Common-Reflection-Surface stack for OBS and VSP geometries and multi-component seismic reflection data

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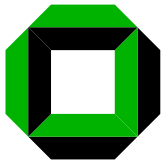


September 14, 2005

Overview

Introduction

Traveltime formulas

- General case: arbitrary acquisition geometry
- OBS and VSP geometries

Multi-component data

- General idea
- Paraxial rays

Implementation

Synthetic data examples

- Complex OBS data, single-component
- Simple land data, multi-component

Conclusion & Outlook

Acknowledgments

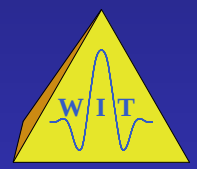
Introduction

“Conventional” CRS stack:

- zero-offset simulation
- normal central rays
  - coinciding up- and downgoing ray branches
  - no converted waves
- description in terms of normal and NIP waves

Finite-offset CRS stack:

- arbitrary source/receiver offsets
- arbitrary central rays
- description in terms of two-way experiments



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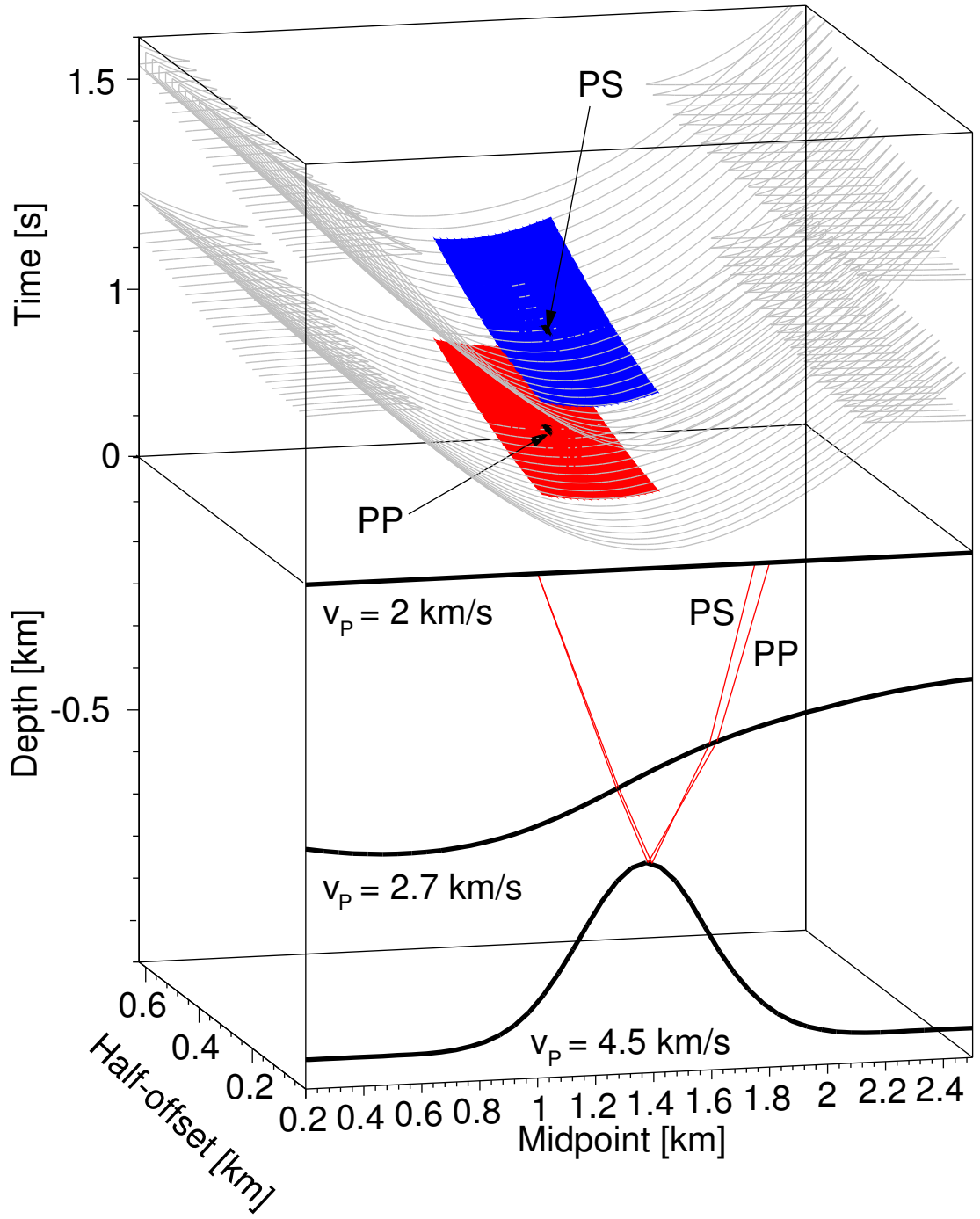

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  - distinction between wave types after CRS stack
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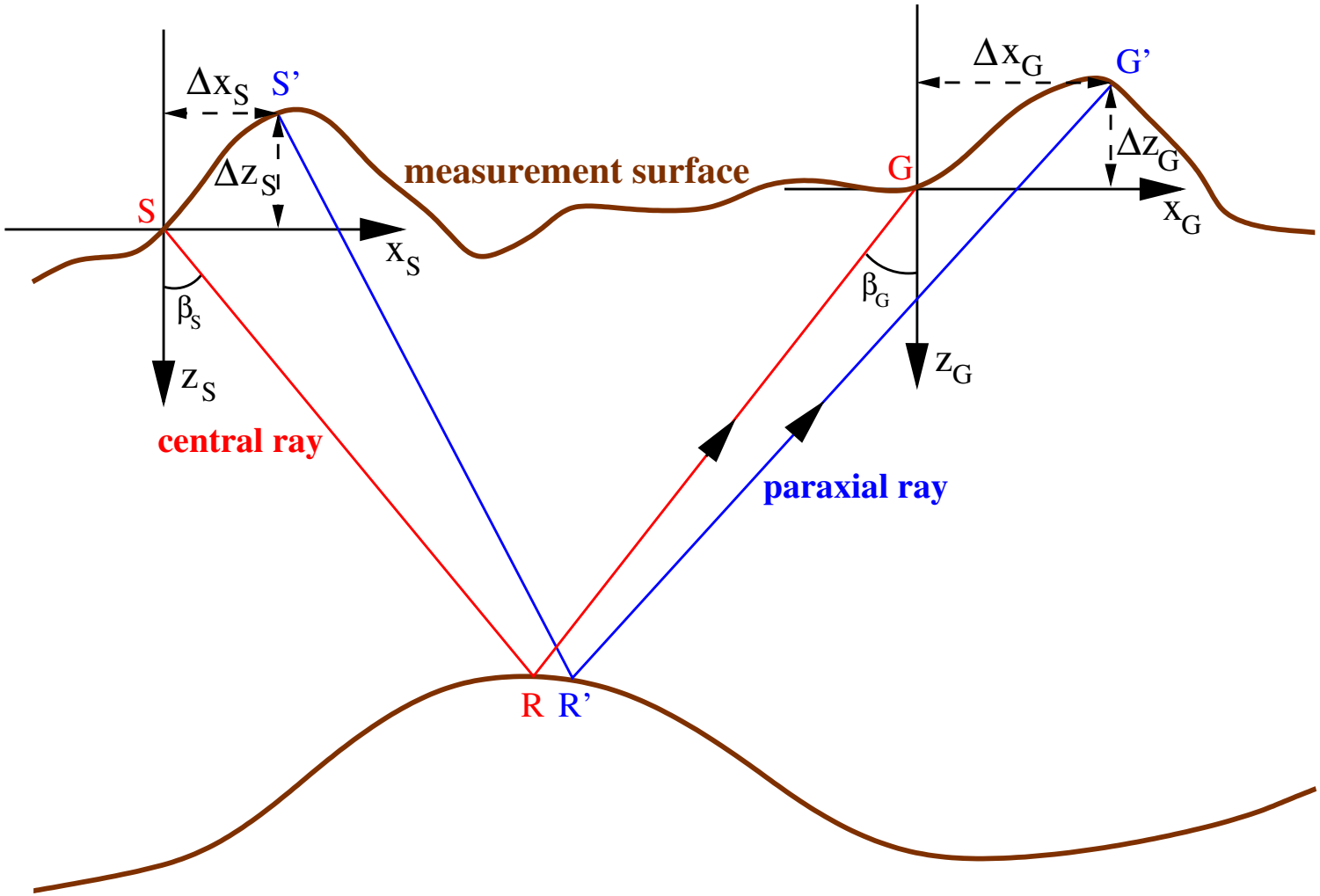
General traveltime formula

Arbitrary acquisition geometry



General traveltime formula

$$
\begin{aligned}
T^2(\Delta x_S, \Delta x_G, \Delta z_S, \Delta z_G) = \\
&\left(t_0 + \frac{\sin\beta_G}{v_G}\Delta x_G - \frac{\sin\beta_S}{v_S}\Delta x_S + \frac{\cos\beta_G}{v_G}\Delta z_G - \frac{\cos\beta_S}{v_S}\Delta z_S\right)^2 \\
&+ t_0 DB^{-1}(\Delta x_G - \Delta z_G \tan\beta_G)^2 \\
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&- 2t_0 B^{-1}(\Delta x_G - \Delta z_G \tan\beta_G)(\Delta x_S - \Delta z_S \tan\beta_S)
\end{aligned}
$$

t_0 : Traveltime along central ray

β_S, β_G : Incidence and emergence angle of central ray

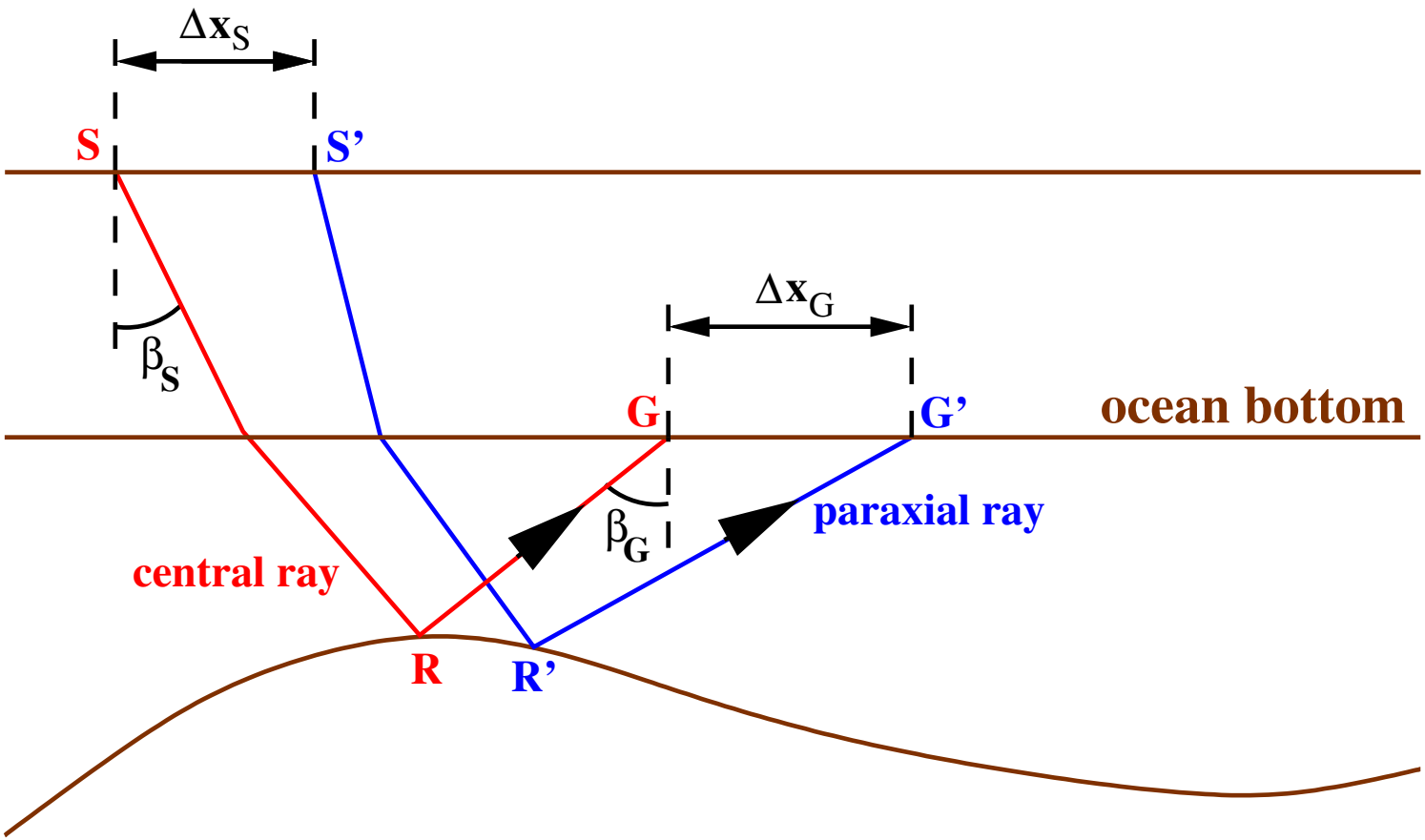
A, B, D : Elements of the propagator matrix

$\Delta x_S, \Delta x_G, \Delta z_S, \Delta z_G$: Source and receiver dislocations

v_S, v_G : Near-surface velocity at source or receiver

OBS acquisition geometry

- $\Delta z_S = \Delta z_G \equiv 0$ (horizontal seafloor)



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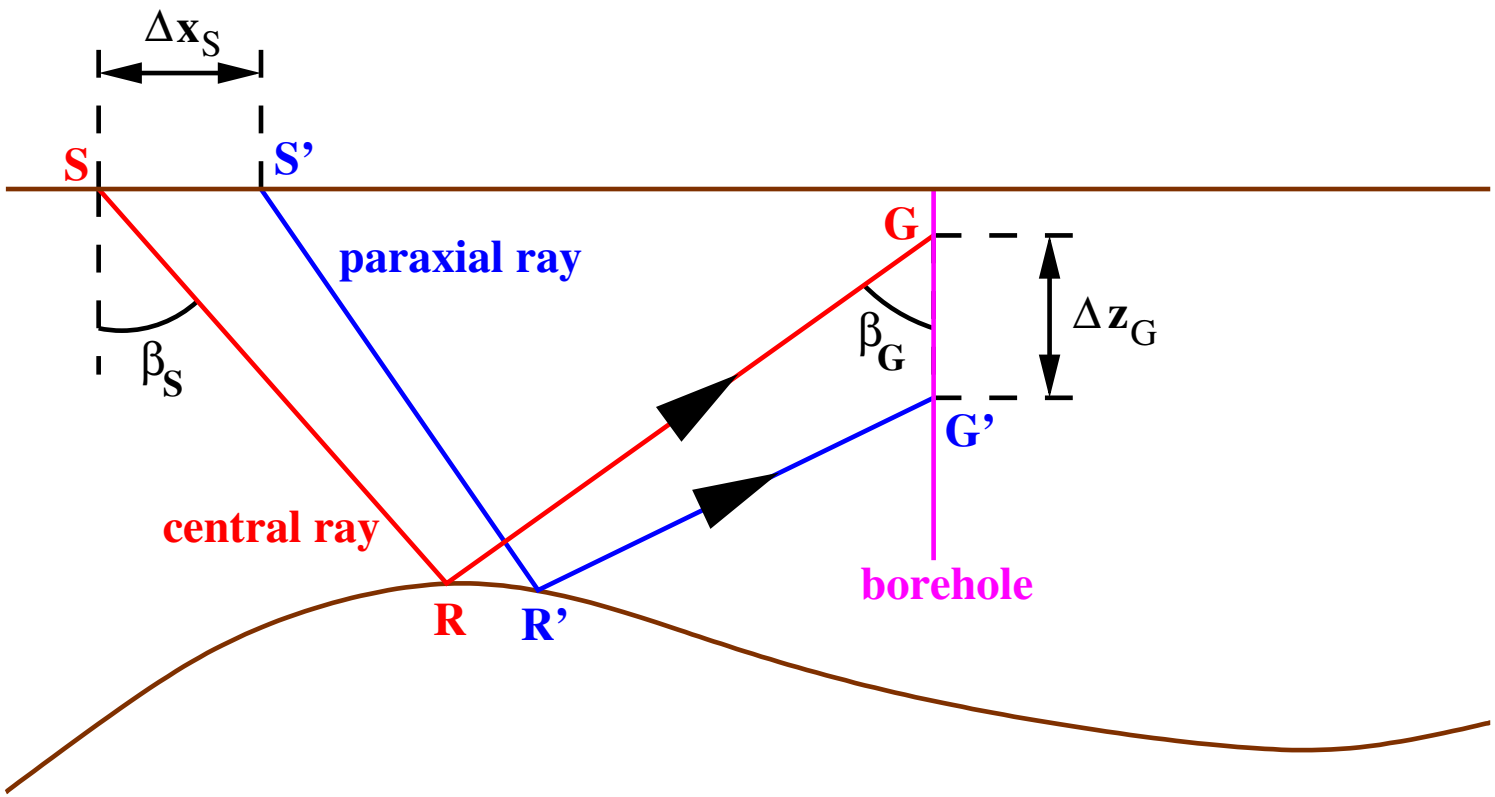
VSP acquisition geometry

- $\Delta z_S = \Delta x_G \equiv 0$ (vertical borehole, no topography)



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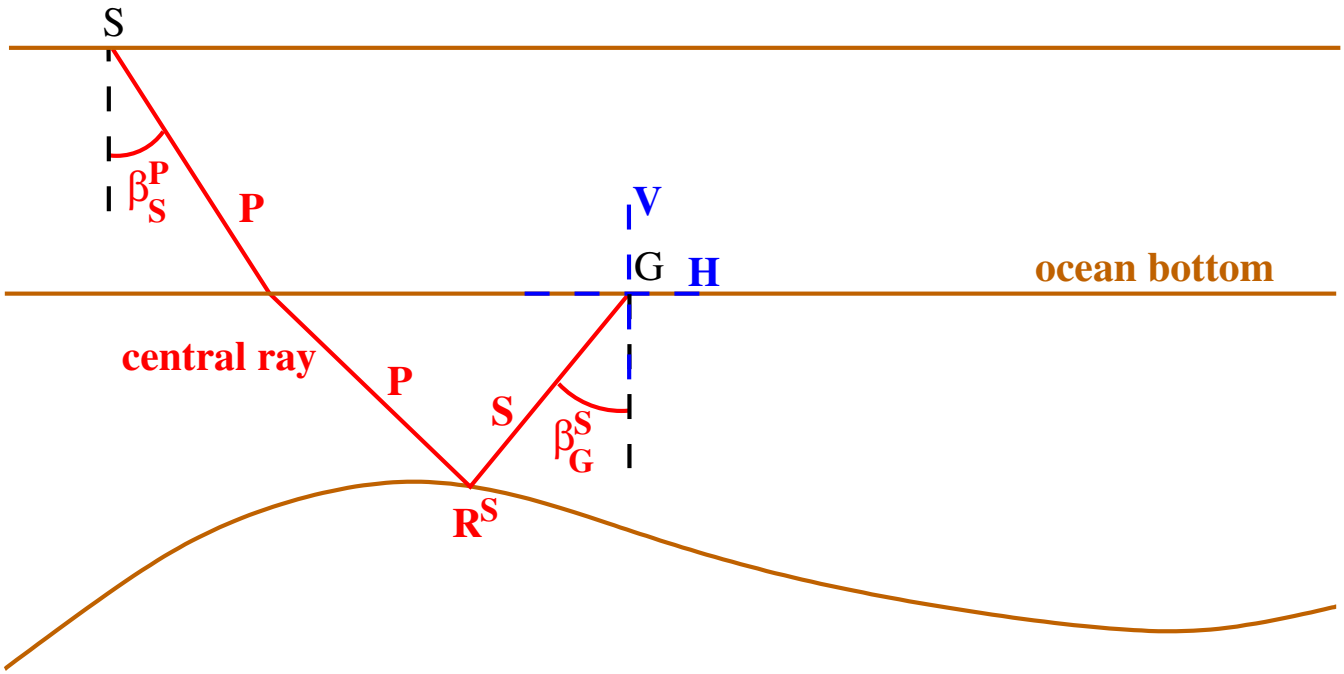
Multi-component data



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- Consideration of upgoing P- and S-waves
- Both wave types are present on both components

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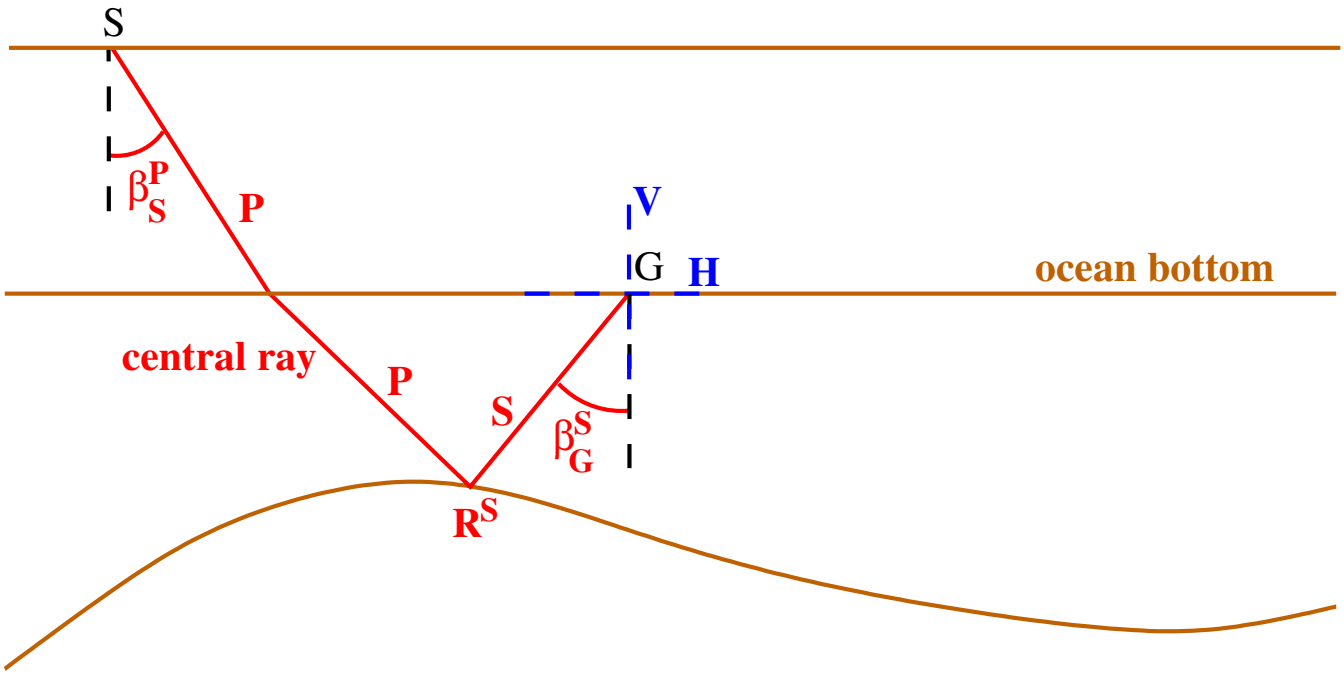

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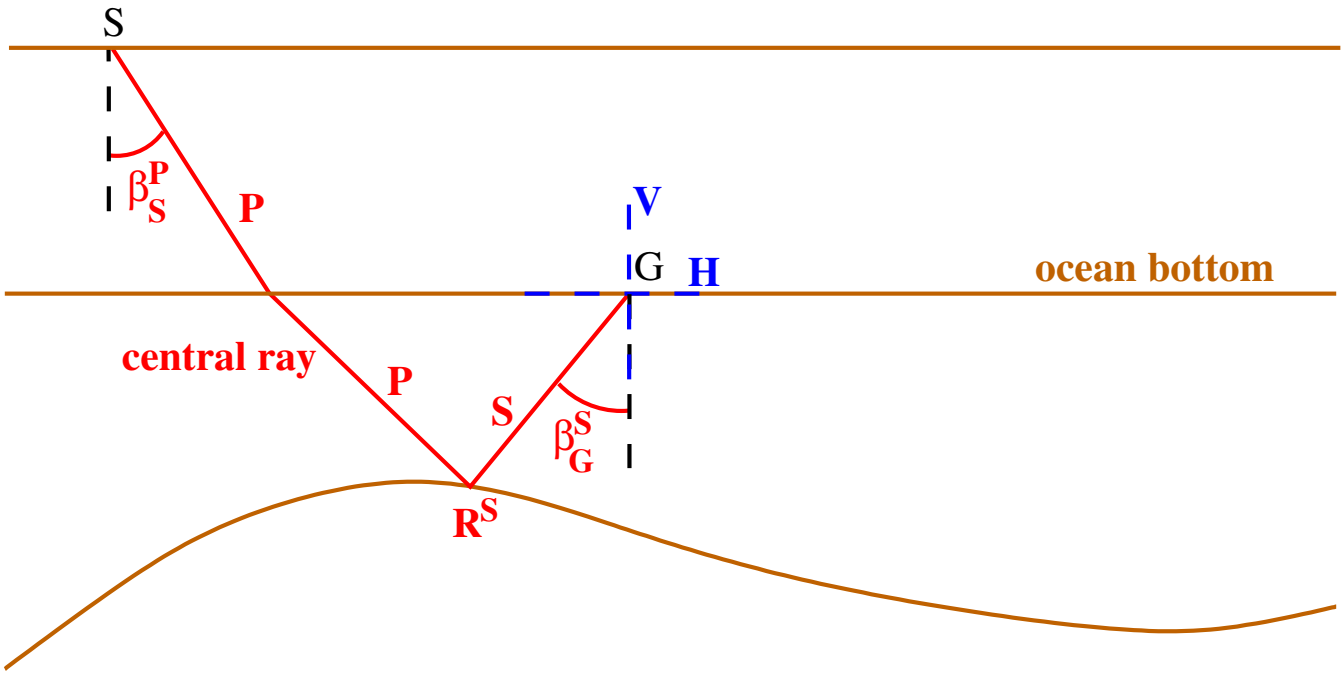

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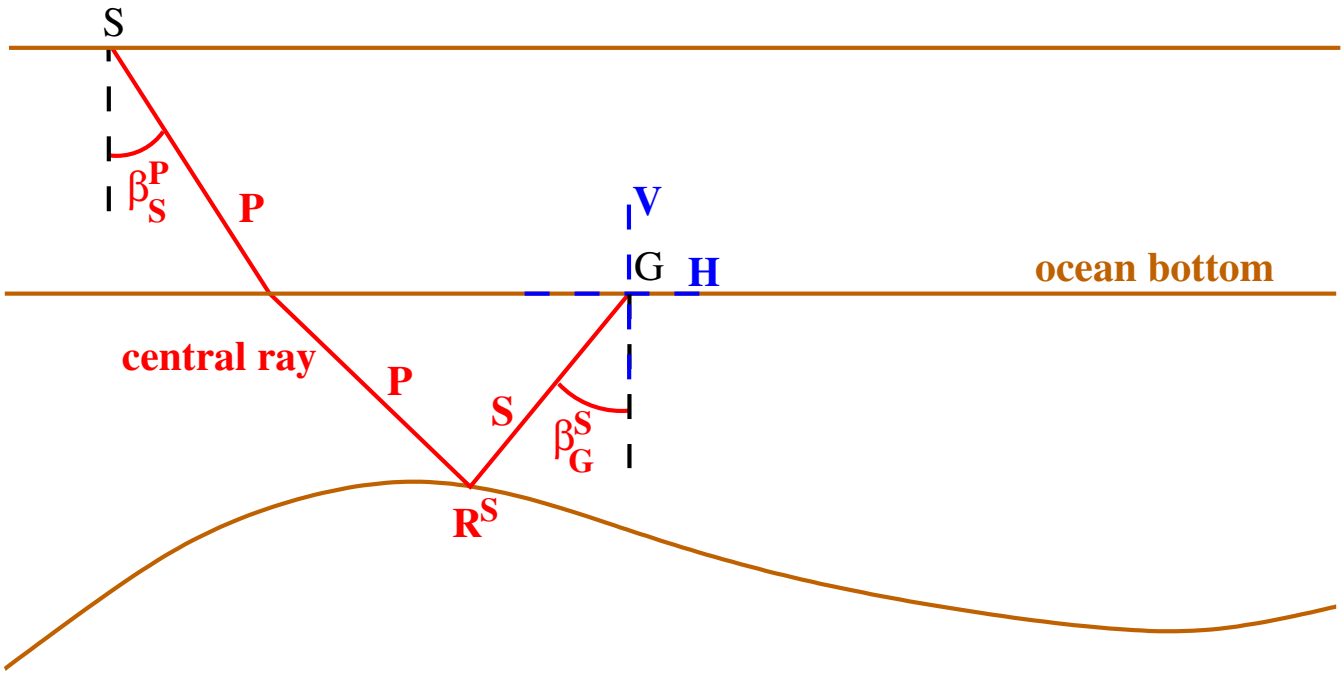

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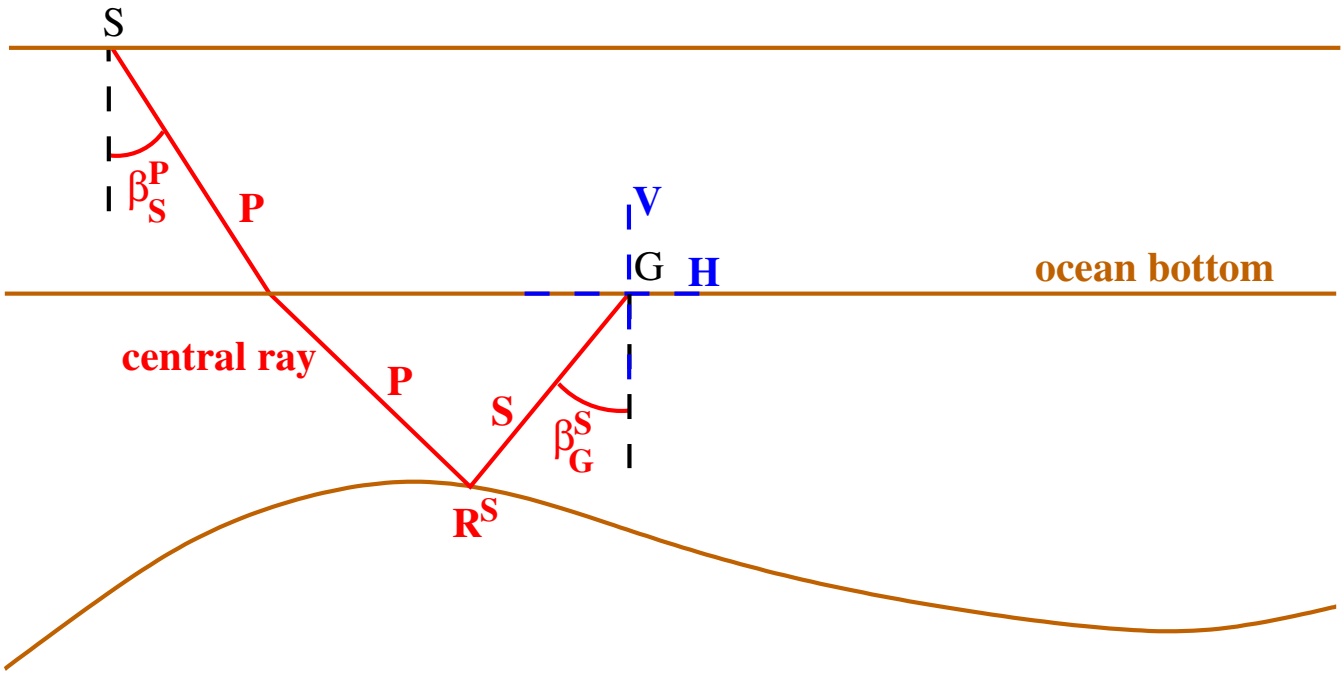

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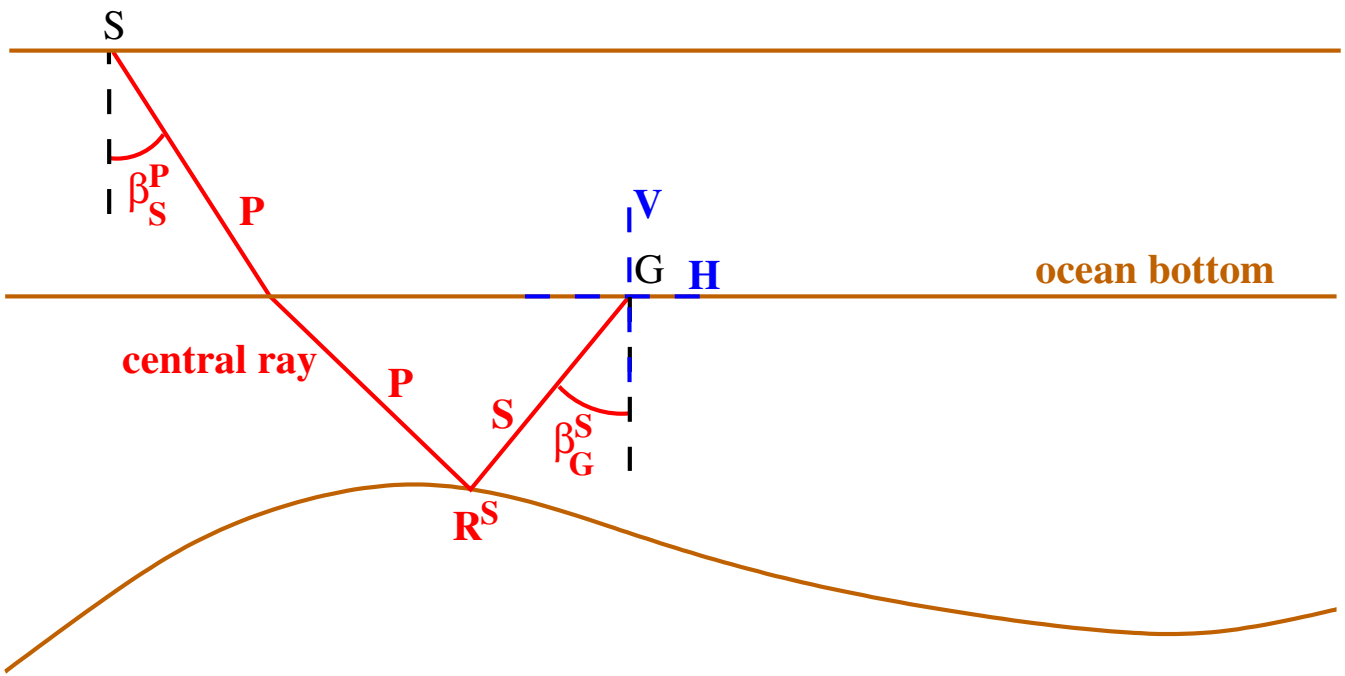
During search for the optimum stacking operator:

- determine emergence angles of central and paraxial rays at the receivers
- separate coherence analyses and stacks for longitudinal and transversal components



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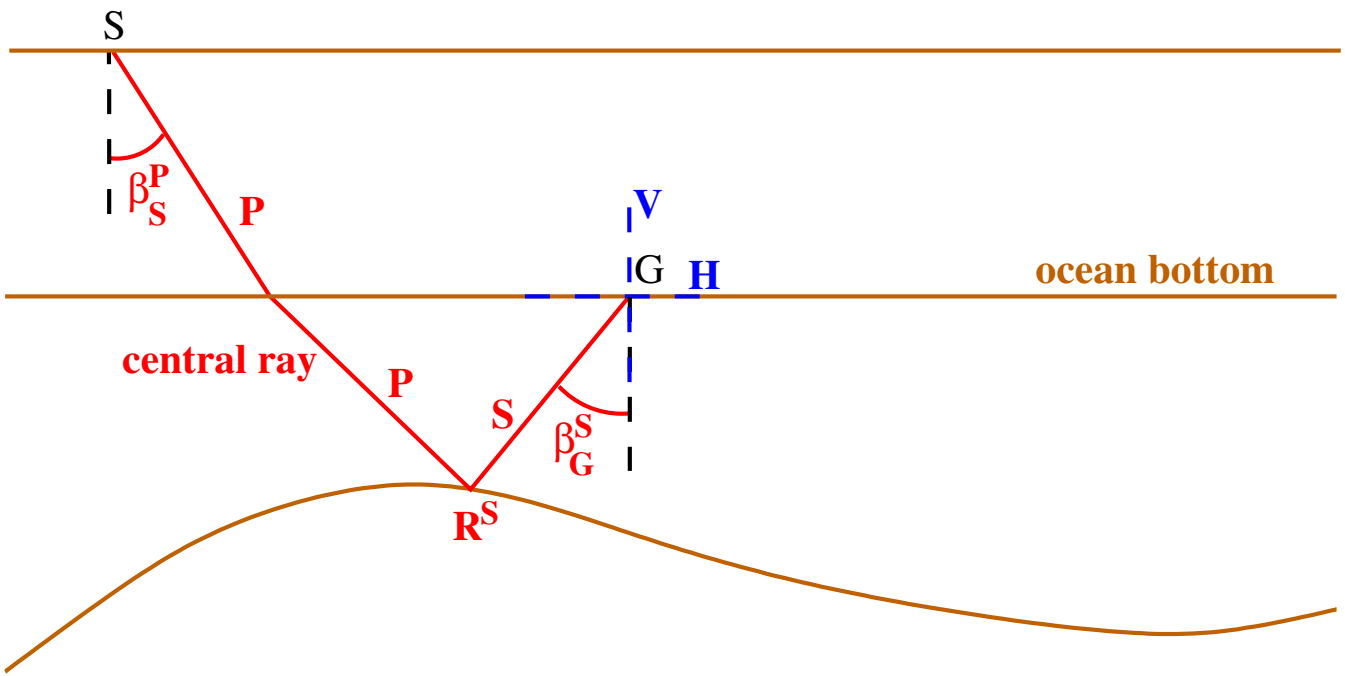

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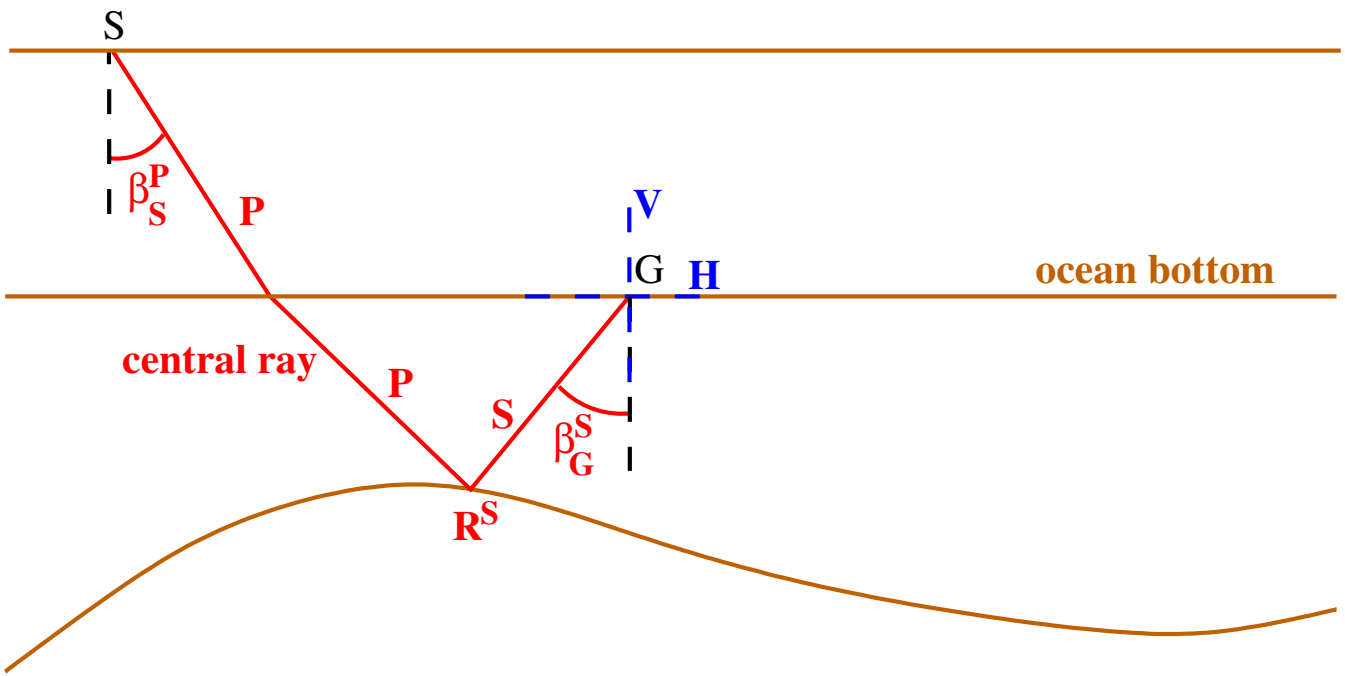

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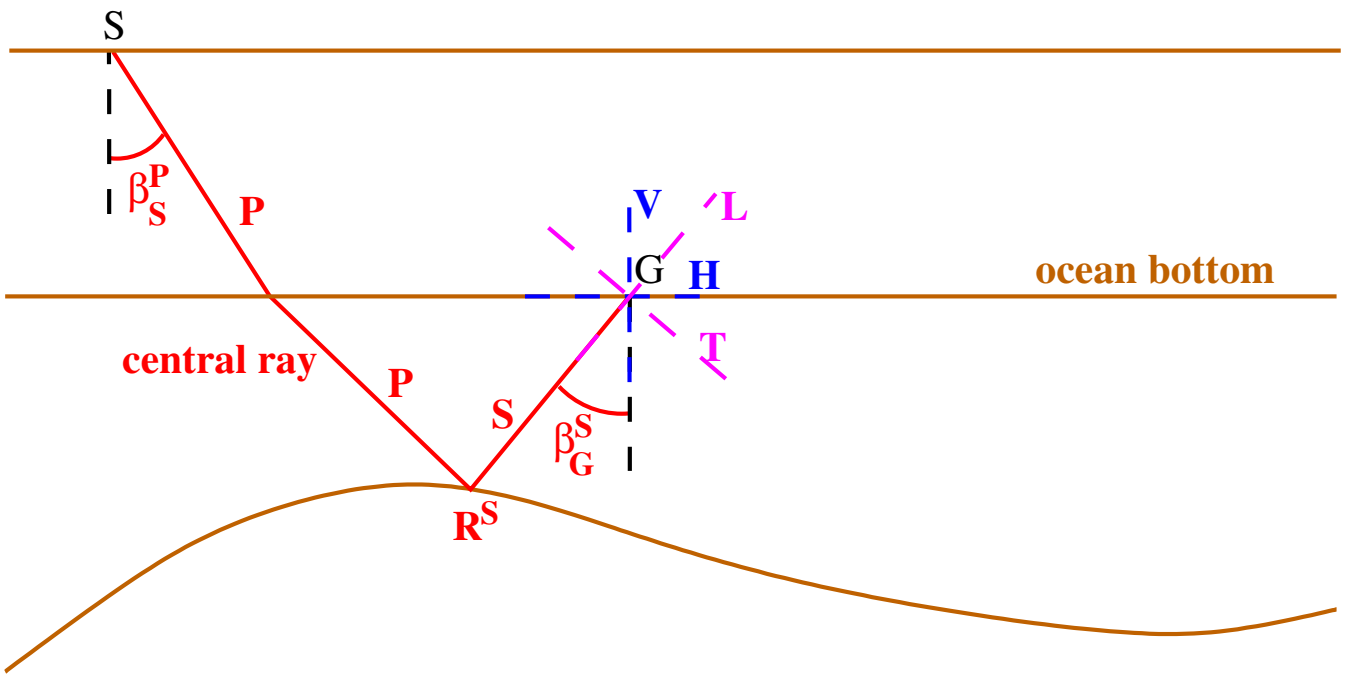

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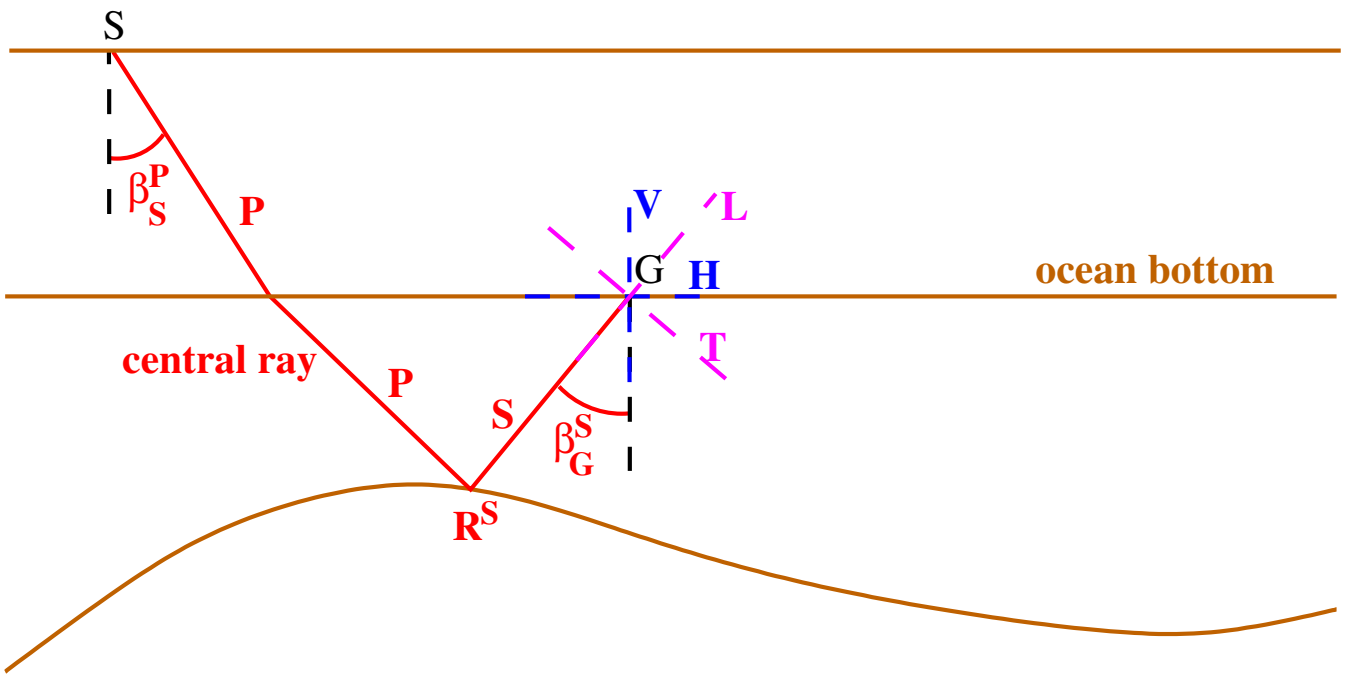

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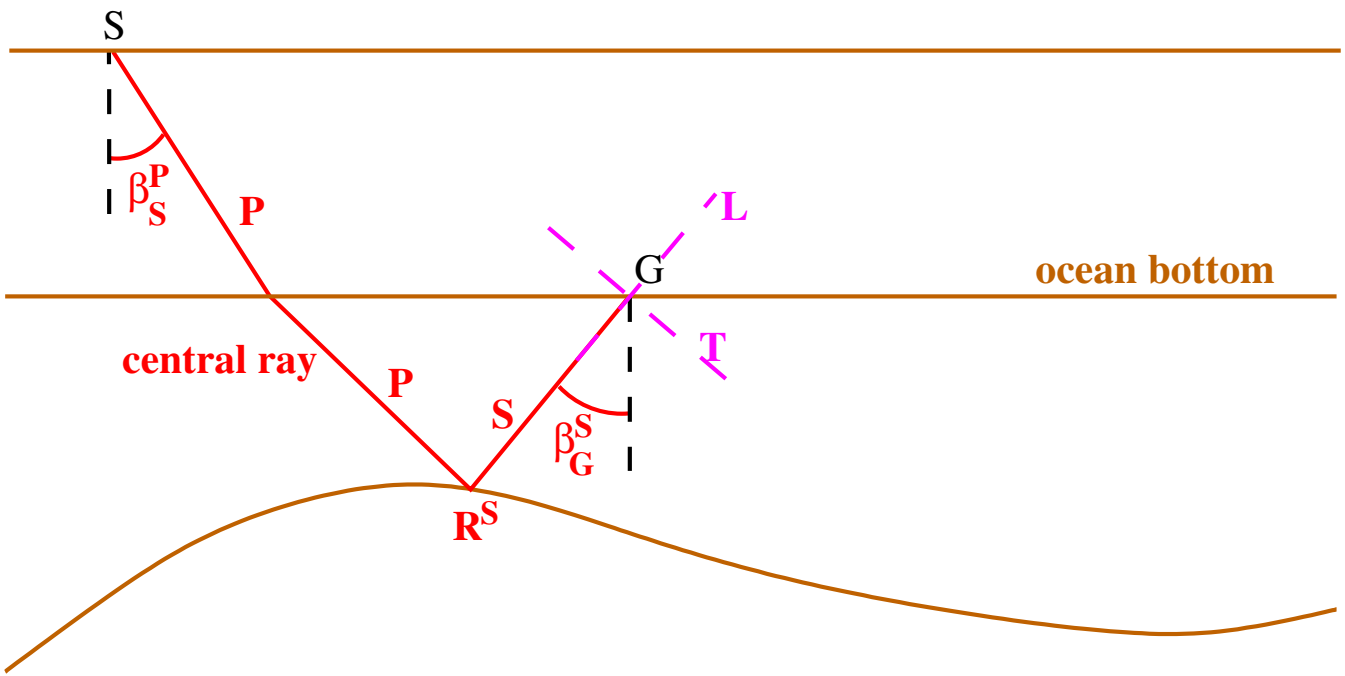

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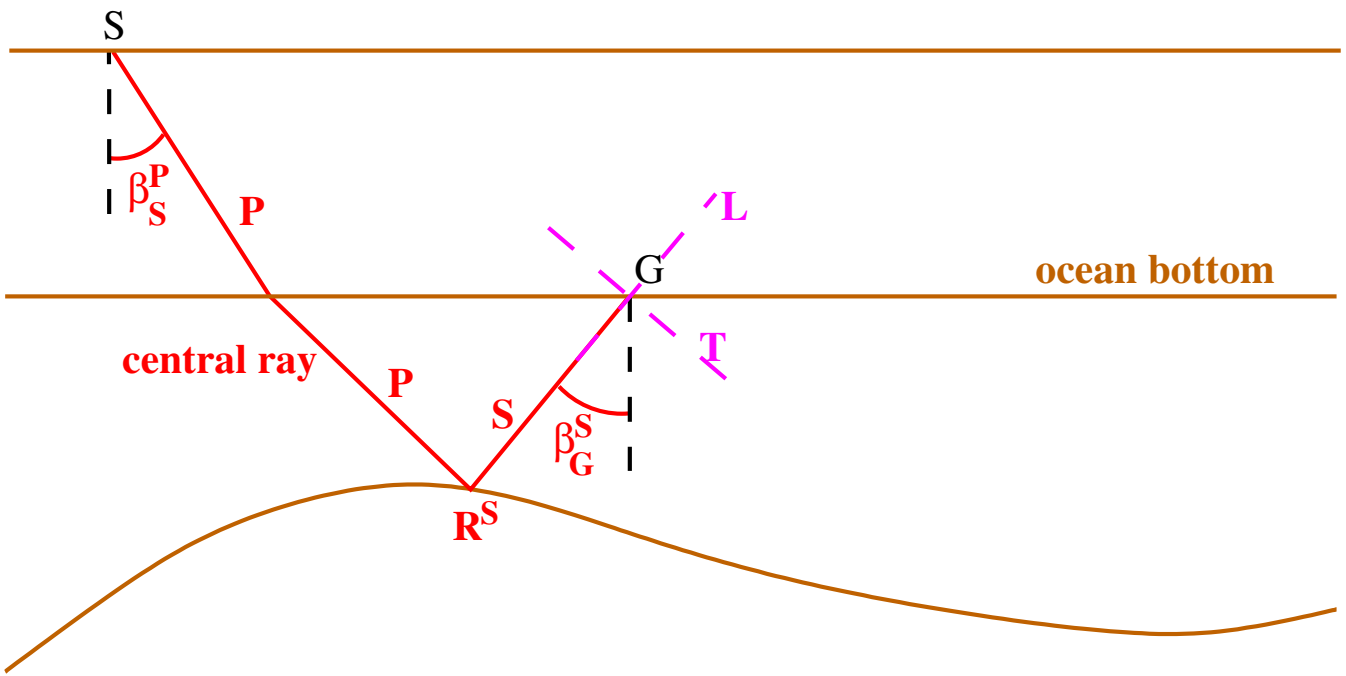

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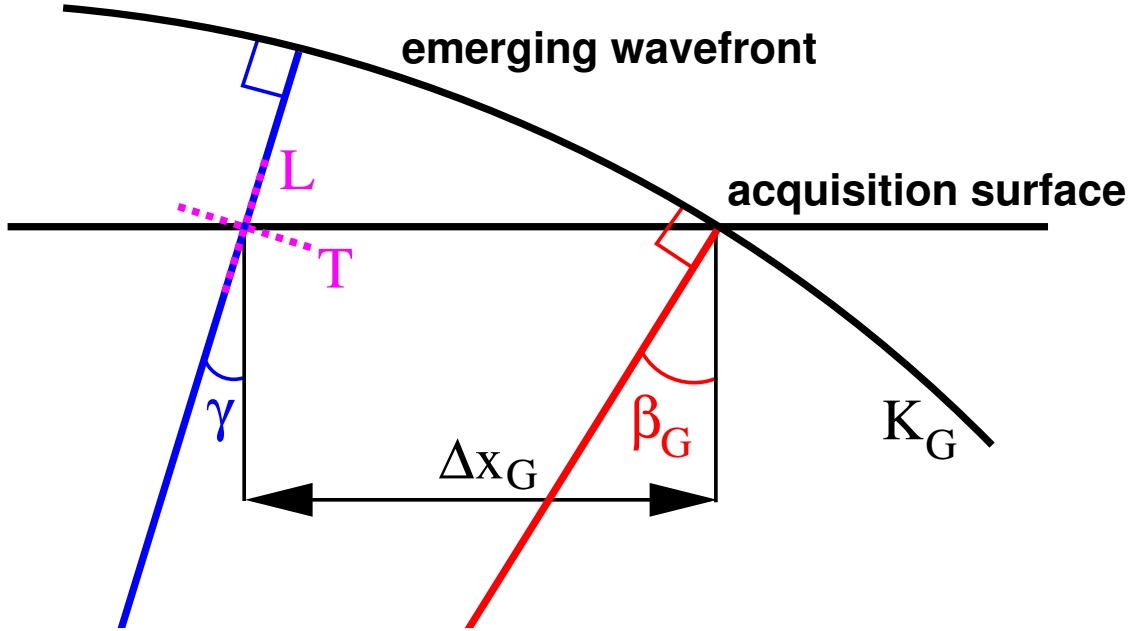

$$\sin\gamma = \mathrm{sign}(R_G)\,\frac{R_G \sin\beta_G + \Delta x_G}{\sqrt{R_G^2 + 2R_G\Delta x_G \sin\beta_G + \Delta x_G^2}}$$

γ : emergence angle of paraxial ray

β_G : emergence angle of central ray

$R_G = 1/K_G$: radius of curvature at receiver

Δx_G : receiver dislocation

Implementation

Pragmatic search strategy (similar to ZO CRS stack):

1. Common-shot search: determine β_G and $K_G = K_{CS}^G$
2. Common-offset search: determine angle and curvature in separate PP- and PS-stack section
3. Common-midpoint search: determine curvature in prestack data
4. Final CRS stack with spatial operator for all source/receiver pairs:

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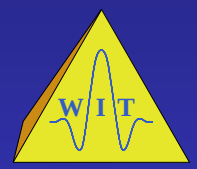
   - polarization along multi-stacking operator



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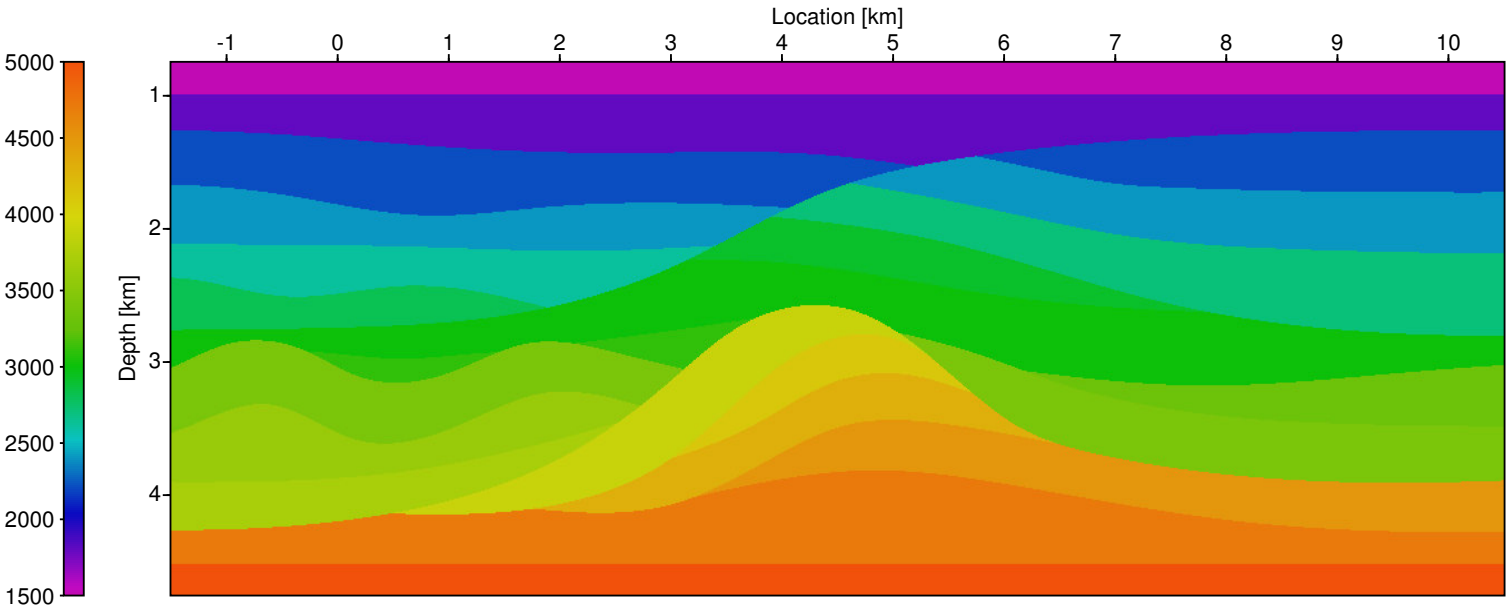
Example: single-component OBS data



Modeling parameters:

- sources in water at constant depth of 6 m
- receivers on seafloor at constant depth of 1 km
- 25 m midpoint and offset spacing
- maximum CMP fold: 81
- only primary PP-events simulated

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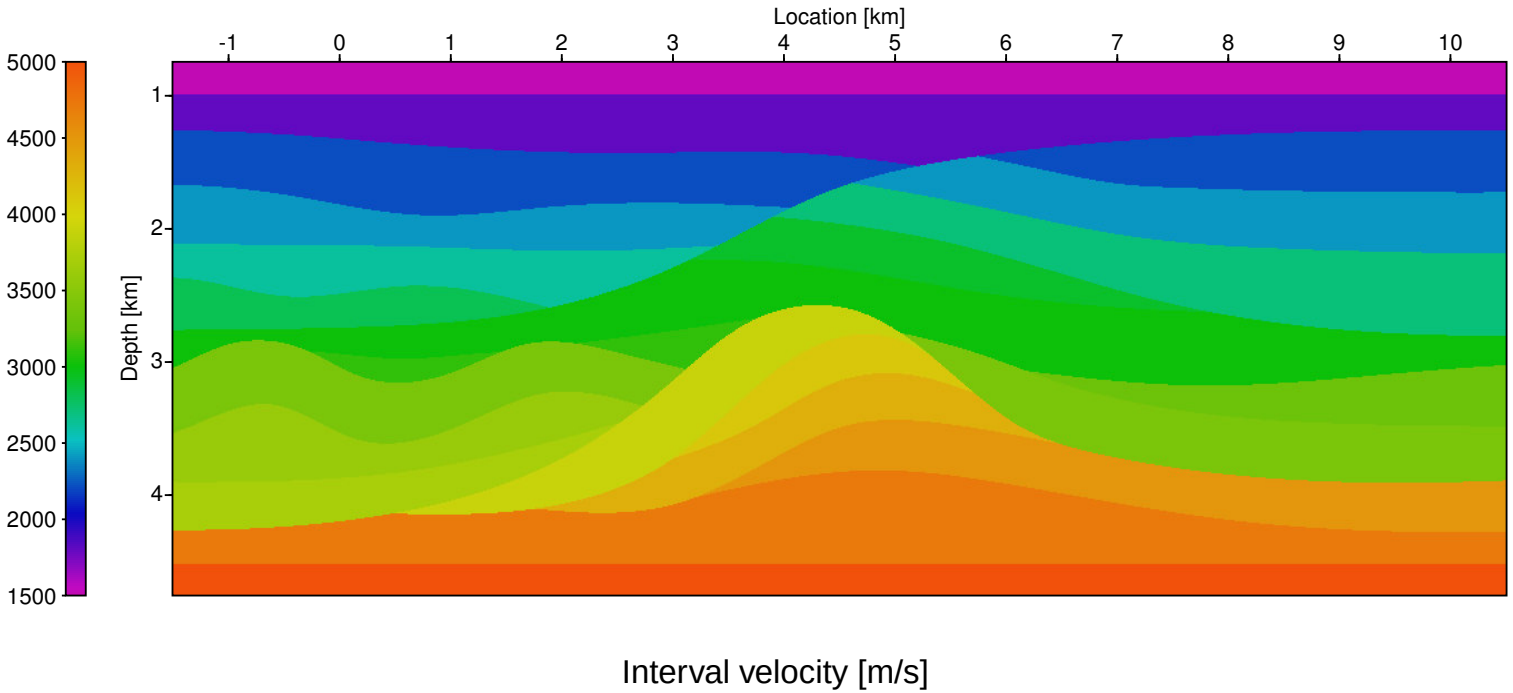

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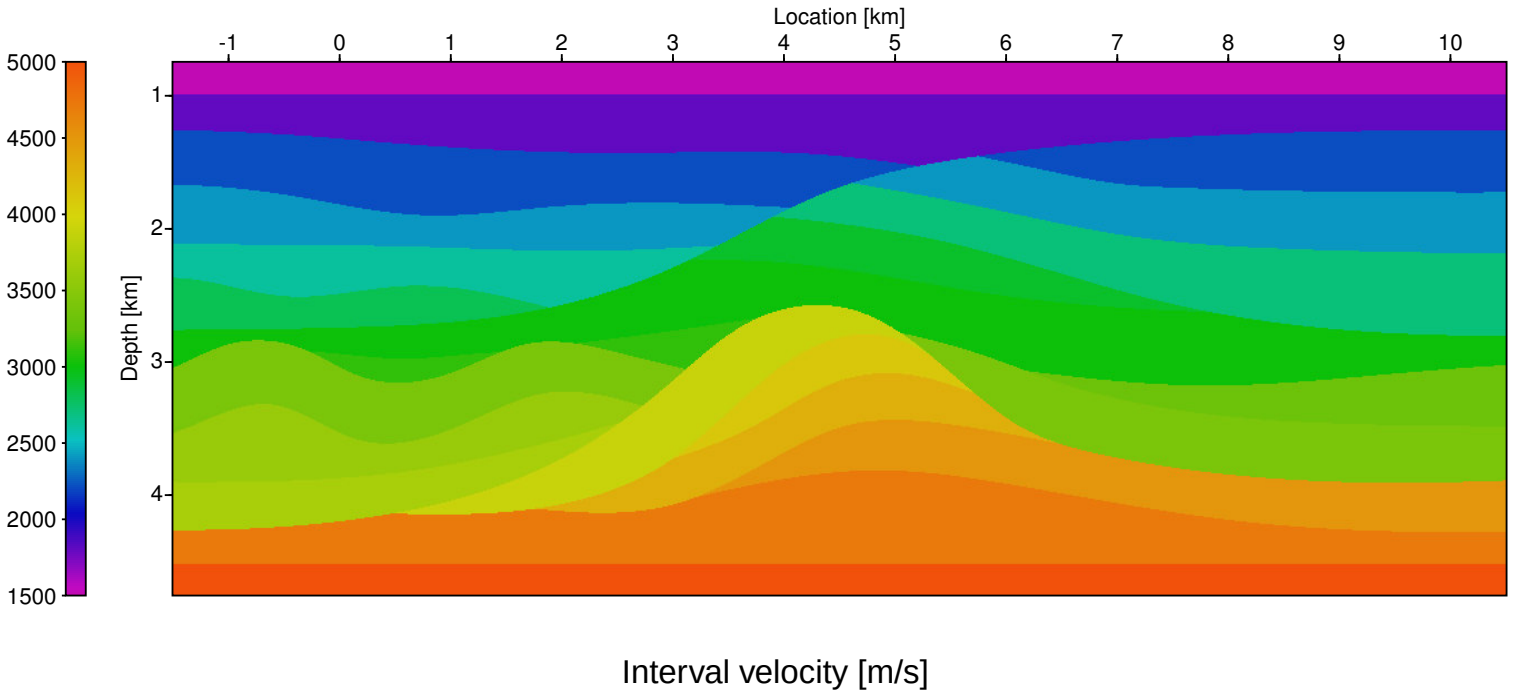

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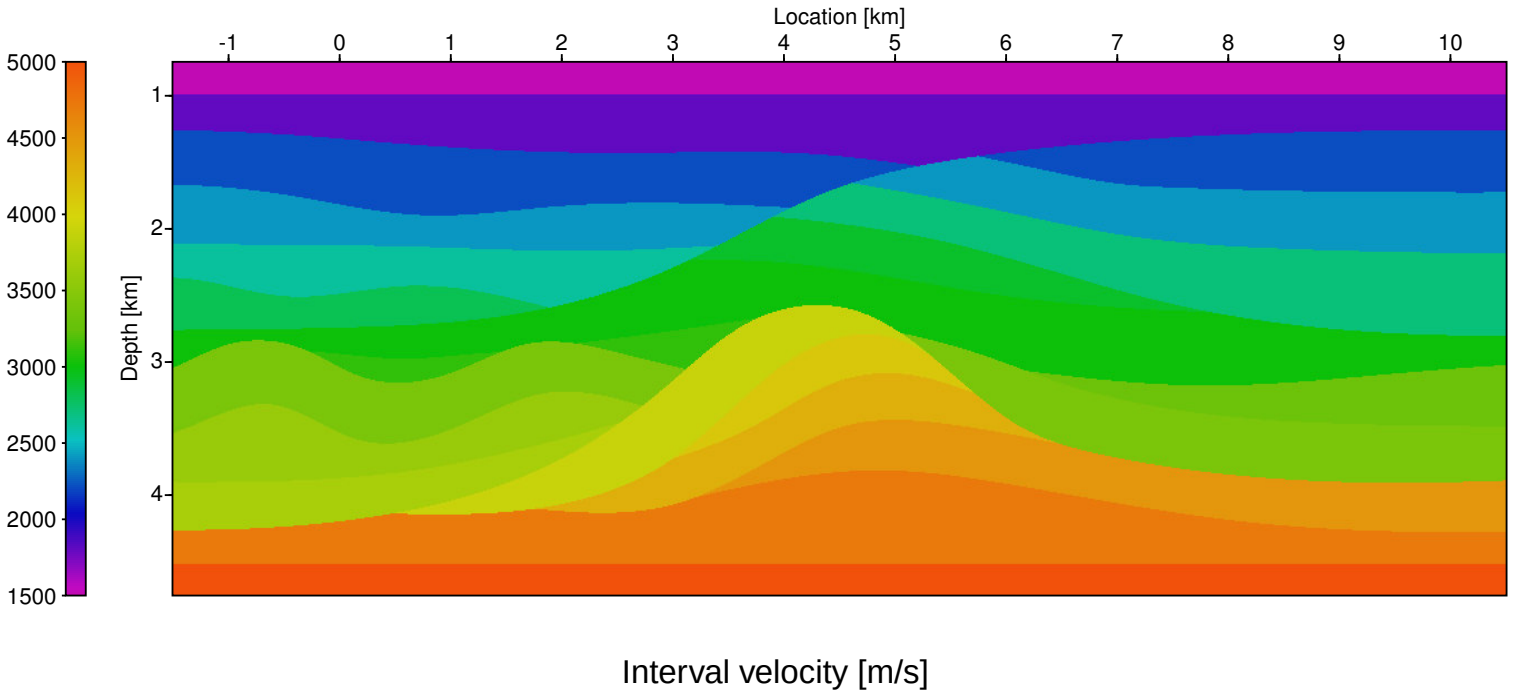

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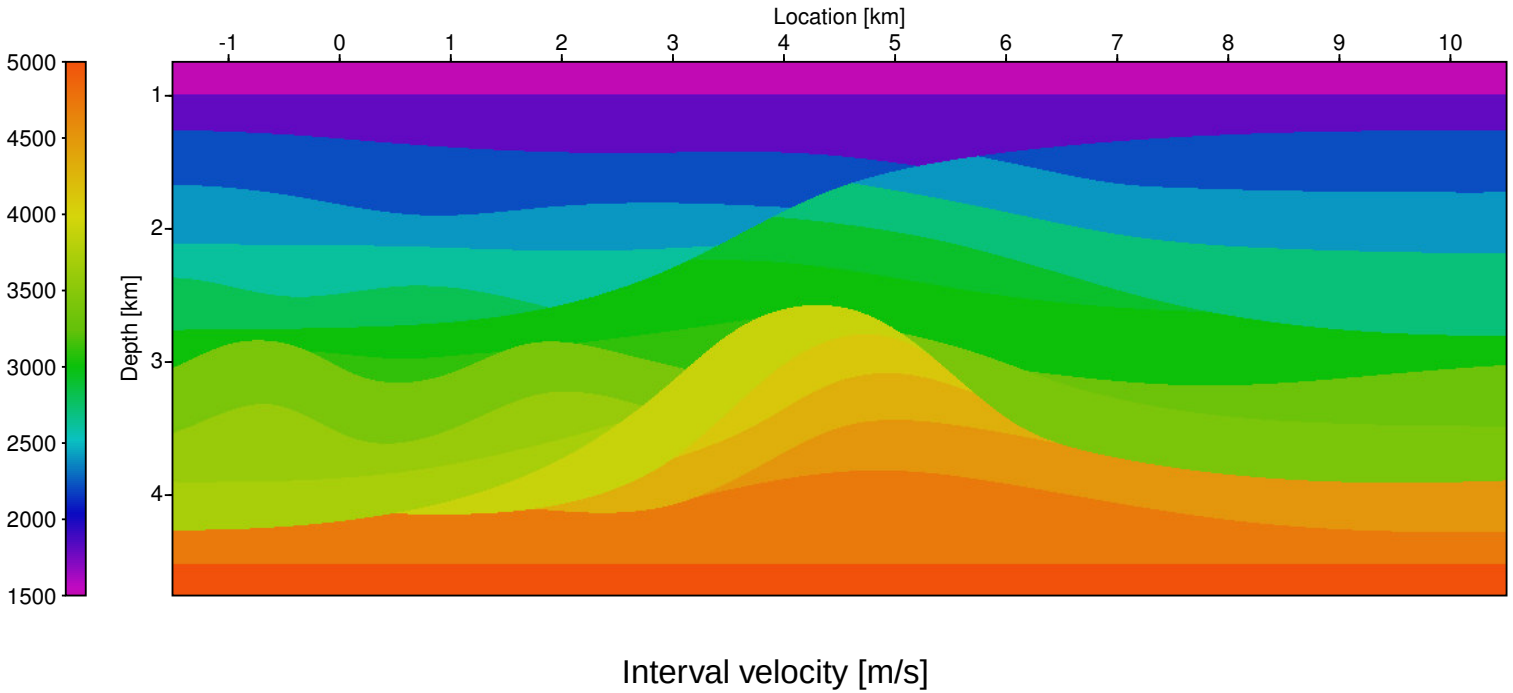

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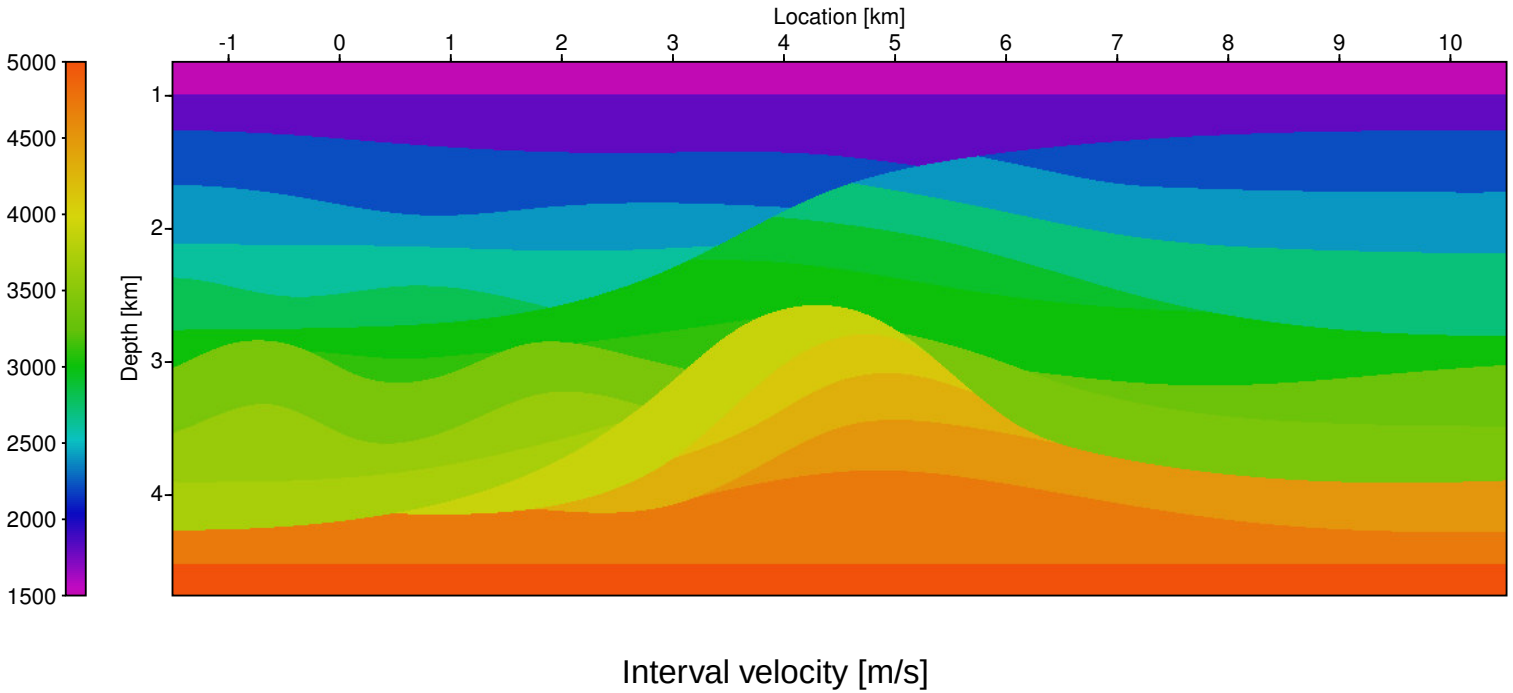

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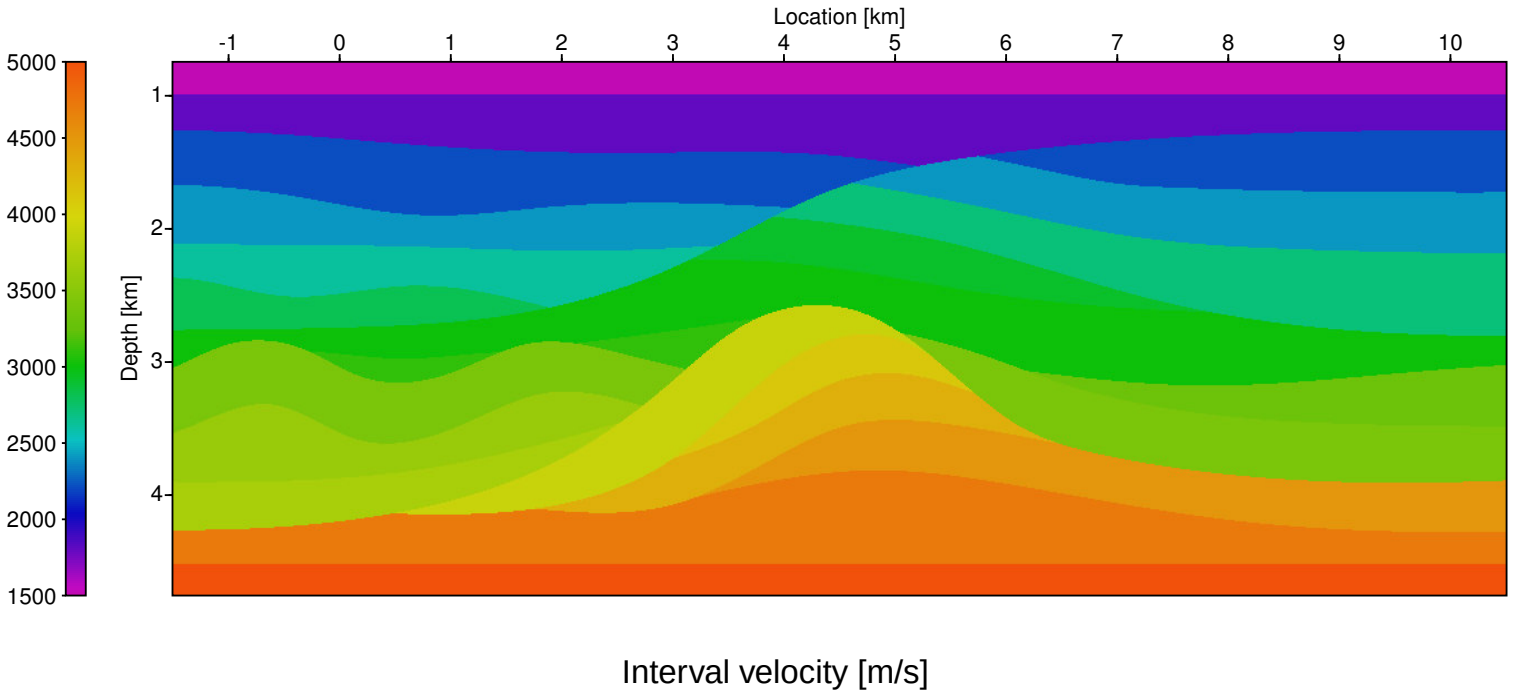

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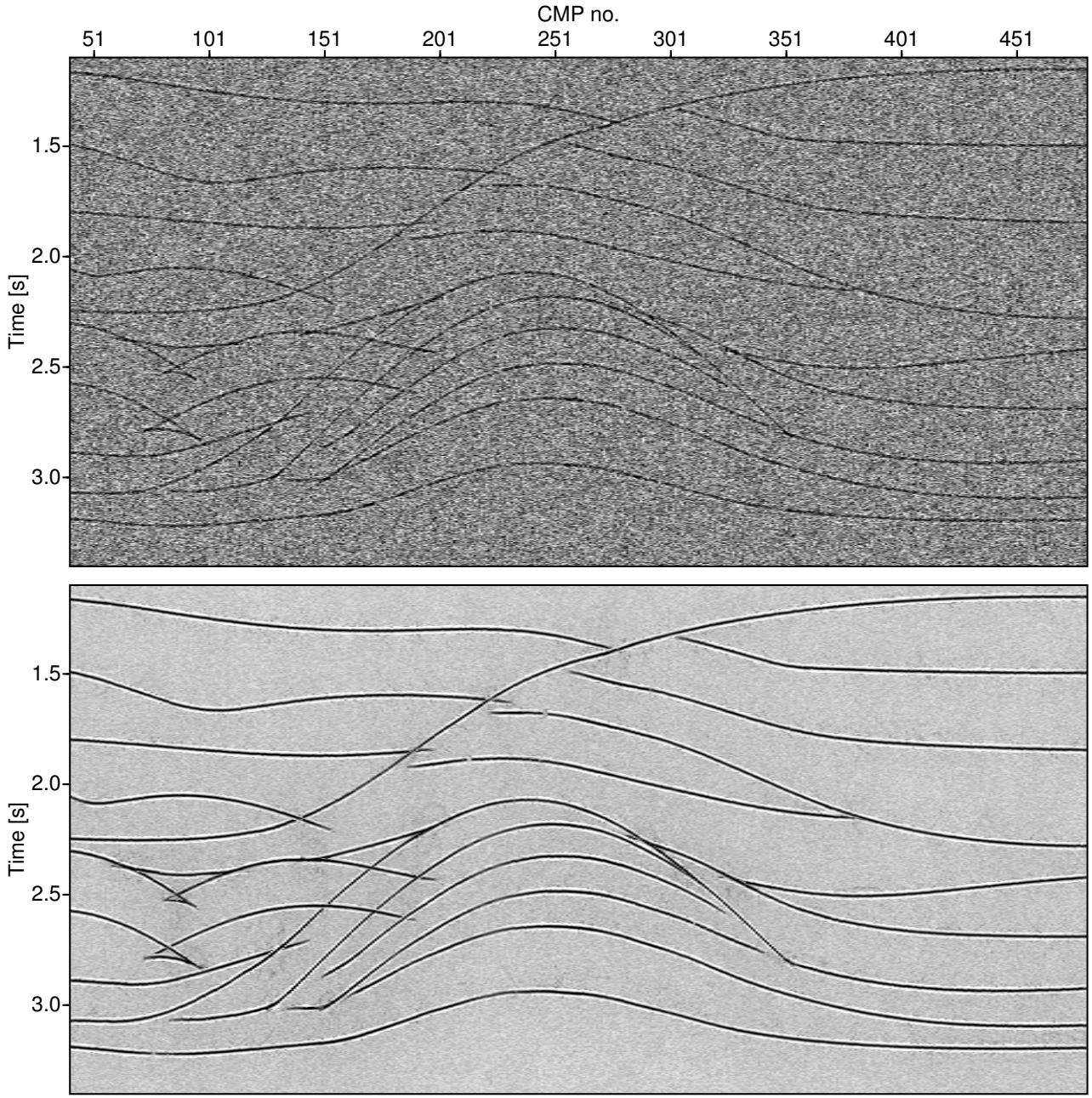
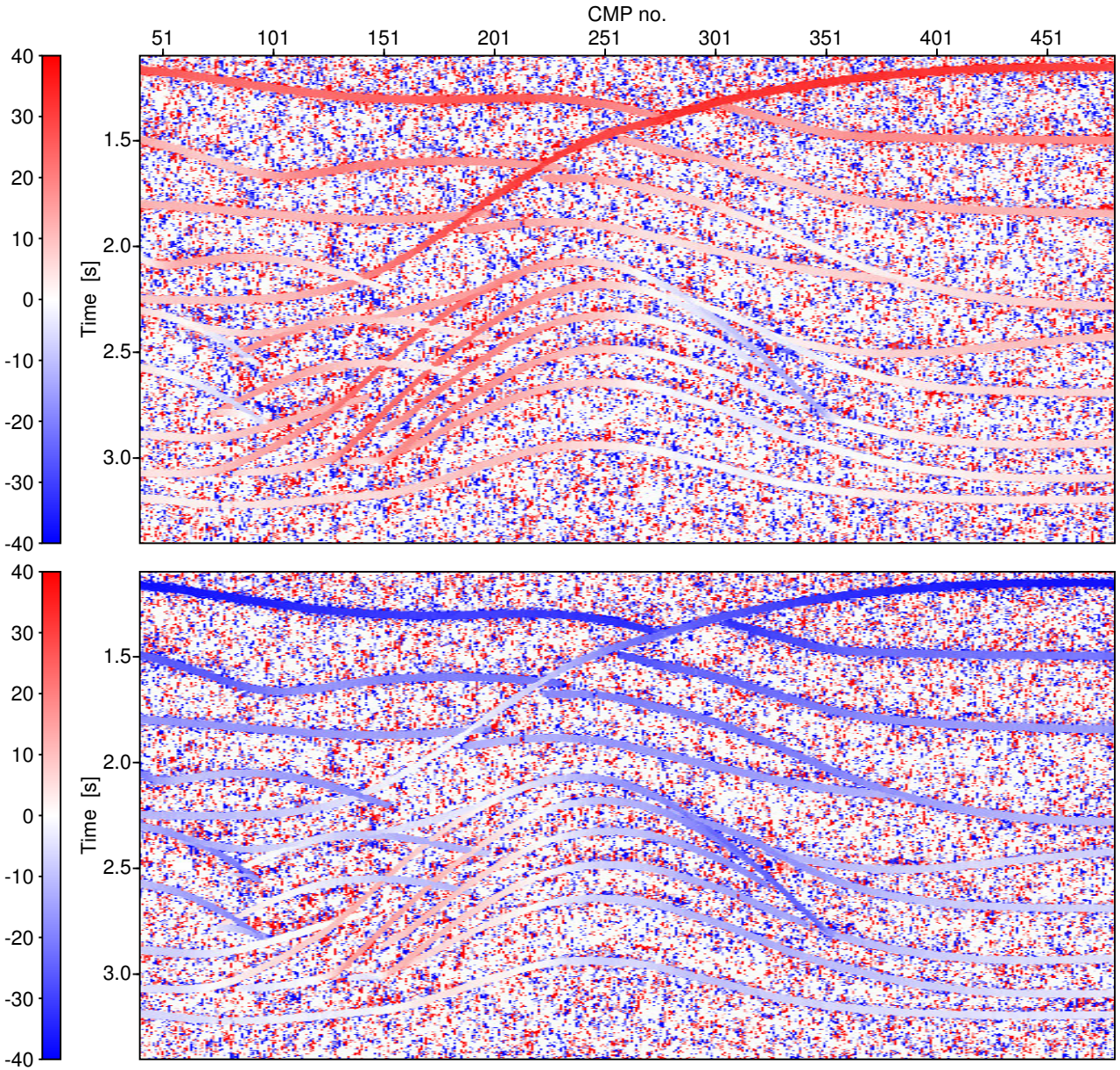
Prestack data vs. stack result



Emergence angles [°] section



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Model characteristics:

- single horizontal reflector
- primary PP- and PS-events simulated
- both events present on both components

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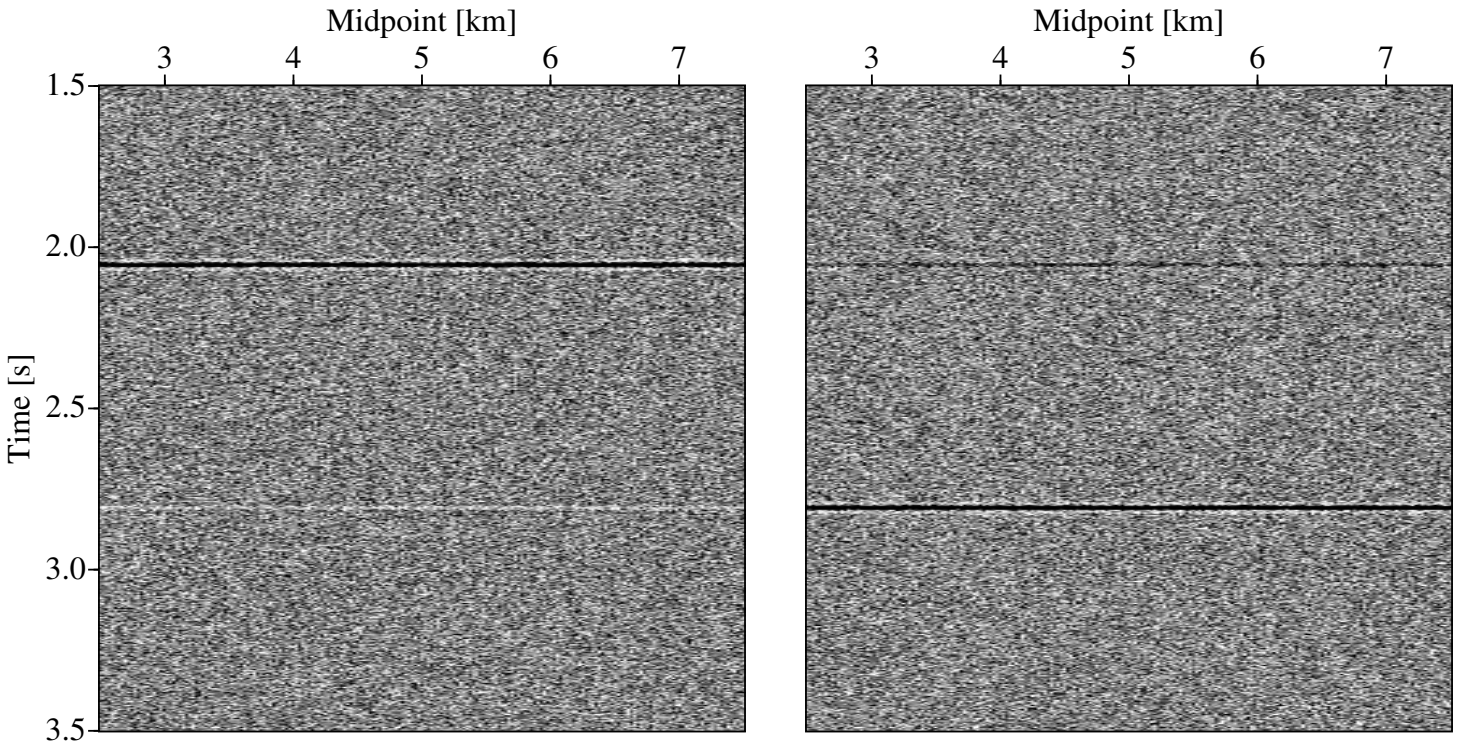
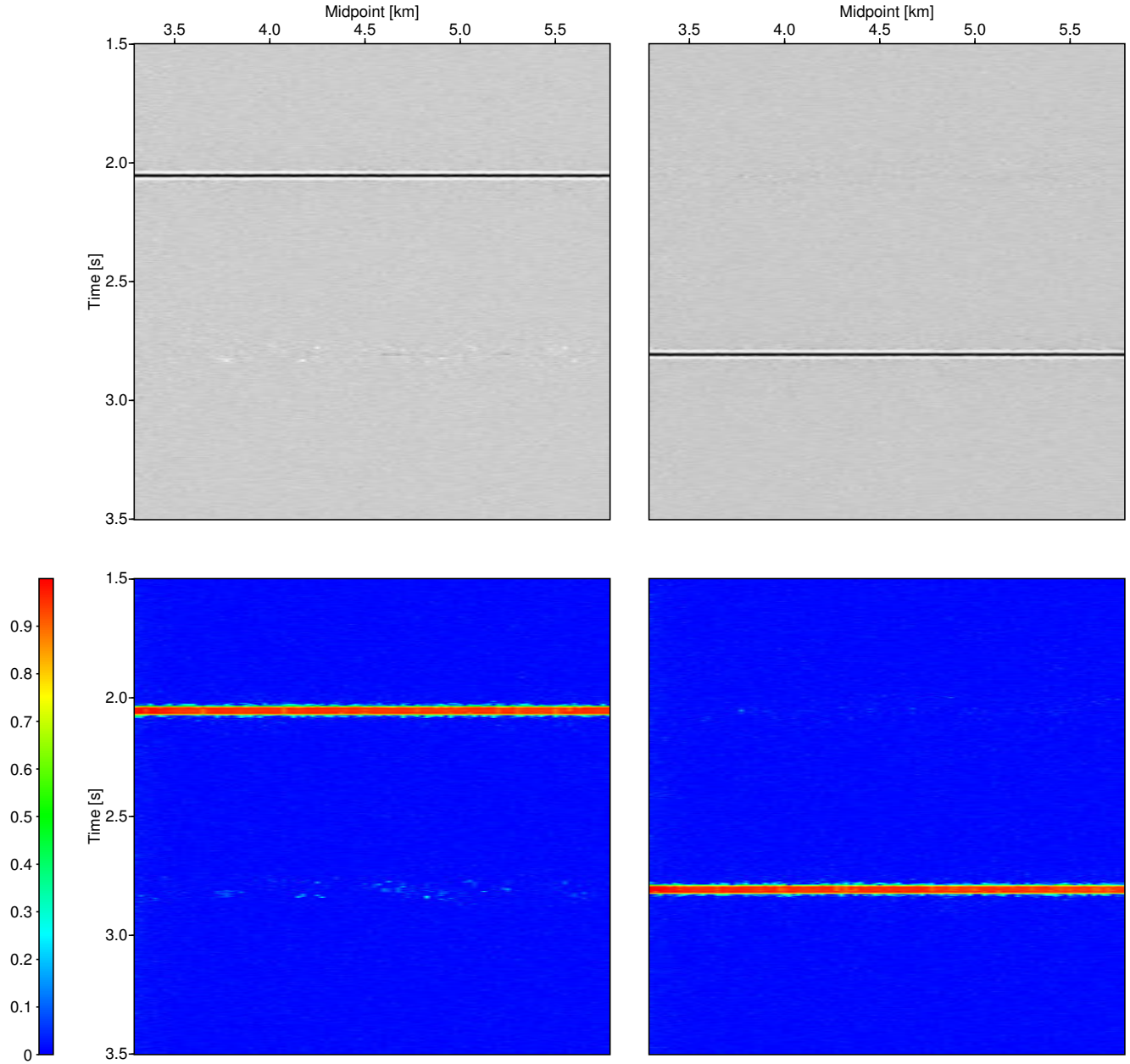
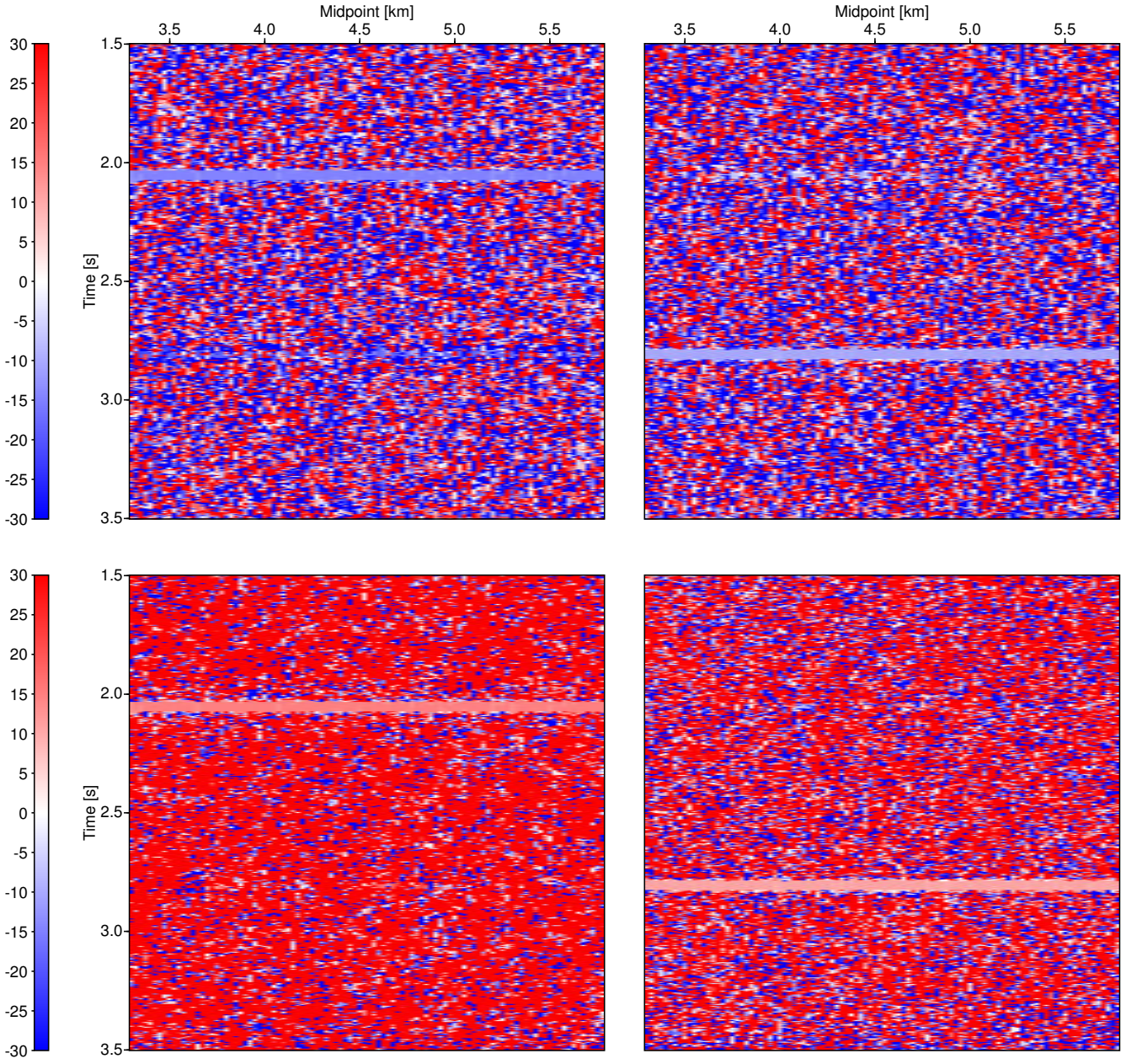


Vertical component Horizontal component

Stack and coherence sections



Emergence/incidence angle [°] sections



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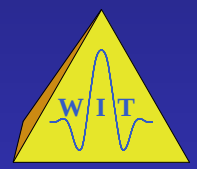

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- Extension to the general 3-D case

VSP data:

- Implementation of search strategy
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Acknowledgments

This work was kindly supported by the sponsors of the Wave Inversion Technology (WIT) Consortium, Karlsruhe, Germany

Related presentations

Workshop WS-2 “Velocity analysis for depth imaging”, Monday afternoon:

- 13:30 Common-Reflection-Surface stack – a generalized stacking velocity analysis tool

Session “Seismic Imaging”, Wednesday morning:

- 09:20 Smoothing and automated picking of kinematic wavefield attributes
- 09:45 CRS-stack-based seismic imaging for land data and complex near-surface conditions
- 11:00 True-amplitude CRS-based Kirchhoff time migration for AVO analysis