Wave-Equation Migration Velocity Analysis

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EAGE 2004 Workshop on Velocity

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Deep-water subsalt imaging

Deep-water subsalt imaging - Velocity problem?

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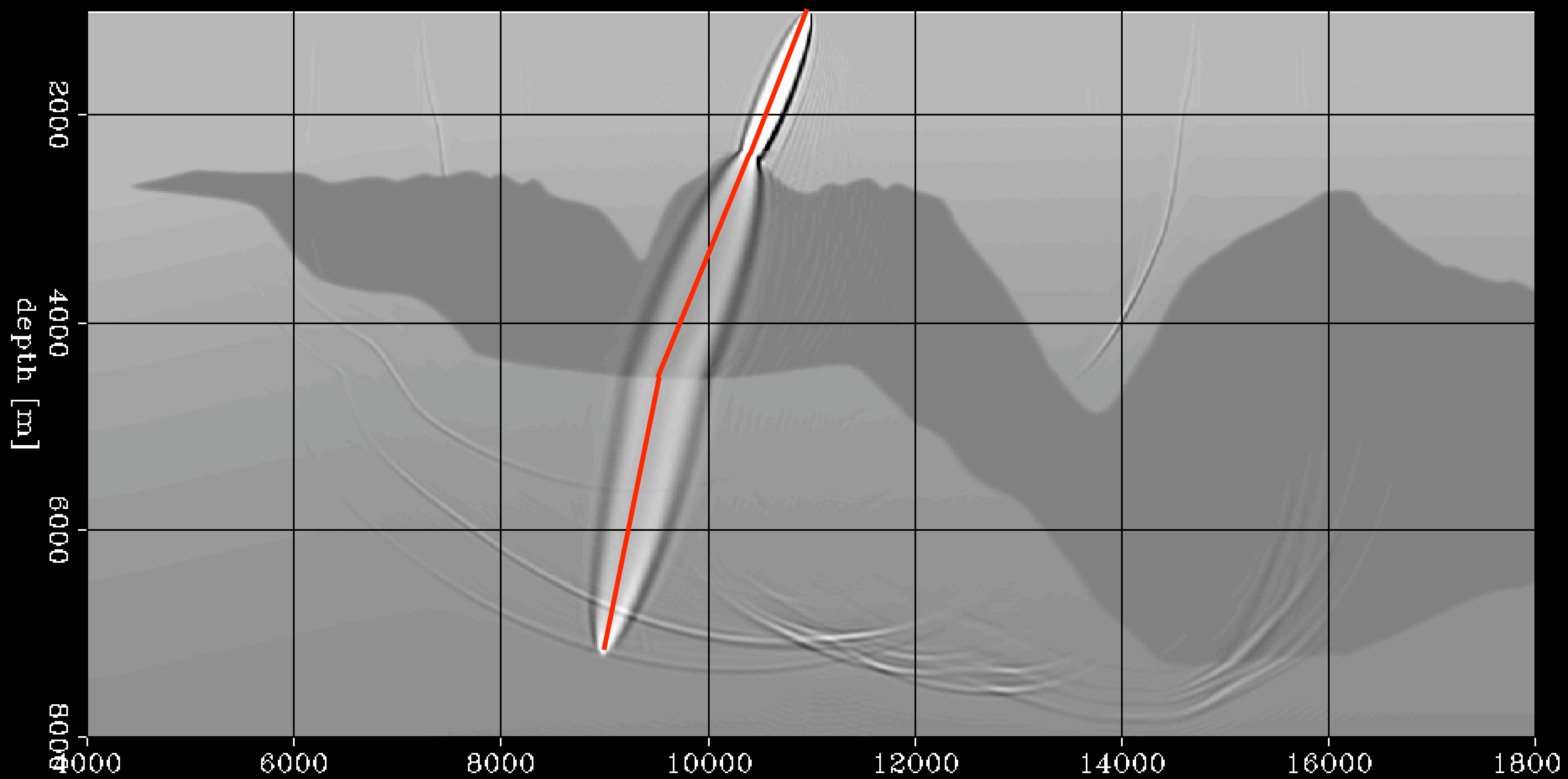
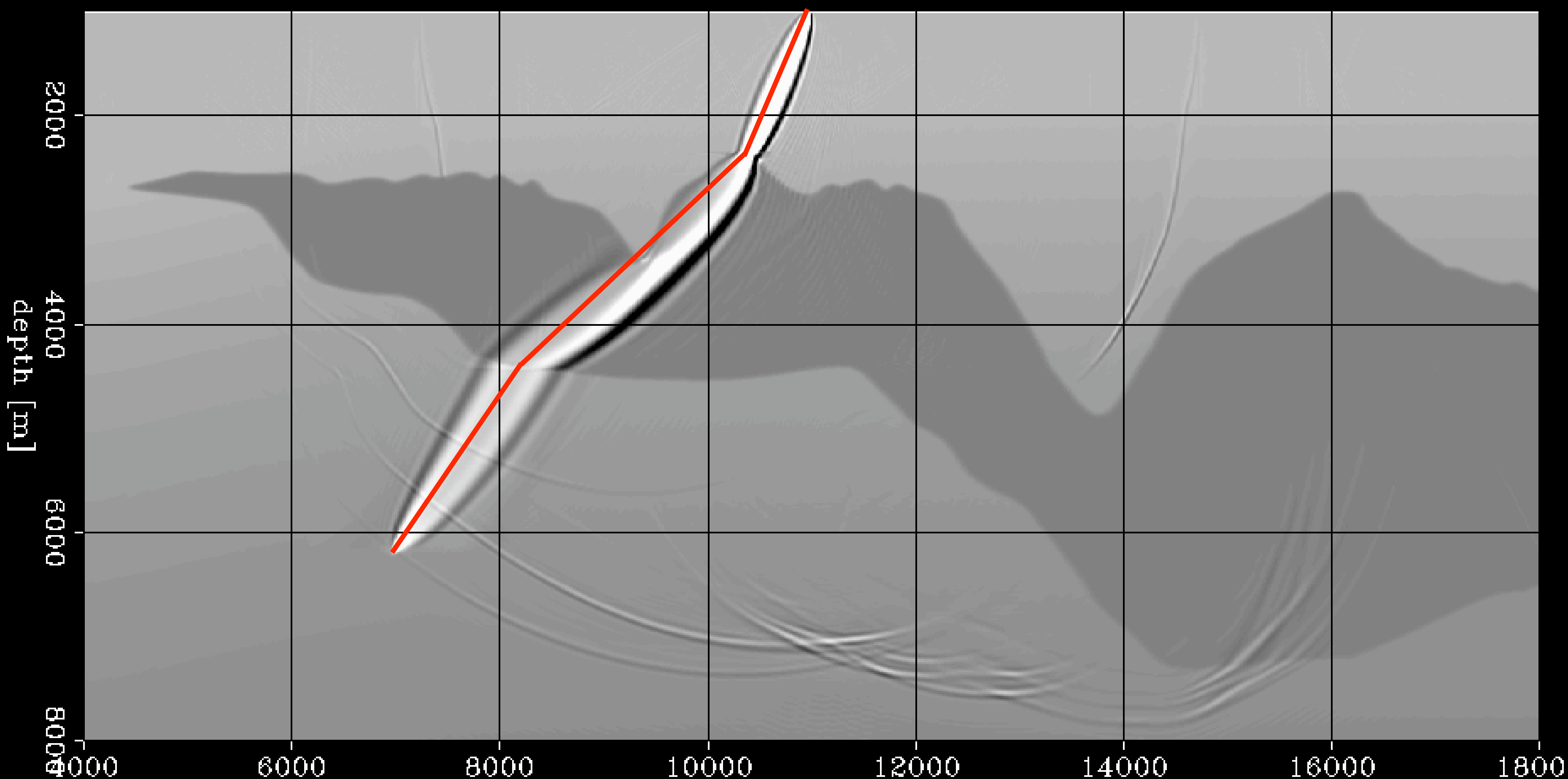
Deep-water subsalt imaging - Illumination?

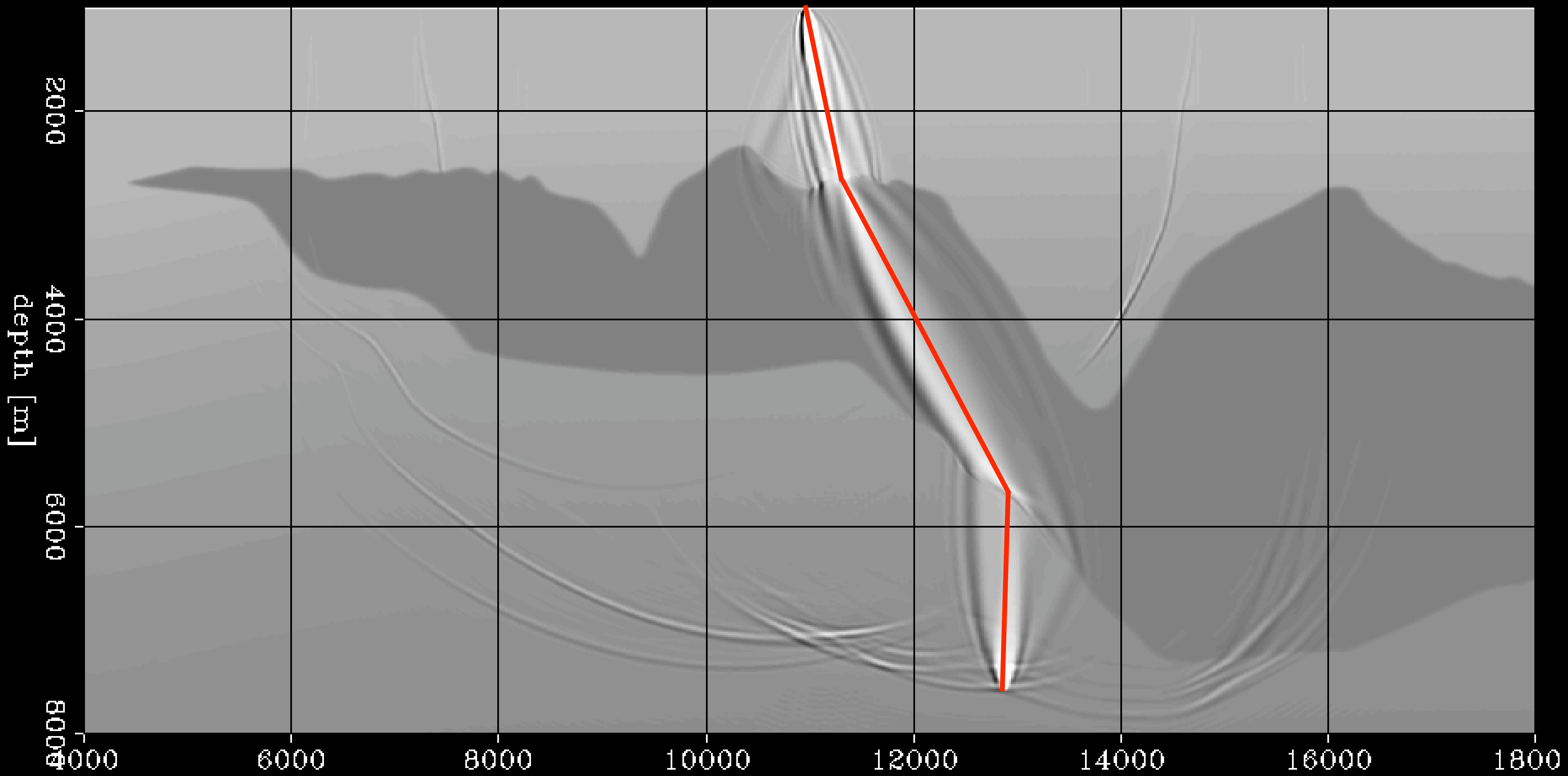
“Simple” wavepath with f=1⇔26 Hz



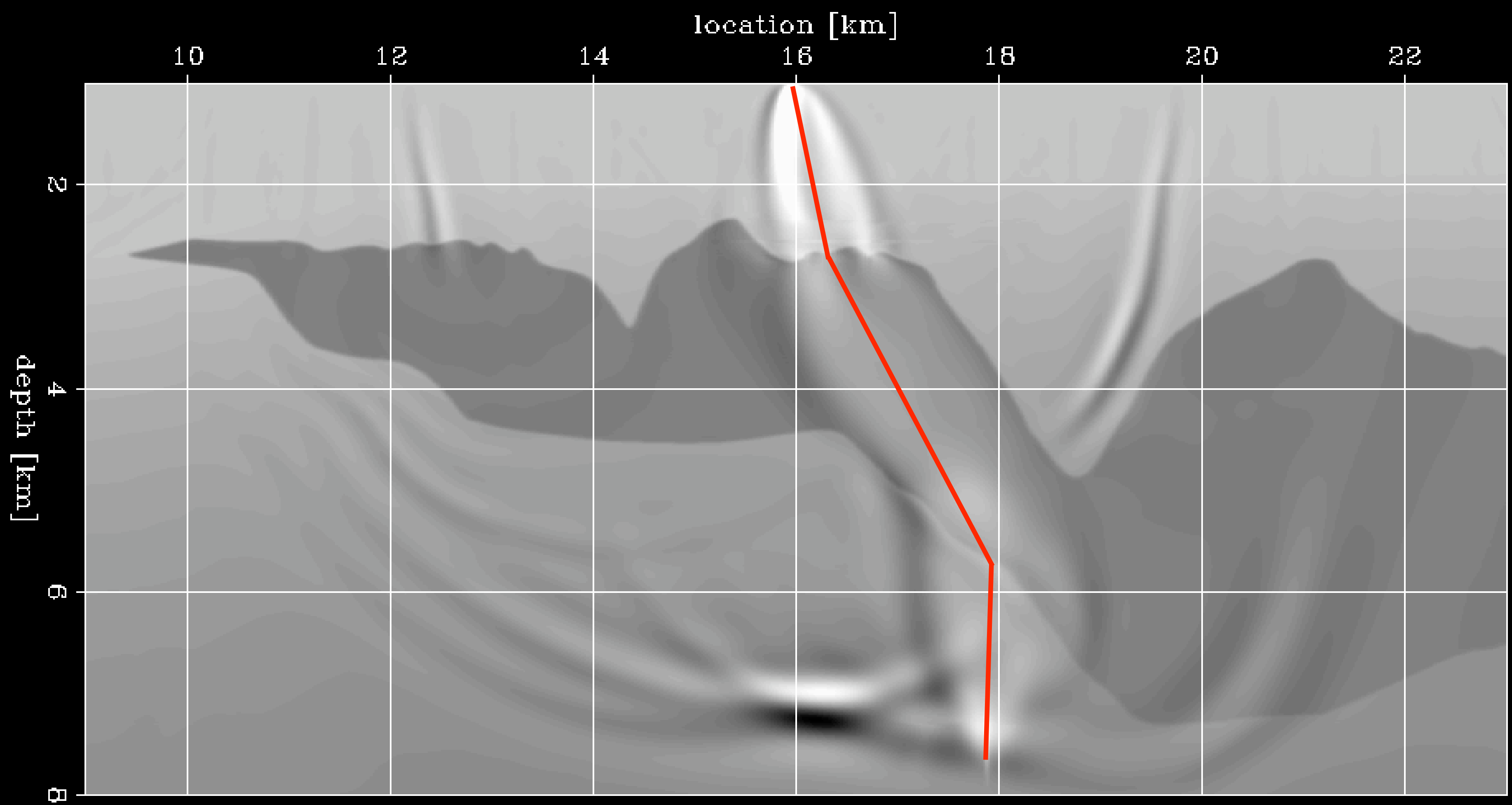
“Complex” wavepath with f=1⇔26 Hz



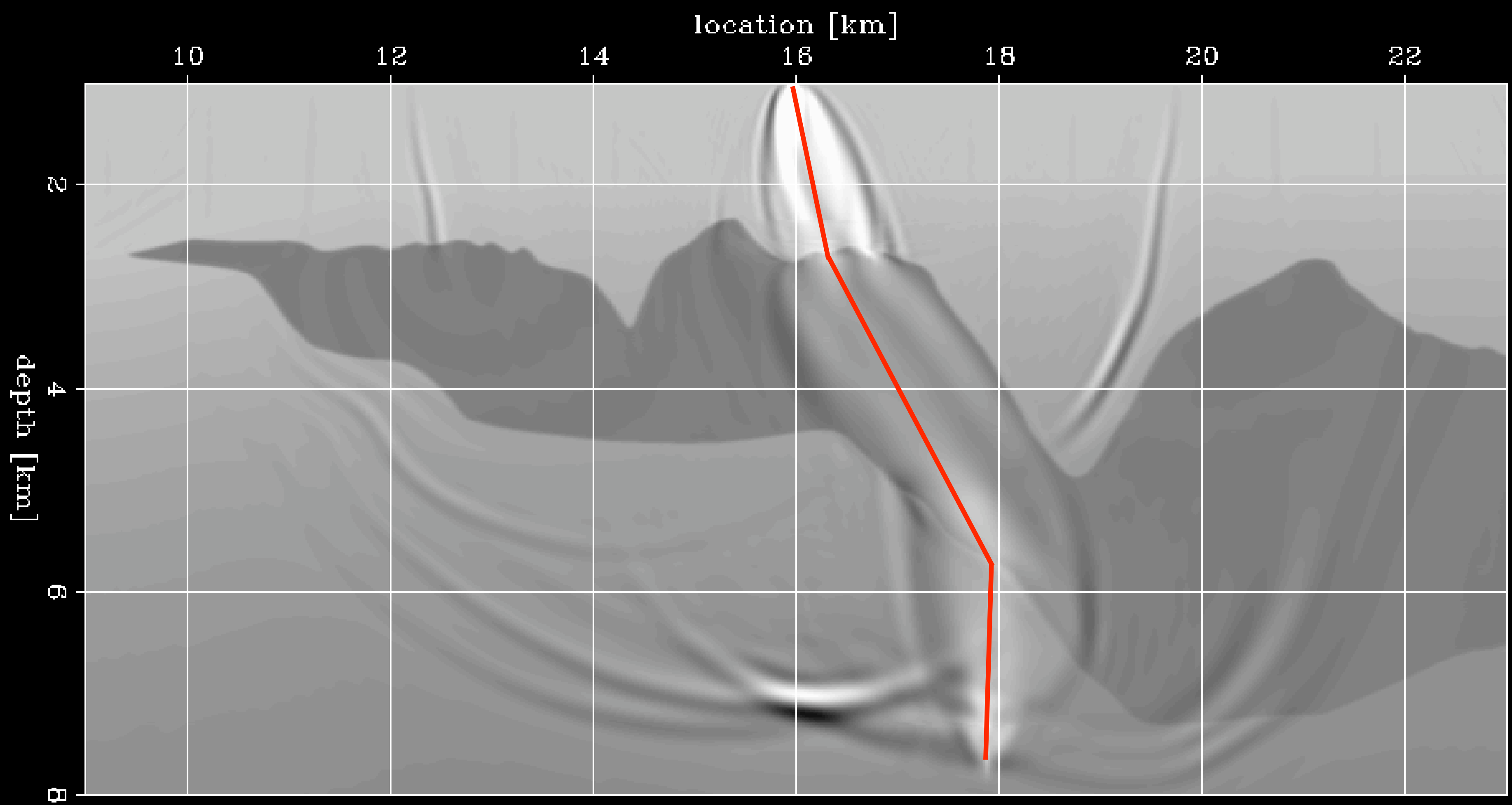
“Messy” wavepath with f=1⇔26 Hz



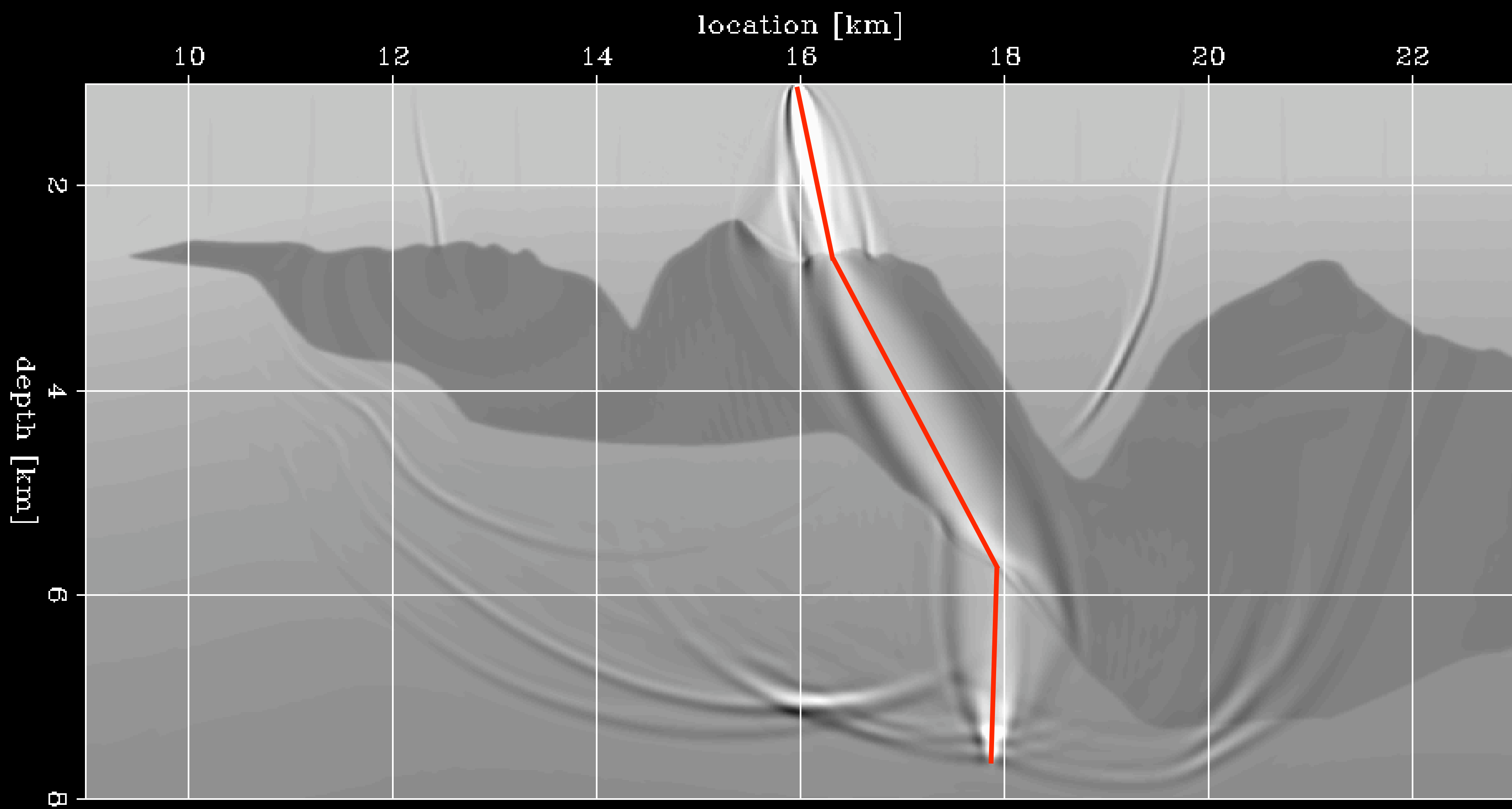
“Messy” wavepath with f=1⇔3 Hz



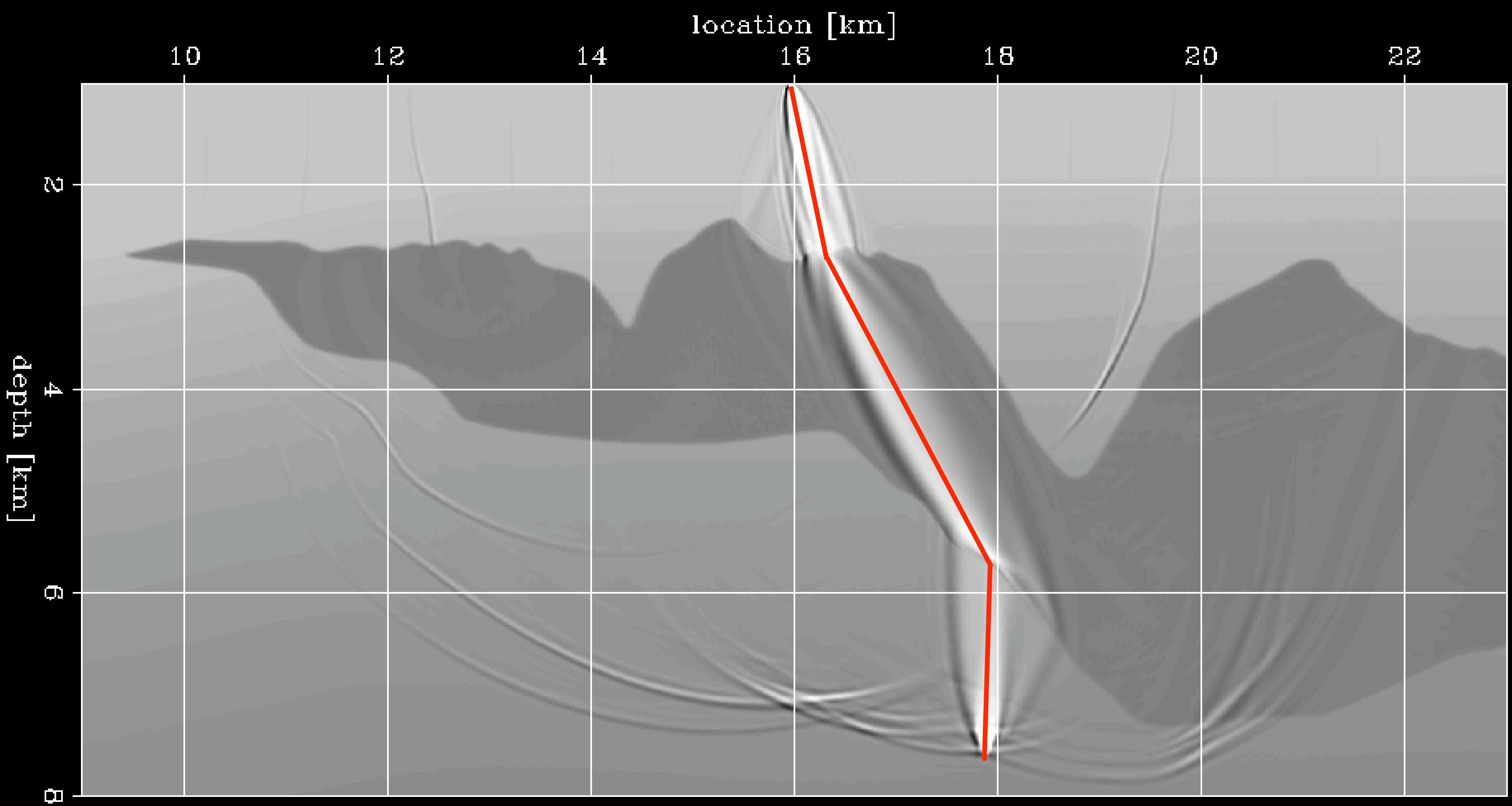
“Messy” wavepath with f=1⇔5 Hz



“Messy” wavepath with f=1⇔12 Hz



"Messy" wavepath with f=1⇔16 Hz



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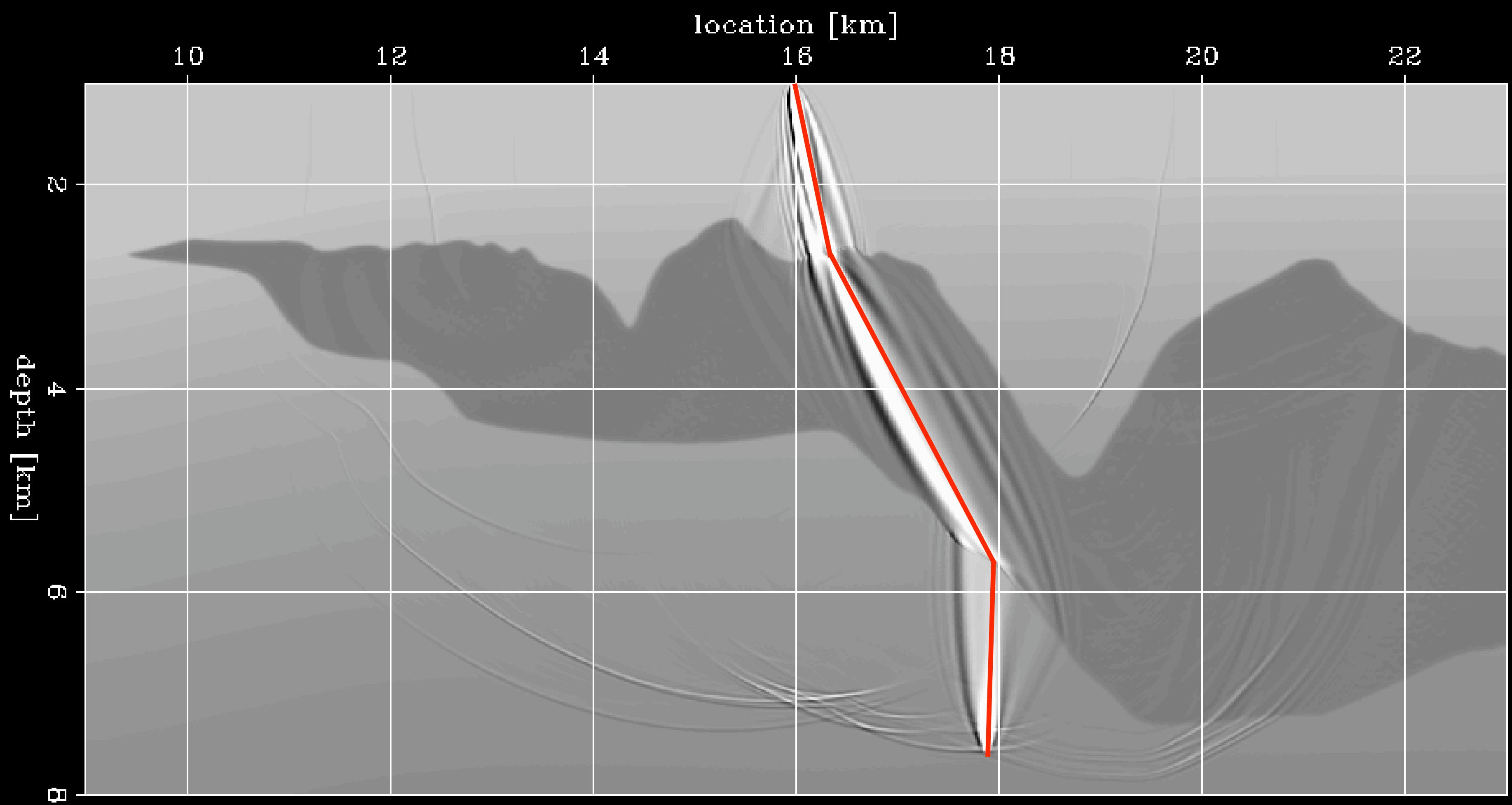
“Messy” wavepath with f=1⇔26 Hz



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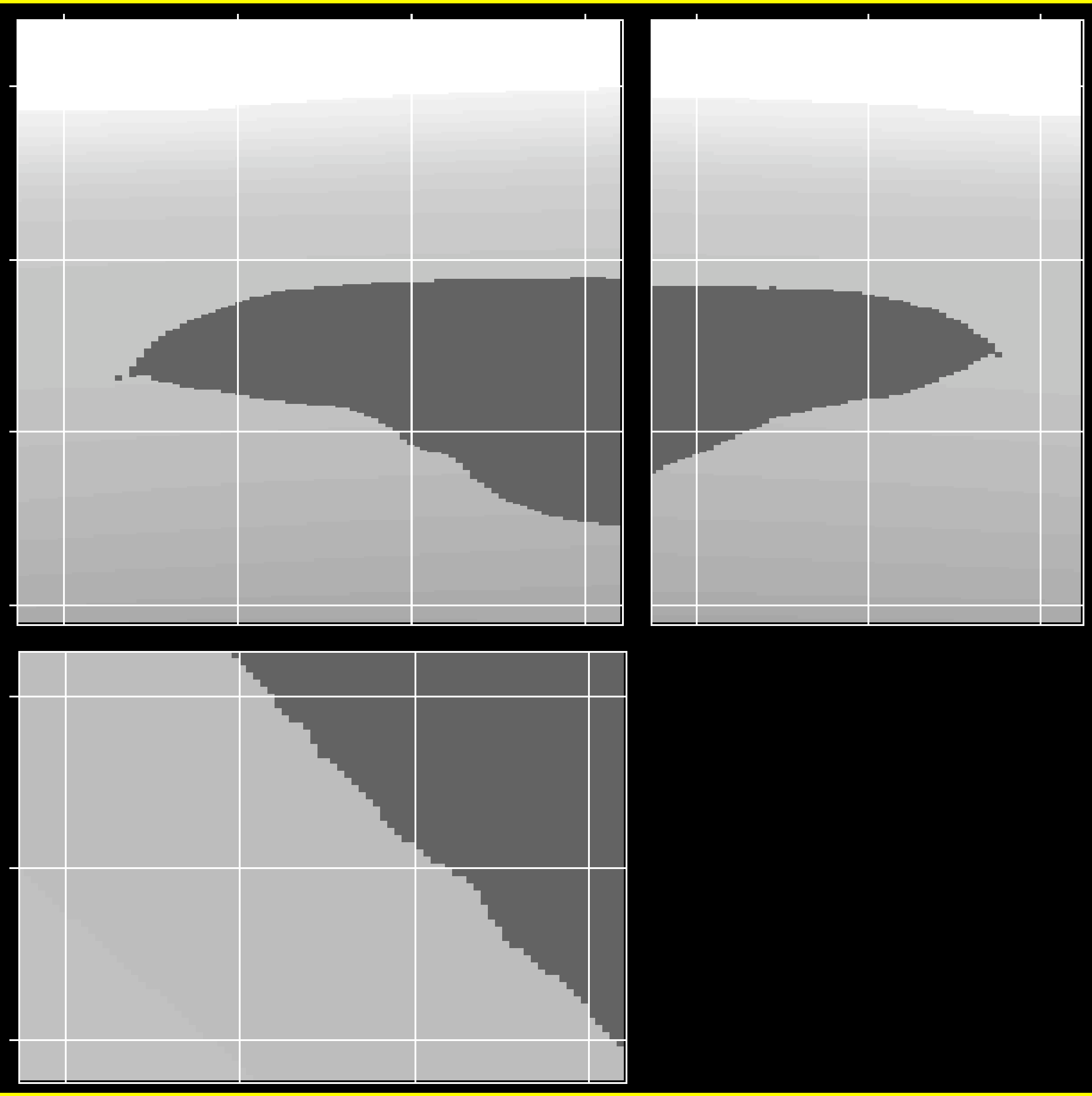
Wavepaths in 3-D



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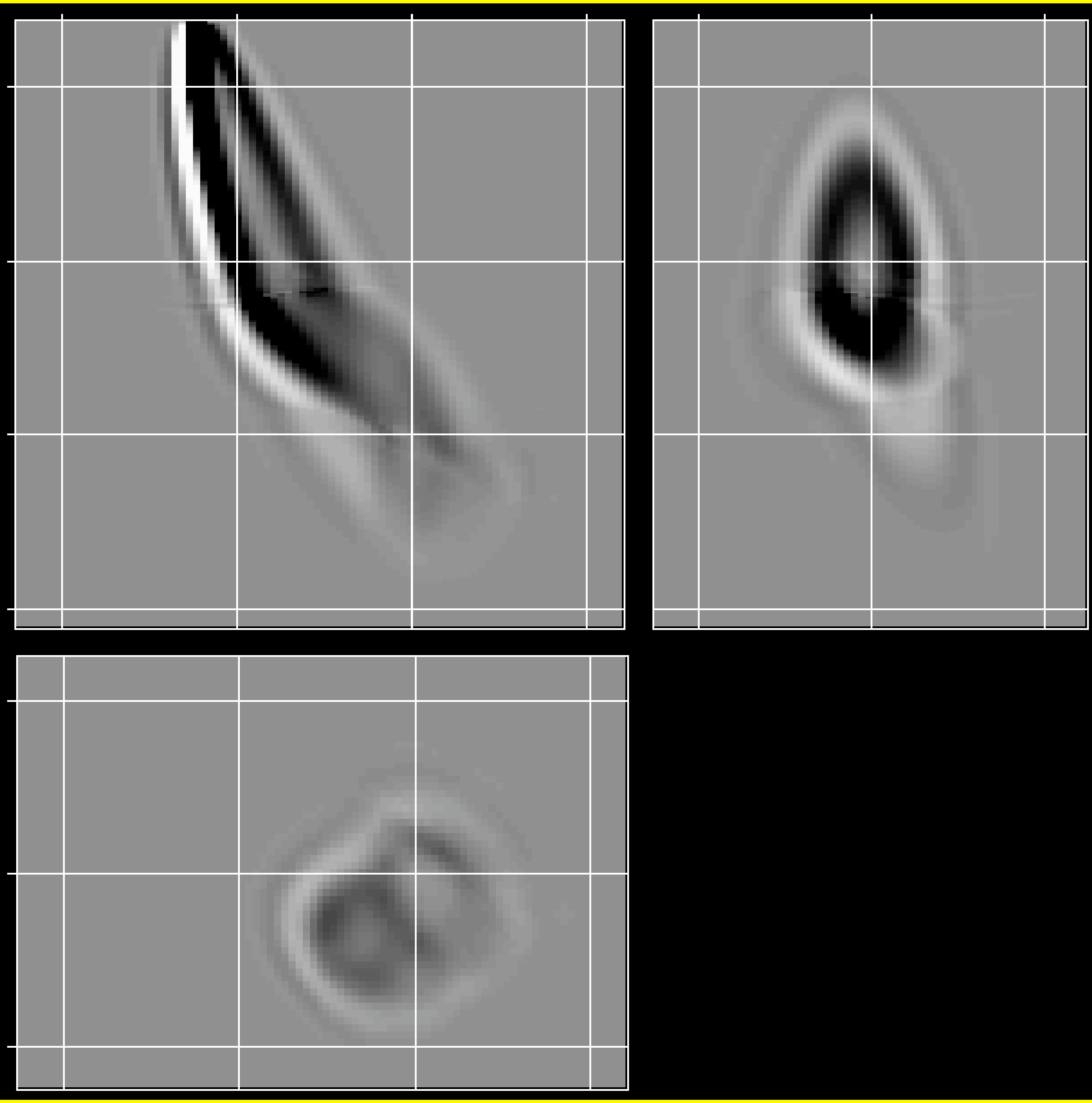
Wavepaths in 3-D – Banana or doughnuts?



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Velocity Analysis and wavefield methods

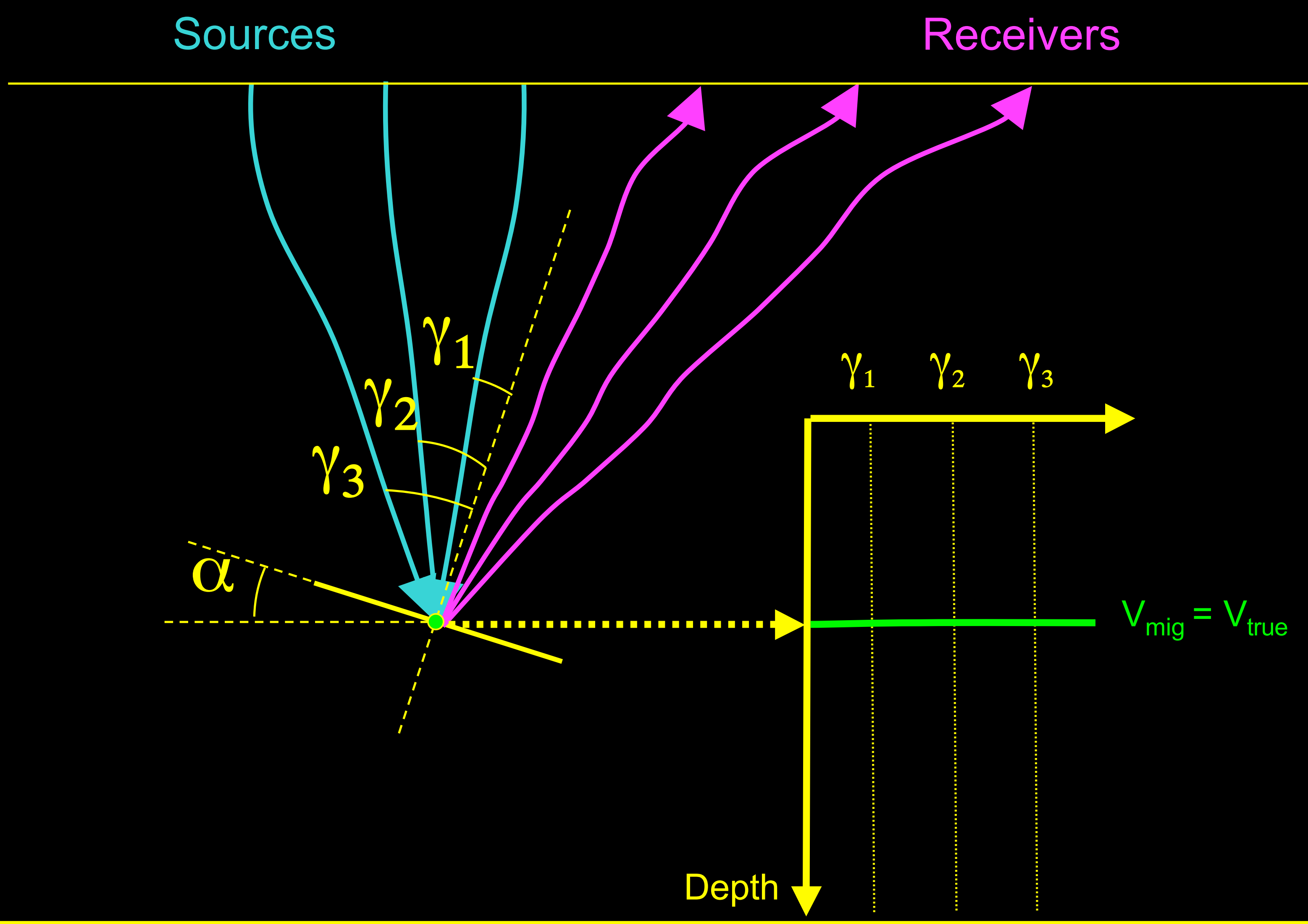
Brief history of velocity estimation with wavefield methods

- Full waveform inversion (Tarantola, 1984, Pratt, today)
- Diffraction tomography (Devaney and Oristaglio, 1984)
- Wave-equation tomography (Woodward, 1990; Luo and Schuster 1991)
- Differential Semblance Optimization (Symes and Carazzone, 1991)

Challenges of velocity estimation with wavefield methods

- Limitations of the first-order Born linearization (“Born limitations”)
  - Problems with large (in extent and value) velocity errors
  - Dependent on accurate amplitudes both in the data and in the modeling
- Computational and storage requirements of explicit use of wavepaths

Velocity information in ADCIGs - Correct velocity



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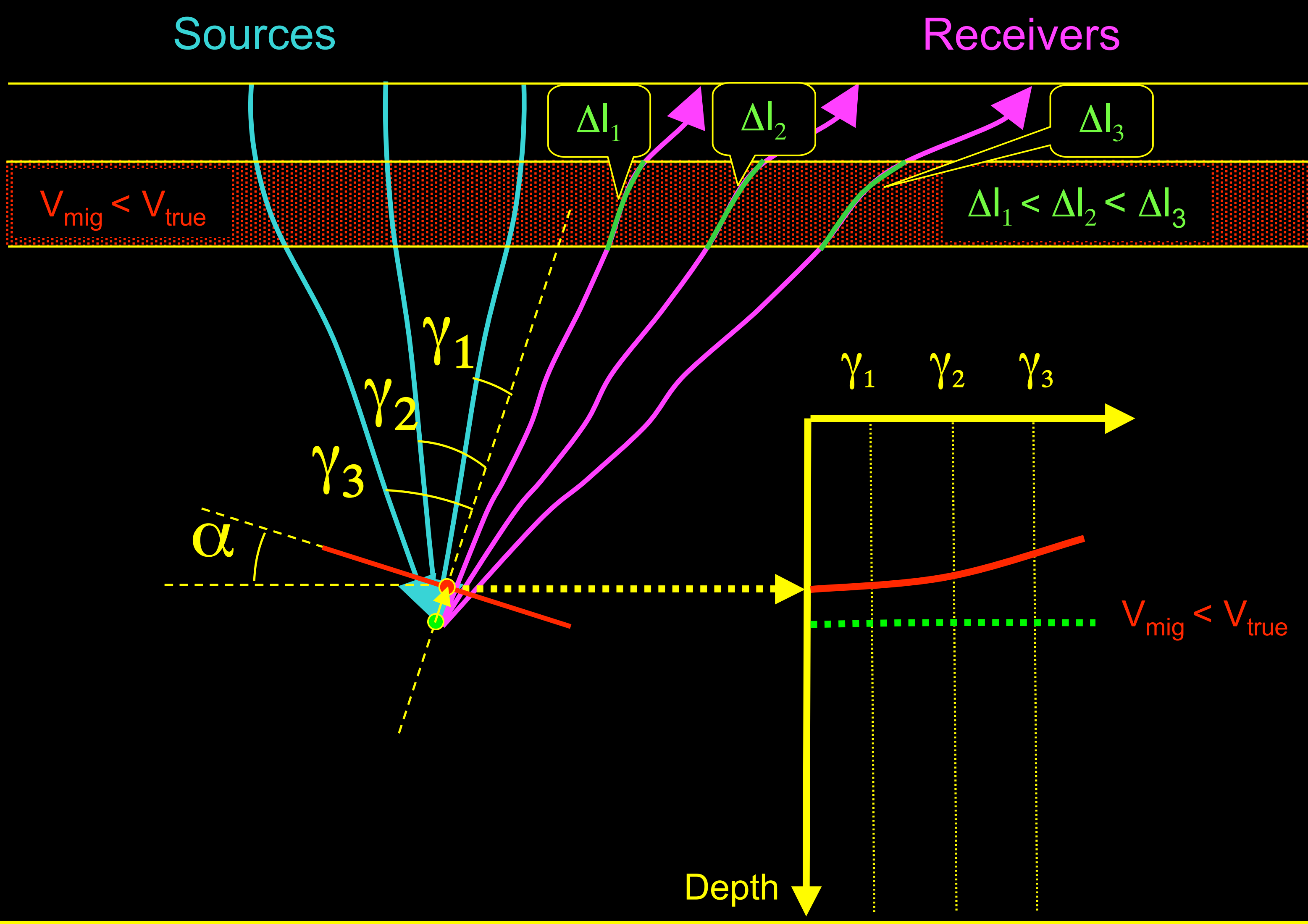
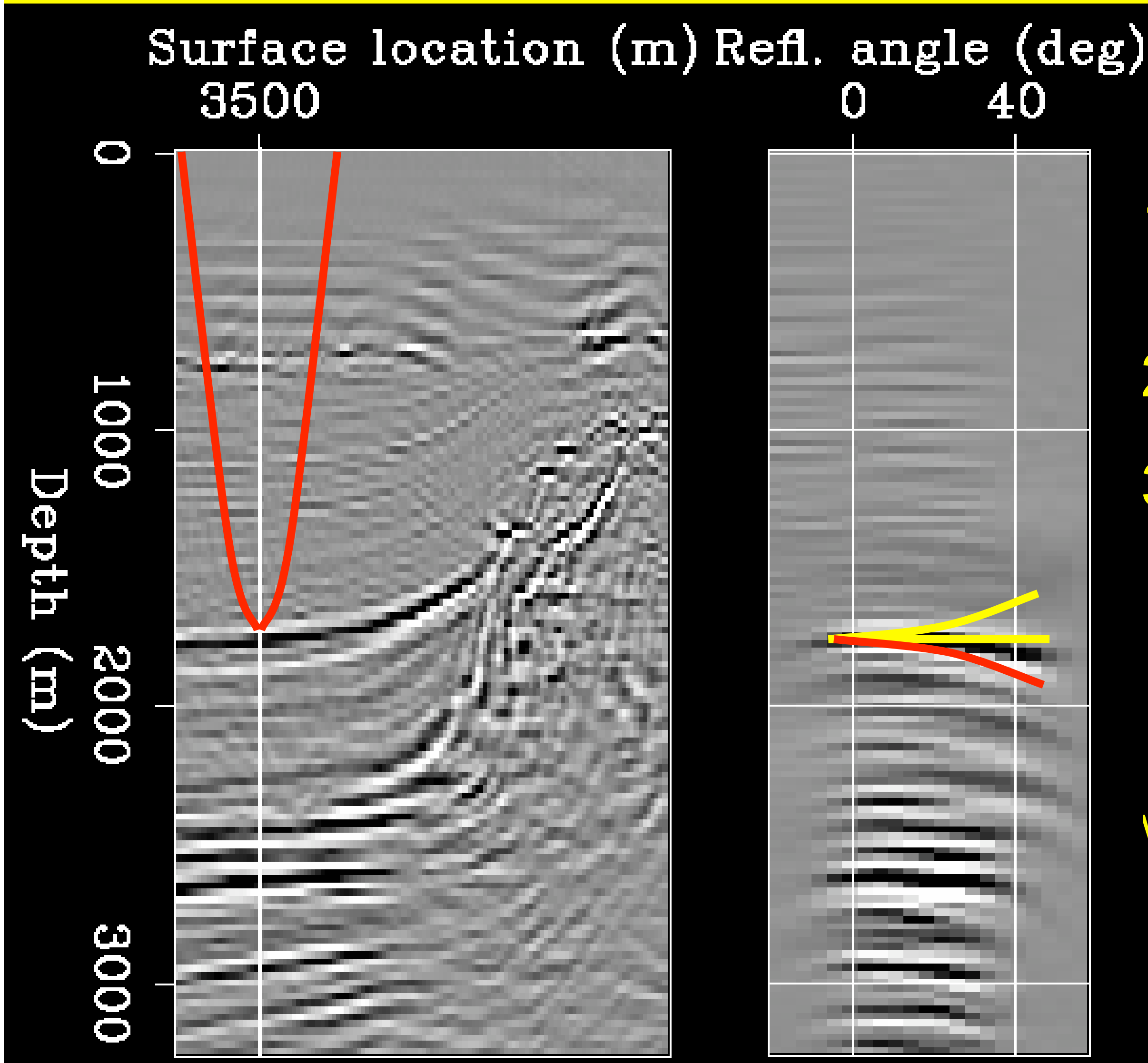
Velocity information in ADCIGs - Low velocity



Ray-tomography Migration Velocity Analysis



1) Measure errors in ADCIGs by measuring curvature (ρ)

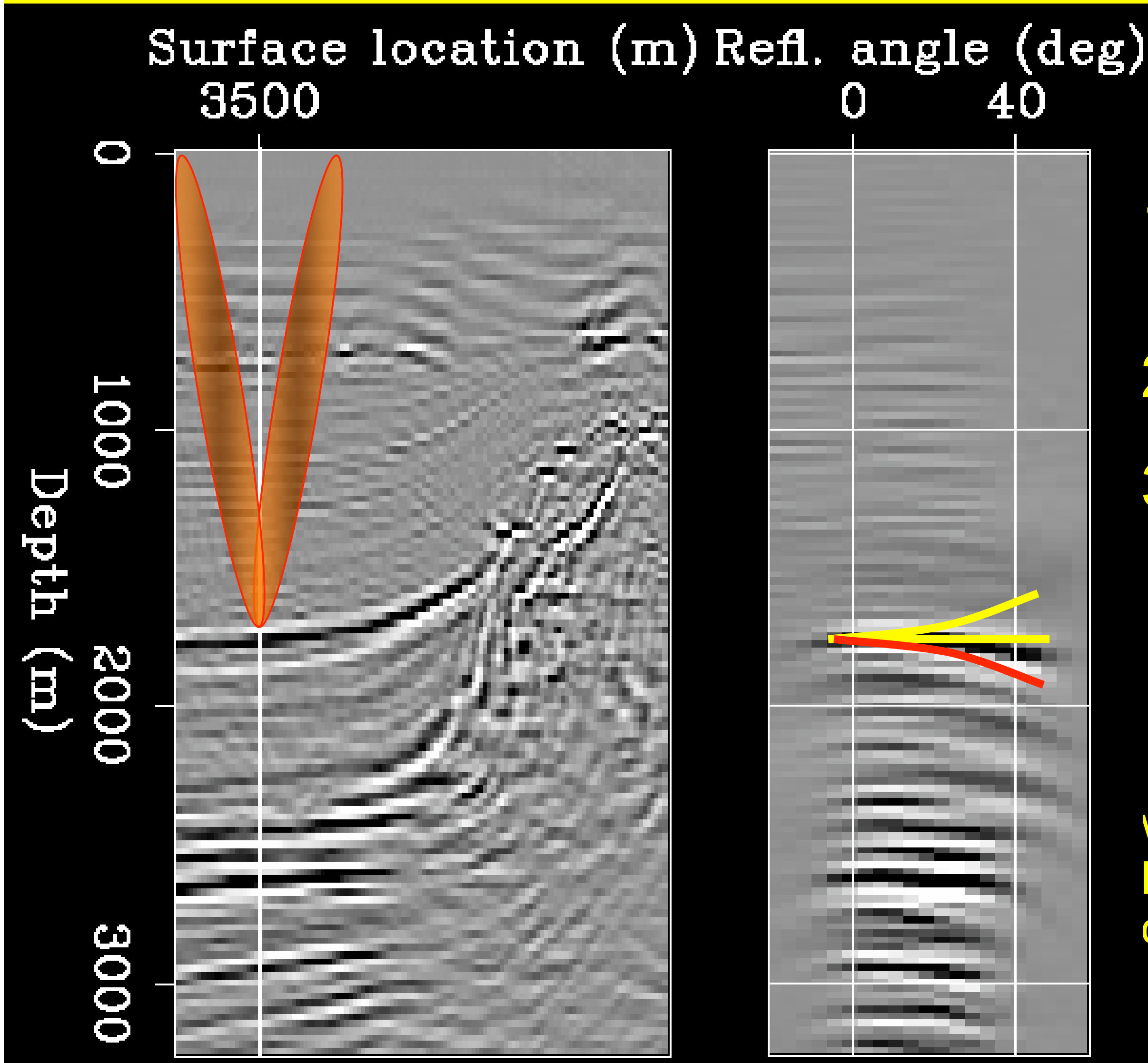
2) Convert measured ρ into Δz

3) Invert Δz into Δs by solving:

$$\min_{\Delta s} \left\| \mathbf{W}\left(\Delta z - \mathbf{L}^{\mathrm{ray}} \Delta s\right) \right\|_2$$

where $\mathbf{L}^{\mathrm{ray}}$ is given by raytracing

Wave-Equation Migration Velocity Analysis



1) Measure errors in ADCIGs by measuring curvature (ρ)

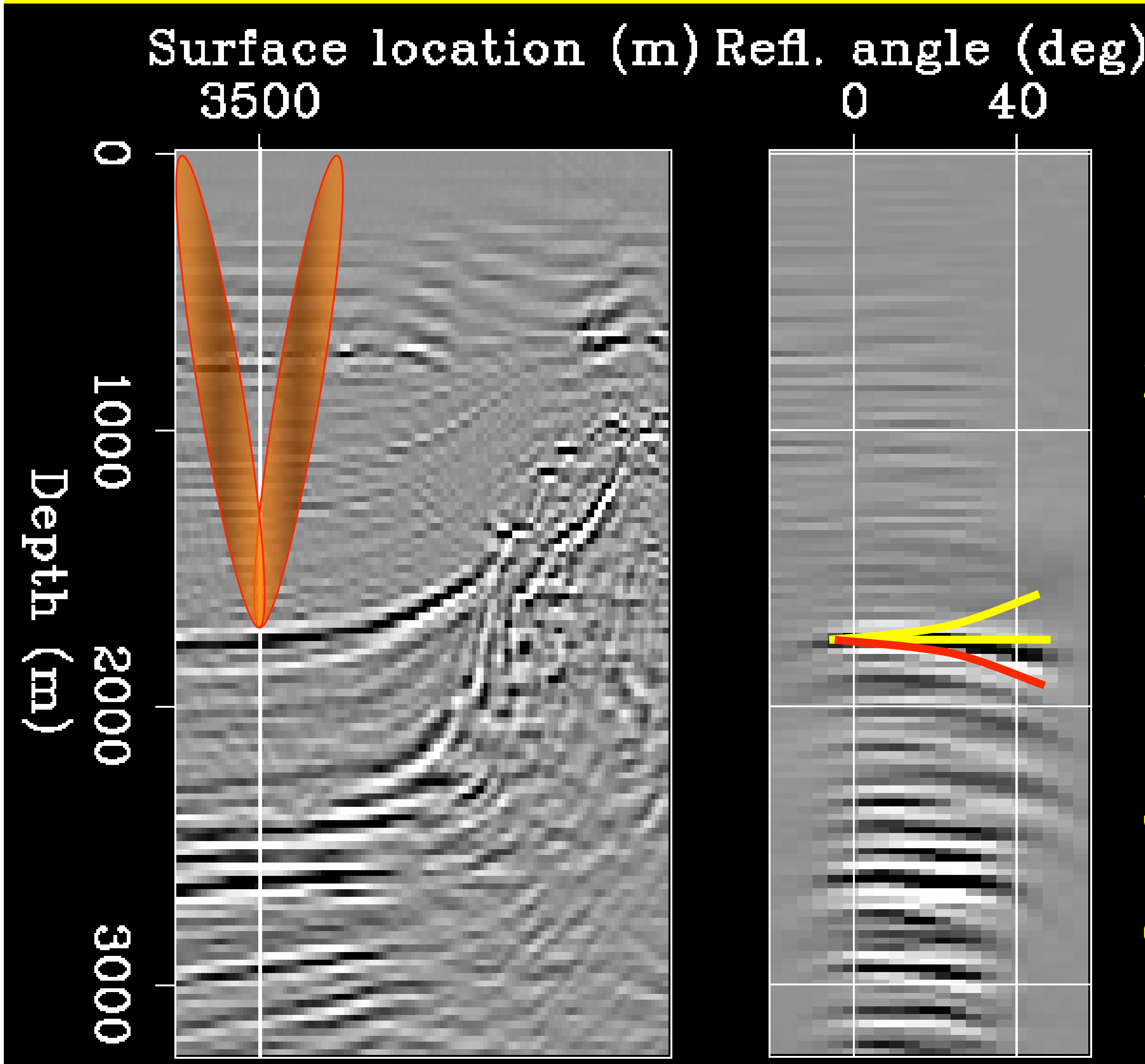
2) Convert measured ρ into ΔI

3) Invert ΔI into Δs by solving:

$$\min_{\Delta s} \left\| \mathbf{W}\left(\Delta I - \mathbf{L}^{\text{wave}} \Delta s\right) \right\|_2$$

where $\mathbf{L}^{\text{wave}}$ is given by first-order Born linearization of wavefield continuation

Wave-Equation Migration Velocity Analysis



Sava and Biondi (2004)
Important!

1) Me… by me… (ρ)

2) Convert measured ρ into ΔI

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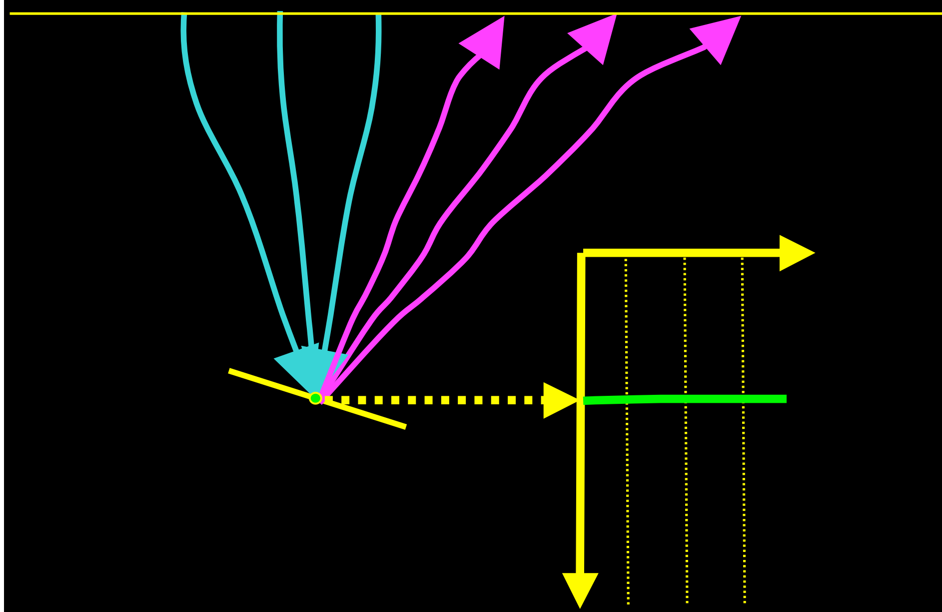
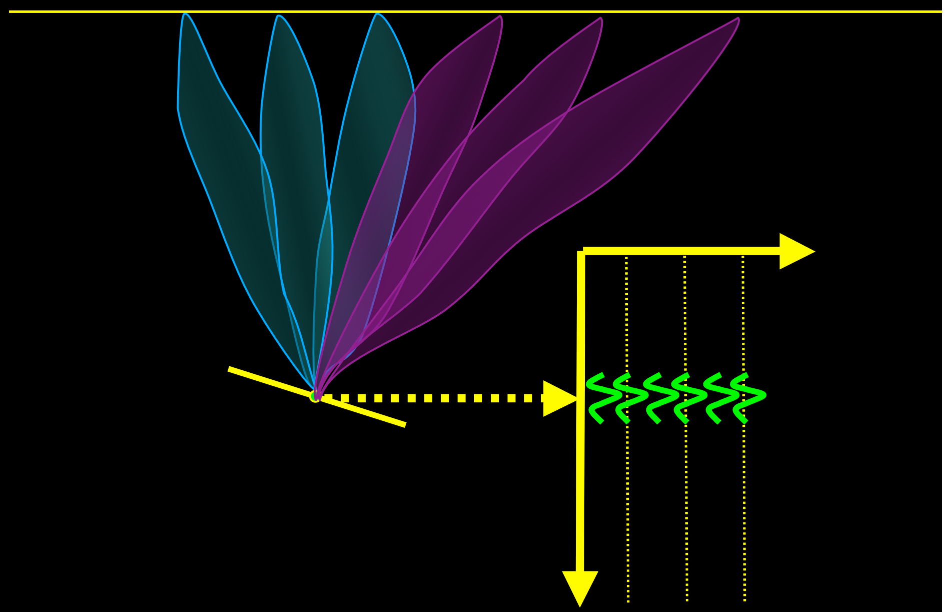
Ray tomography MVA ⇔ Wave-Equation MVA



$\mathbf{L}^{\mathrm{ray}}$



$\mathbf{L}^{\mathrm{wave}}$

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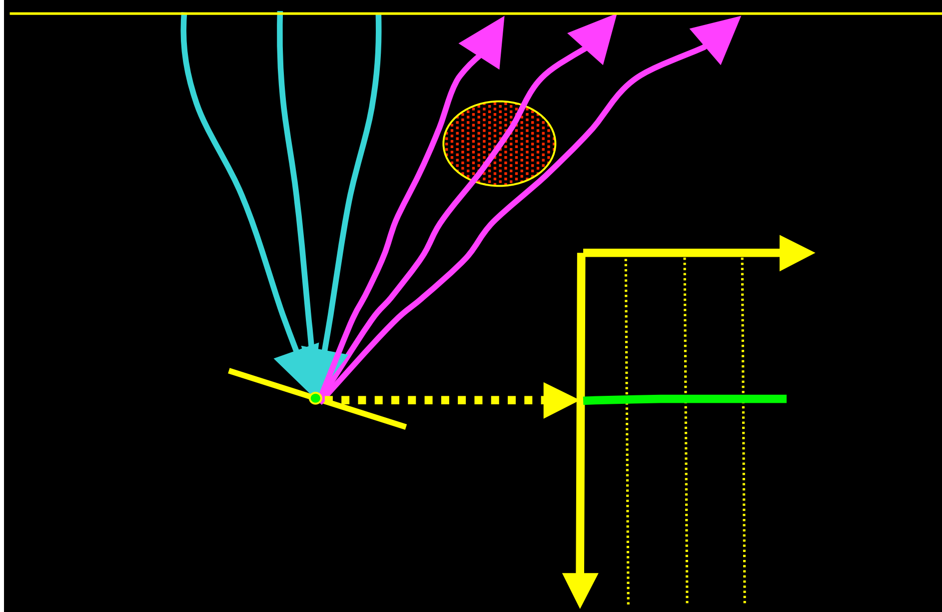
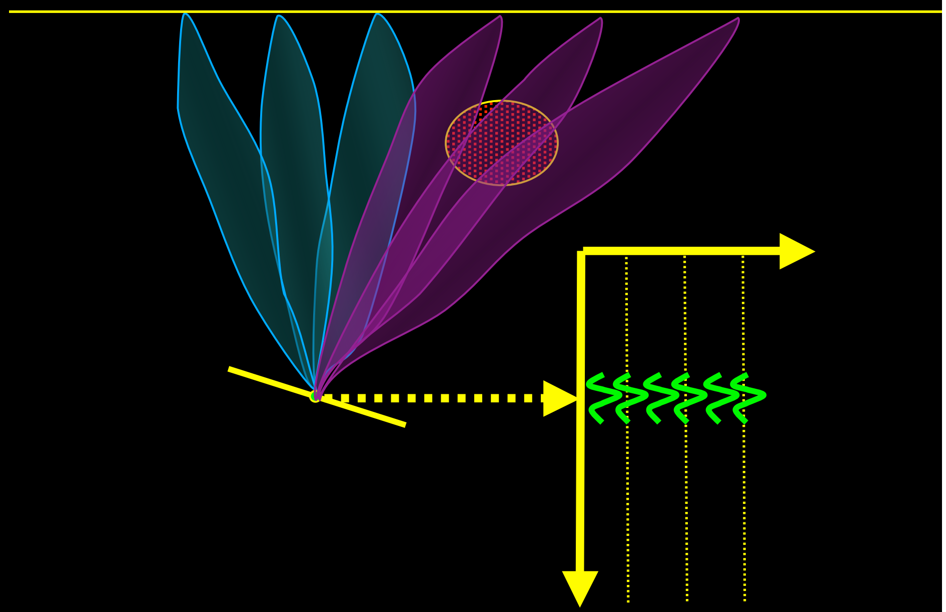


$$\mathbf{L}^{ray}$$



$$\mathbf{L}^{wave}$$

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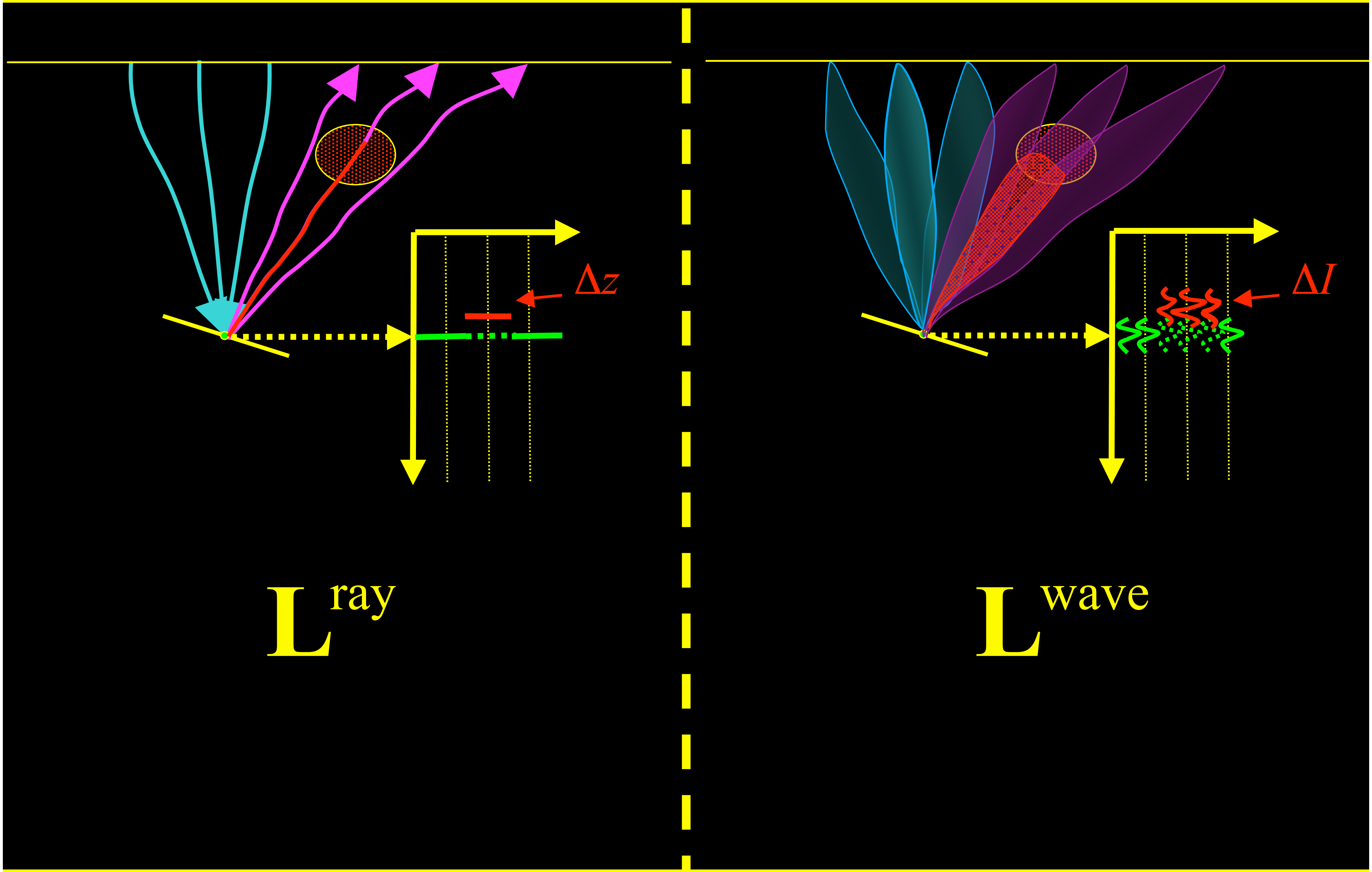

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Deep-water subsalt data

Deep-water subsalt data - Initial velocity

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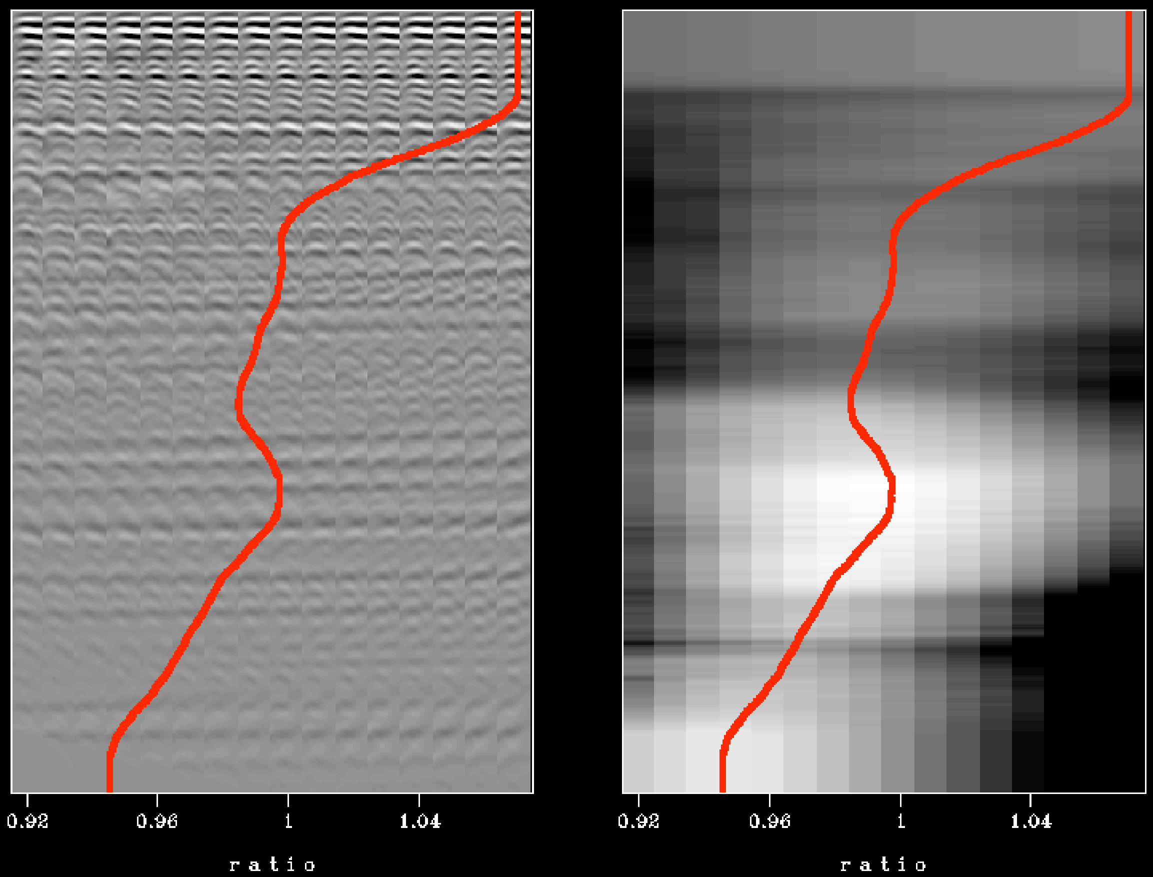
Deep-water subsalt data – WEMVA step 1)



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Deep-water subsalt data – WEMVA step 1)

$$\Delta\rho = \rho - 1$$

1) Measure errors in ADCIGs by measuring curvature (ρ)
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1) Measure errors in ADCIGs by measuring curvature (ρ)

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3) Invert ΔI into Δs by solving:

ΔI

$$\min_{\text{Ä}s} \left\| \mathbf{W}\left(\text{Ä} I - \mathbf{L}^{\text{wave}} \Delta s\right) \right\|_2$$

Deep-water subsalt data – WEMVA step 2)

1) Measure errors in ADCIGs by measuring curvature (ρ)

2) Convert measured ρ into Δ*I*

3) Invert Δ*I* into Δ*s* by solving:

$$\Delta\rho = \rho - 1$$

$$\min_{\ddot{A}s} \left\| \mathbf{W}\left(\ddot{A}\,I - \mathbf{L}^{\text{wave}} \Delta s \right) \right\|_2$$

Deep-water subsalt data – WEMVA step 3)

1) Measure errors in ADCIGs by measuring curvature (ρ)

2) Convert measured ρ into ΔI

3) Invert ΔI into Δs by solving:

ΔI

$$\min_{\Delta s} \left\| \mathbf{W} \left(\Delta I - \mathbf{L}^{\text{wave}} \Delta s \right) \right\|_2$$

$\mathbf{W}$

Deep-water subsalt data – WEMVA step 3)

1) Measure errors in ADCIGs by measuring curvature (ρ)

2) Convert measured ρ into Δ*I*

3) Invert Δ*I* into Δ*s* by solving:

$$\min_{\Delta s} \left\| \mathbf{W}\left(\Delta I - \mathbf{L}^{\text{wave}} \Delta s\right) \right\|_2$$

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Deep-water subsalt data – Initial velocity

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Deep-water subsalt data – Velocity after 2 iterat.

Deep-water subsalt data – Initial image

Image

Deep-water subsalt data – Image after 2 iterat.

Image

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Deep-water subsalt data – Initial ADCIGs

ADCIGs

Deep-water subsalt data – ADCIGs after 2 iterat.

ADCIGs

biondo@stanford.edu

Deep-water subsalt data – Initial ADCIGs

ADCIGs

biondo@stanford.edu

Deep-water subsalt data – ADCIGs after 2 iterat.

ADCIGs

Deep-water subsalt data – Initial $\Delta\rho = \rho - 1$

$\Delta\rho = \rho - 1$

White ⇔ flat ADCIGs

Deep-water subsalt data – Δρ after 2 iterations

$\Delta\rho = \rho - 1$

White ⇔ flat ADCIGs

Deep-water subsalt data – W after 2 iterations

Weights

White ⇔ reliable ρ picks

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Conclusions

- **Ray-based Migration Velocity Analysis (MVA) methods have been successful in complex structure, but they are challenged by subsalt velocity estimation.**

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Conclusions

- Ray-based Migration Velocity Analysis (MVA) methods have been successful in complex structure, but they are challenged by subsalt velocity estimation.
- Wave-equation MVA (WEMVA) can be accomplished while preserving the work-flow of conventional ray-based MVA methods.
- The velocity function estimated by the use of our WEMVA method results in flatter ADCIGS and more coherent reflectors, even if we started from a high-quality velocity function that was estimated with ray-based MVA.

Conclusions

- Ray-based Migration Velocity Analysis (MVA) methods have been successful in complex structure, but they are challenged by subsalt velocity estimation.
- Wave-equation MVA (WEMVA) can be accomplished while preserving the work-flow of conventional ray-based MVA methods.
- The velocity function estimated by the use of our WEMVA method results in flatter ADCIGS and more coherent reflectors, even if we started from a high-quality velocity function that was estimated with ray-based MVA.
- Poor illumination prevents the extraction of reliable velocity information from ADCIGs at every location, and thus presents a challenge also for WEMVA.

Acknowledgments

- ❖ BP and ExxonMobil, and Frederic Billette at BP, for Deep Water GOM data.
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