Measuring image focusing for velocity analysis

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SEP 136 pp. 43-54

SEP 138 pp. 59-80

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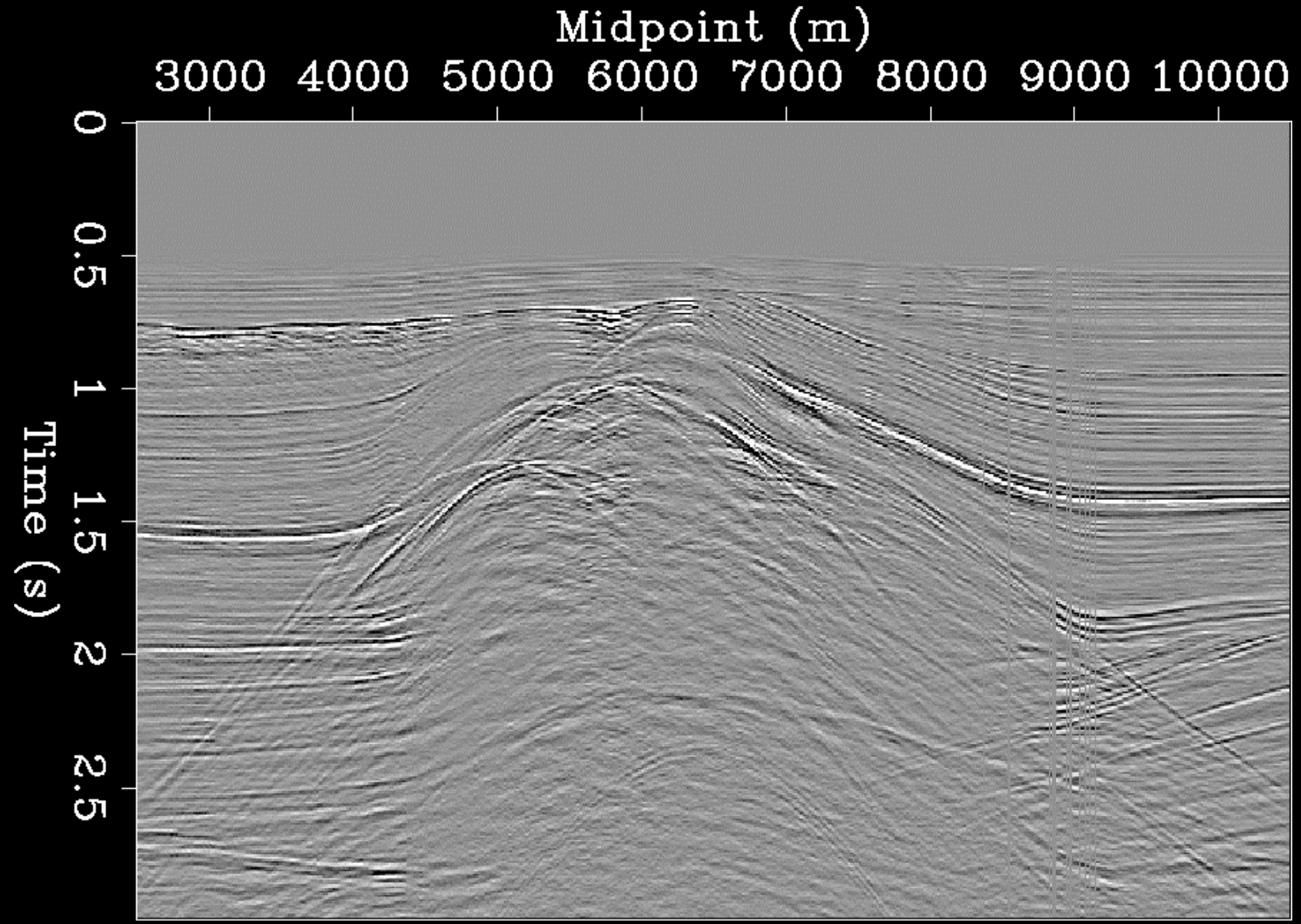
Is there velocity information along midpoints?



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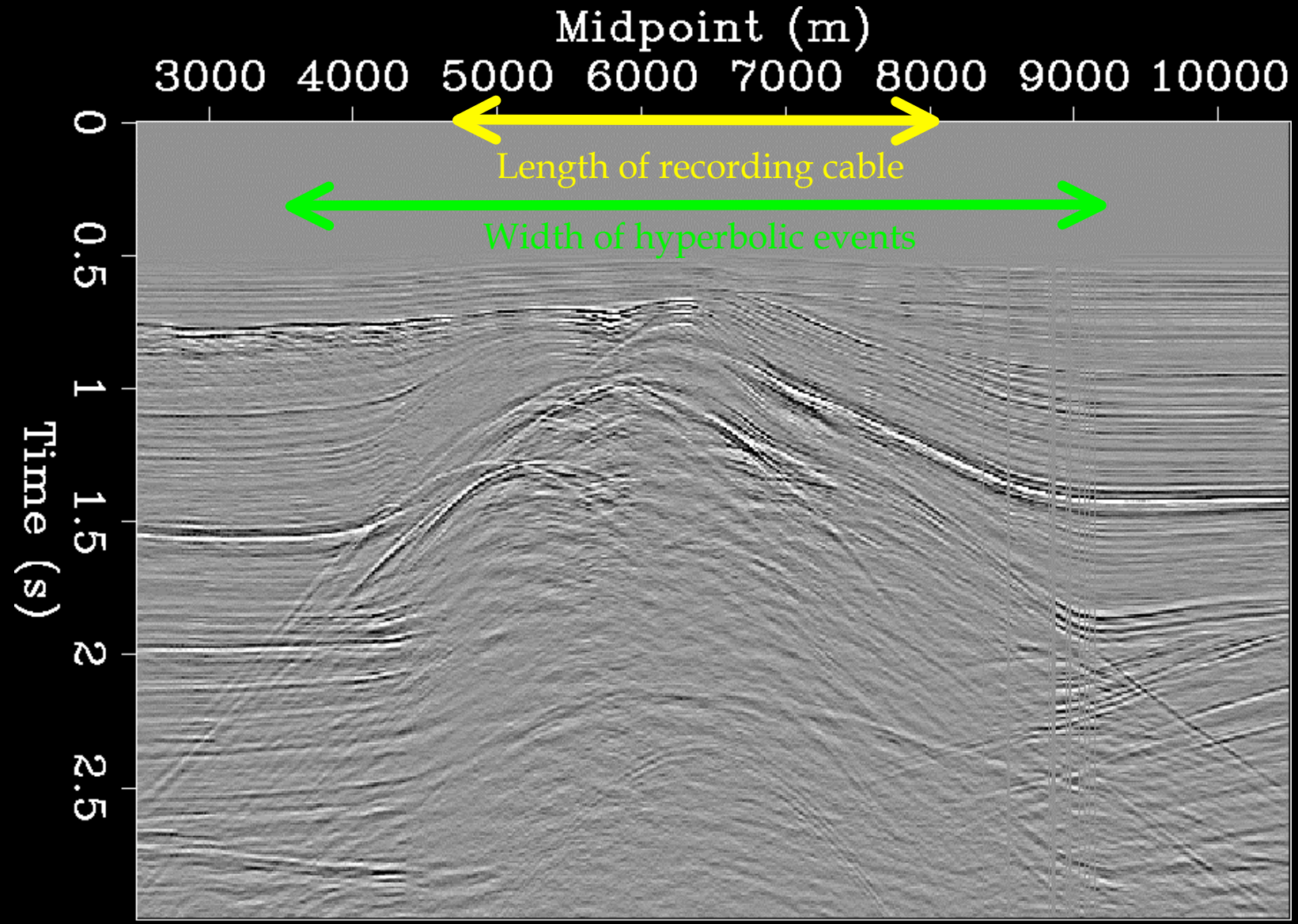
There is velocity information along midpoints!



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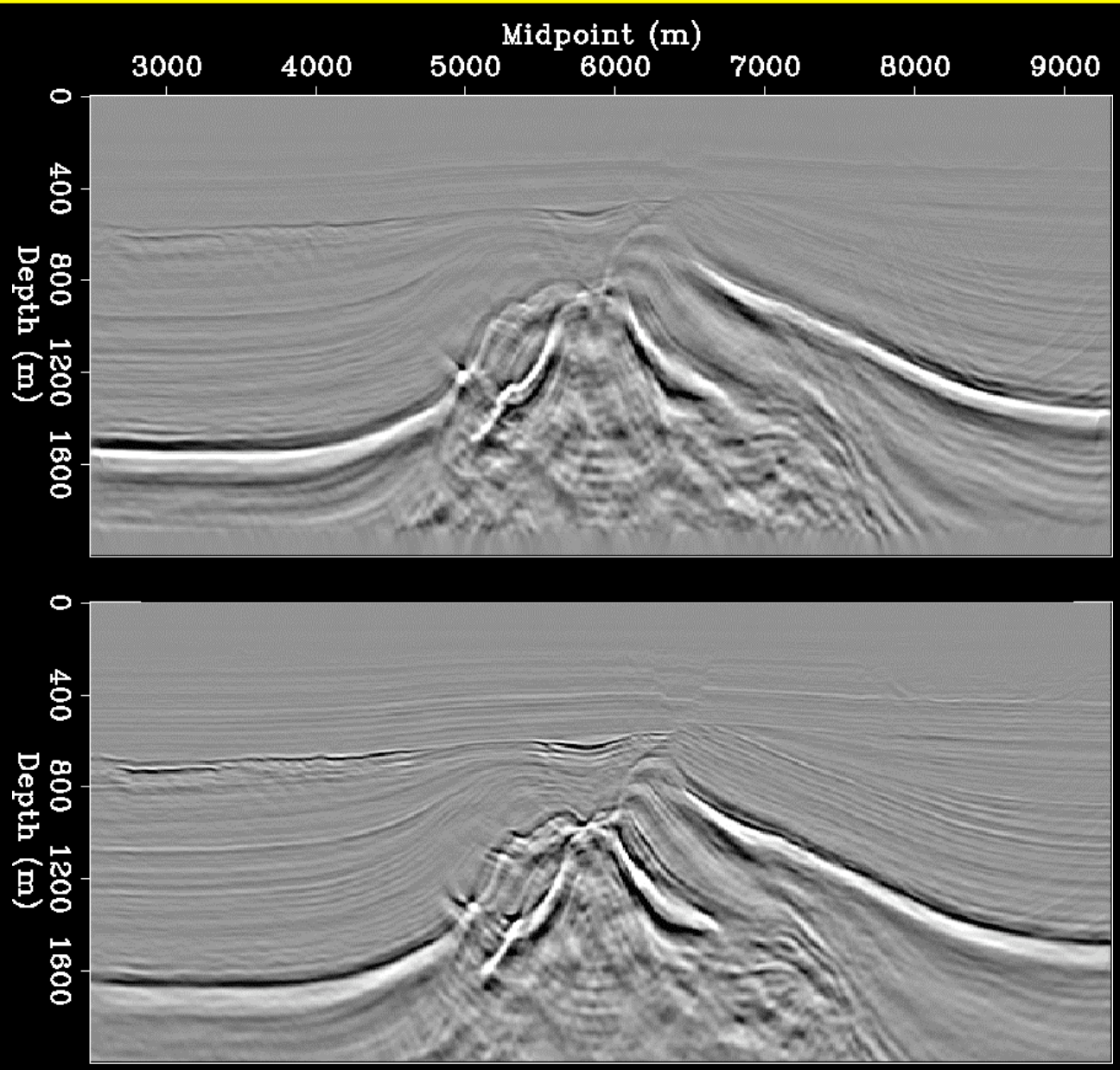
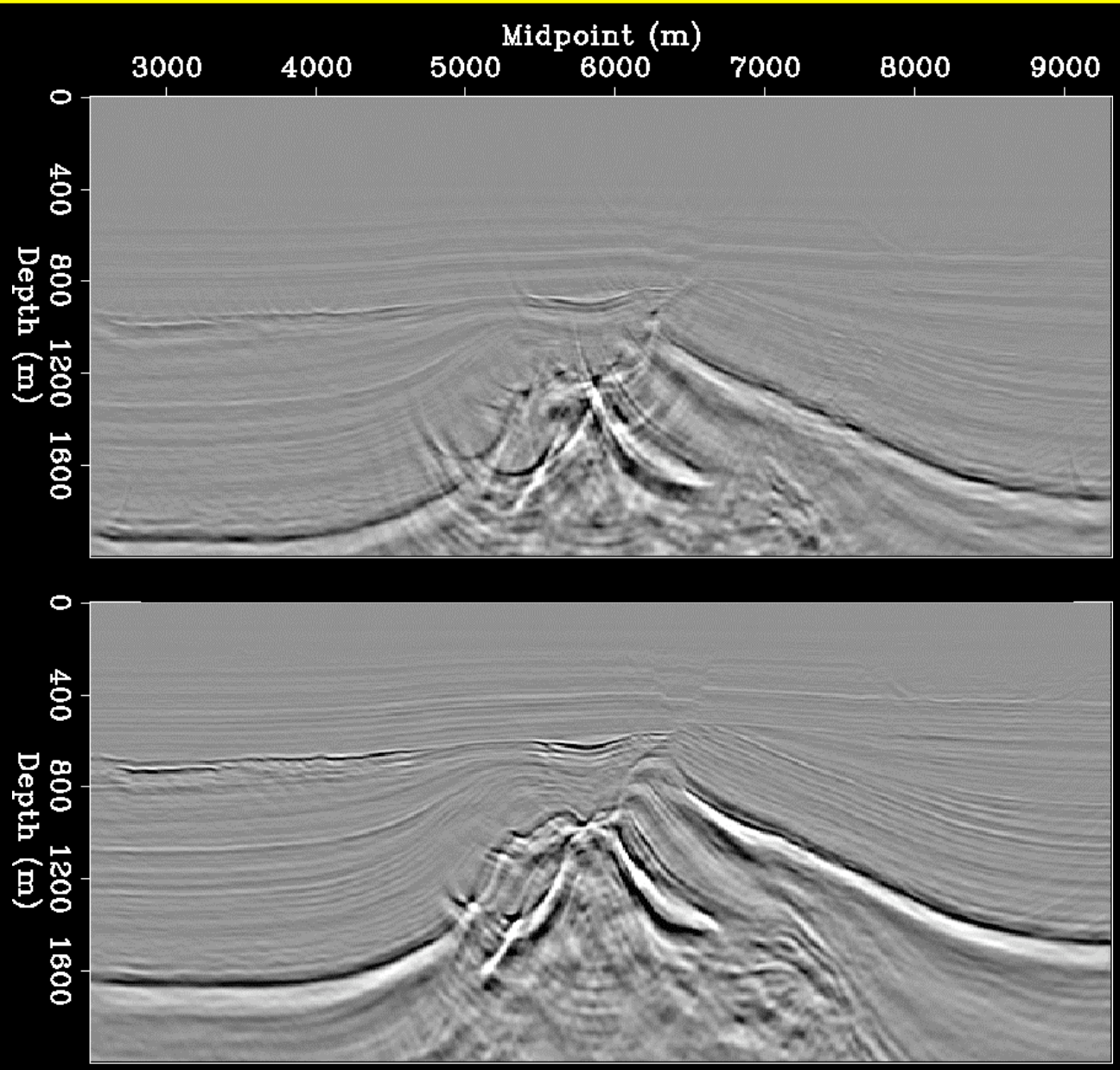
Low velocity ⇔ Image focusing



Undermigrated

"Correctly" migrated

High velocity ⇔ Image focusing



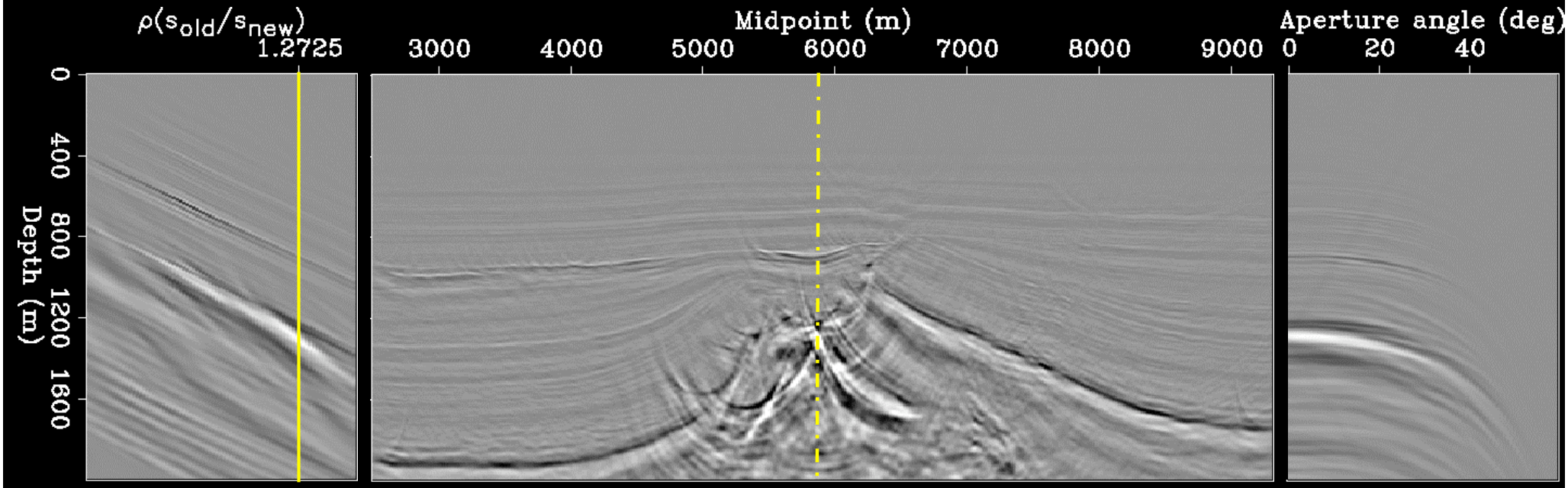
Overmigrated

"Correctly" migrated

Issues with current measures of image focusing

Stack power

Angle gather



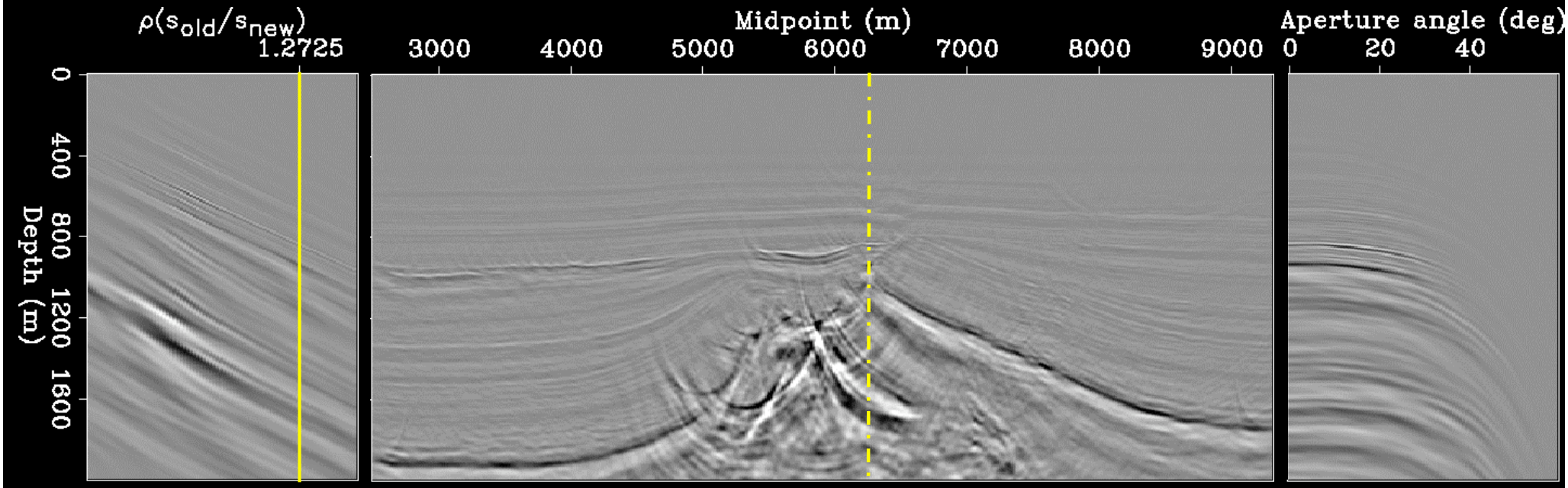
Biased

Inconsistent with angle (offset) information

We need new tools to measure image focusing!

Stack power

Angle gather



Biased

Inconsistent with angle (offset) information

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Outline

- Introduction
- Image-focusing semblance
- Curvature correction
- Synthetic and field data examples
- Velocity information in zero-offset data?
- Conclusions

Image focusing ⇔ Dip-decomposed images

1) $I(\mathbf{x},\gamma) \xrightarrow{\text{Residual migration}} I(\mathbf{x},\gamma,\rho)$

2) $I(\mathbf{x},\gamma,\rho) \xrightarrow{\text{Dip decomposition}} I(\mathbf{x},\gamma,\alpha,\rho)$

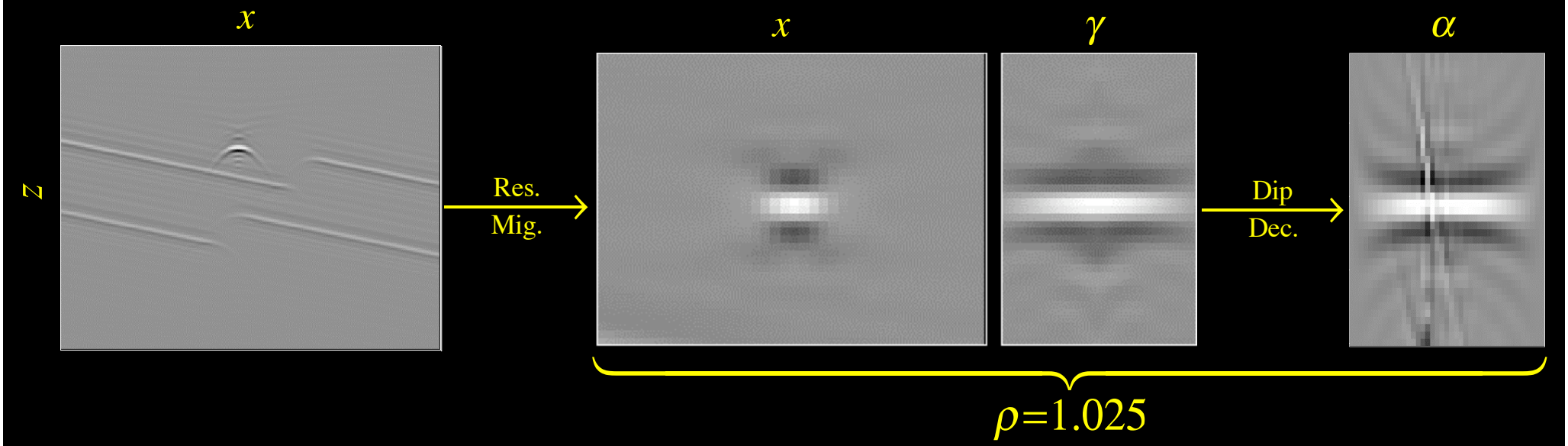
Where: I is the image

$\mathbf{x}(z,x)$ are spatial-coordinates

γ is aperture angle

ρ is s_{old} / s_{new}

α is structural dip



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Measuring image focusing by semblance

Image-focusing semblance:

$$S_{\gamma,\alpha}[\rho] = \frac{\left[\sum_{\gamma}\sum_{\alpha} I(\mathbf{x},\gamma,\alpha,\rho)\right]^2}{N_\gamma N_\alpha \sum_{\gamma}\sum_{\alpha} I(\mathbf{x},\gamma,\alpha,\rho)^2}$$

Where: N_γ is the number of aperture angles γ

N_α is the number of structural-dip angles α

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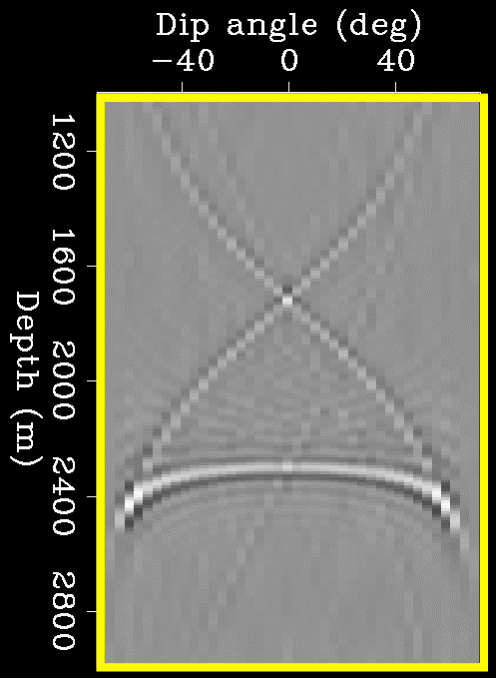
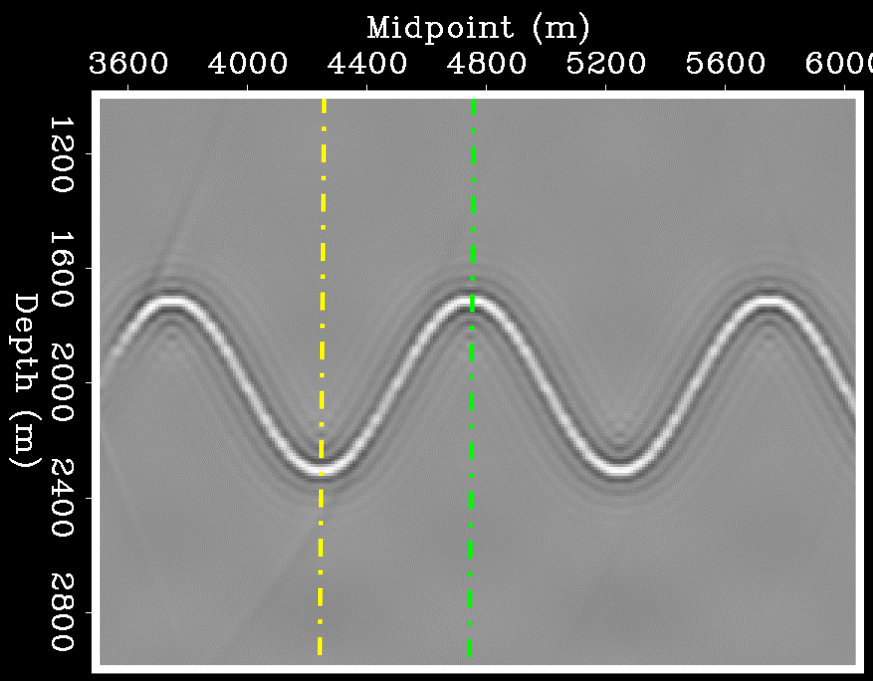
Bias caused by reflectors curvature

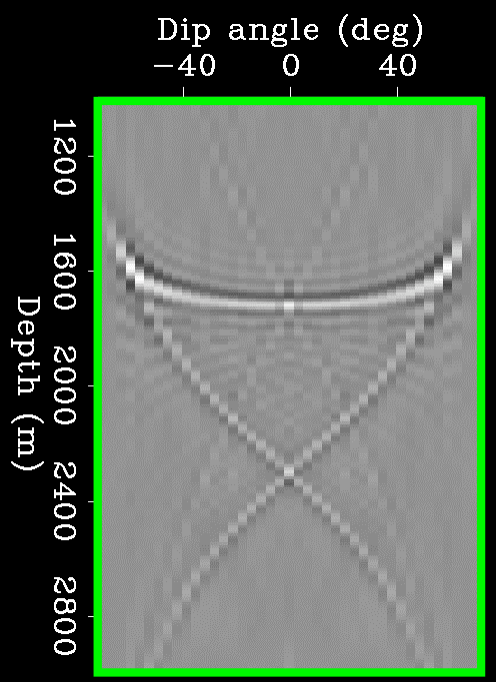
Dip gather at 4.250 m



Normal-incidence section (γ=0)



Dip gather at 4.750 m



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Correcting for bias caused by reflectors curvature

$$I(\mathbf{x},\gamma,\alpha,\rho) \xrightarrow{\text{Curvature correction}} I(\mathbf{x},\gamma,\alpha,\rho,R)$$

Where: R is radius of curvature

$$\text{Curvature correction : } \Delta\mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha-\bar{\alpha})\tan(\alpha-\bar{\alpha})}{2} R\mathbf{n}$$

Where: $\bar{\alpha}$ is local reflector dip

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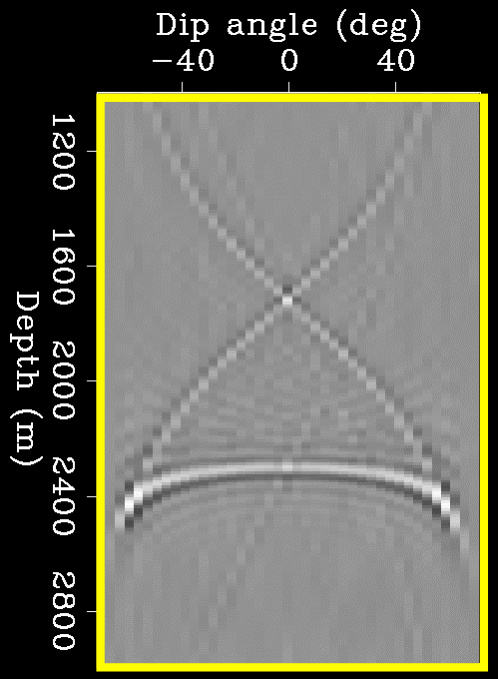
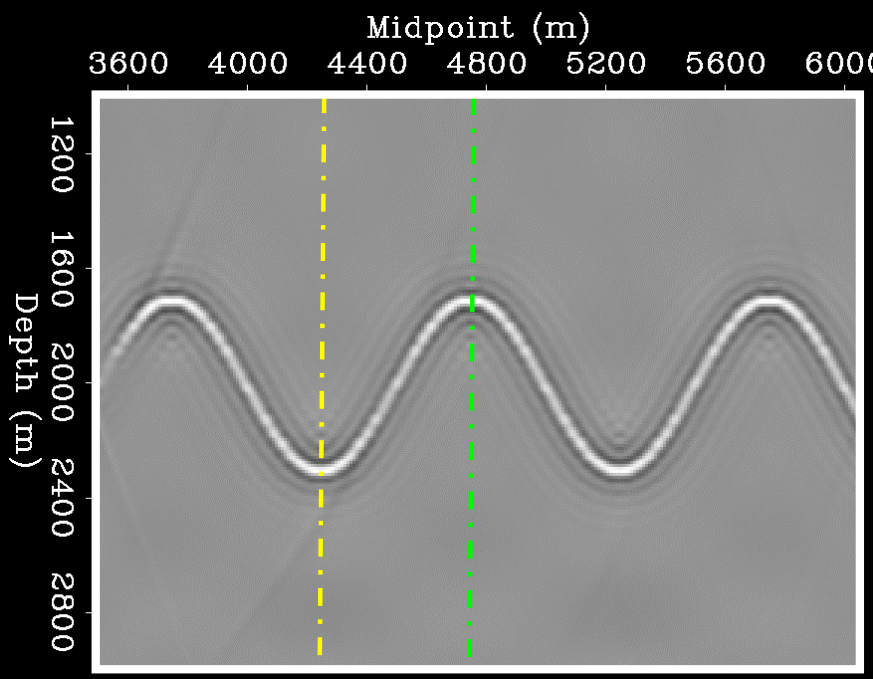
Bias caused by reflectors curvature ($\bar{\alpha}$=0°)

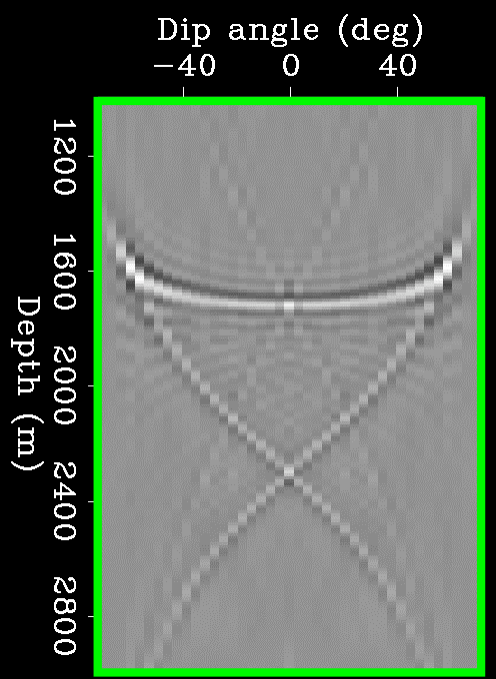
Dip gather at 4.250 m



Normal-incidence section (γ=0)



Dip gather at 4.750 m



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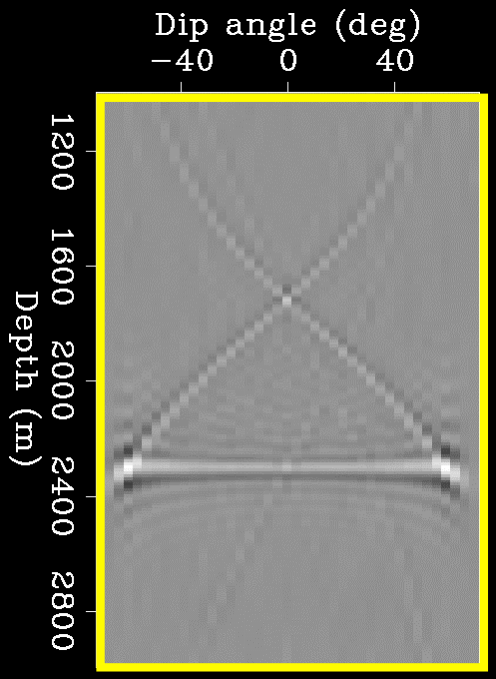
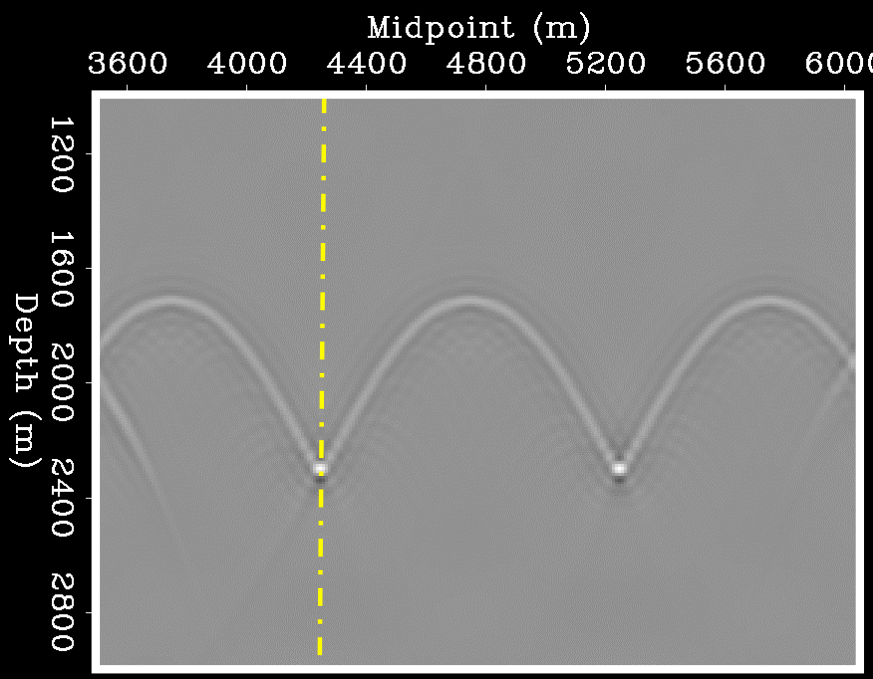
Curvature correction ($\bar{\alpha}$=0°, R=-90 m)

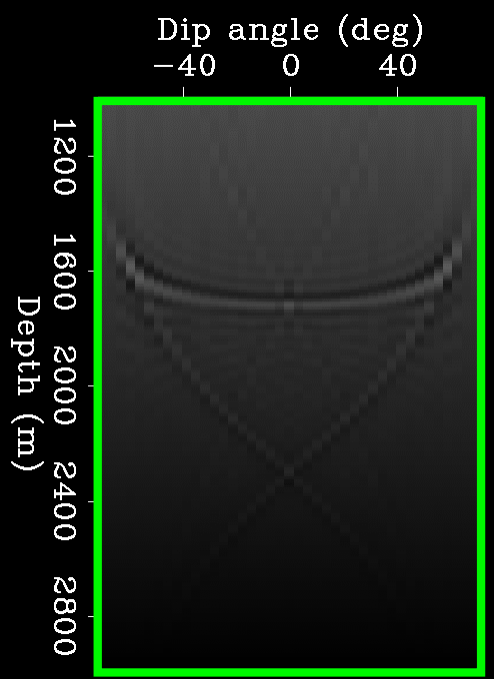
Dip gather at 4.250 m



Normal-incidence section (γ=0)



Dip gather at 4.750 m



$$\text{Curvature correction : } \Delta\mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha-\bar{\alpha})\tan(\alpha-\bar{\alpha})}{2} R\mathbf{n}$$

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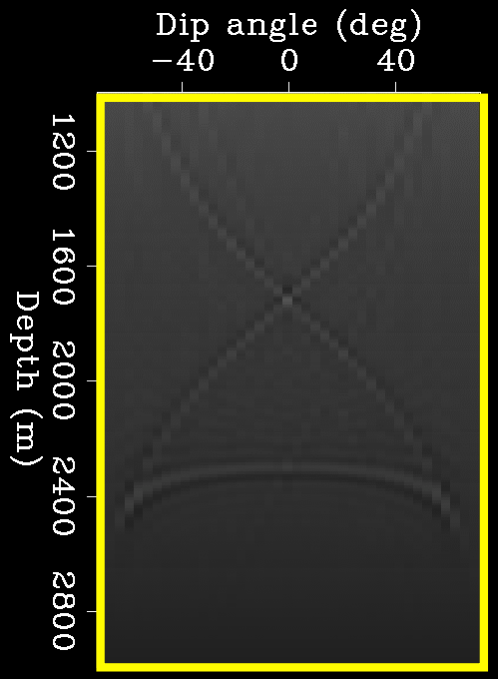
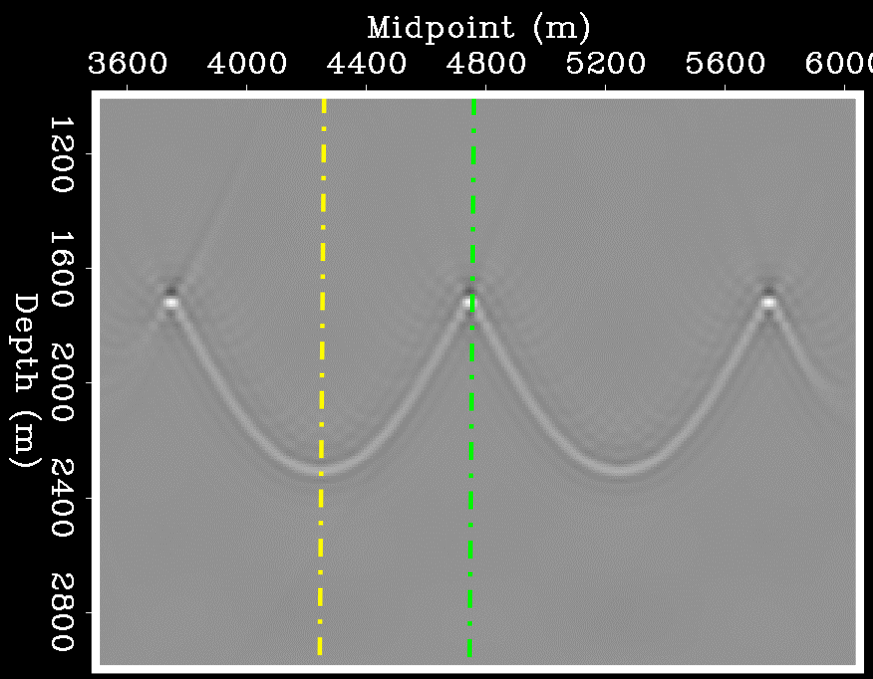
Curvature correction ($\bar{\alpha}$=0°, R=90 m)

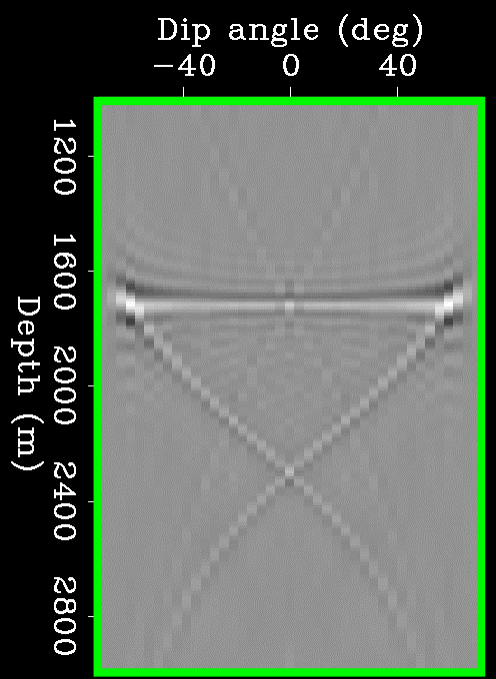
Dip gather at 4.250 m



Normal-incidence section (γ=0)



Dip gather at 4.750 m



$$\text{Curvature correction : } \Delta\mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha-\bar{\alpha})\tan(\alpha-\bar{\alpha})}{2} R\mathbf{n}$$

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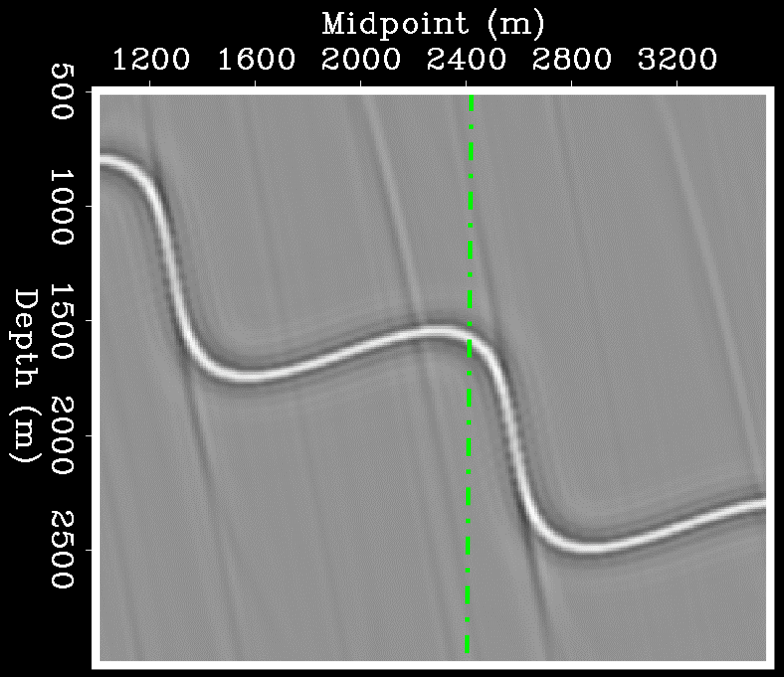
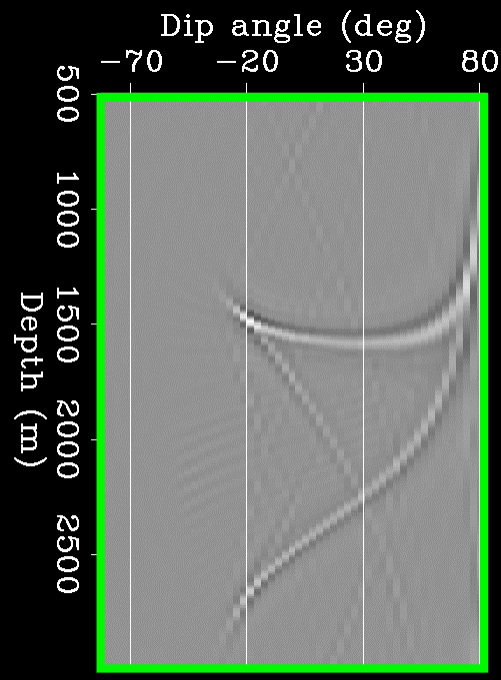
Bias caused by reflectors curvature ($\bar{\alpha}$=30^o)

Normal-incidence section (γ=0)



Dip gather at 2.410 m



$$\text{Curvature correction : } \Delta\mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha-\bar{\alpha})\tan(\alpha-\bar{\alpha})}{2} R\mathbf{n}$$

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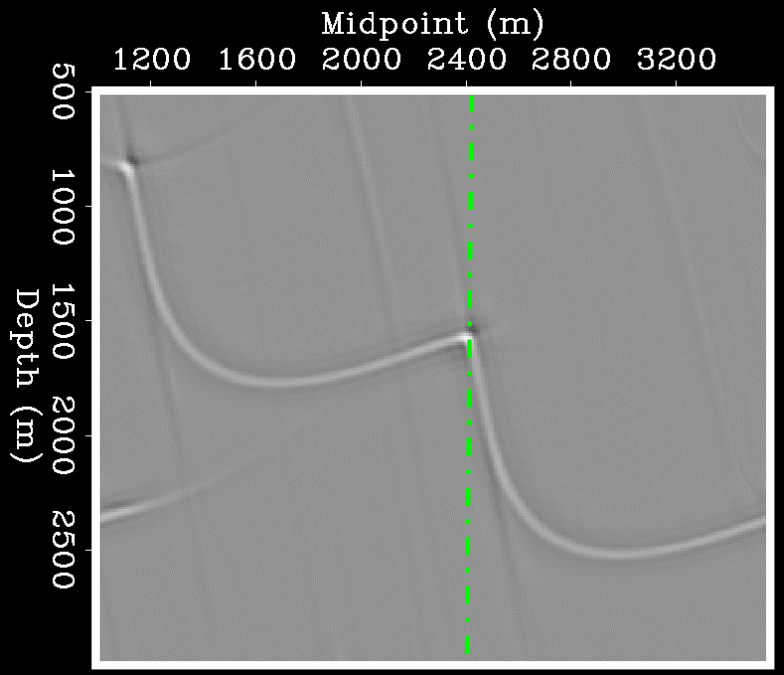
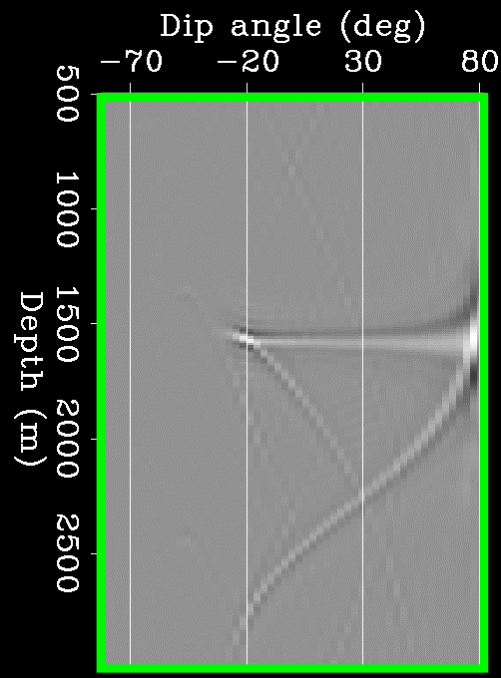
Curvature correction ($\bar{\alpha}$=30°, R=180 m)

Normal-incidence section (γ=0)



Dip gather at 2.410 m



$$\text{Curvature correction : } \Delta\mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha-\bar{\alpha})\tan(\alpha-\bar{\alpha})}{2} R\mathbf{n}$$

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Image-focusing semblance unbiased by curvature

$$S_{\gamma,\alpha}[\rho,R]=\frac{\left[\sum_{\gamma}\sum_{\alpha} I(\mathbf{x},\gamma,\alpha,\rho,R)\right]^2}{N_\gamma N_\alpha \sum_{\gamma}\sum_{\alpha} I(\mathbf{x},\gamma,\alpha,\rho,R)^2}$$

Curvature correction by interpolation along ρ

$$S_{\gamma,\alpha}\left[\bar{\rho},R\right]=\frac{\left\{\sum_{\gamma}\sum_{\alpha} I\left[\mathbf{x},\gamma,\alpha,\rho\left(\bar{\rho},R,\bar{\alpha}\right),R\right]\right\}^2}{N_\gamma N_\alpha \sum_{\gamma}\sum_{\alpha} I\left[\mathbf{x},\gamma,\alpha,\rho\left(\bar{\rho},R,\bar{\alpha}\right),R\right]^2}$$

Where: $\rho\left(\bar{\rho},R,\bar{\alpha}\right)=\bar{\rho}+\dfrac{\sin\left(\alpha-\bar{\alpha}\right)\tan\left(\alpha-\bar{\alpha}\right)\left(\cos^2\alpha-\sin^2\gamma\right)}{2z_0\cos\alpha}R$

with z_0 a "reference" depth

Image-focusing ρ-*R* scan vs. conventional ρ scan

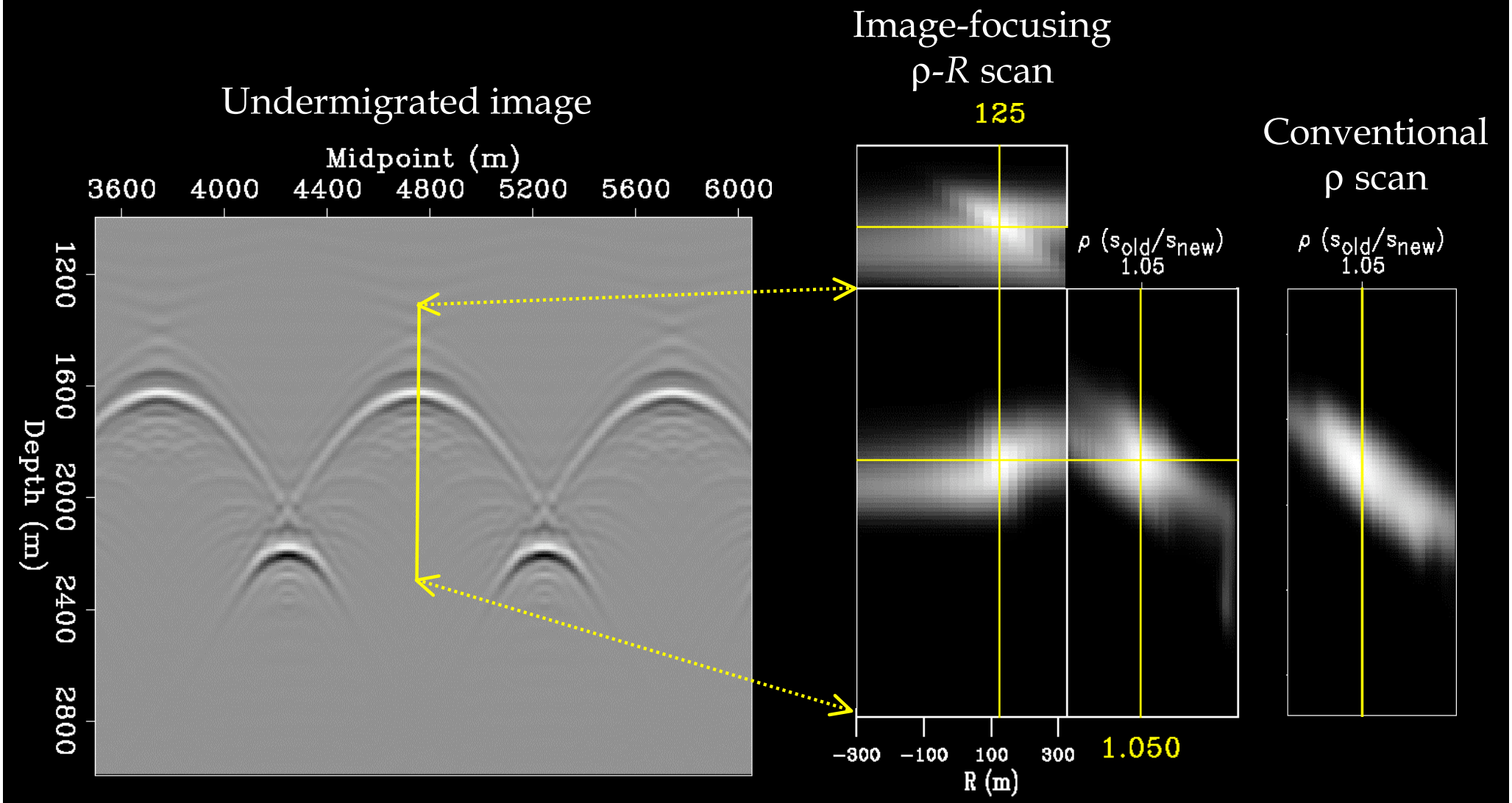

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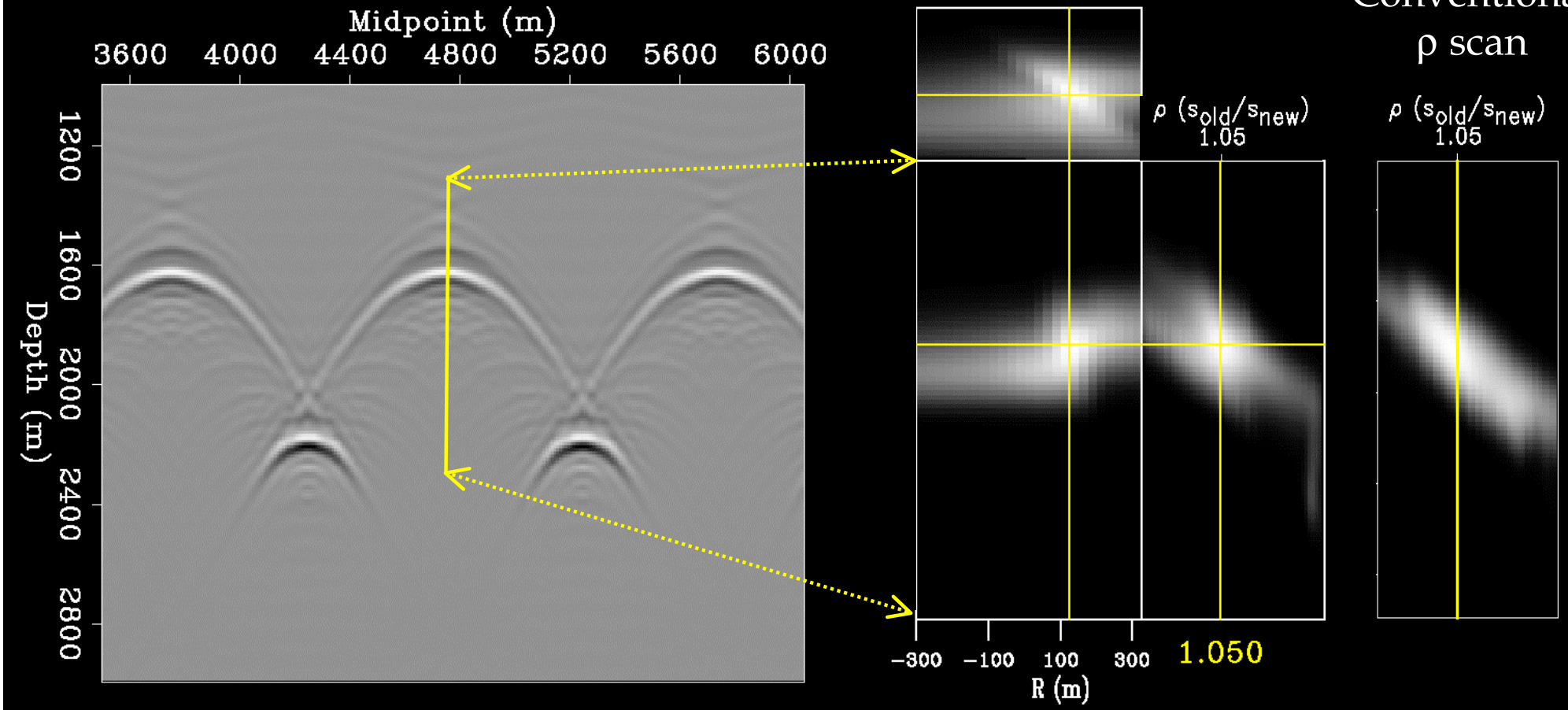
Image-focusing ρ-*R* scan vs. conventional ρ scan

1) Unbiased

2) Consistent with angle information



Application to 2D field data set

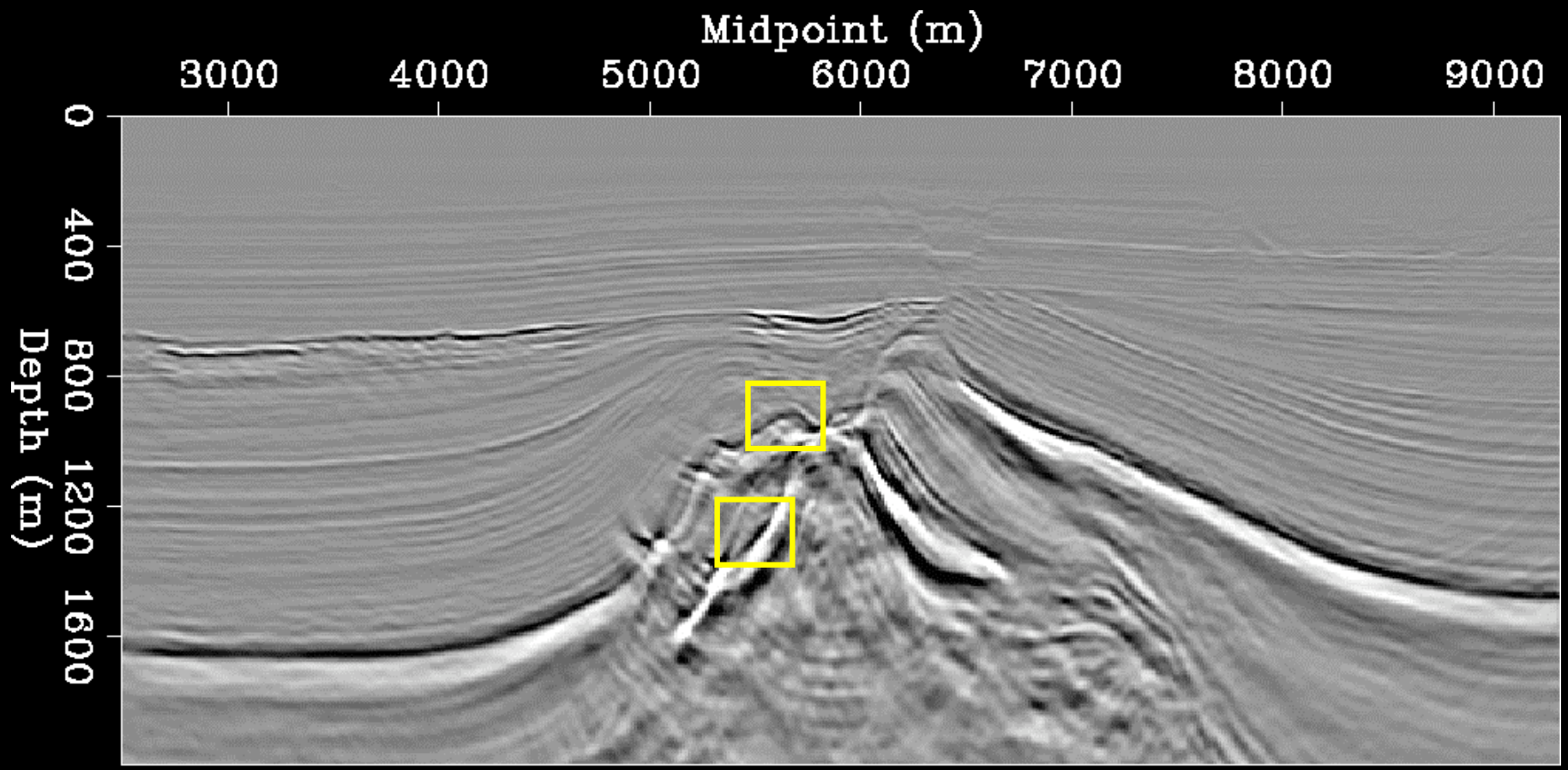


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Image-focusing ρ-*R* scan vs. conventional ρ scan

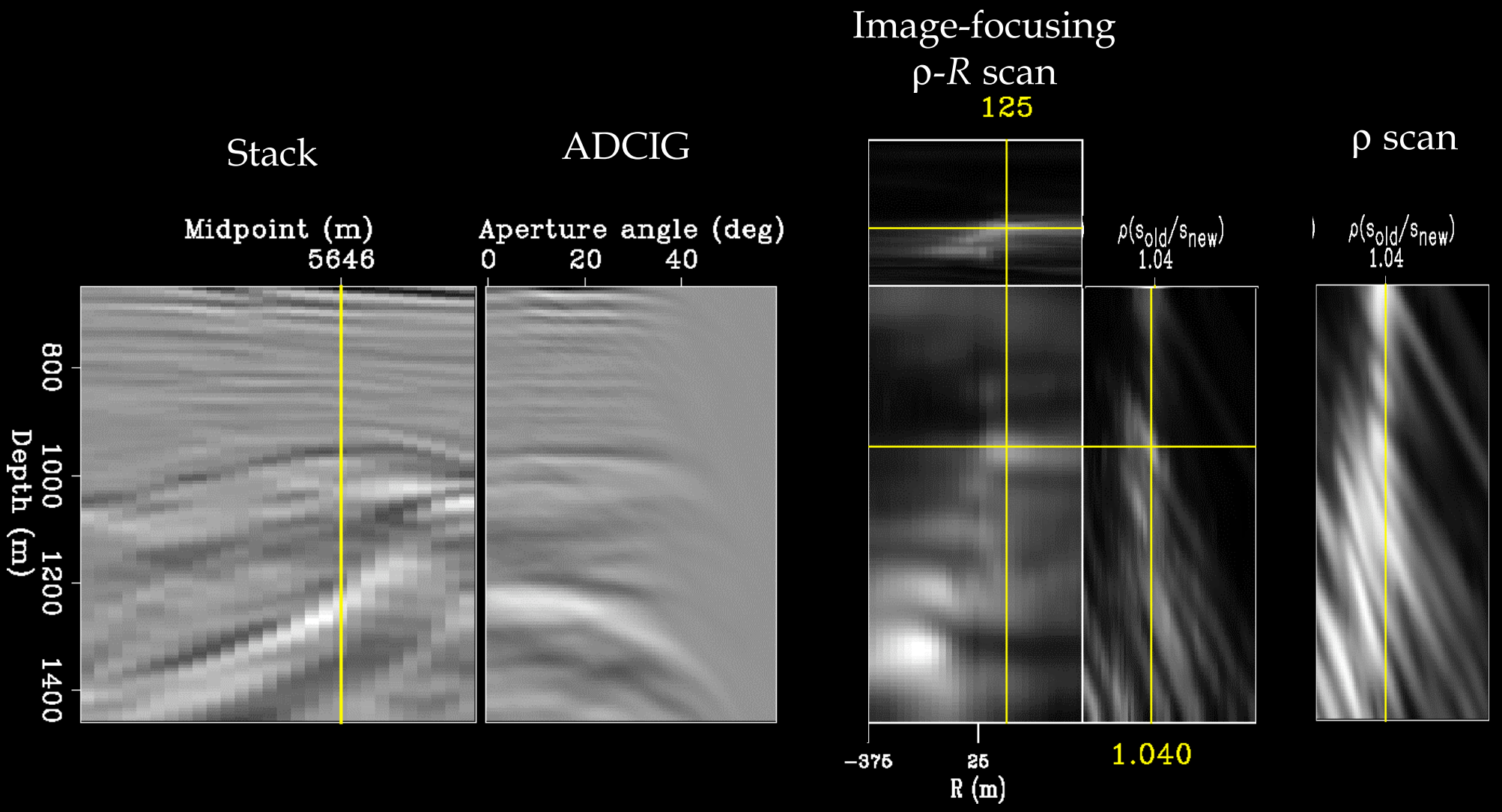

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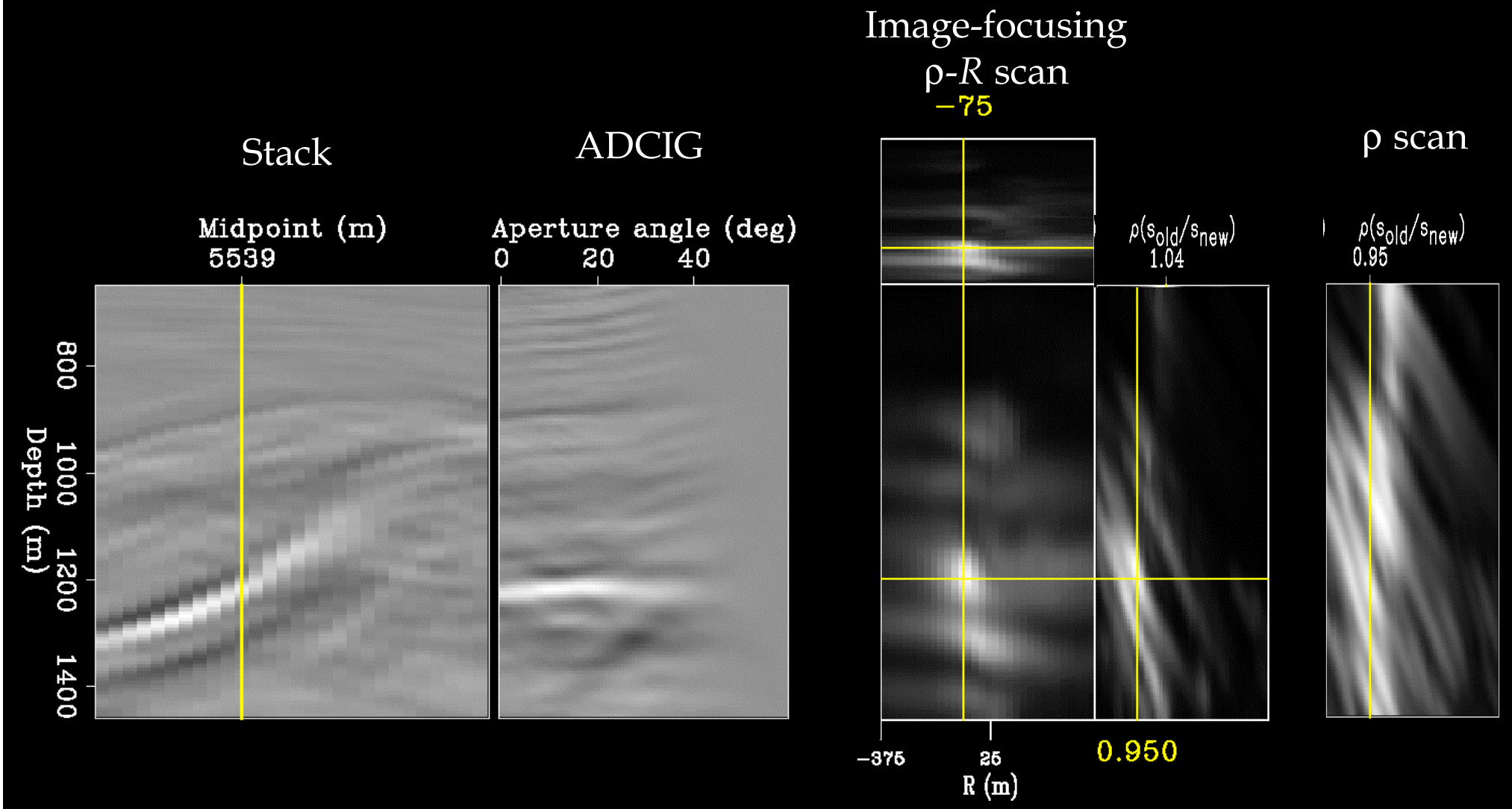
Image-focusing ρ-*R* scan vs. conventional ρ scan



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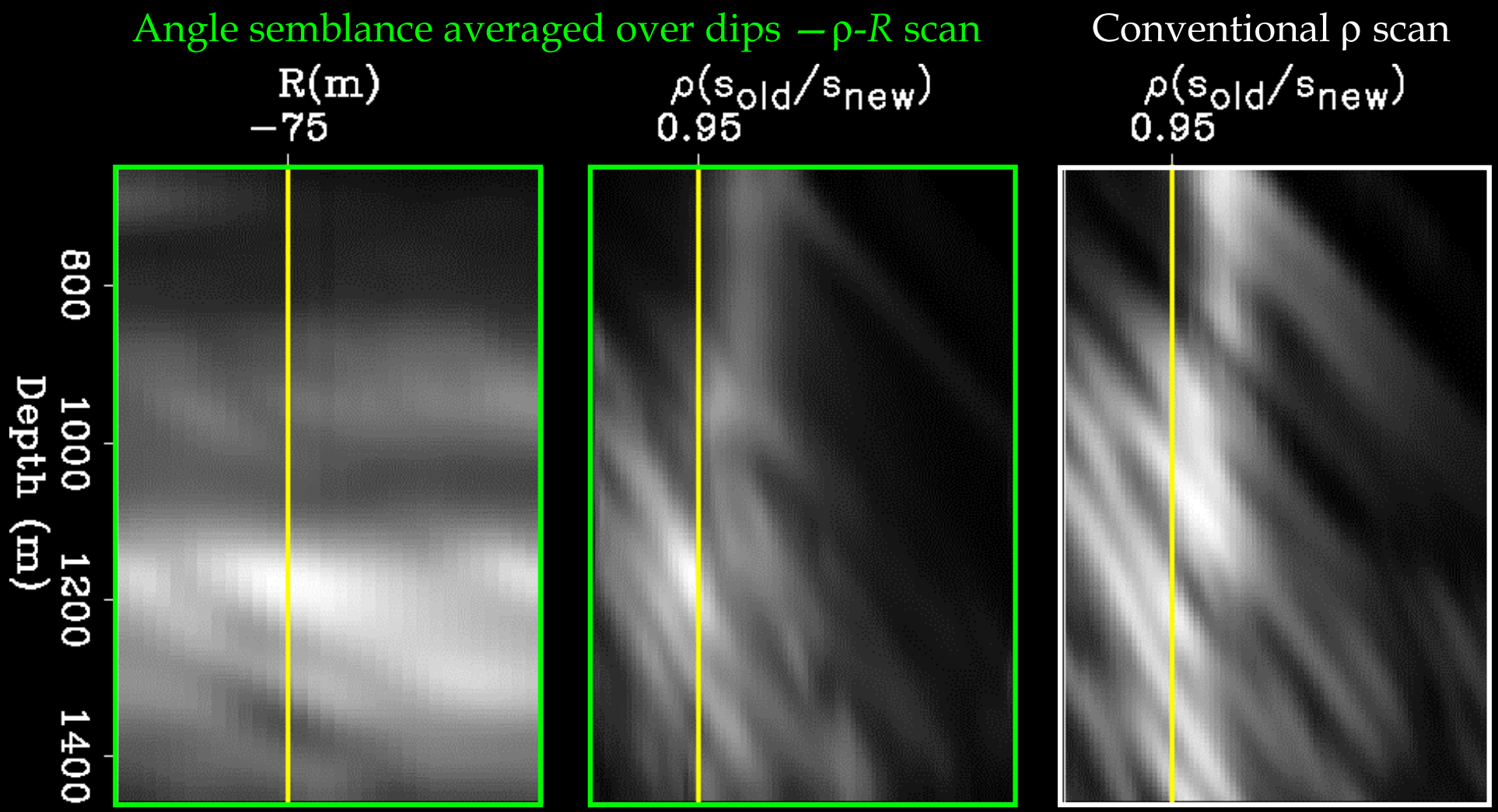
Angle semblance averaged over dips

$$S_\gamma\left[\bar{\rho},R\right]=\frac{\sum_\alpha\left\{\sum_\gamma I\left[\mathbf{x},\gamma,\alpha,\rho\left(\bar{\rho},R,\bar{\alpha}\right),R\right]\right\}^2}{\sum_\alpha N_\gamma\sum_\gamma I\left[\mathbf{x},\gamma,\alpha,\rho\left(\bar{\rho},R,\bar{\alpha}\right),R\right]^2}$$

Where: $\rho\left(\bar{\rho},R,\bar{\alpha}\right)=\bar{\rho}+\frac{\sin\left(\alpha-\bar{\alpha}\right)\tan\left(\alpha-\bar{\alpha}\right)\left(\cos^2\alpha-\sin^2\gamma\right)}{2z_0\cos\alpha}R$

with z_0 a "reference" depth

Advantages of averaging over dips



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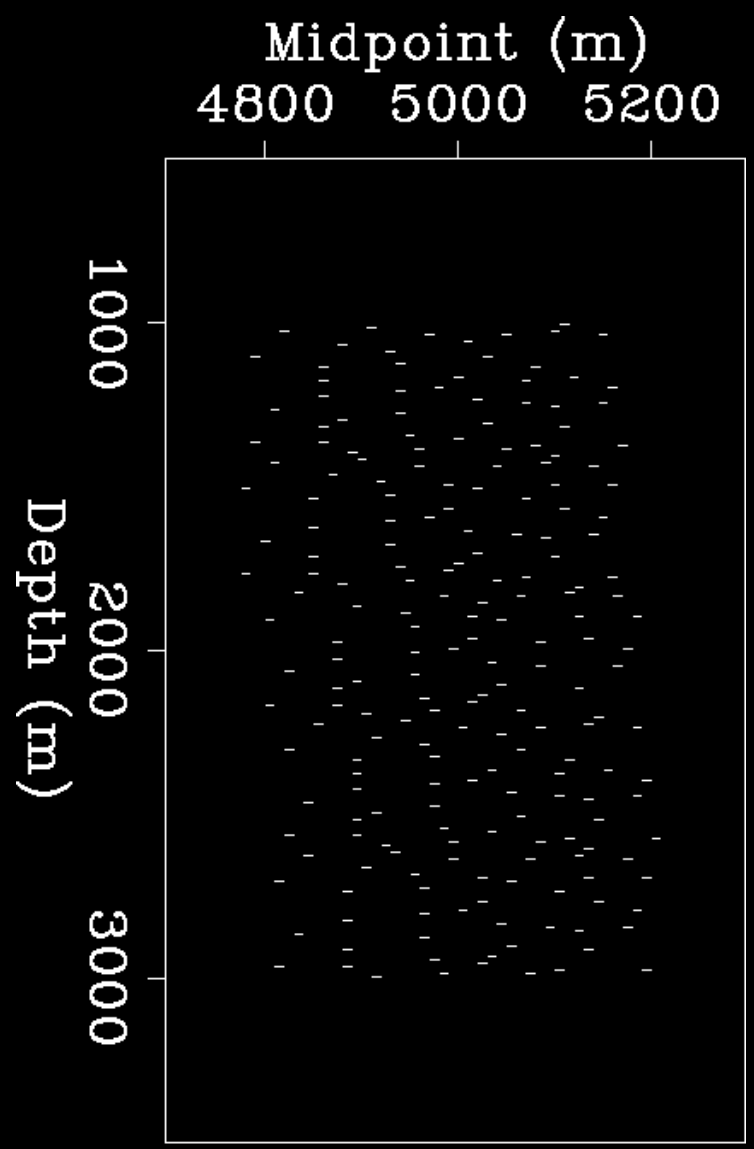
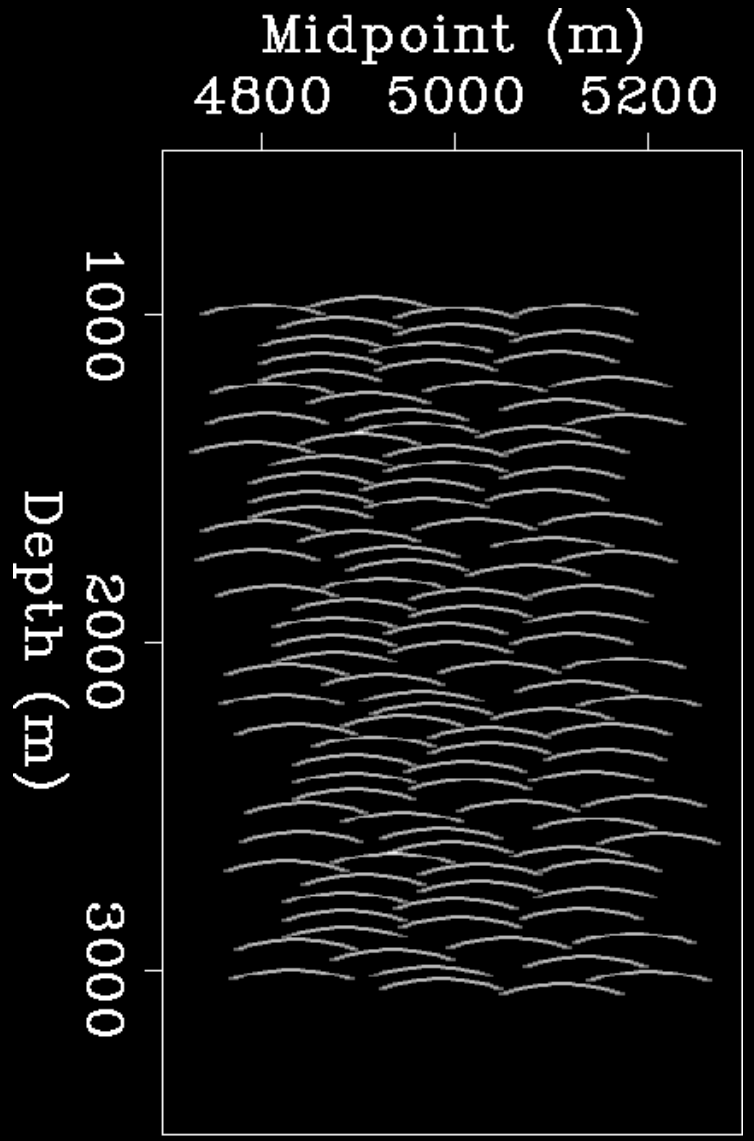
Velocity information in zero-offset data?

Point diffractors



Convex reflectors



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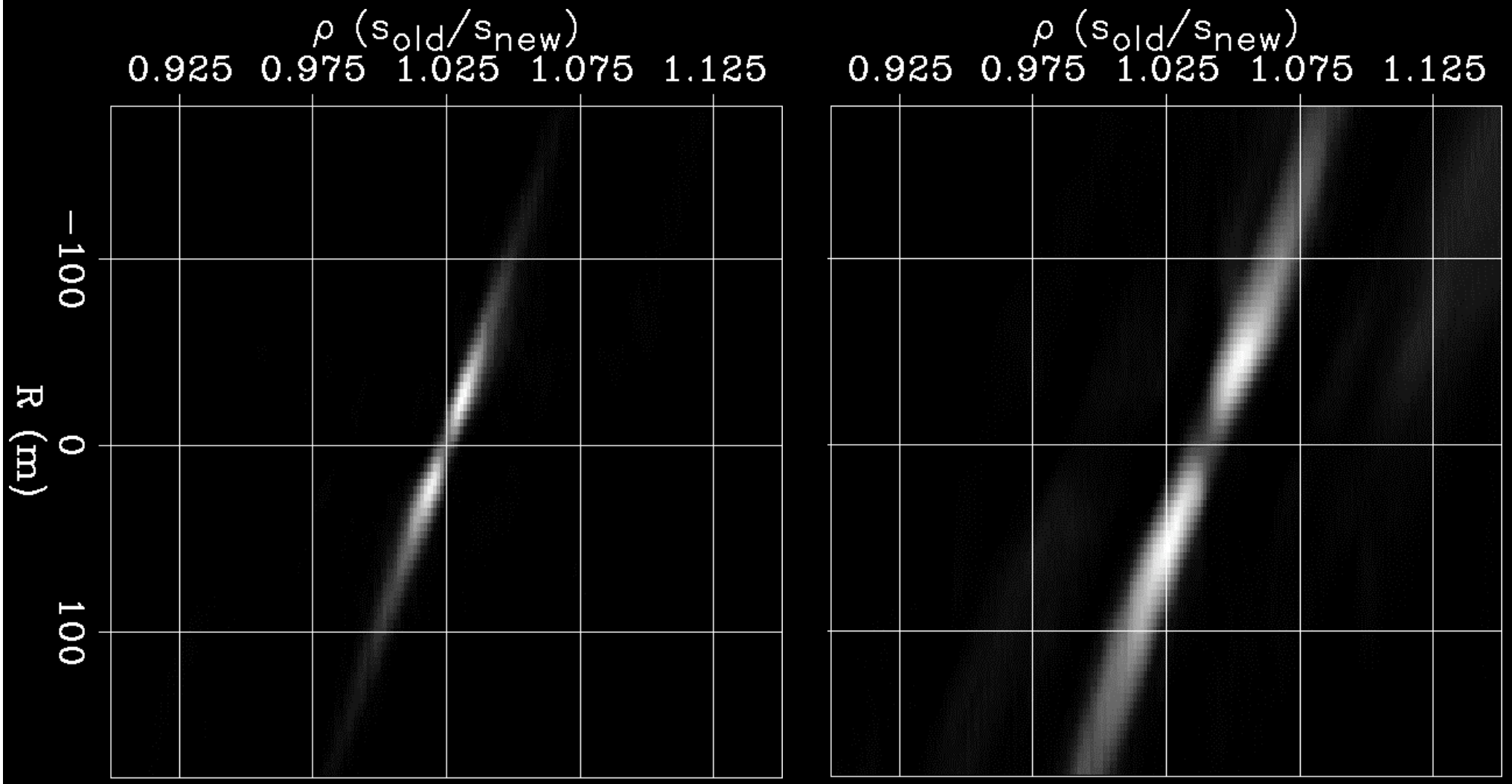
Spatial average of image-focusing semblance



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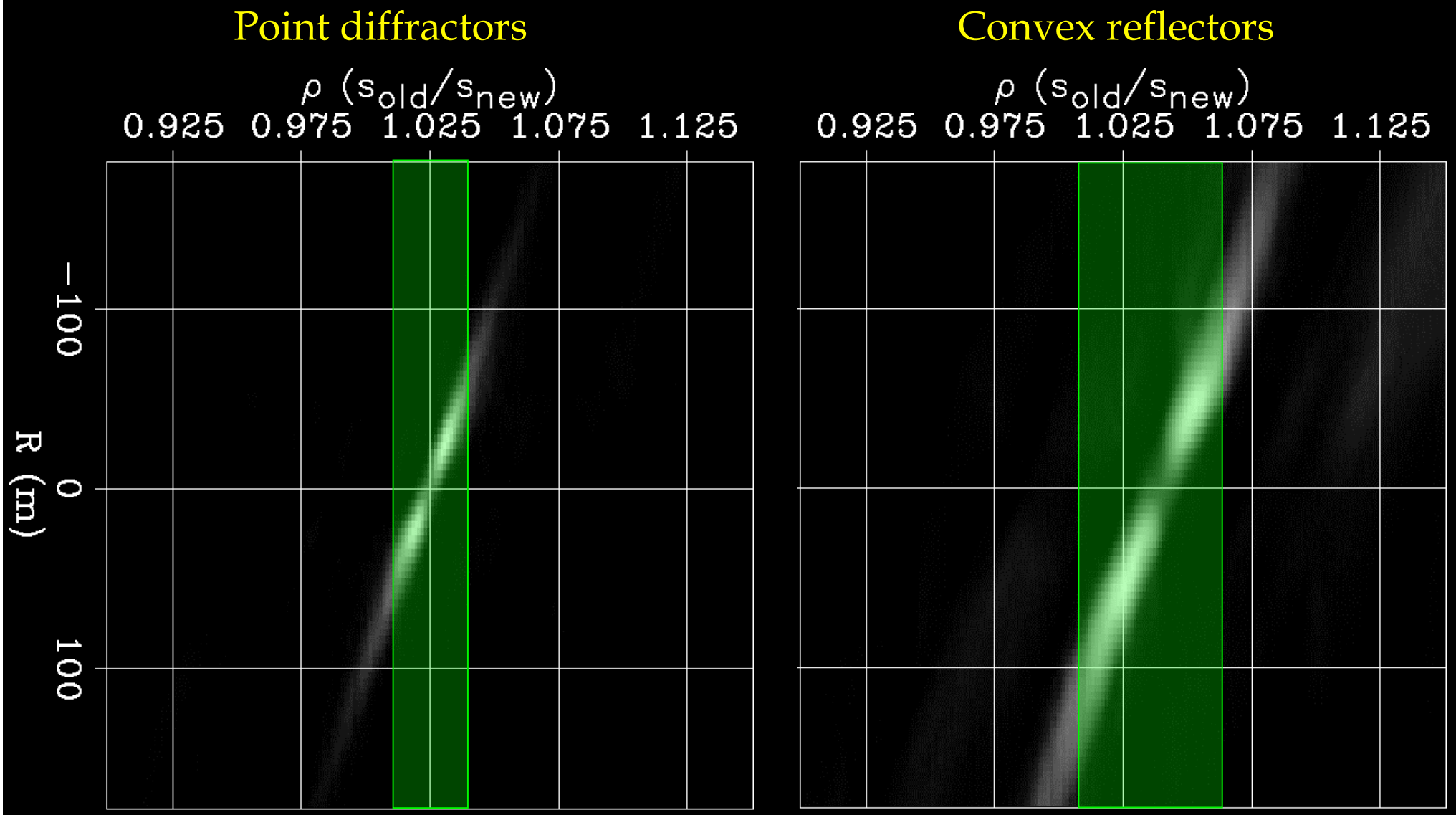
Provides estimates of likely ρ ranges

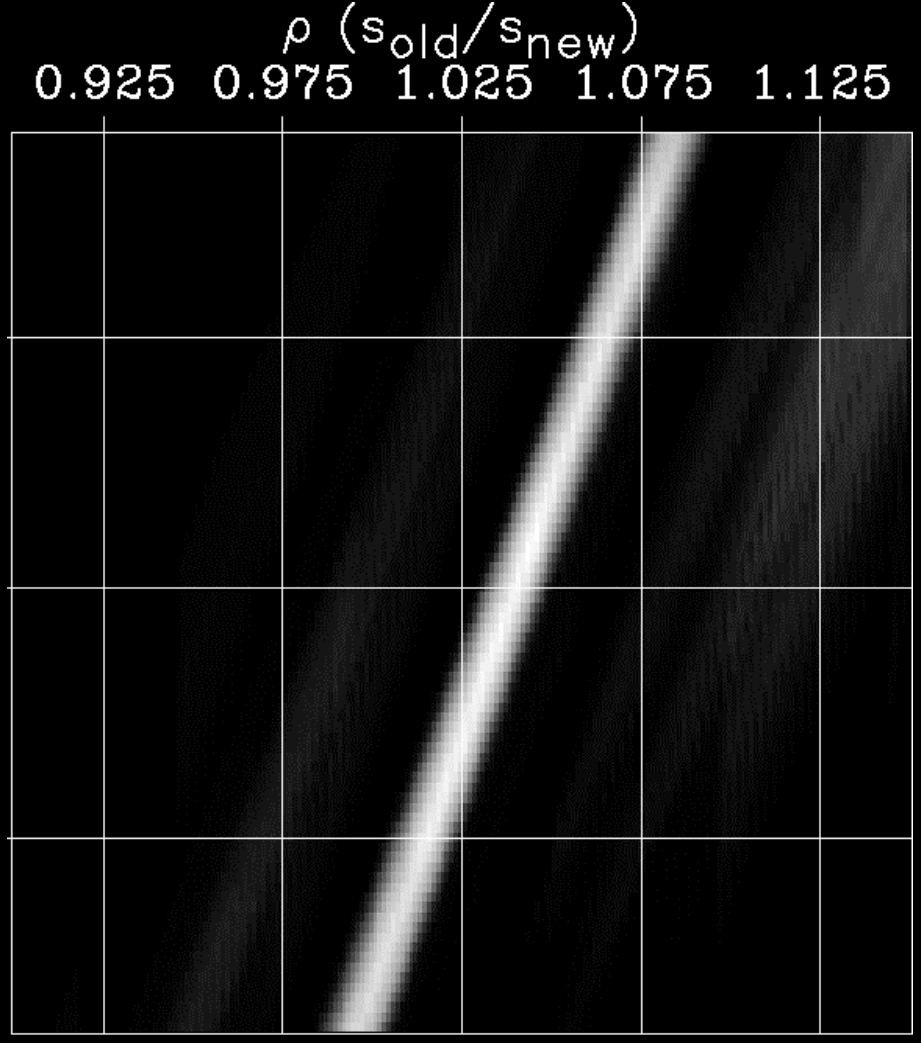


Role played by local reflector dip ($\bar{\alpha}$)

Curvature correction :

$$\Delta \mathbf{n}_{\text{Curv}} = \frac{\sin(\alpha - \bar{\alpha})\tan(\alpha - \bar{\alpha})}{2} R\mathbf{n}$$

Convex reflectors (fixed $\bar{\alpha}$=0)



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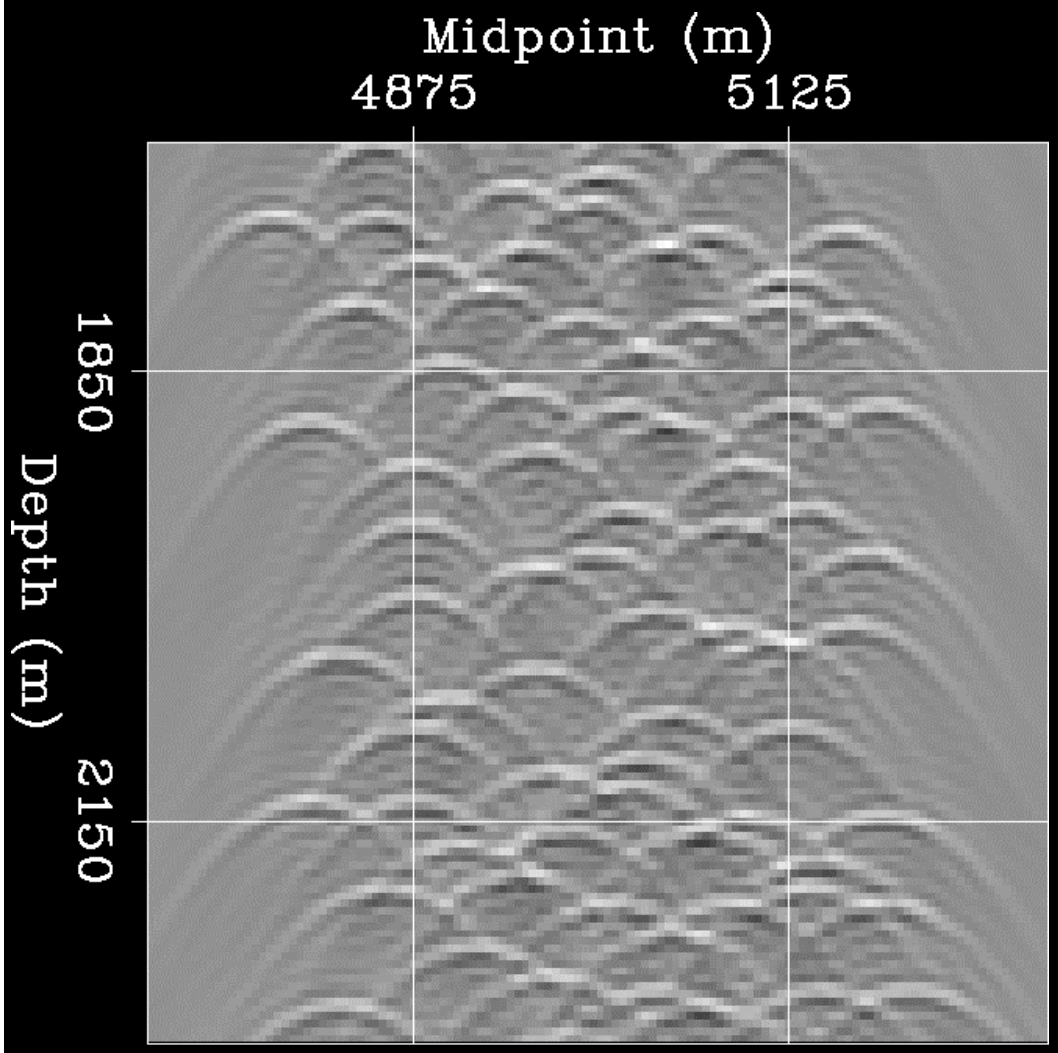
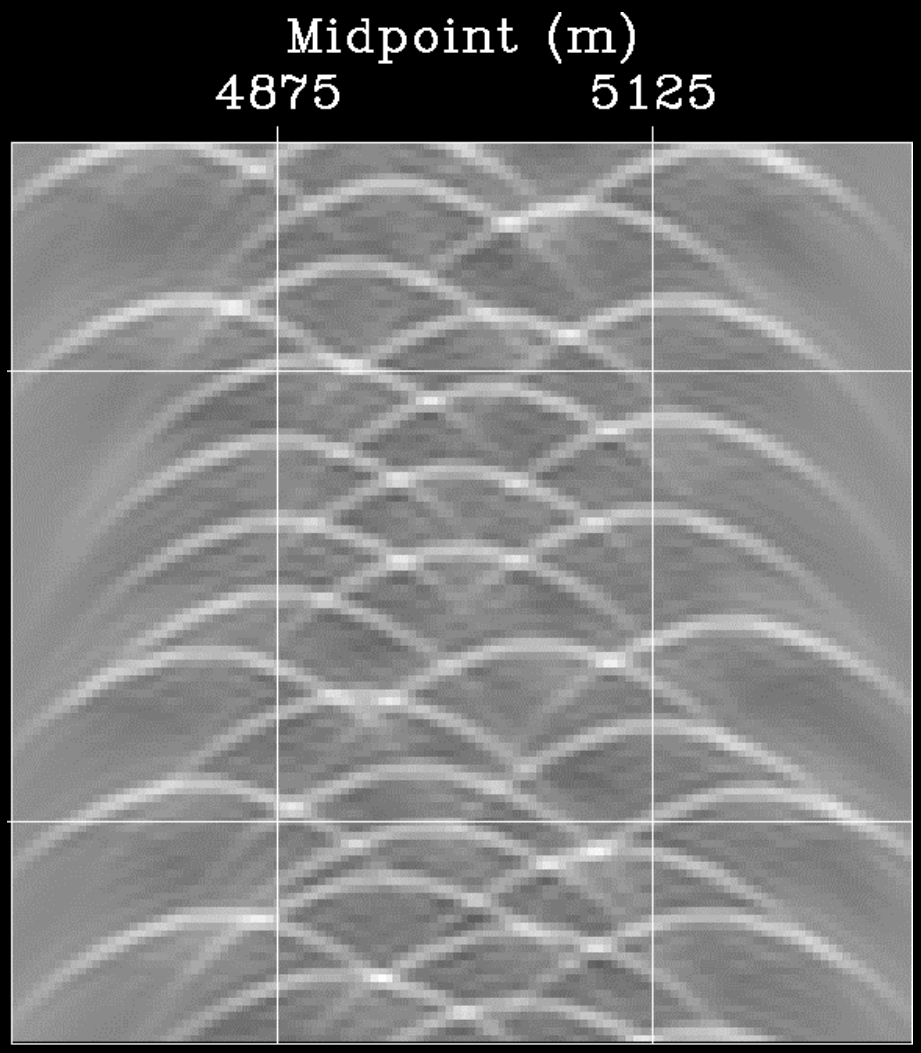
Images at low-velocity end of ρ ranges

Point diffractors



$\rho = 1.0125$

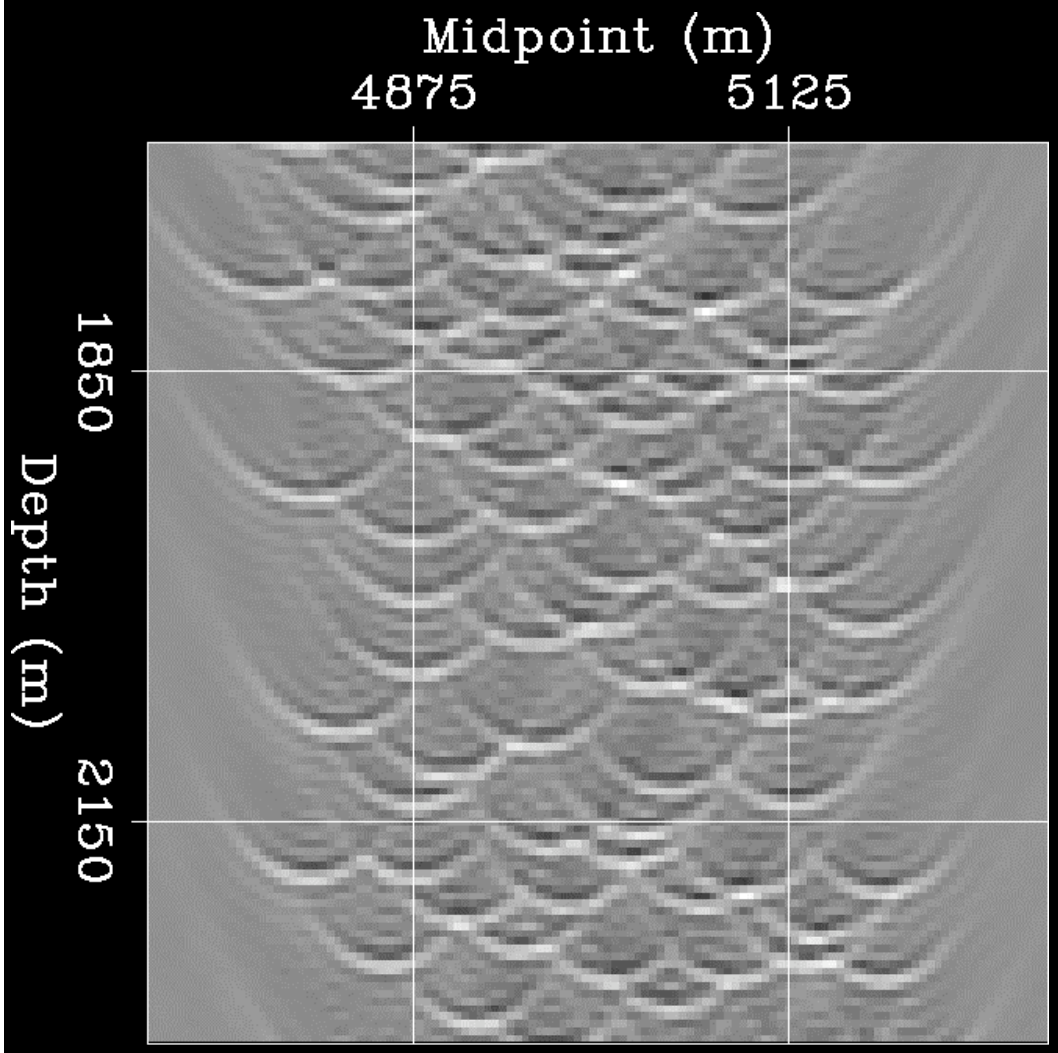
Convex reflectors



$\rho = 1.01$

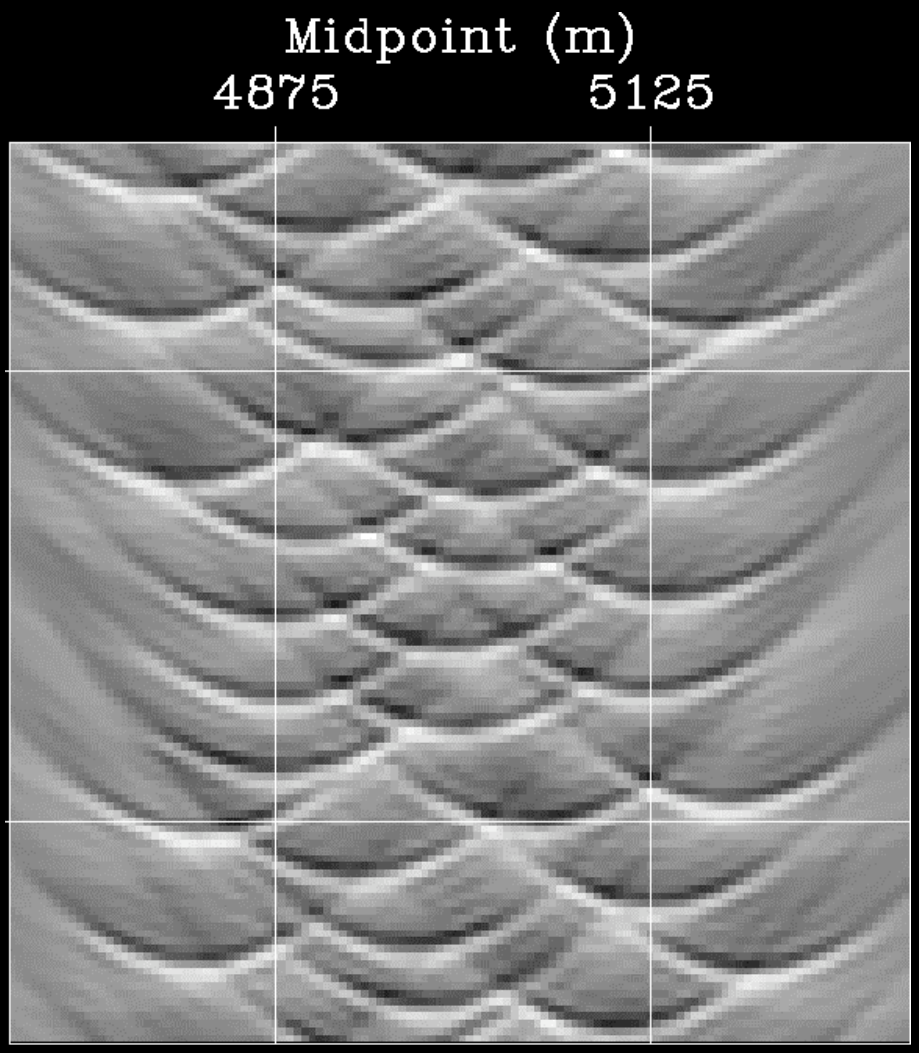
Images at high-velocity end of ρ ranges

Point diffractors



$\rho = 1.0375$

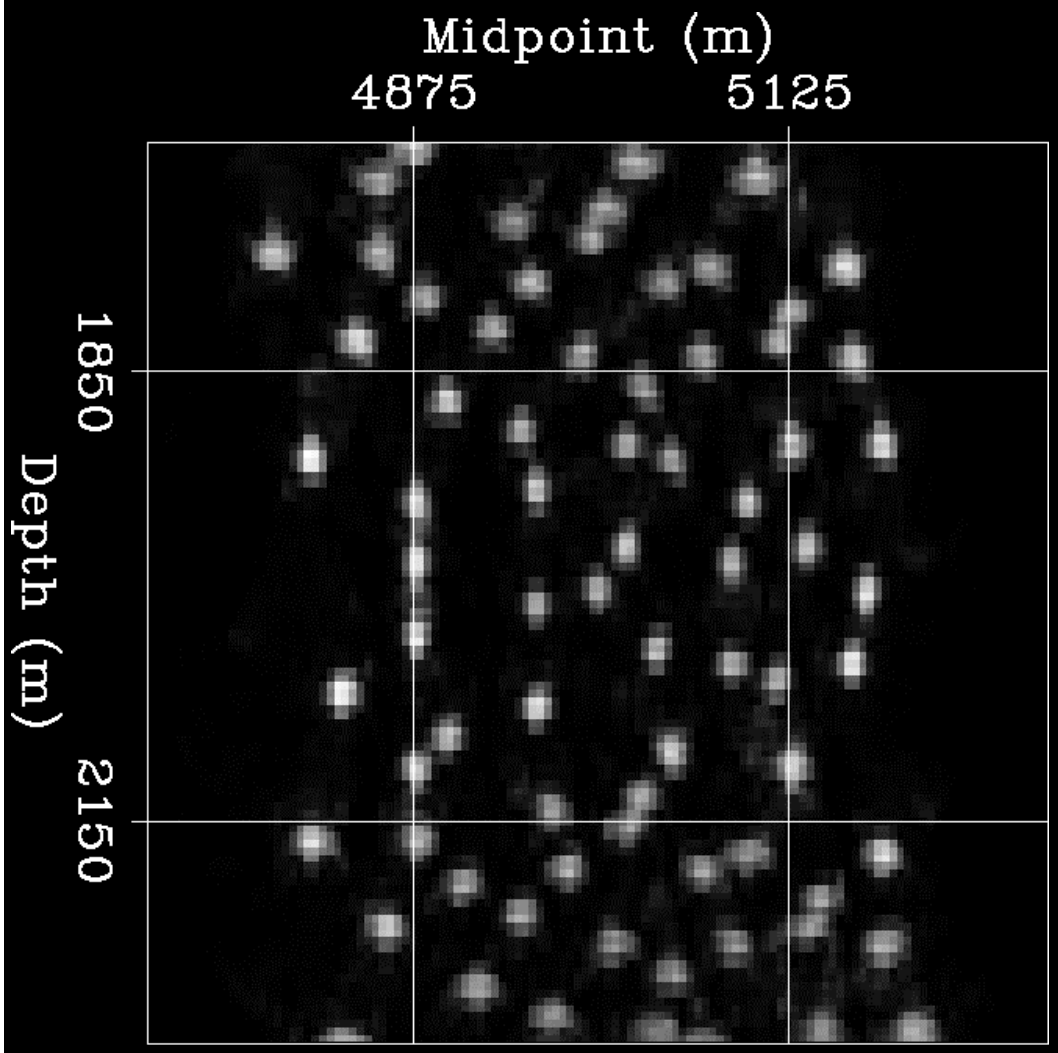
Convex reflectors



$\rho = 1.07$

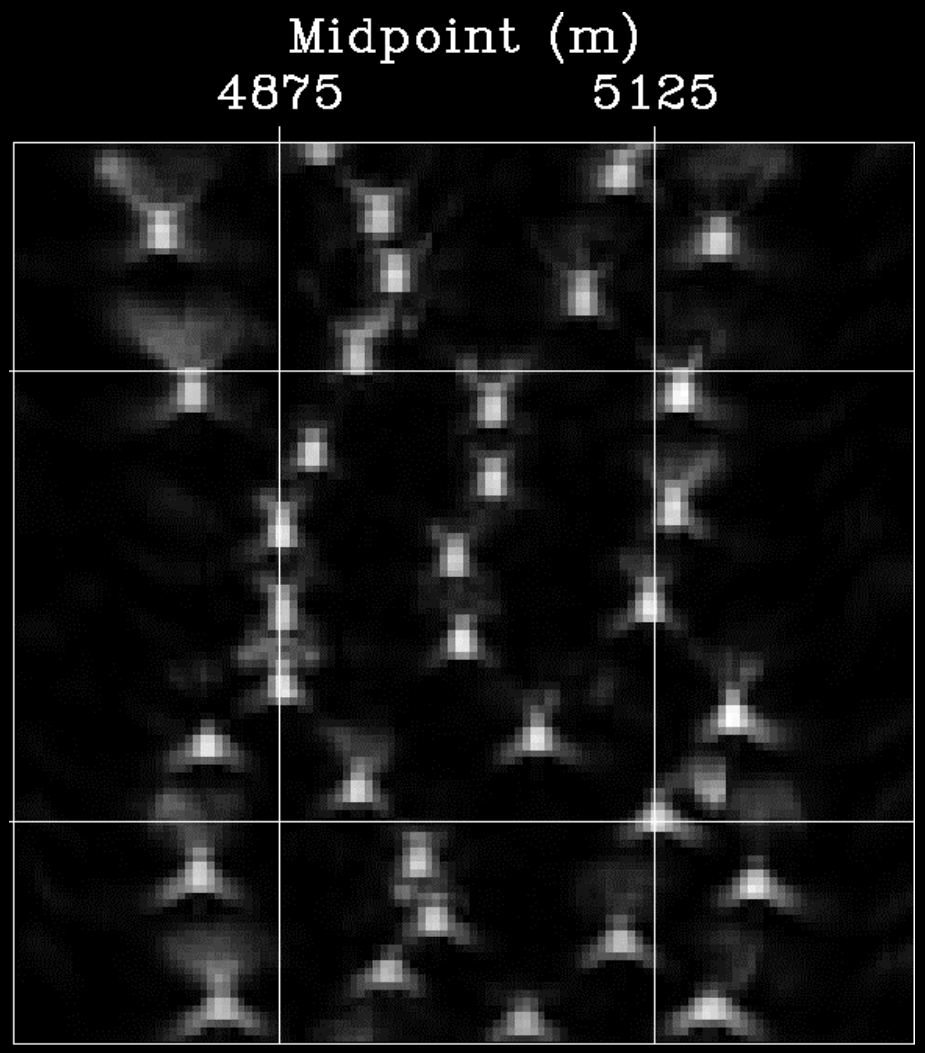
Semblance at center of ρ ranges

Point diffractors



$\rho = 1.025,\ R = 0\,\mathrm{m}$

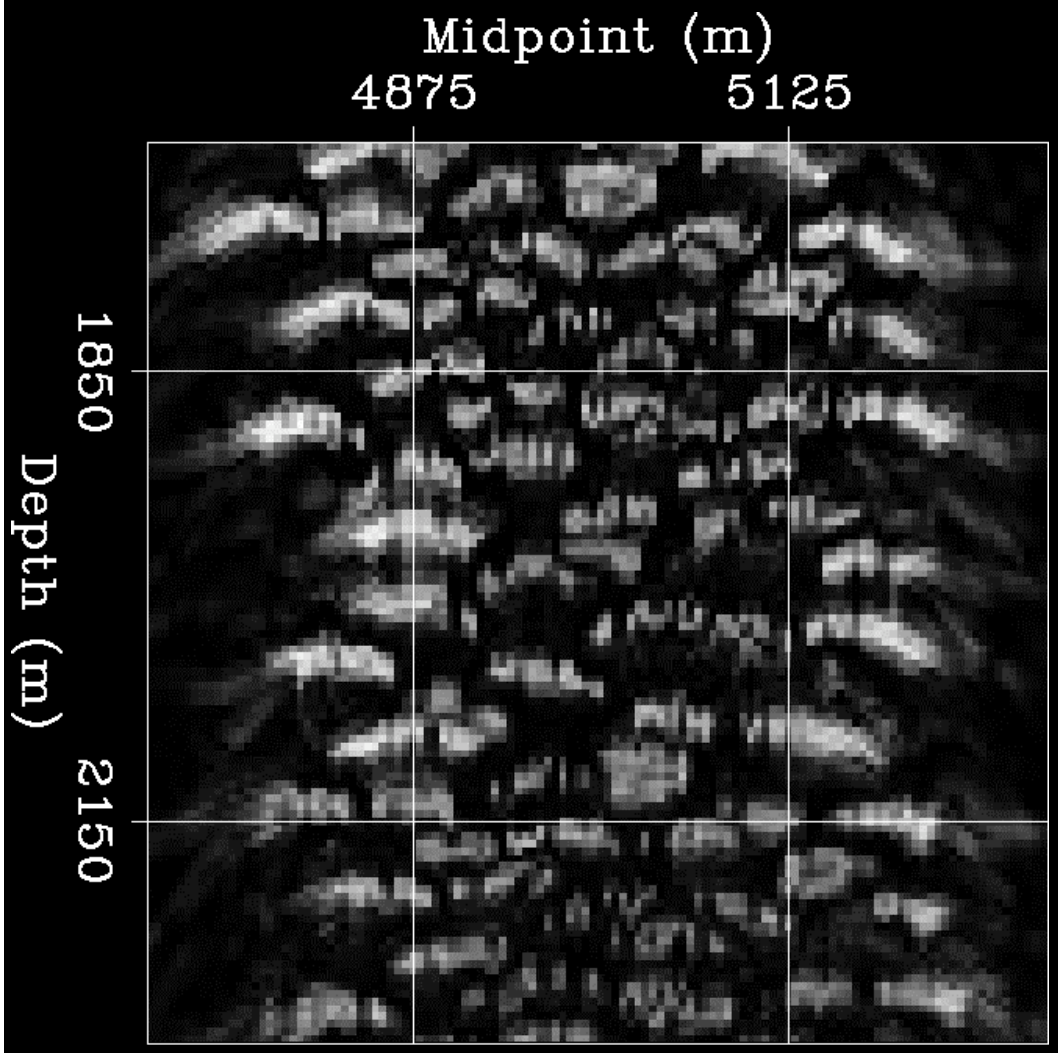
Convex reflectors



$\rho = 1.04,\ R = 0\,\mathrm{m}$

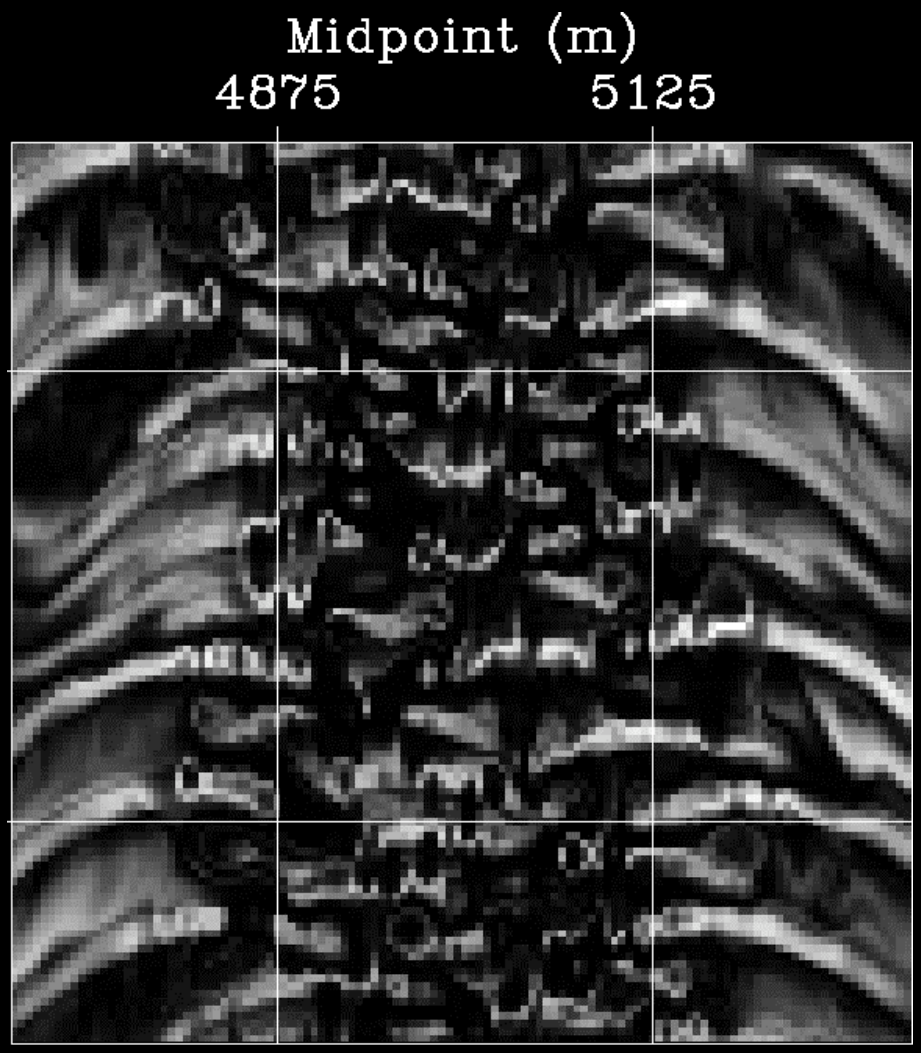
Semblance at low-velocity end of ρ ranges

Point diffractors



$\rho = 1.0125,\ R = 40\,\mathrm{m}$

Convex reflectors



$\rho = 1.01,\ R = 120\,\mathrm{m}$

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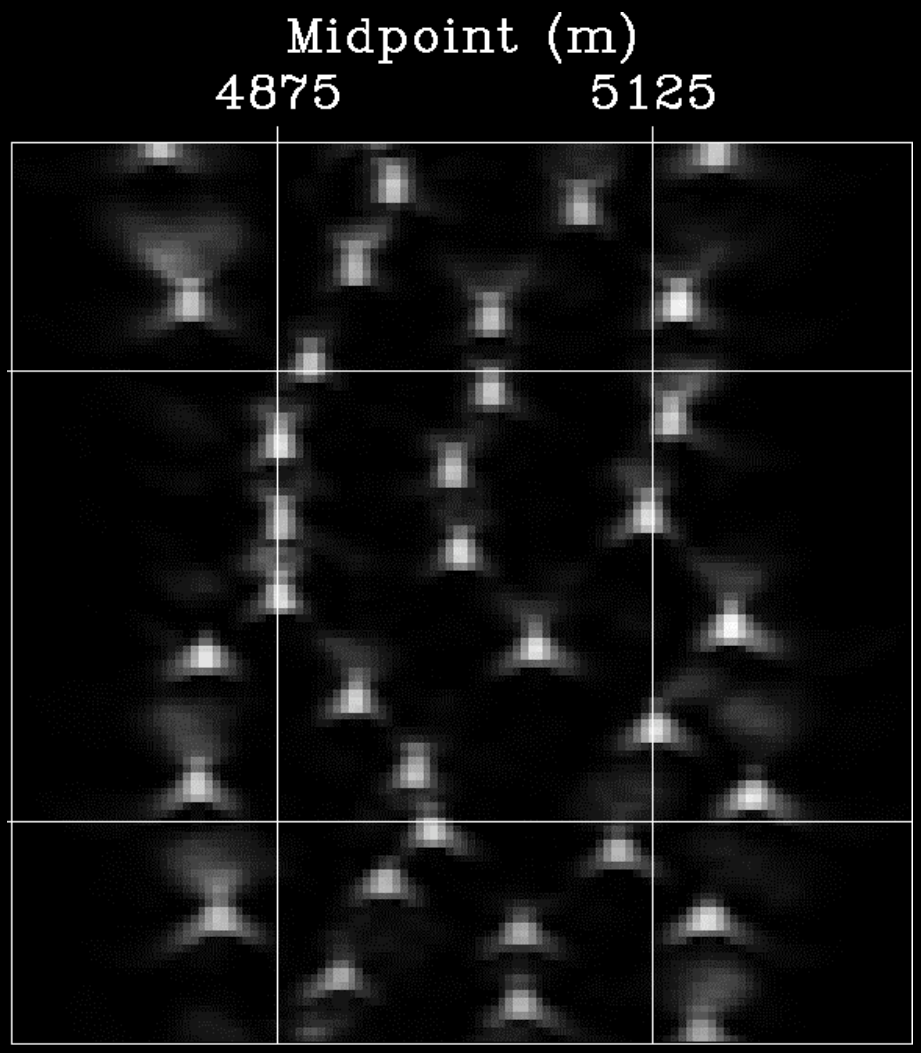
Semblance at low-velocity end of ρ range ($\bar{\alpha}$=0)

Convex reflectors (fixed α=0)



$\rho = 1.01,\ R = 120\,\mathrm{m}$

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Conclusions

- The analysis of image focusing/defocusing along midpoints can provide useful velocity information.

Conclusions

- The analysis of image focusing/defocusing along midpoints can provide useful velocity information.
- Velocity estimates based on the proposes image-focusing semblance functional are:
  1) Unbiased by reflectors curvature,
  2) Consistent with angle (offset) velocity information.

Conclusions

- The analysis of image focusing/defocusing along midpoints can provide useful velocity information.
- Velocity estimates based on the proposes image-focusing semblance functional are:
  1) Unbiased by reflectors curvature,
  2) Consistent with angle (offset) velocity information.
- Image-focusing may provide useful velocity information from zero-offset data, or data with limited angular aperture (e.g. subsalt or deep reflectors).

Acknowledgments

- Elf (now Total) and Henri Calandra for the field data set