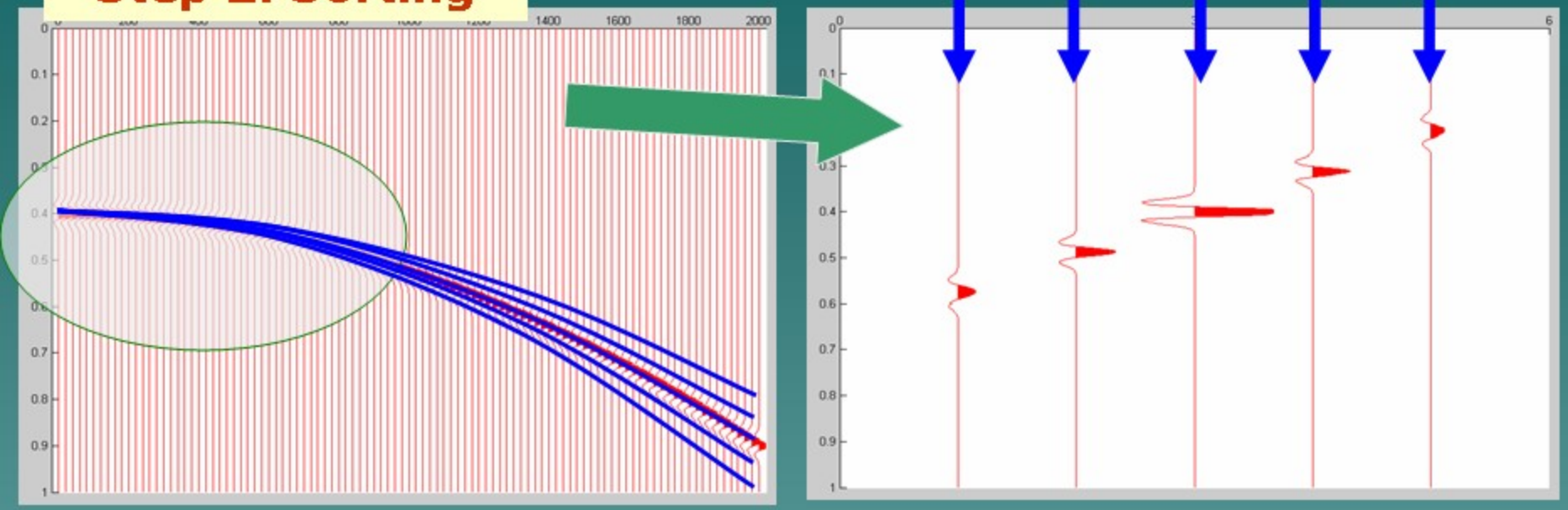
Amplitudes of semblance



Amplitudes of updated Radon

Semblance-weighted Radon transform

Step 2: Sorting



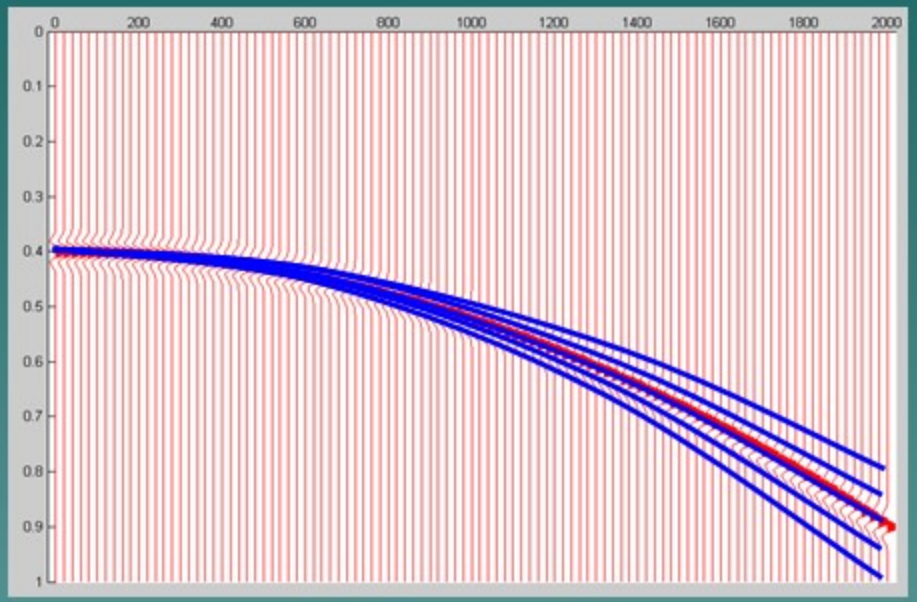
CMP gather **Radon panel**

-Near offsets data are repeatedly transformed into the Radon domain, which causes smearing problem;

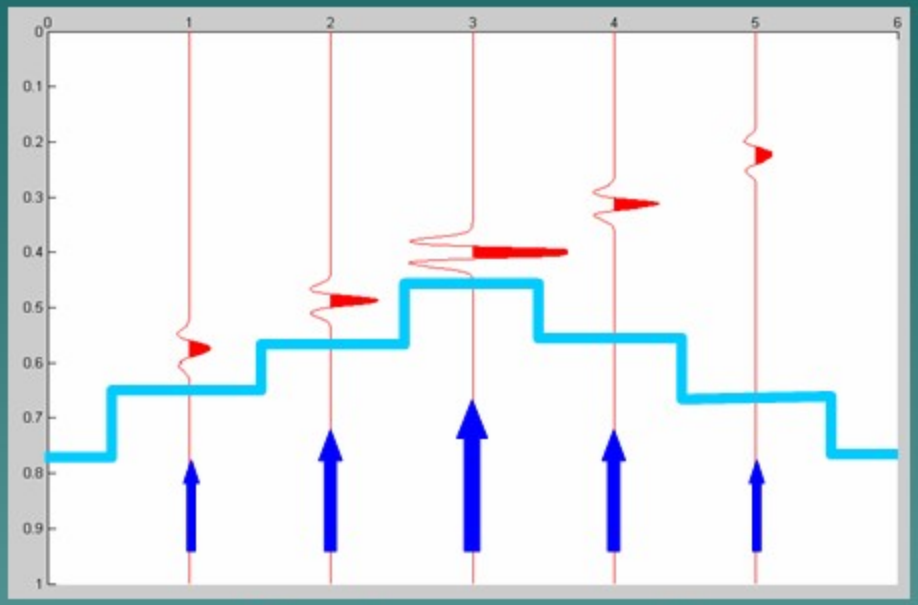
-How to avoid transforming data repeatedly?

-If it is avoided, can we reduce the smearing?

Semblance-weighted Radon transform



CMP gather

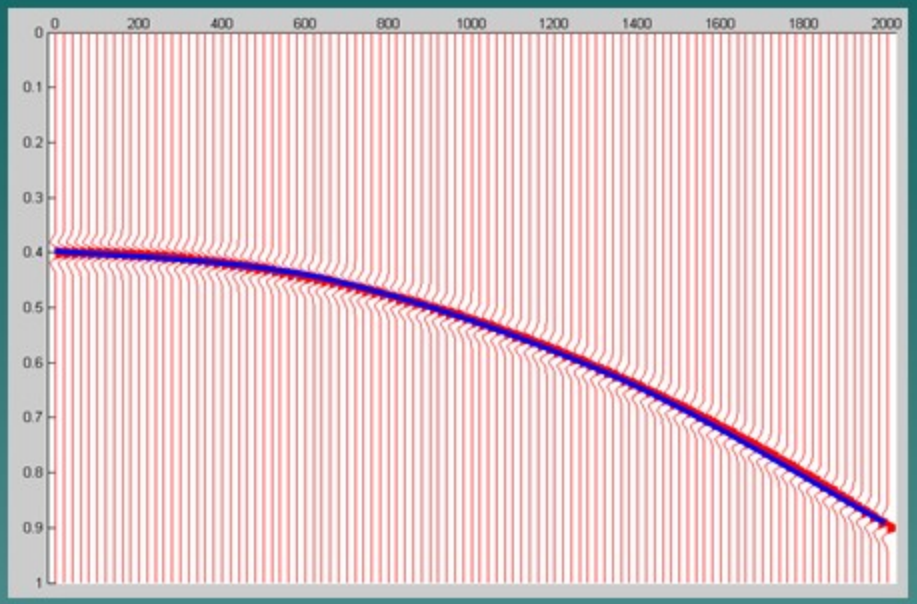


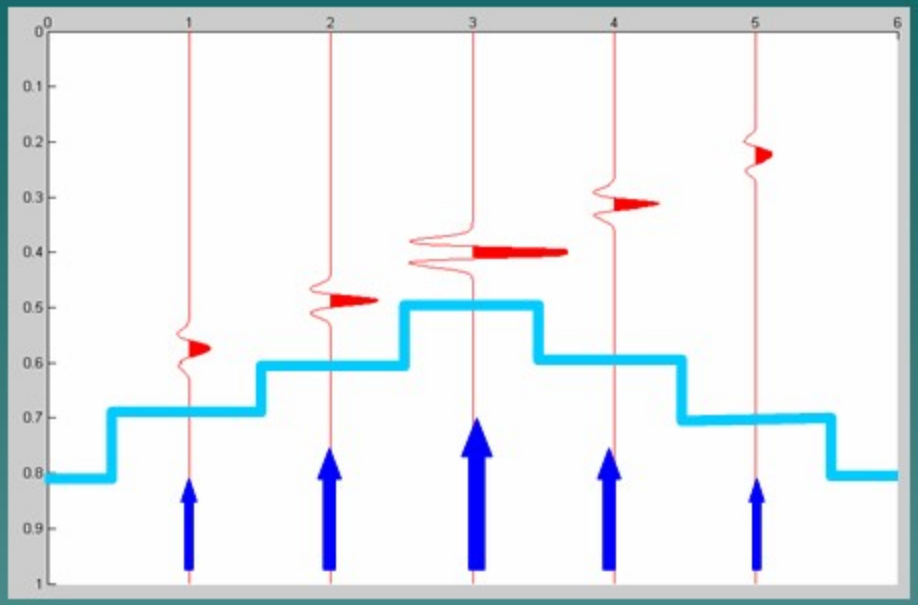
Radon panel

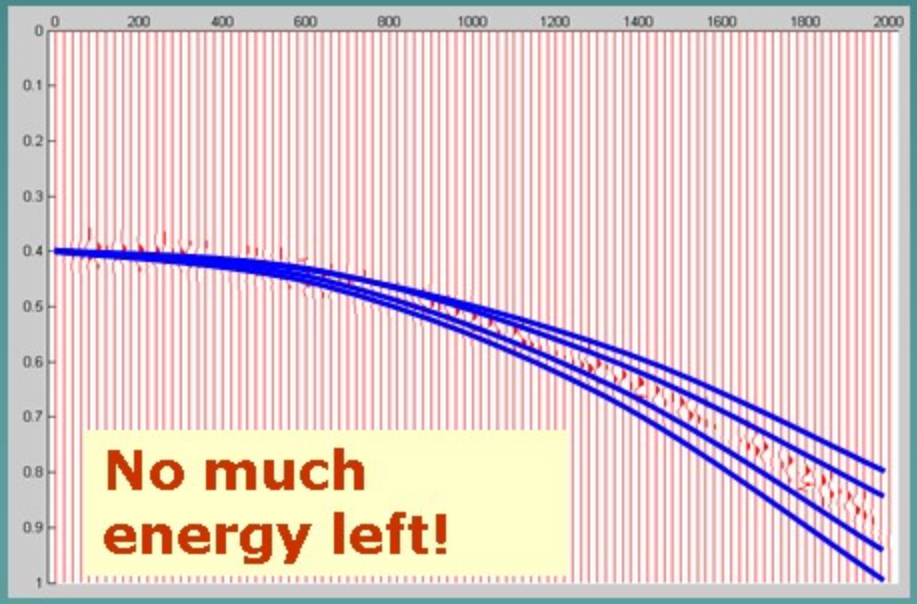
-Once a Radon panel is obtained by the semblance-weighted method, energy along each trace is estimated;

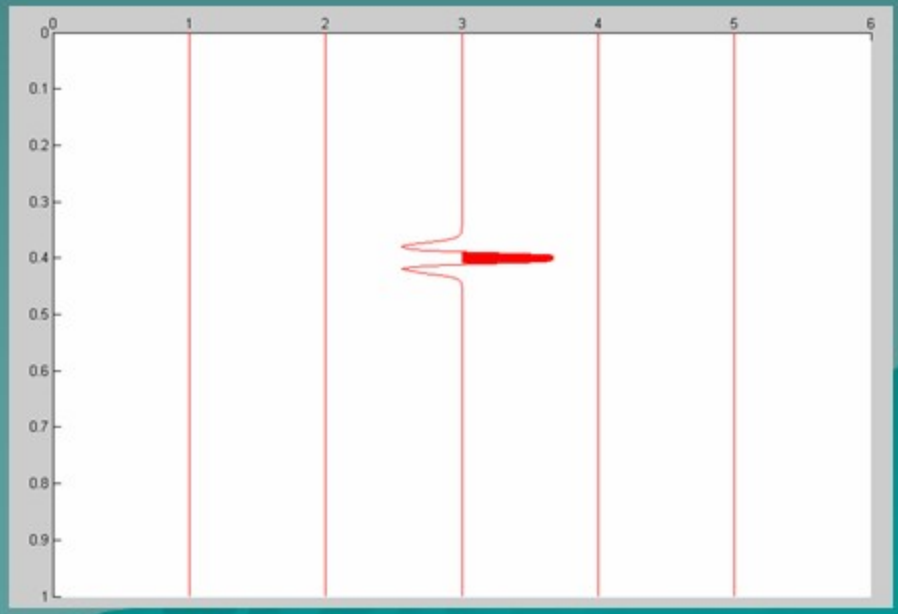
-A new turn of Radon calculation is first performed along the most powerful trace and corresponding data will be removed from the input.

Semblance-weighted Radon transform



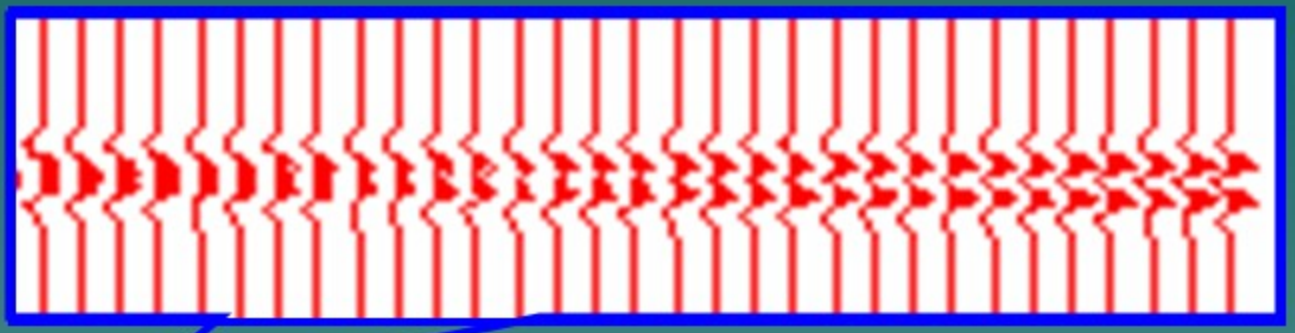


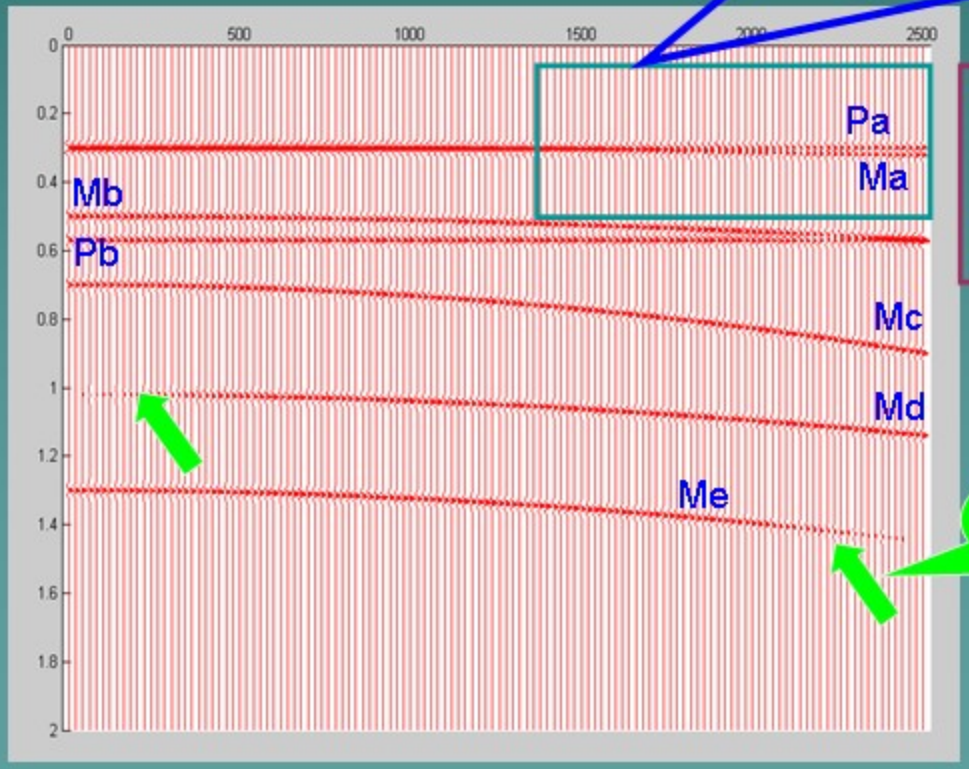




Example: synthetic data

NMO-corrected
CMP gather





Two events

20 ms between the peaks

AVO effect

Example: synthetic data

- Two things: resolution and data loss
- Reconstructed Gather = Gather obtained by inverse transforming the Radon Panel
- Residual Gather = Original Gather - Reconstructed Gather

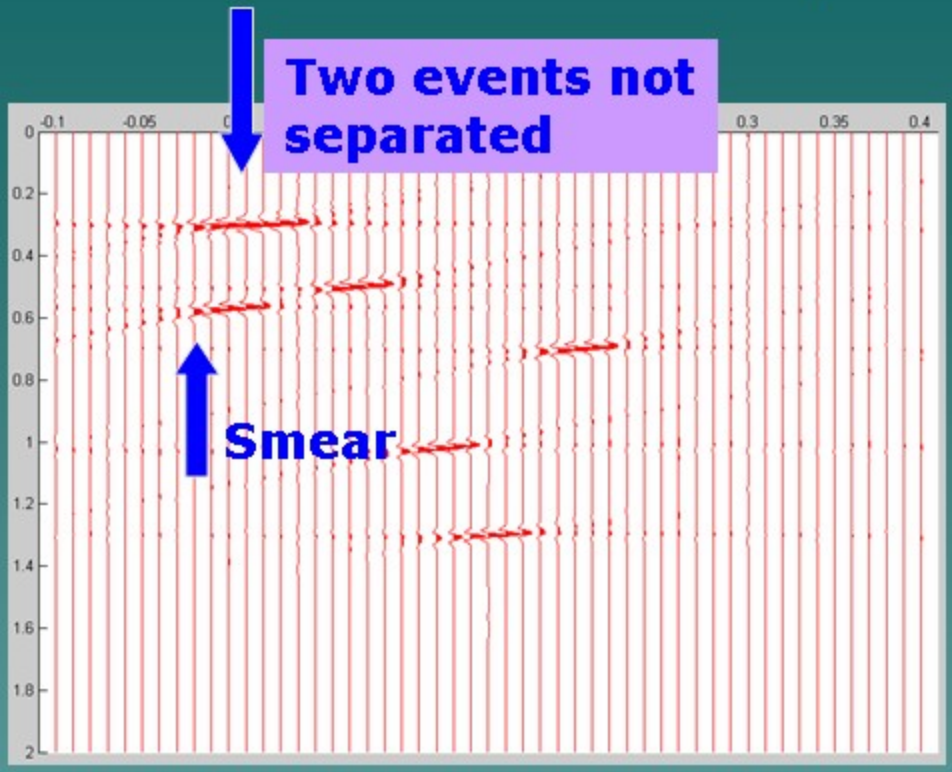
The tool to examine if any data loss or how much data loss

The less energy this gather contains, the less data loss happens.

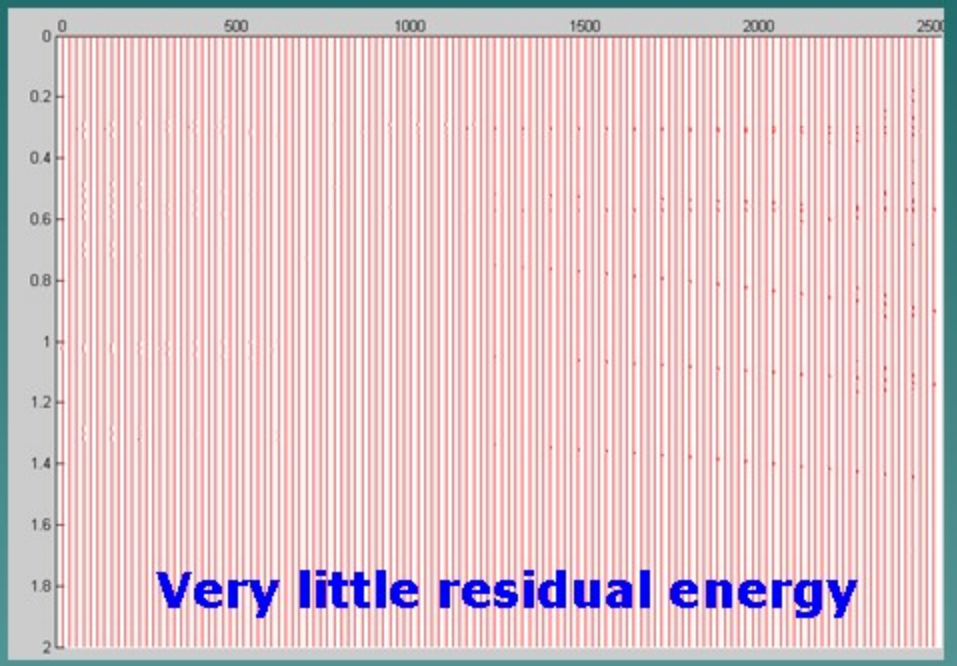
Example: synthetic data

- Methods:
  - Least-squares solution (Thorson and Claerbout, 1985; Hampson 1986; Beylkin,1987; Yilmaz, 1989)
  - Frequency domain high resolution method (Sacchi and Ulrych , 1995)
  - Semblance-weighted Radon transform (Ng and Perz, 2004)

Least-squares solution



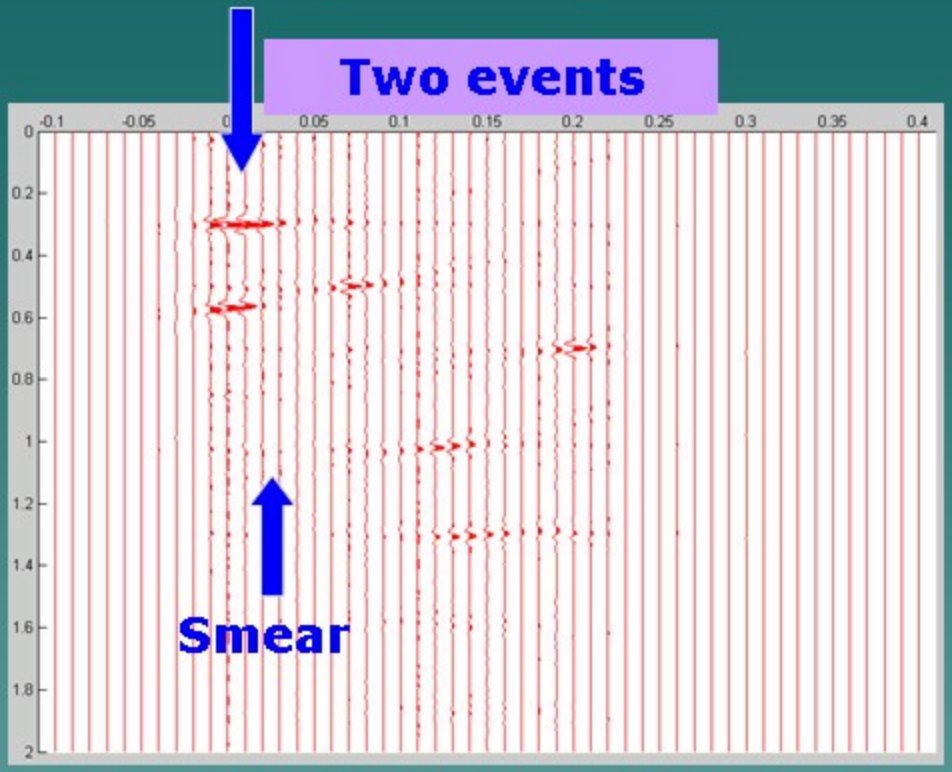
Radon Panel

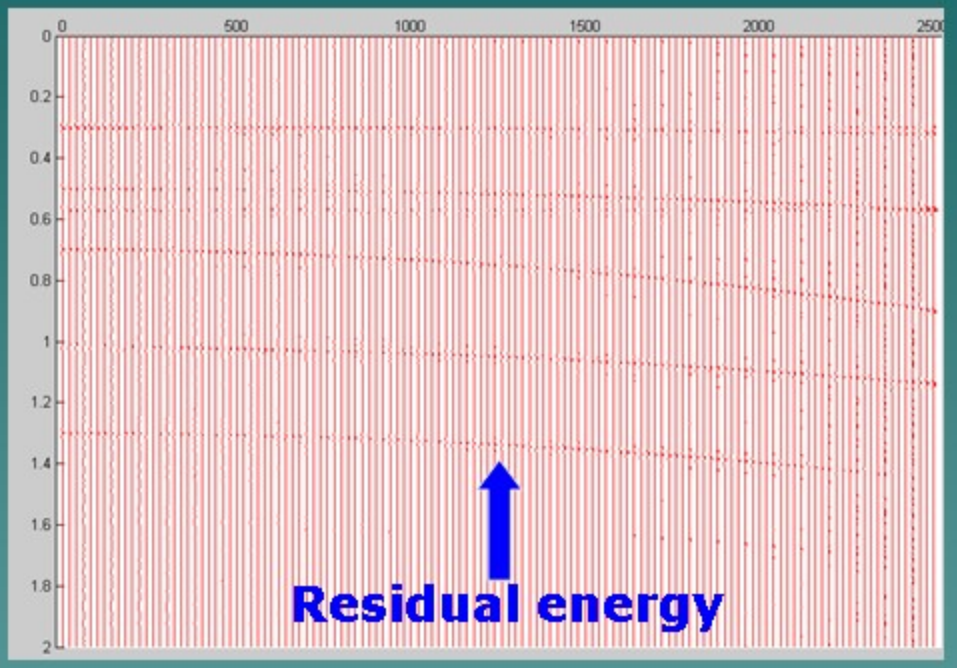


Residual Gather

Thorson and Claerbout (1985), Hampson (1986), Beylkin (1987), Yilmaz (1989)

Frequency domain high-res method



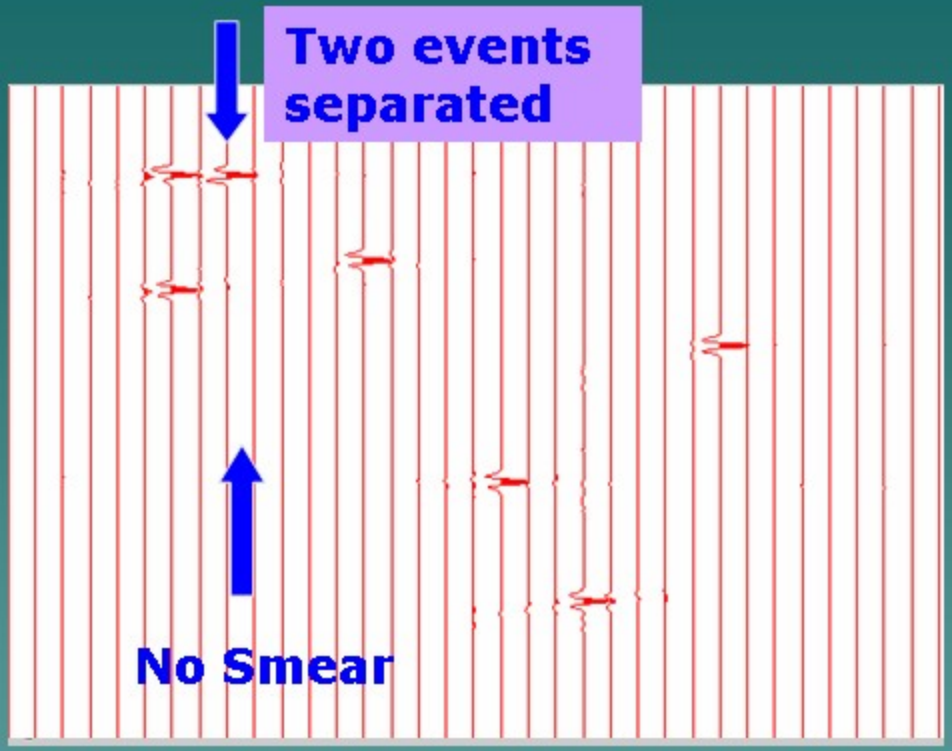


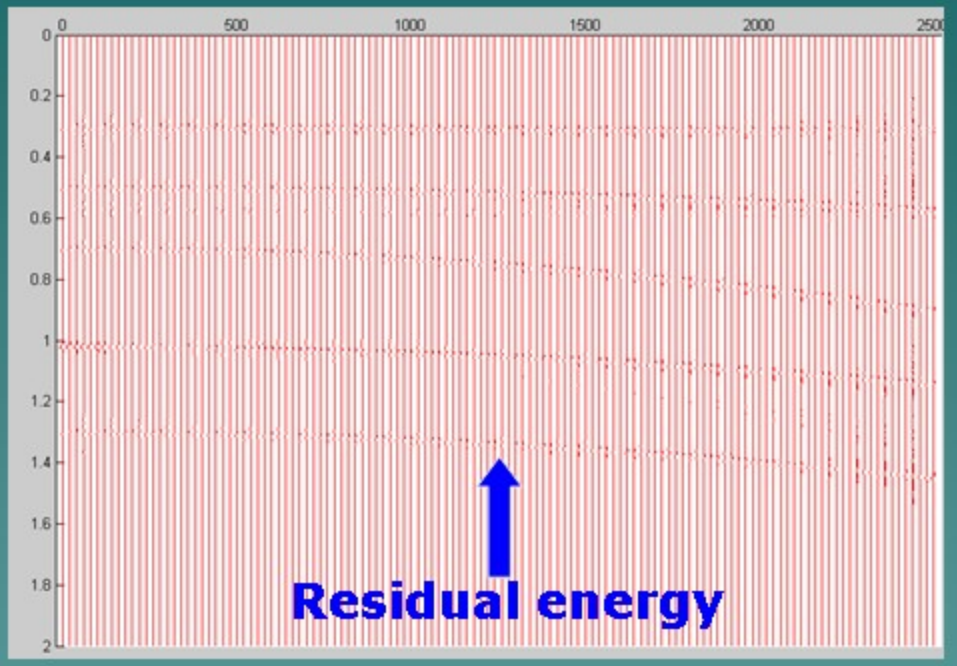
Radon Panel

Residual Gather

Sacchi and Ulrych (1995)

Semblance weighted Radon method



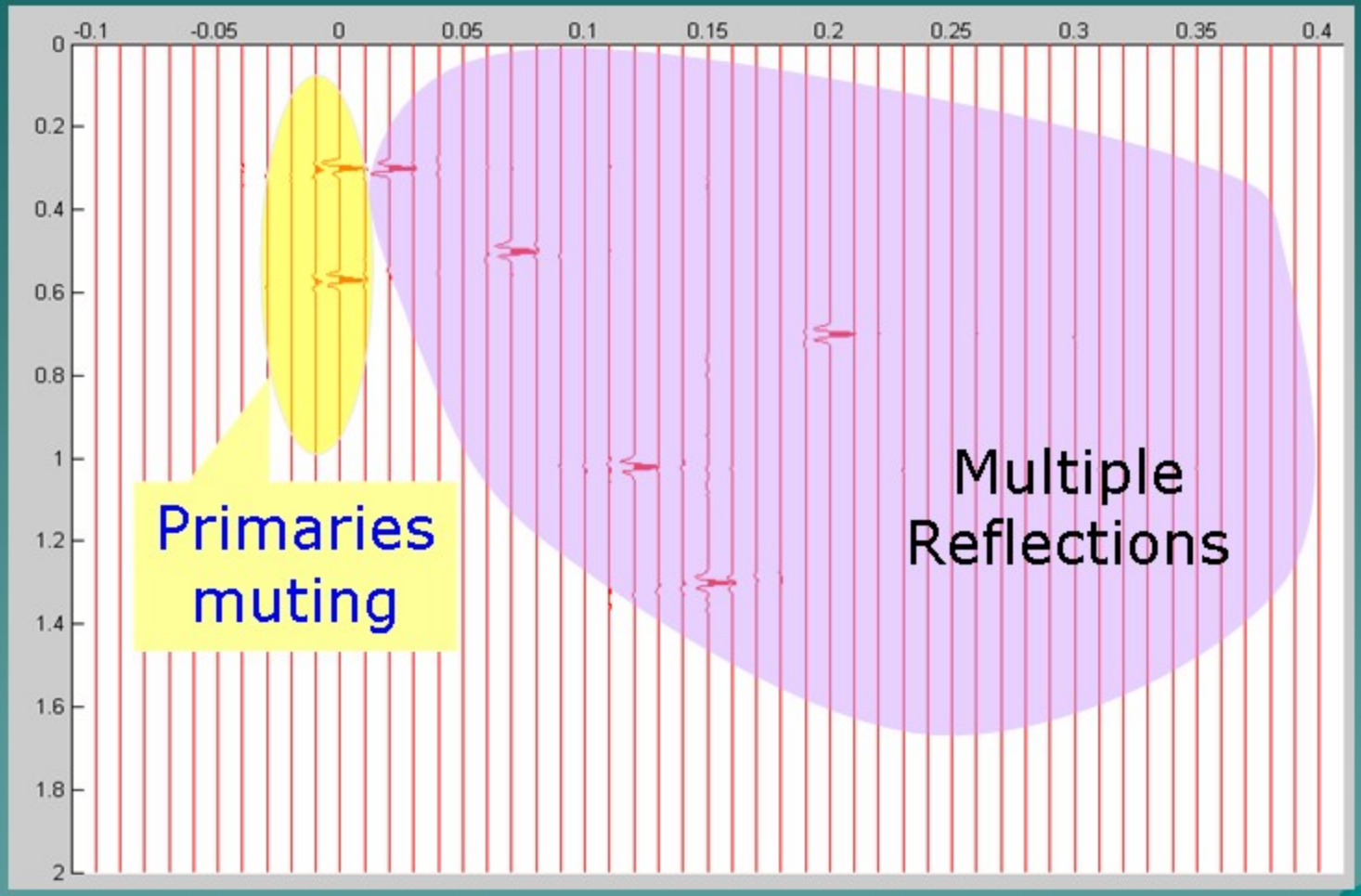


Radon Panel

Residual Gather

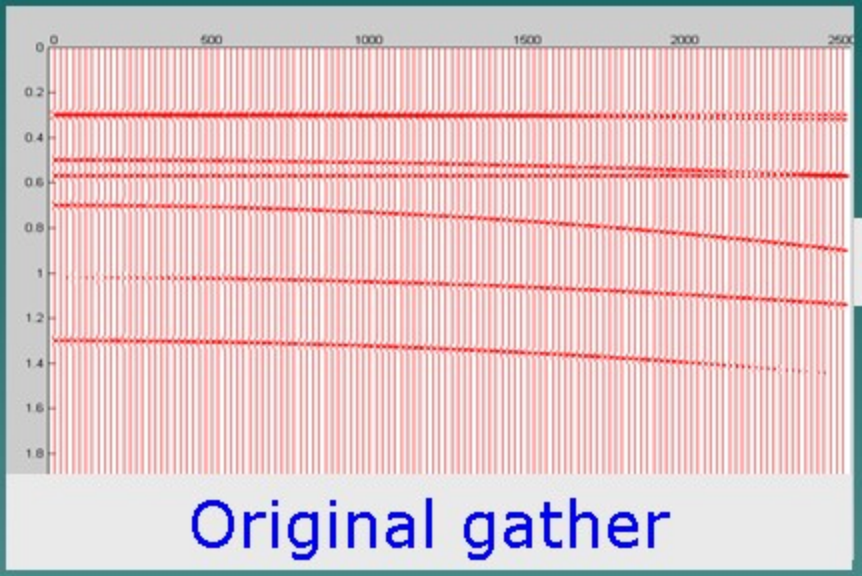
Ng and Perz (2004)

Synthetic Data: multiple attenuation



If primaries are muted, a multiple only CMP gather can be reconstructed from the residual energy.

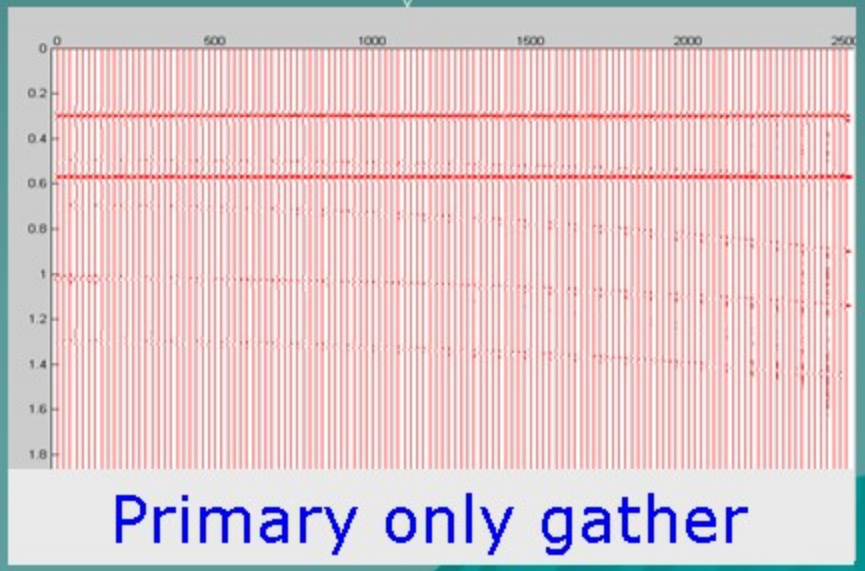
Synthetic Data: multiple attenuation



Original gather

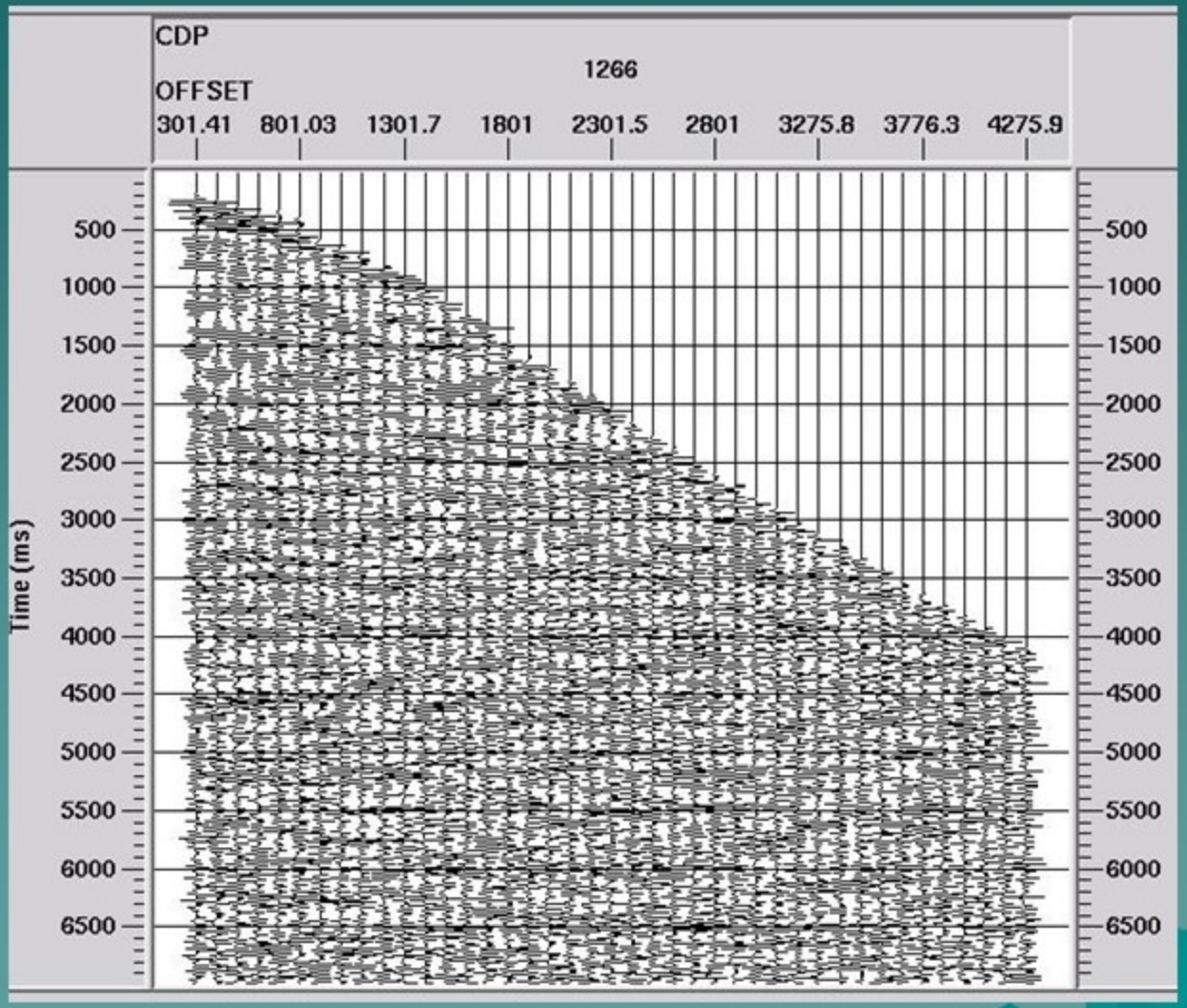
minus

Multiple only gather

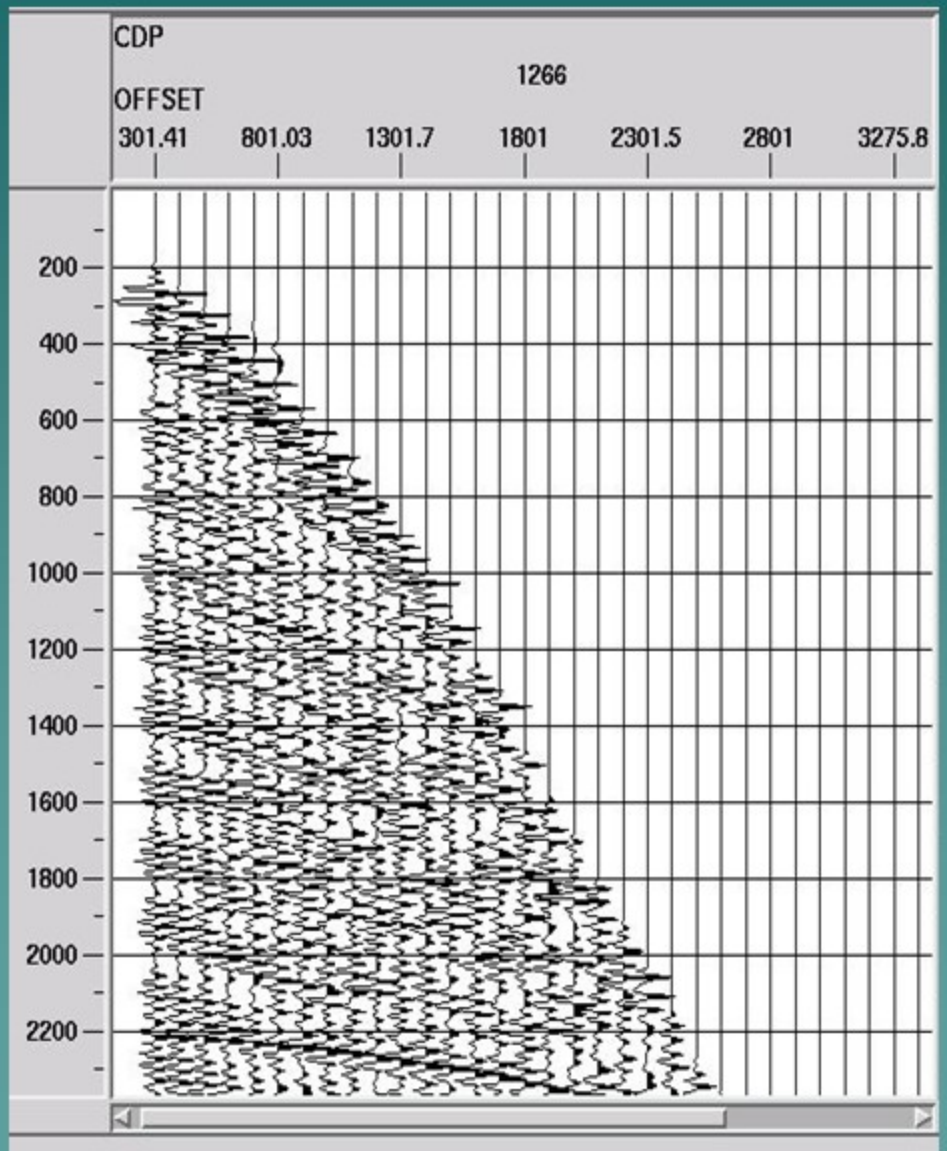


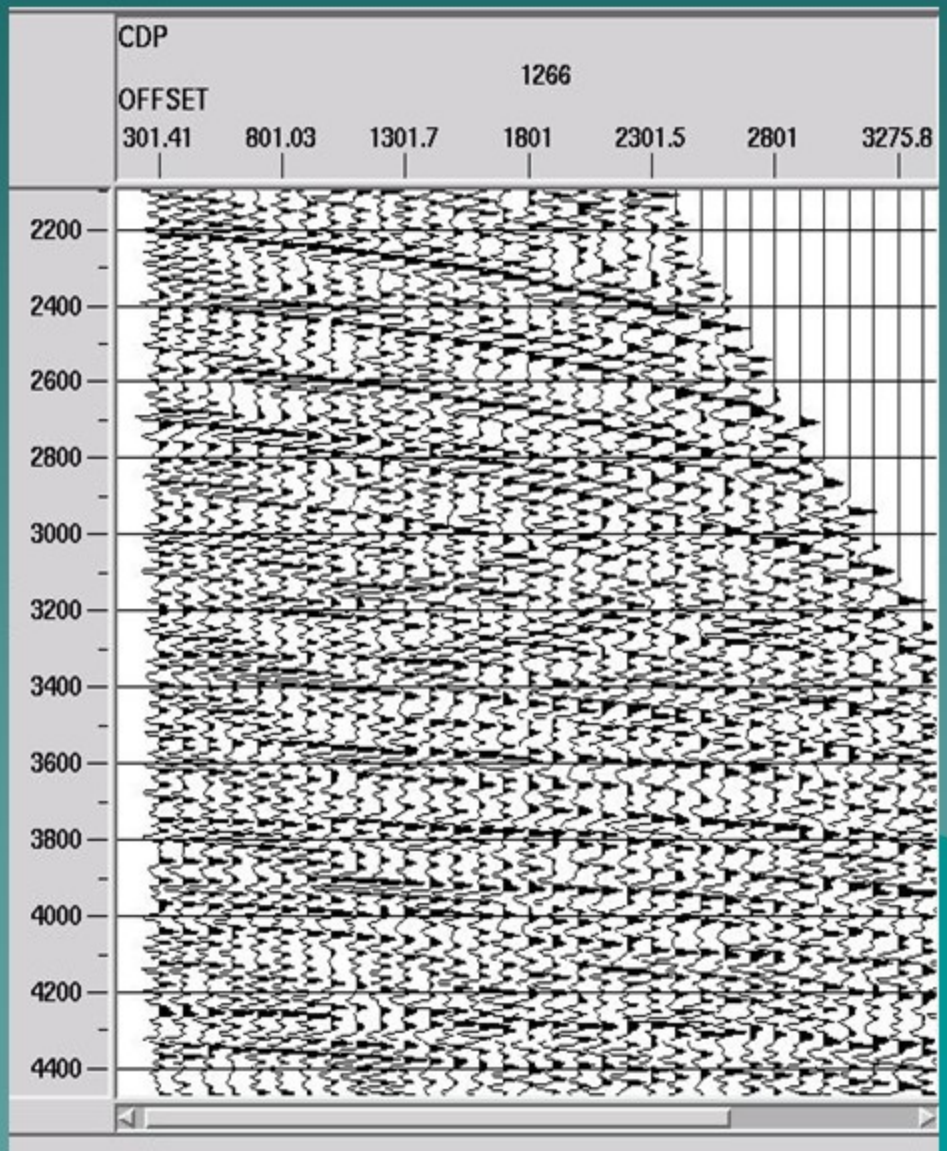
Primary only gather

Real Data: multiple attenuation

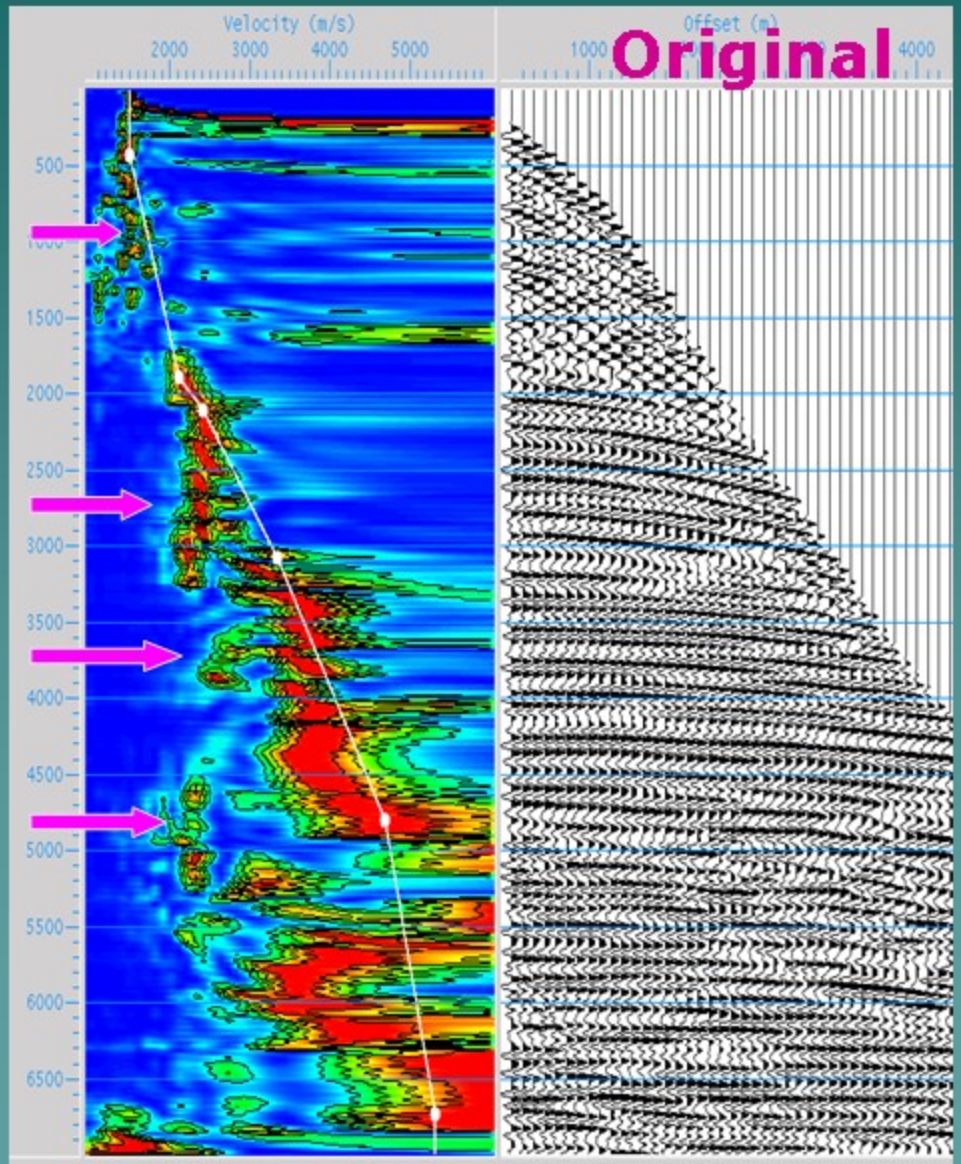


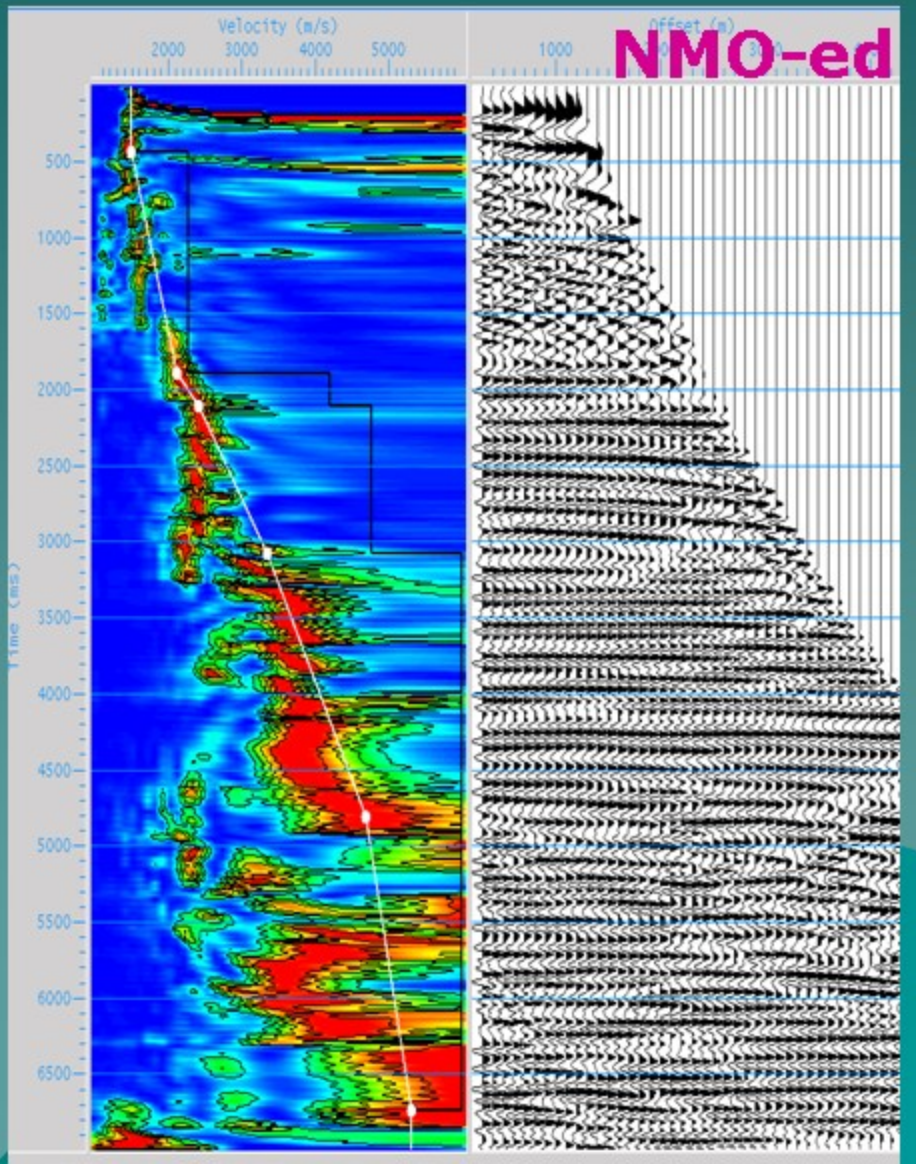
Real Data: multiple attenuation



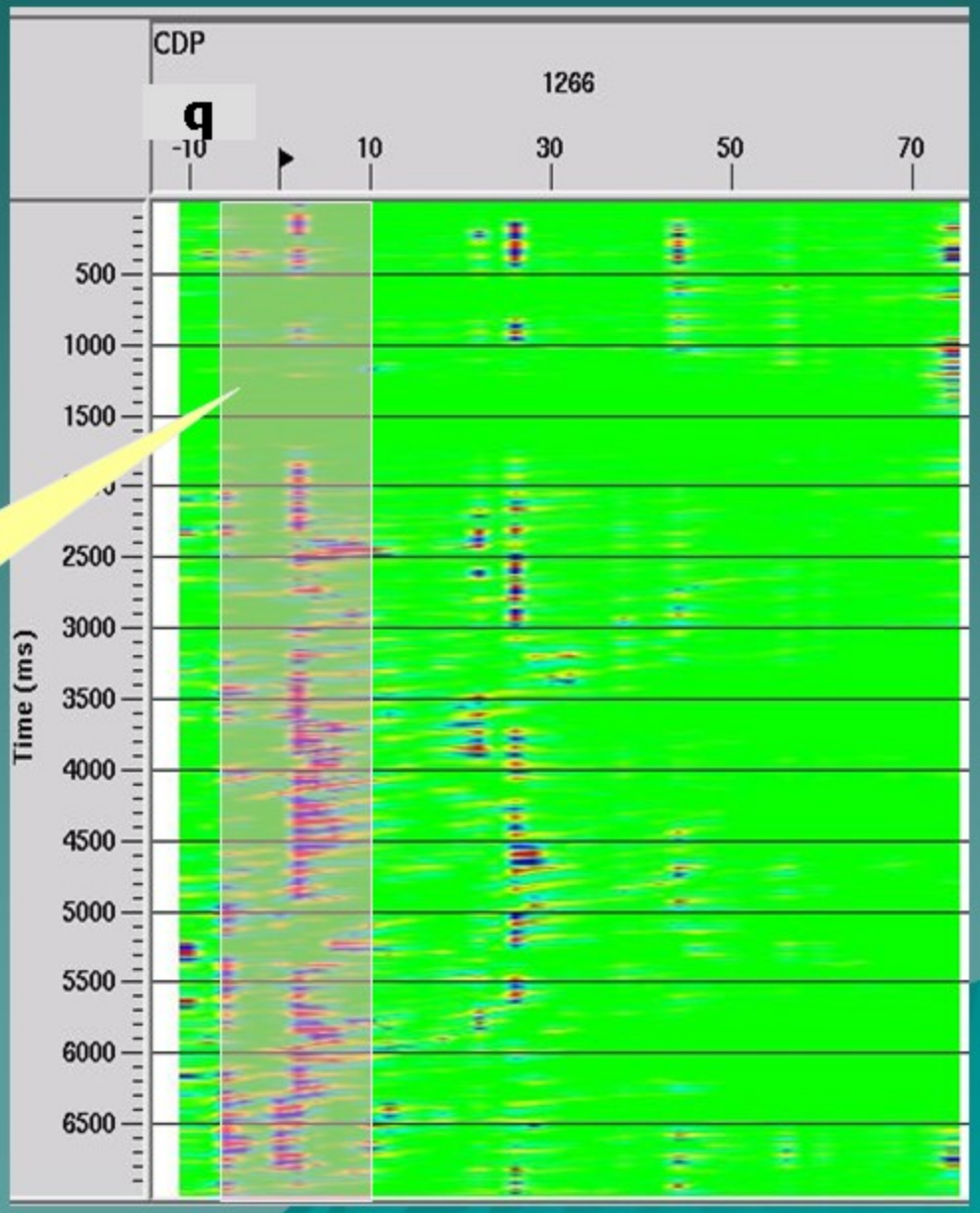


Real Data: multiple attenuation





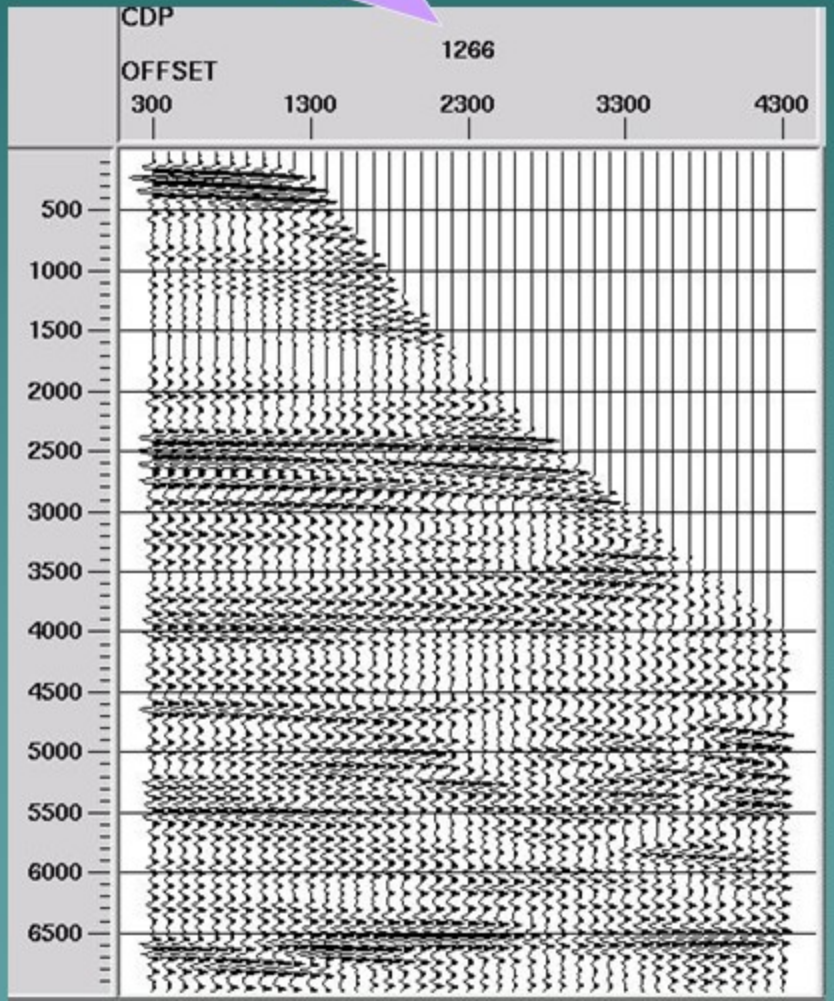
Real Data: multiple attenuation



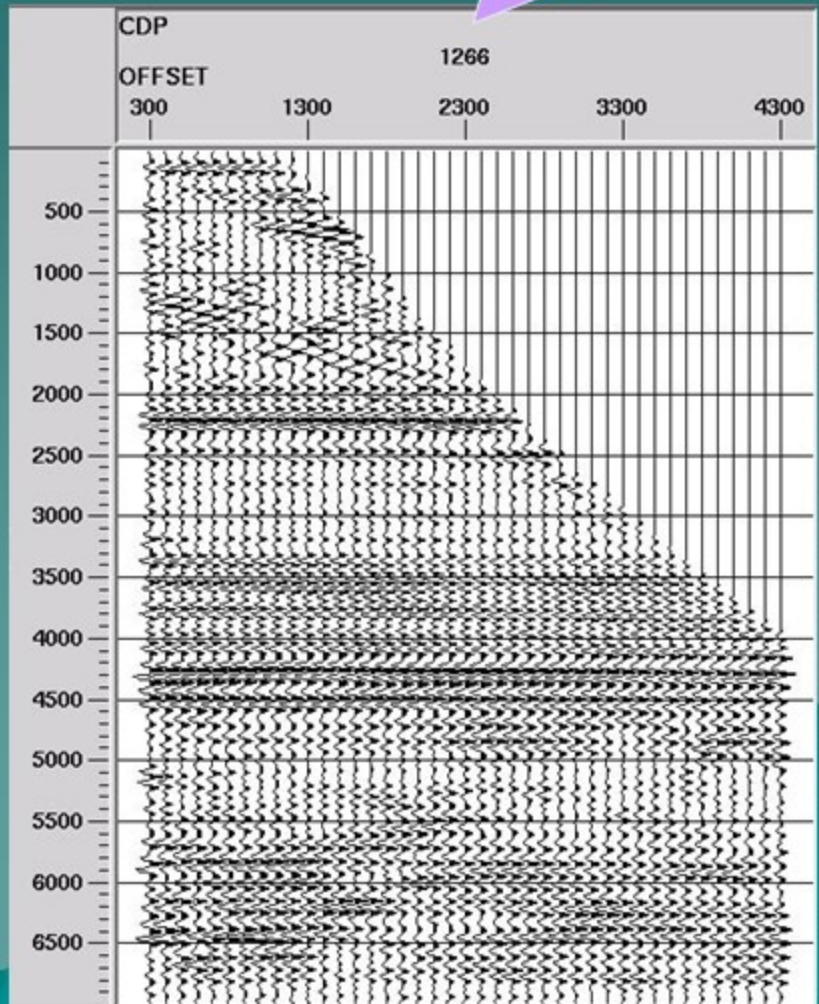
Muting primaries in the Radon domain

Real Data: multiple attenuation

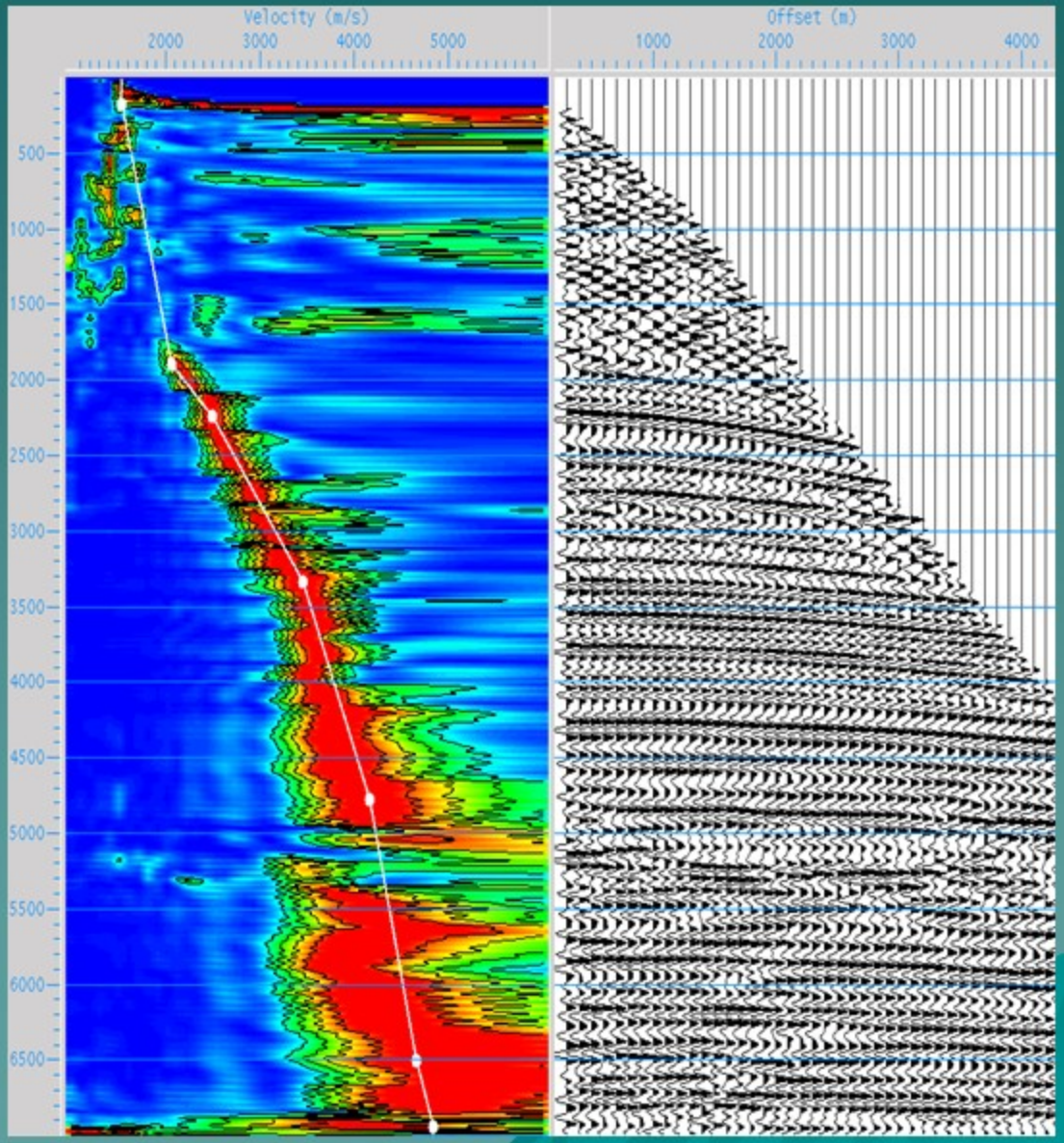
Reconstructed multiple only gather



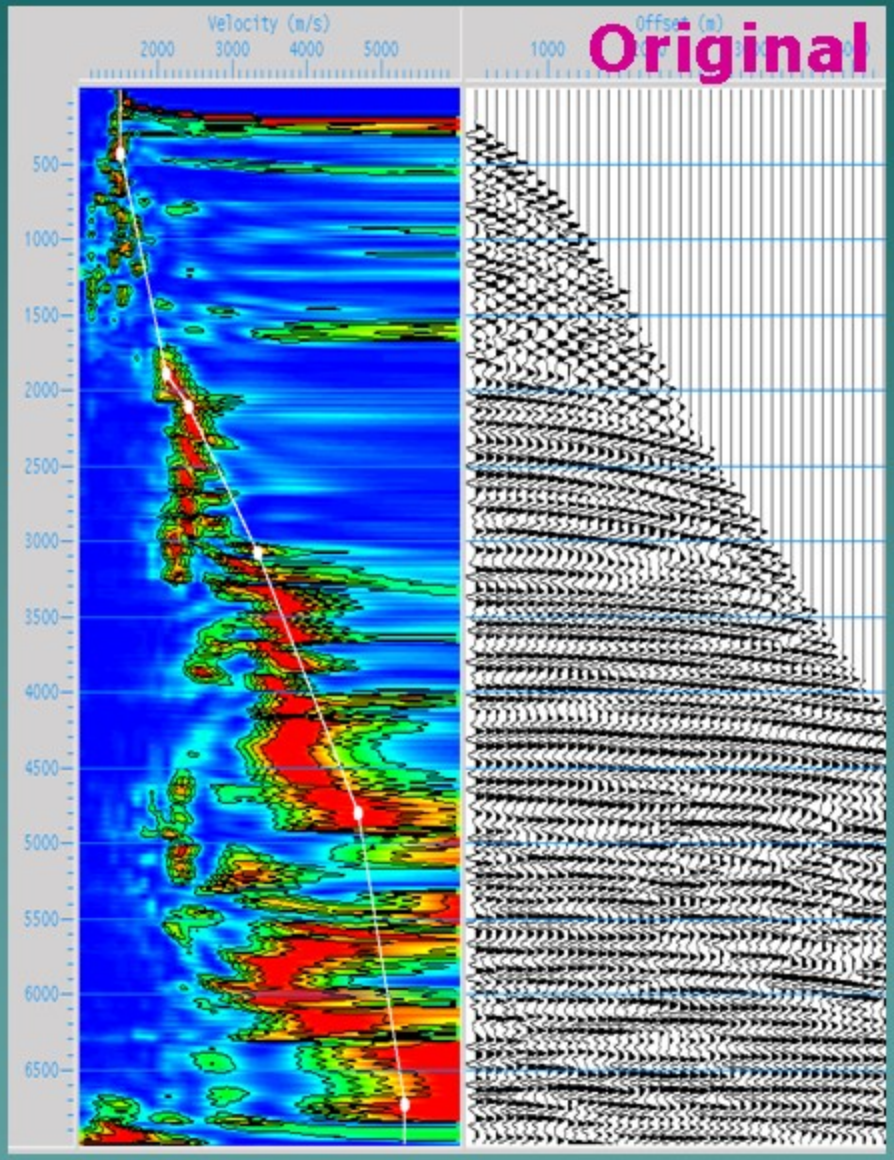
Primary only gather by subtracting …

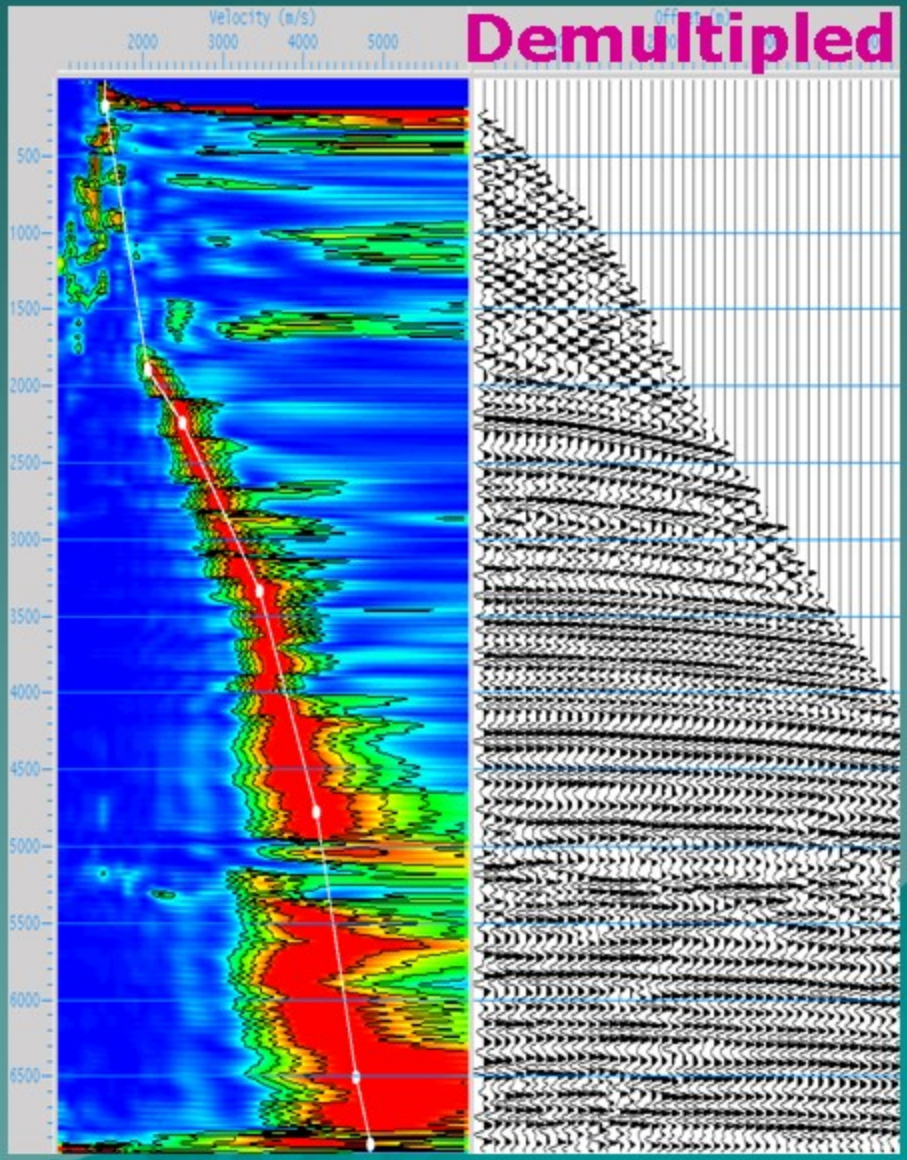


Demultipled Gather

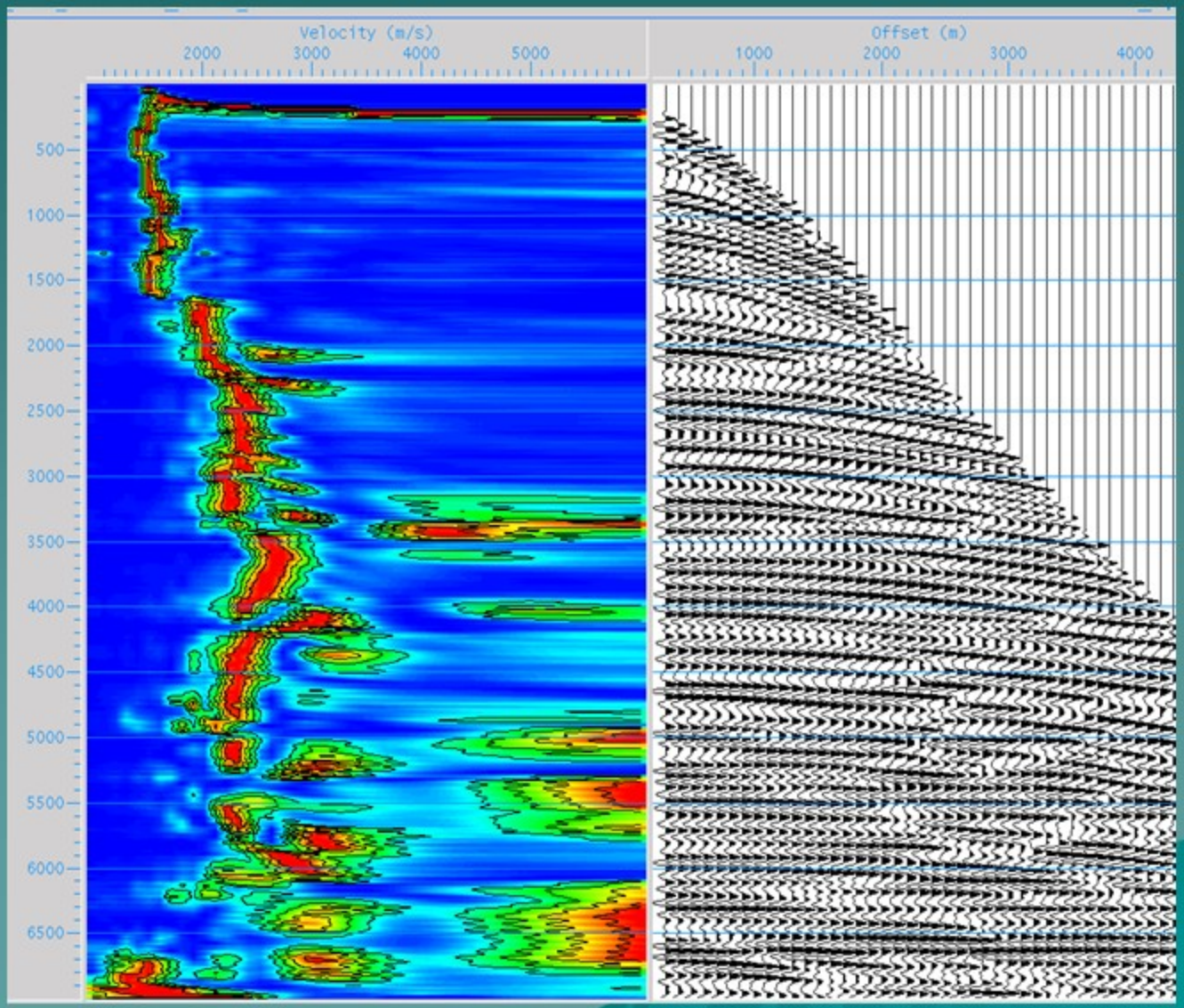


Velocity Analysis





Multiple Reflections



Conclusions

- The three Radon methods examined can preserve data well;
- The semblance weighted high resolution Radon method gives the best resolution in the Radon panel;
- The Radon transform is a very powerful application on multiple attenuation as long as multiples have different velocities from primaries.
- After demultipled, velocity analysis becomes easy work.

Acknowledgements

- Mark Ng (GeoX) and Daniel Trad (Veritas DGC)
- CREWES staffs
- CREWES Project and CREWES Sponsors
- University of Calgary, SEG and CSEG