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THROUGH A GLASS DARKLY: IMPROVING RAYPATH INTERFEROMETRY

Summary

- Principles of raypath interferometry
- Successful field data examples
- The two key algorithms in raypath interferometry
  - ***Reference wavefield construction***
  - ***Raypath domain transform***
- Comparison of new methods with old
- Conclusions

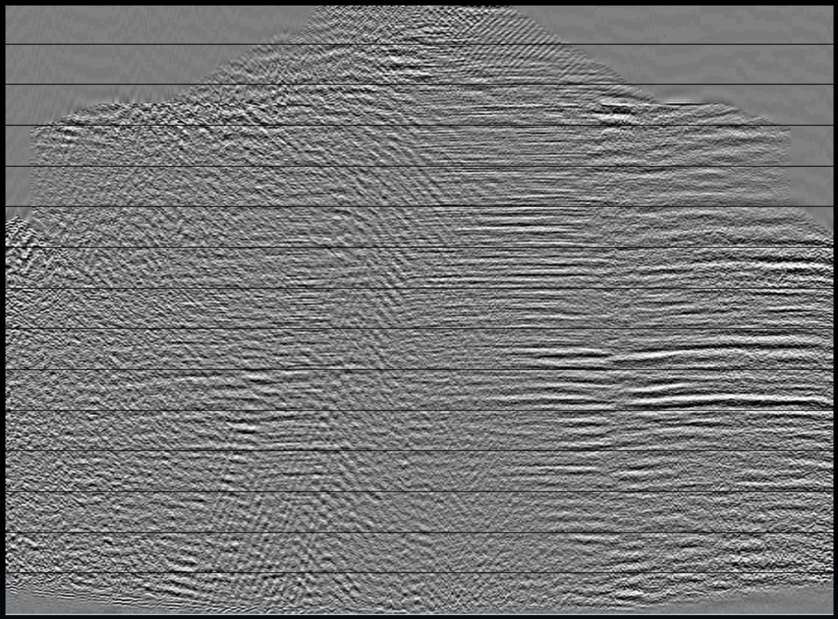
Principles of raypath interferometry

- ***Static shifts*** replaced by ***Deconvolution*** (to include **near-surface effects**)
- ***Surface consistency*** replaced by ***Raypath consistency*** (to include **non-vertical raypaths**)
- ***Surface functions*** introduced (to implement new concepts)
- ***Surface functions*** estimated from ***cross-correlations***, removed by ***inverse filtering***

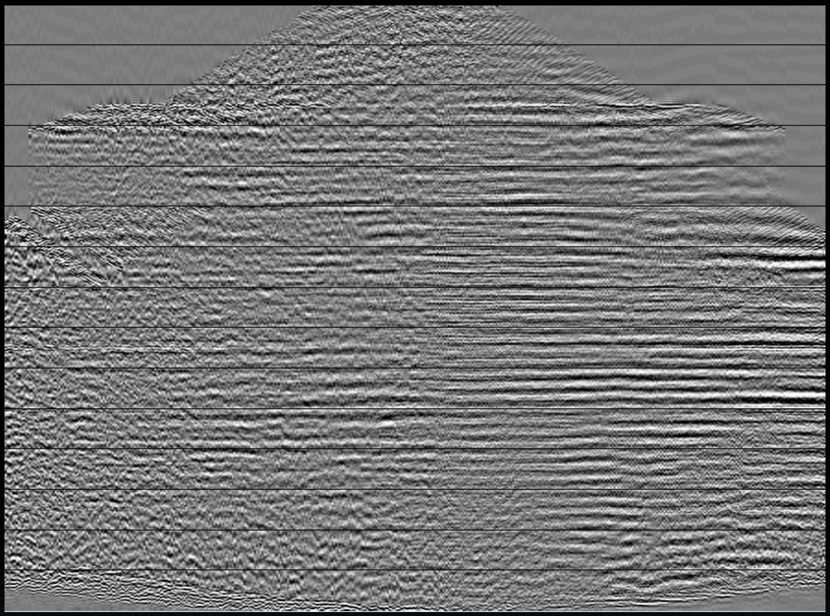
Field data examples

- *Hansen Harbour PP*—surface-consistency ***mildly*** violated, only ***source statics*** needed
- *MacKenzie Delta PP*—very ***large statics***, surface-consistency violated, ***multi-path arrivals***
- *Spring Coulee PS*—very ***large receiver statics***
- *Hussar PP*—good conventional statics
- *Hussar PS*—very ***large receiver statics***, possibly ***nonstationary***

Hansen Harbour PP

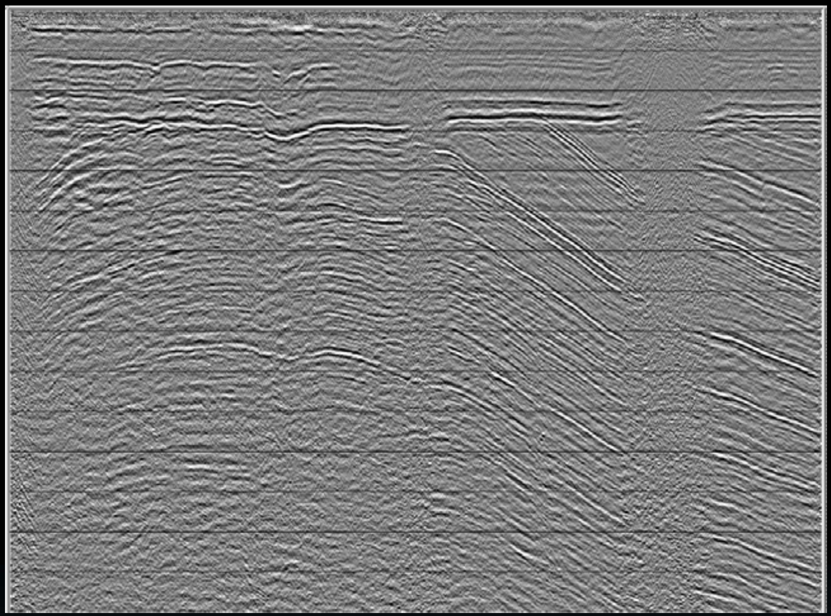


Brute CMP stack—***no statics***

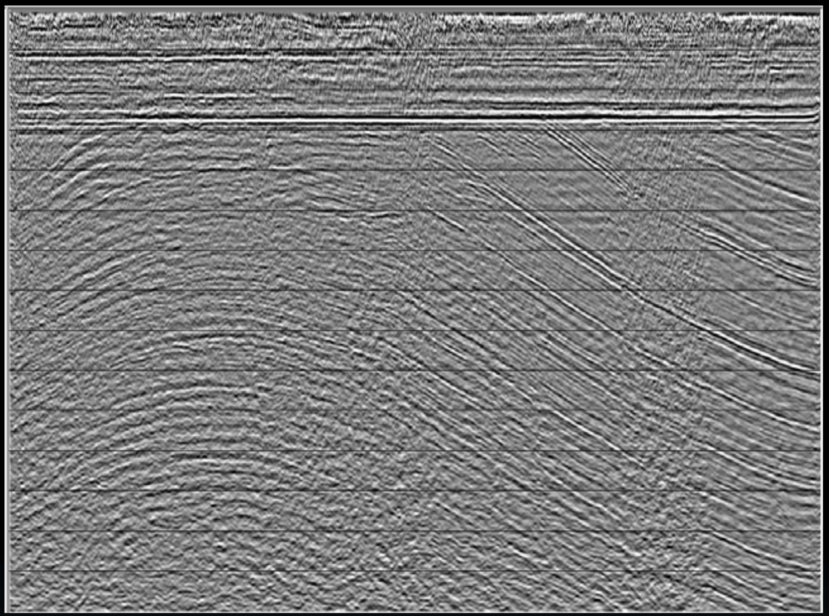


CMP stack—***raypath interferometry***

MacKenzie Delta PP

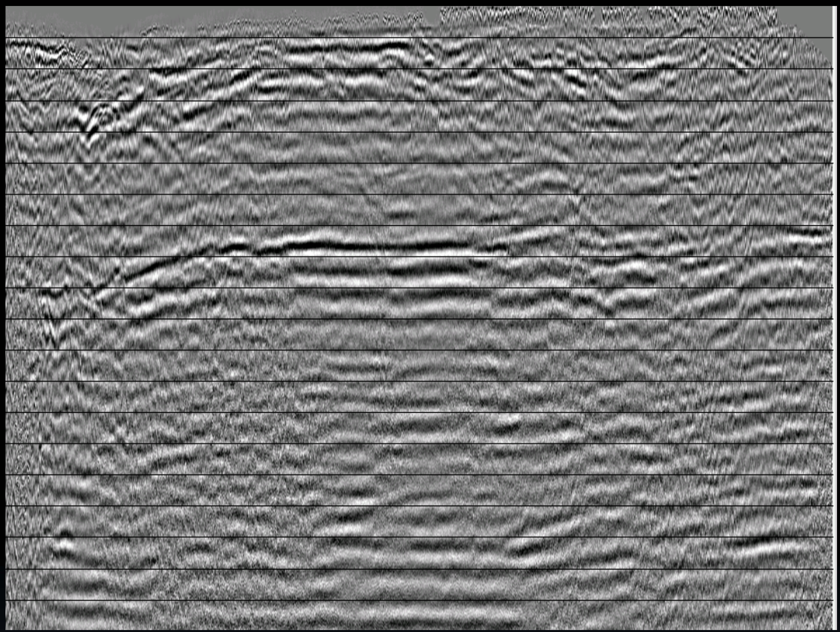


Brute CMP stack—***no statics***

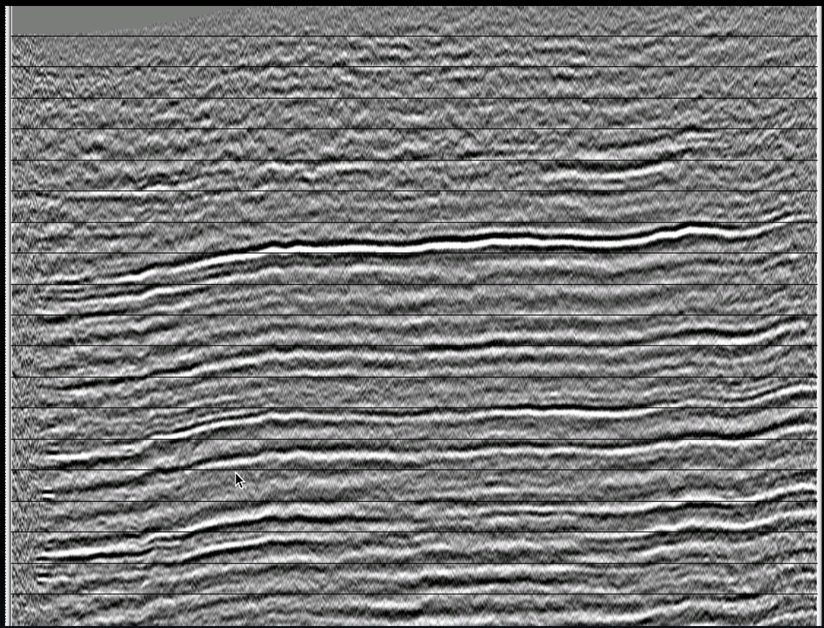


CMP stack—***raypath interferometry***

Spring Coulee PS

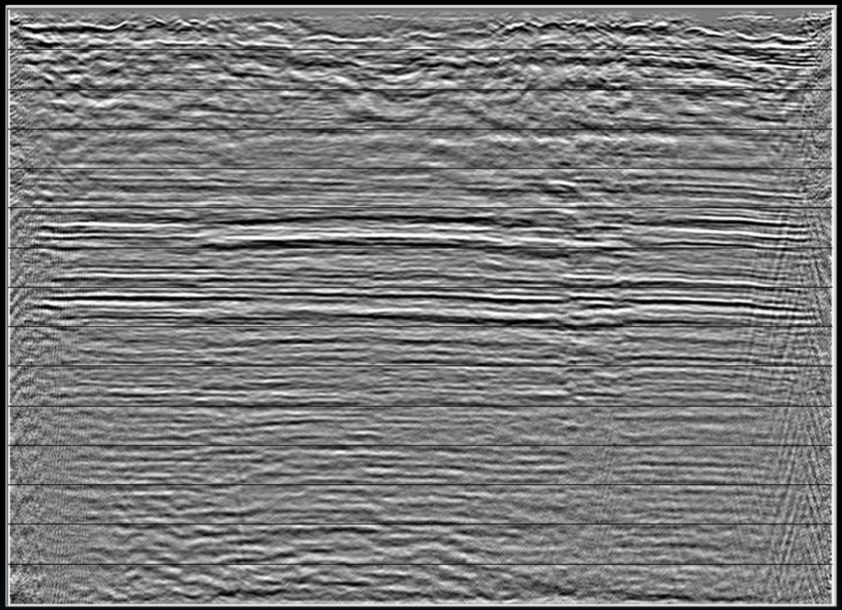


Brute CCP stack—*no statics*

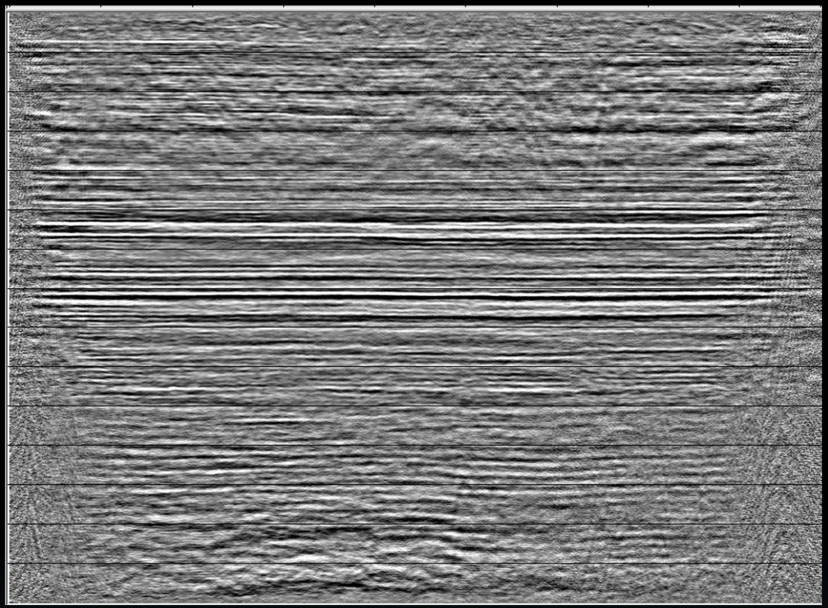


CCP stack—*raypath interferometry*

Hussar PP

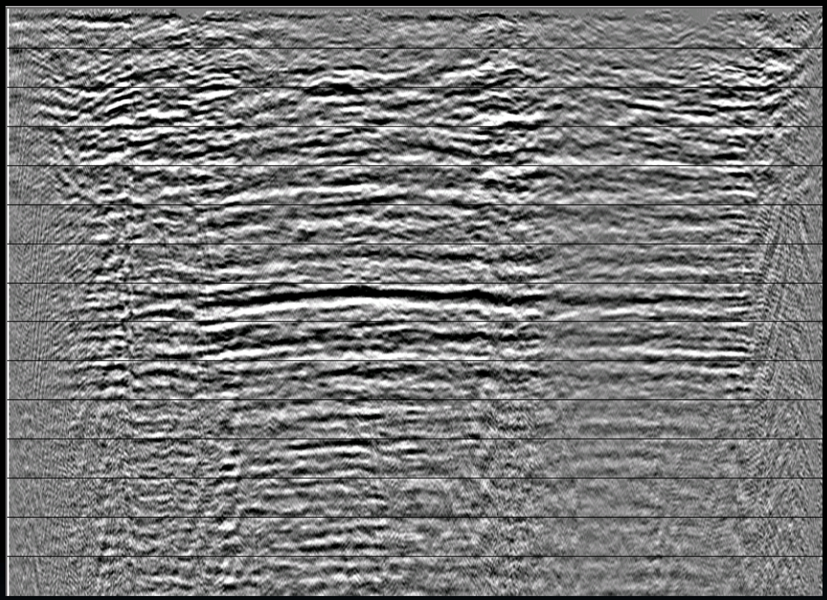


Brute CMP stack—***no statics***

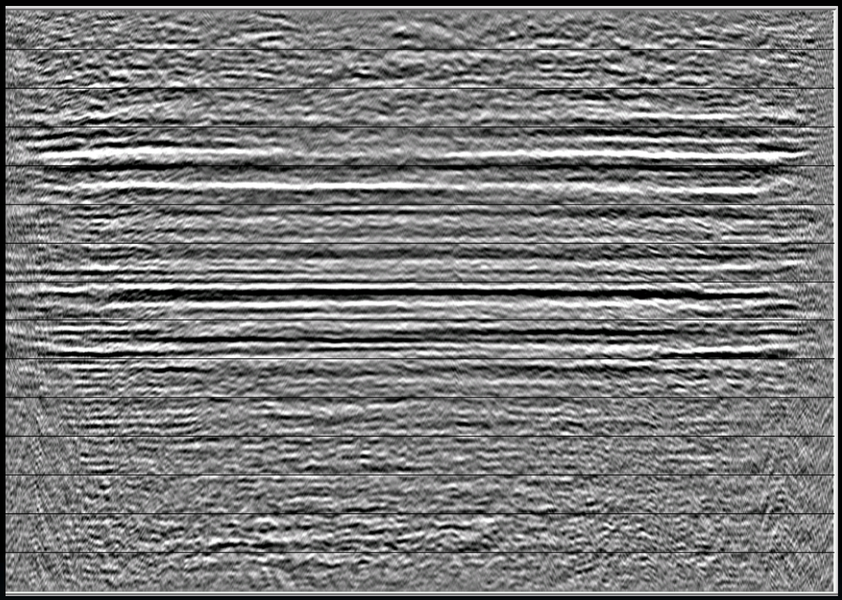


CMP stack—***raypath interferometry***

Hussar PS



Brute CCP stack—***no statics***

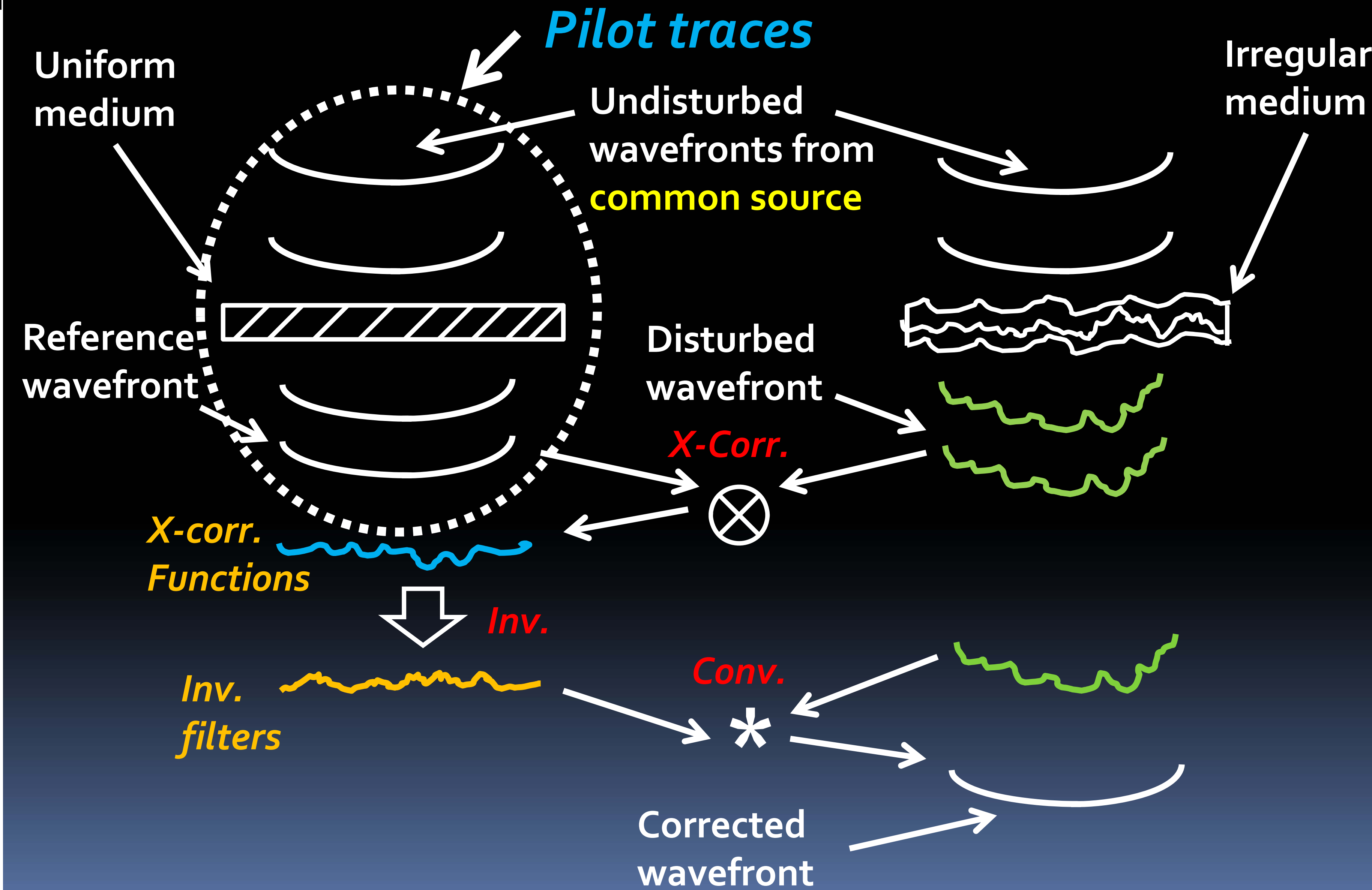


CCP stack—***raypath interferometry***

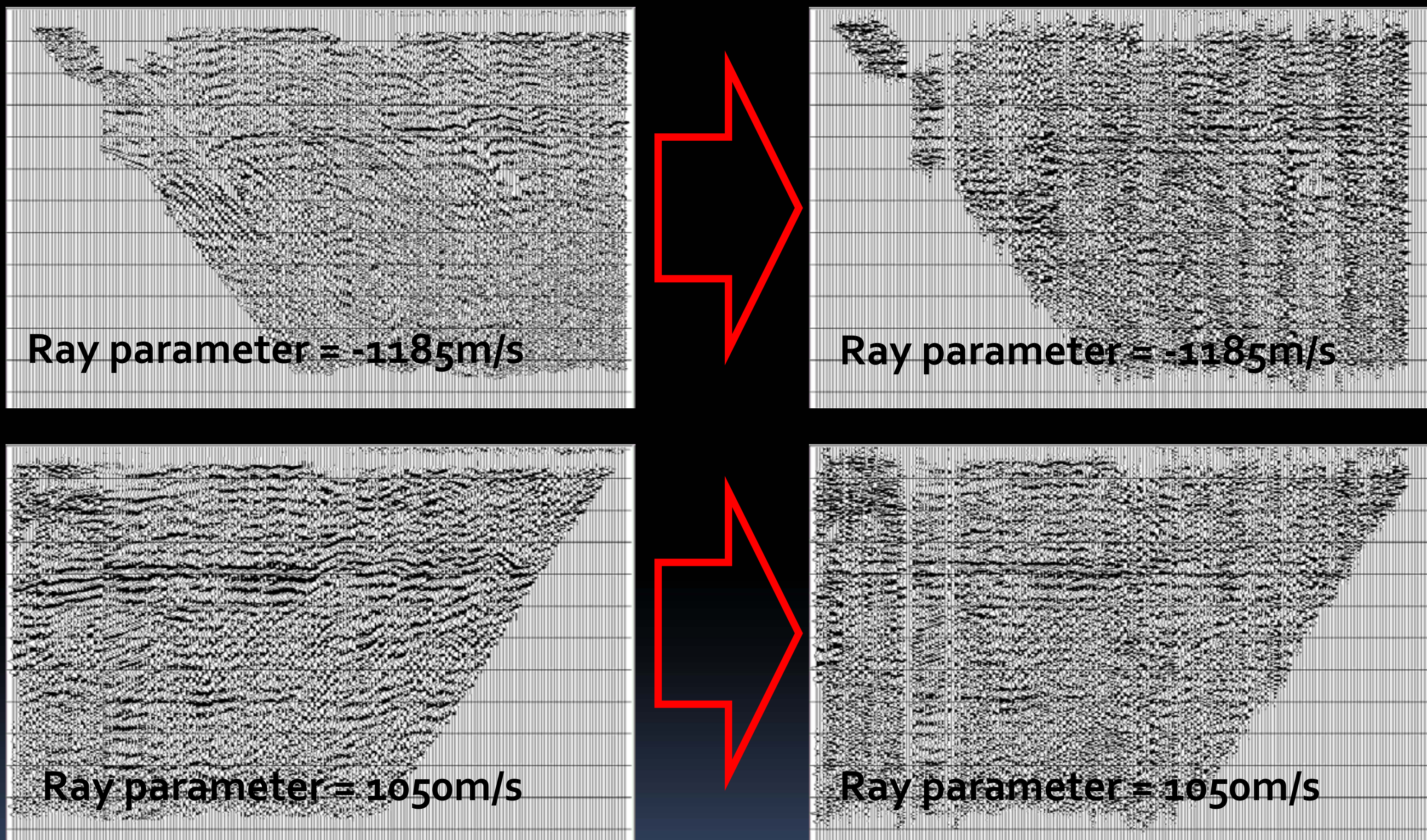
Interferometric correction

- Based on ***optical*** interferometry concept
- Uses ***cross-correlations*** to correct ***degraded wavefronts***
- Requires estimate of ‘***reference wavefield***’
  - ***Several*** approaches possible
  - Successive approximation possible
  - ‘Brute force’ methods help convergence

Interferometry concept



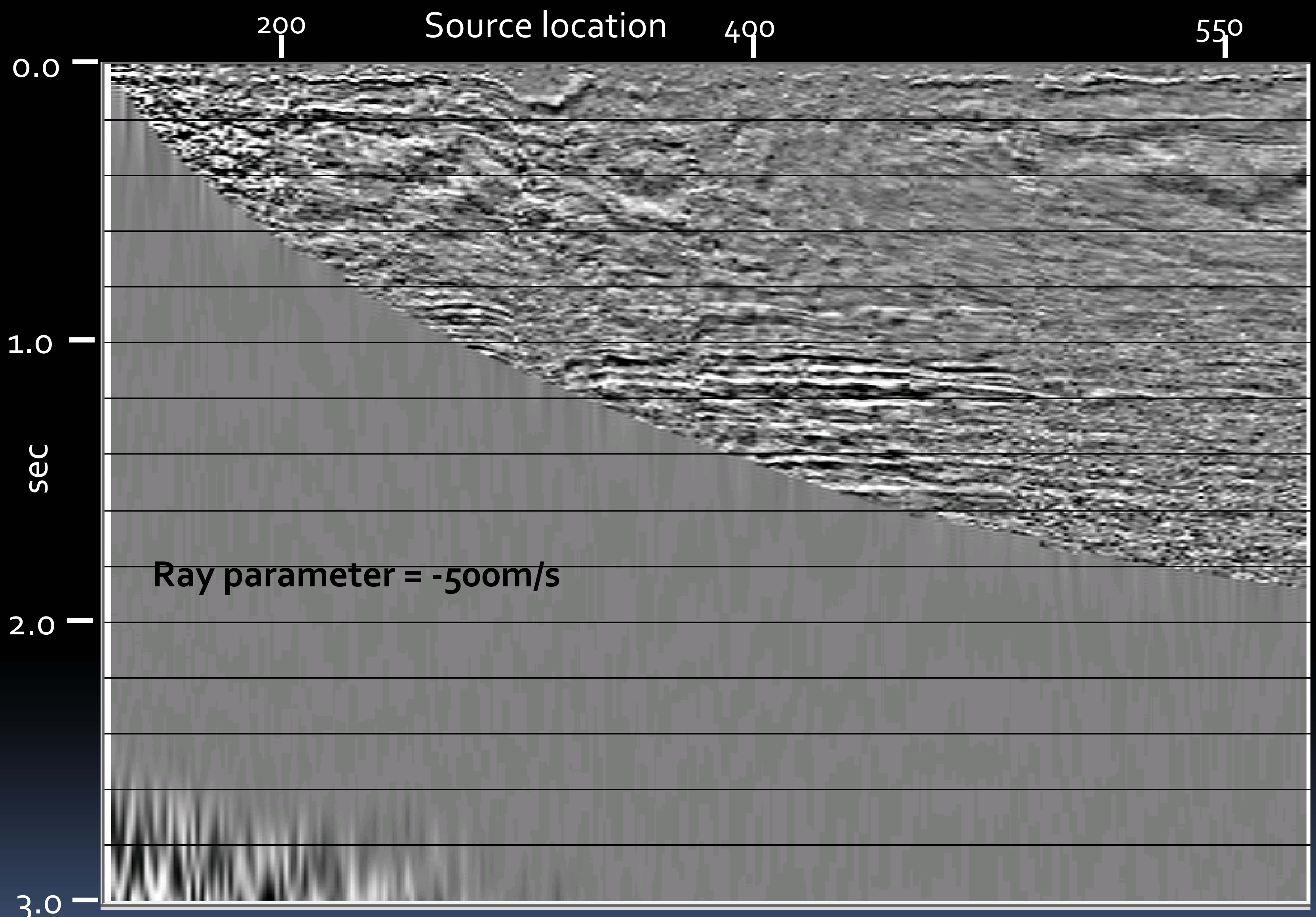
Common-raypath interferometry



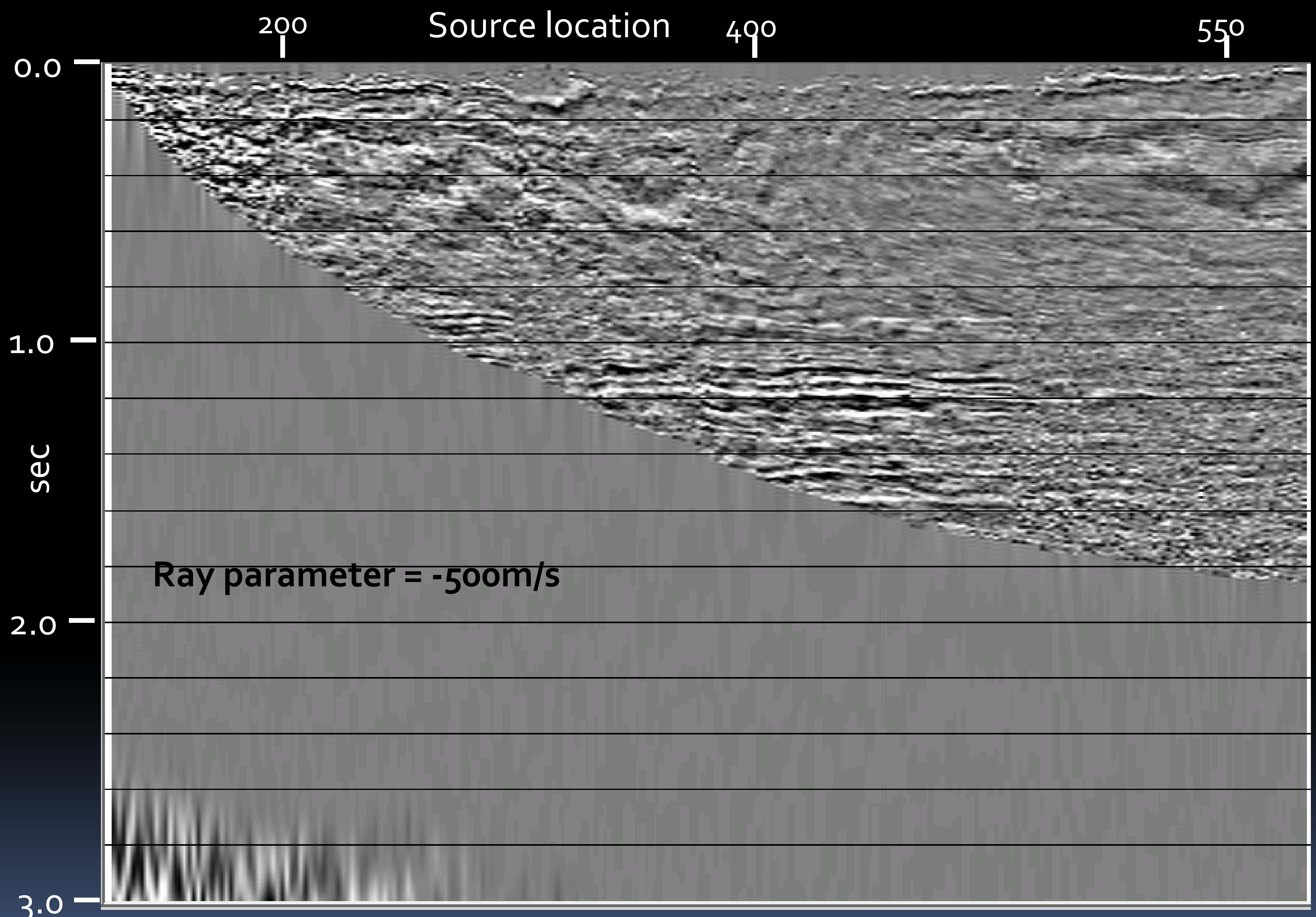
Interferometry applied to ***raw*** common-raypath panels (left) produces ***corrected*** panels (right)

Reference wavefield construction

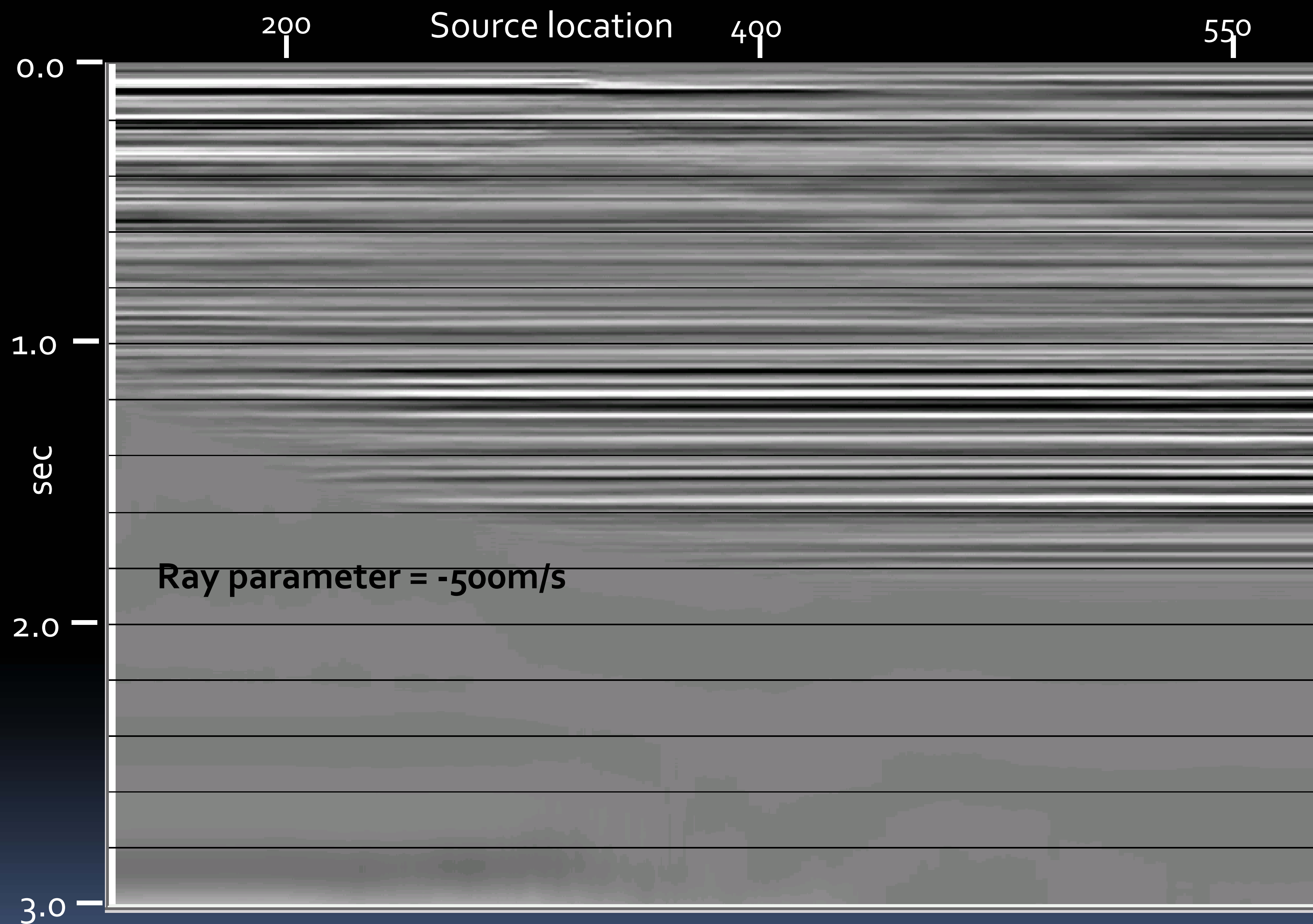
- ***Lateral smoothing*** of raw data ensemble along ***reference horizon***
  - ***Trim statics*** can help ***convergence,*** but not necessary
- ***SVD estimation*** of low-order components of wavefield along ***reference horizon***
  - ***Median smooth*** required to fill gaps



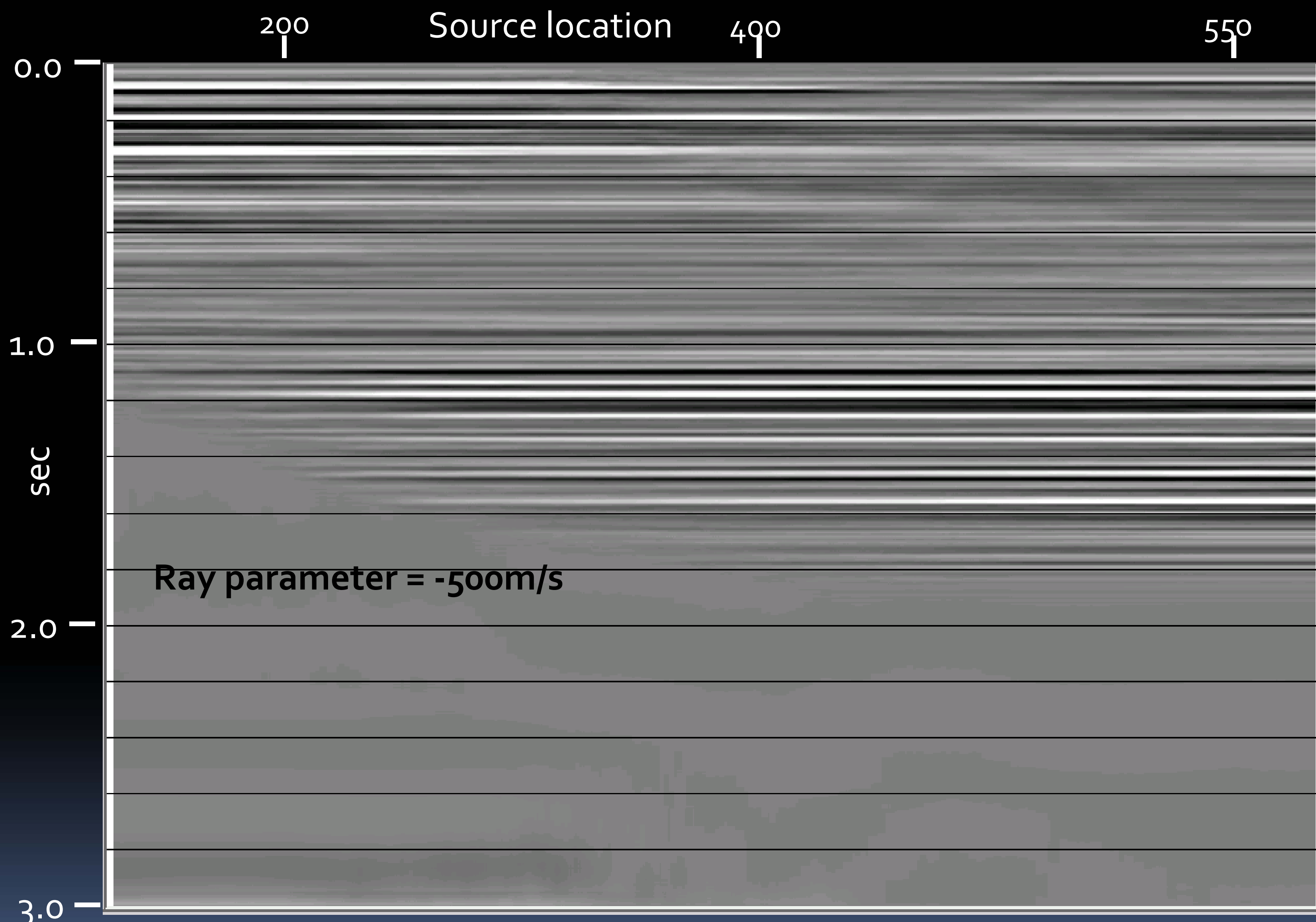
Raw ***common-raypath*** panel for Hussar PP



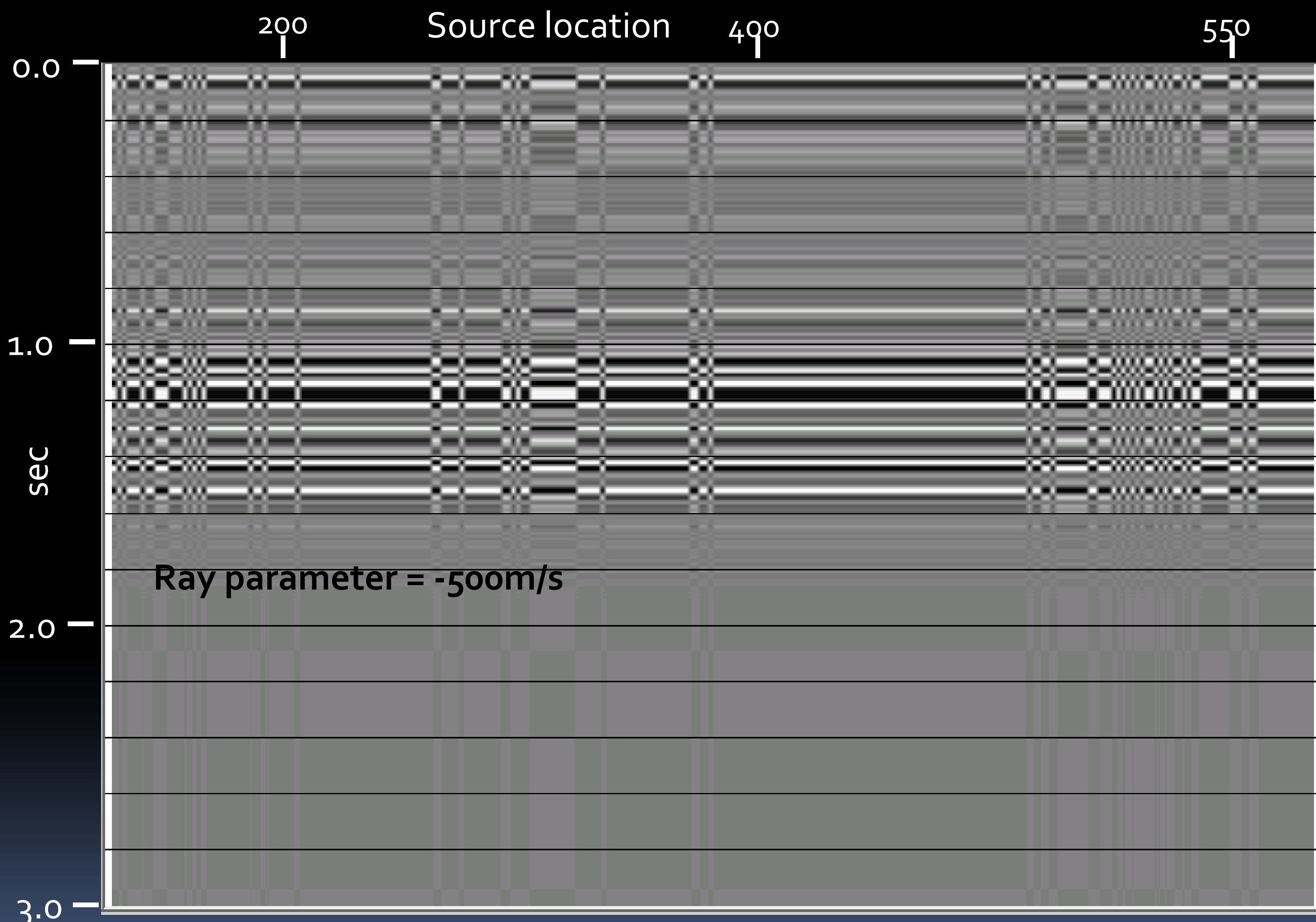
Common-raypath panel for Hussar PP with horizon ***flattening*** applied



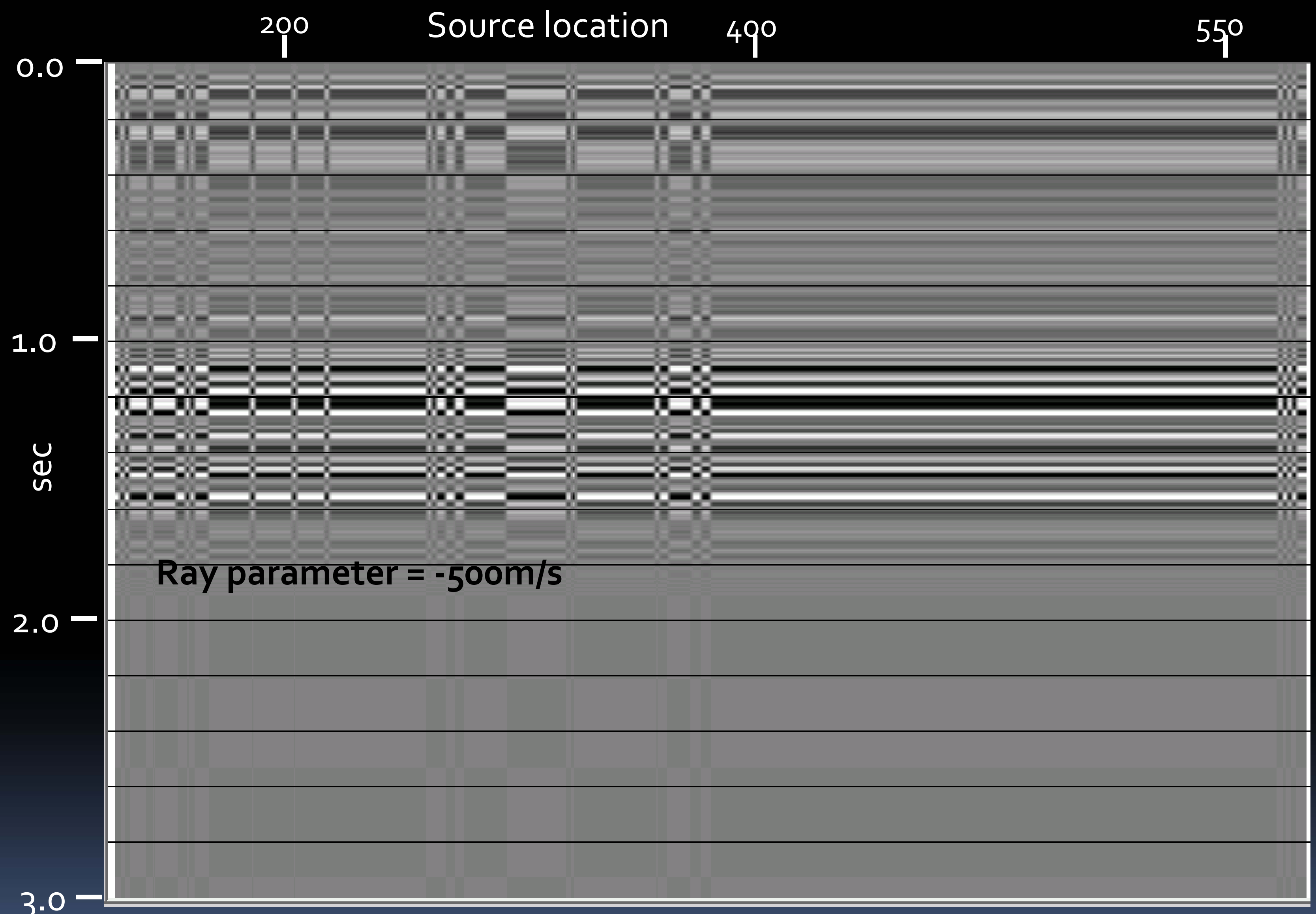
Reference wavefield estimate from ***smoothing along horizon***



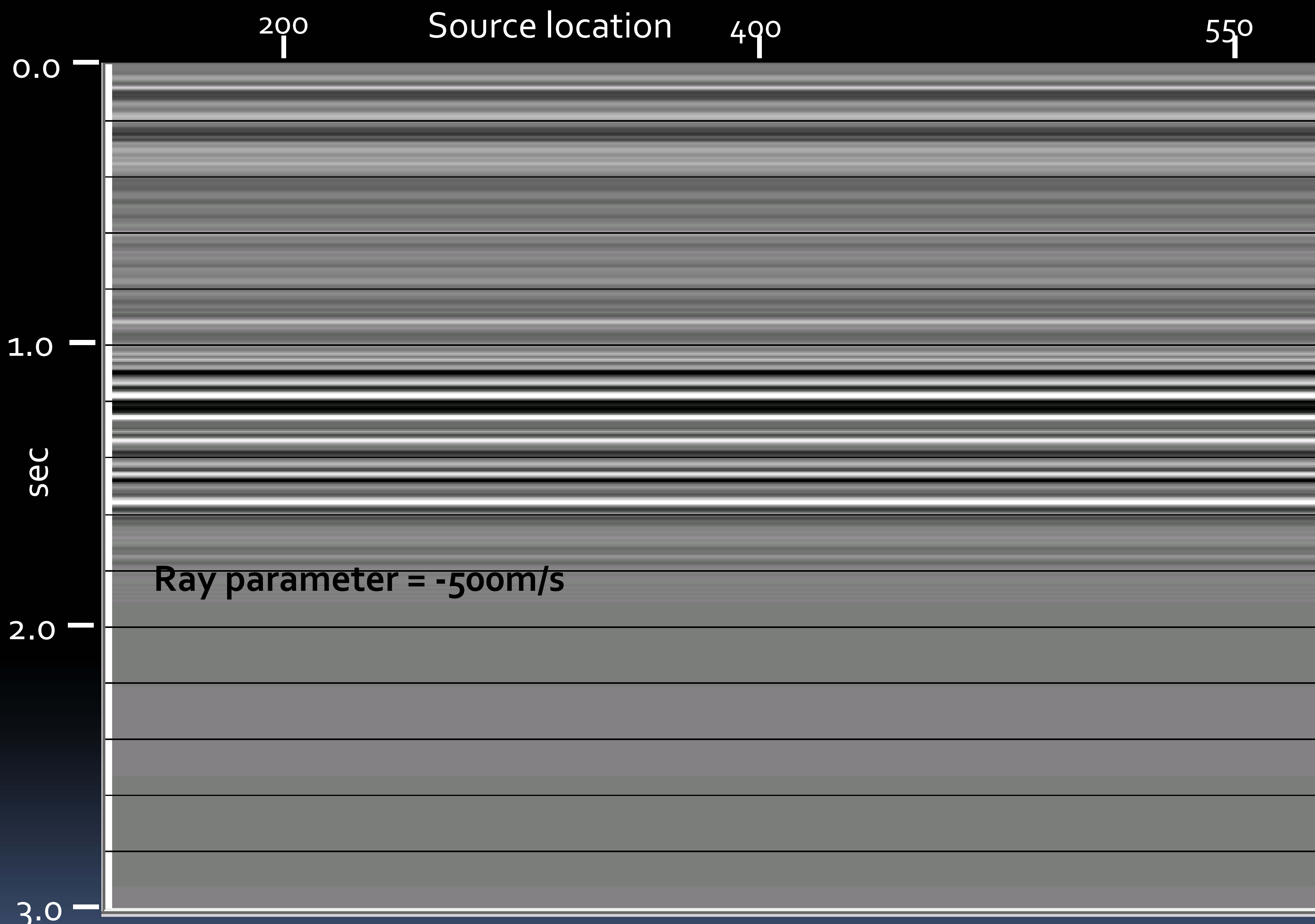
Reference wavefield estimate from ***smoothing along horizon + trim statics***



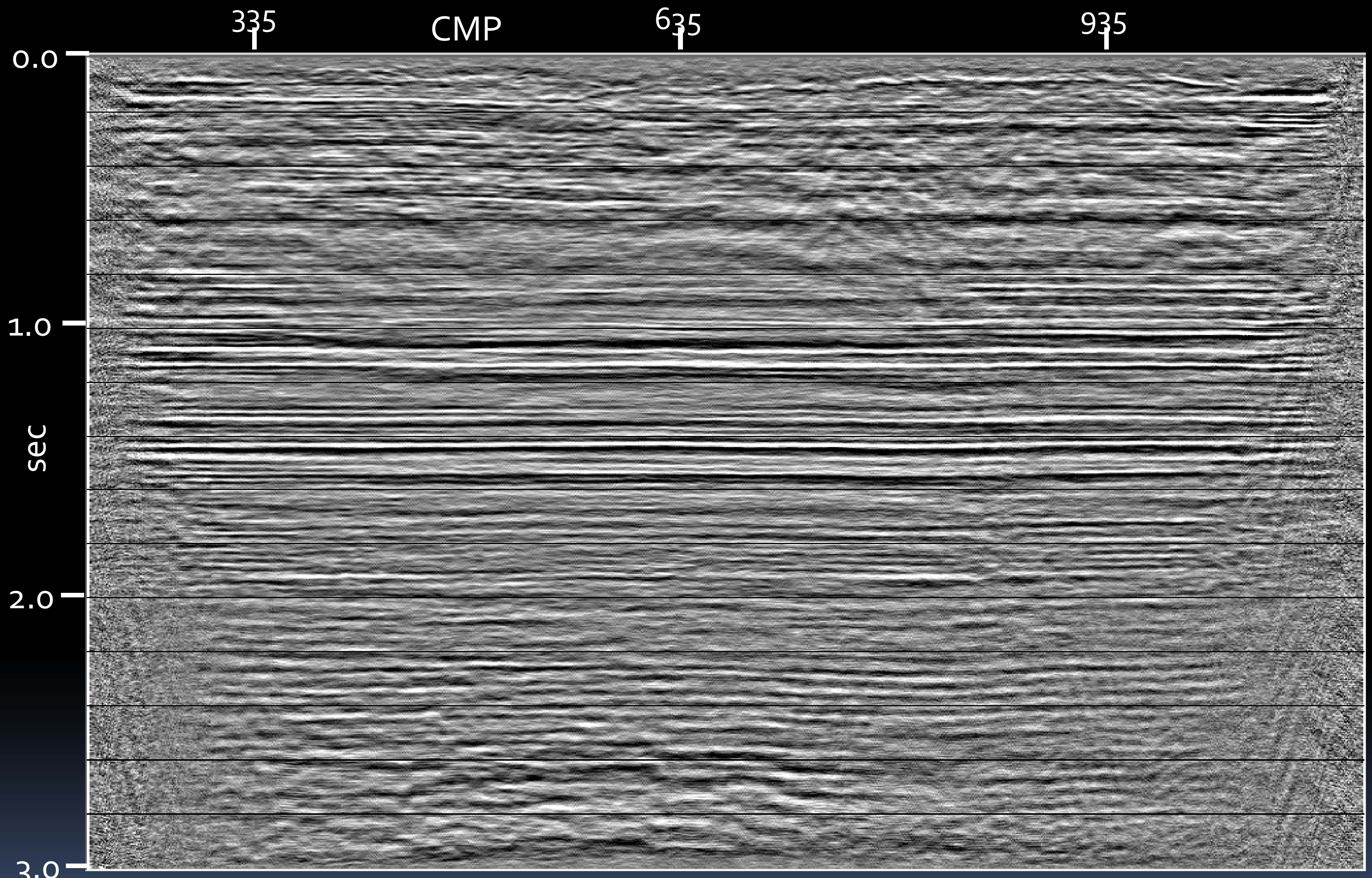
Reference wavefield estimate from low-order ***SVD along horizon***



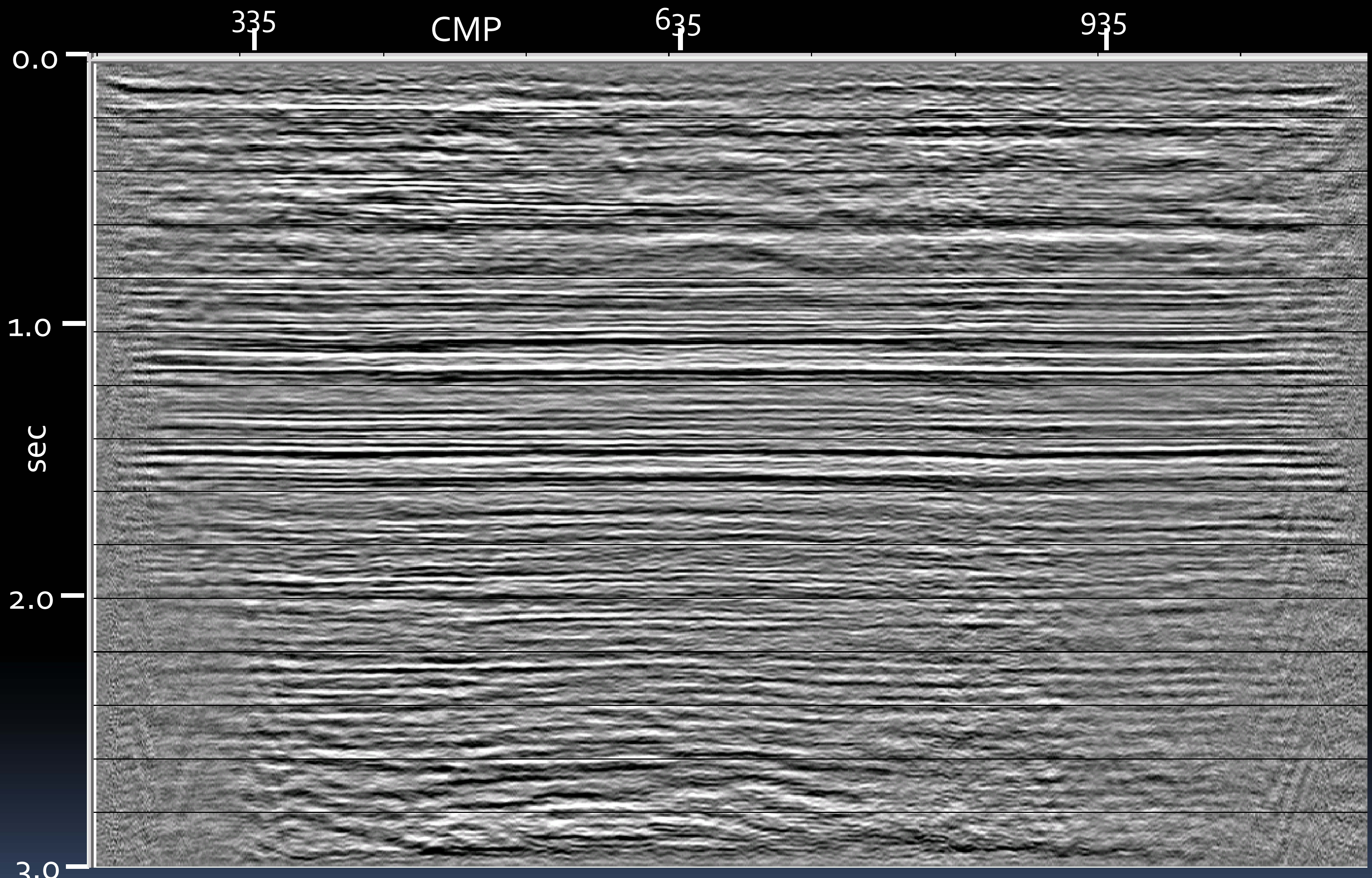
Reference wavefield estimate from low-order ***SVD along horizon*** + ***trim statics***



Reference wavefield estimate from low-order ***SVD***
+ median smooth, with or without ***trim statics***



Hussar PP raypath interferometry—***horizon-smoothed*** wavefield estimate



Hussar PP raypath interferometry—***0-2% low-order SVD along horizon*** wavefield estimate

The raypath domain

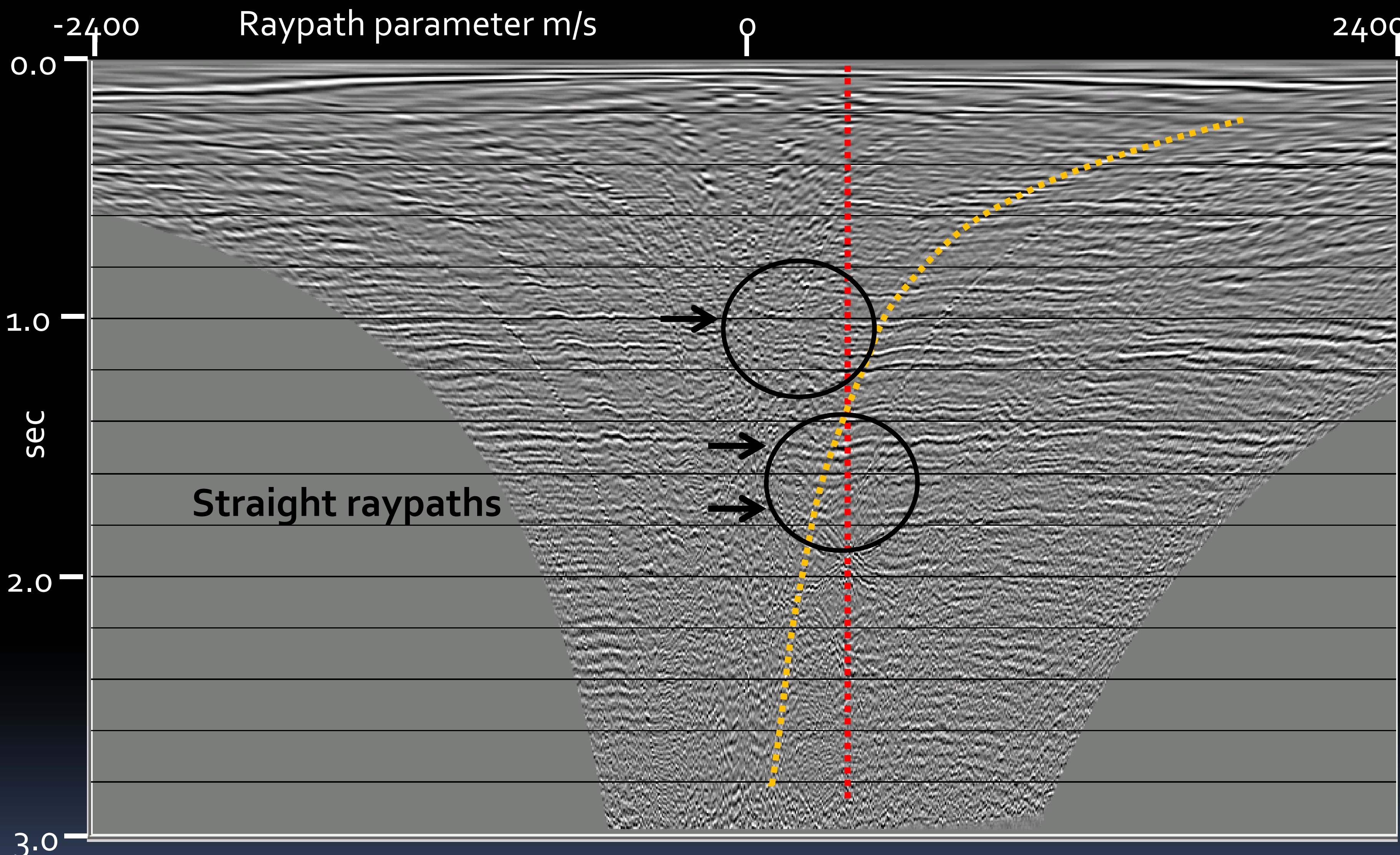
- Enables statics solutions for data which violate ***surface-consistency***
- Inherently ***nonstationary*** (time-varying)
- Several ***'raypath' transforms*** available

Raypath transforms

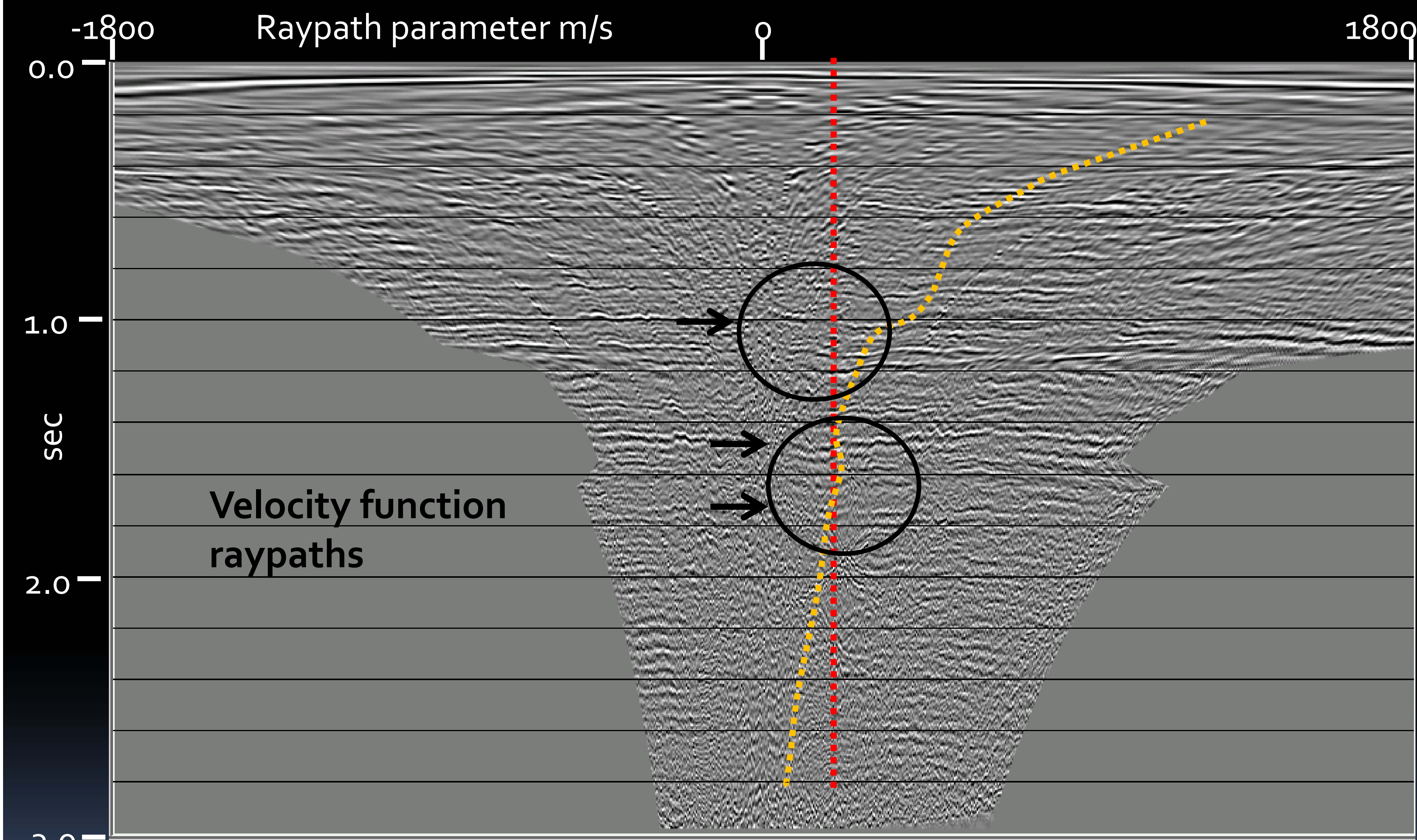
- ***Radial Trace Transform*—*exactly invertible***, raypaths only ***approximate***
- ***Snell Ray Transform*—*exactly invertible***, requires ***velocities***
- ***Tau-P transform*—*no velocities*** needed, but only ***approximately invertible*** (Cova et al)

Hussar PP

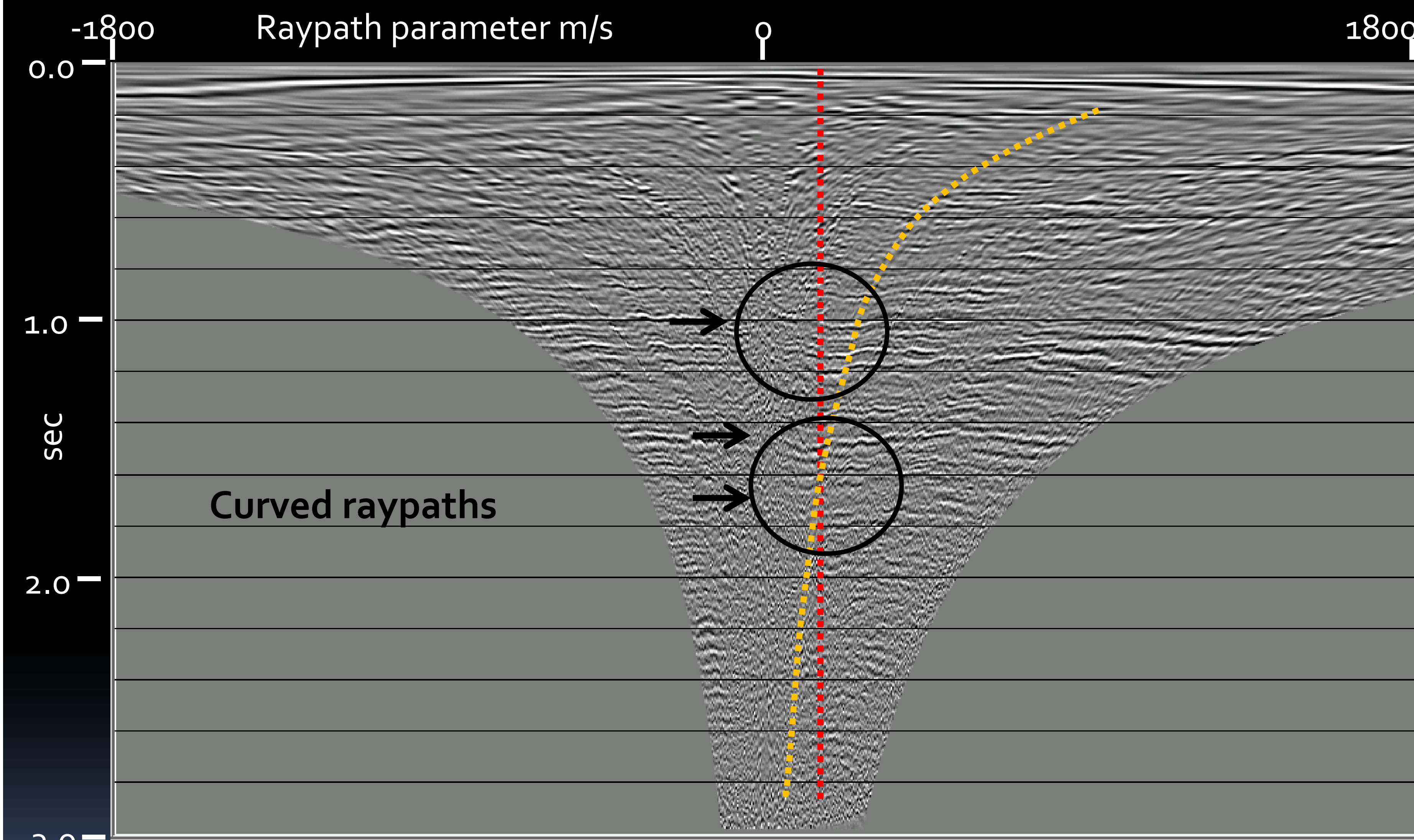
- ***Conventional statics*** and residual NMO analysis ***work well***
- ***Surface consistency*** is ***not violated*** for these data
- ***Raypath domain*** provides an ***alternate solution space***



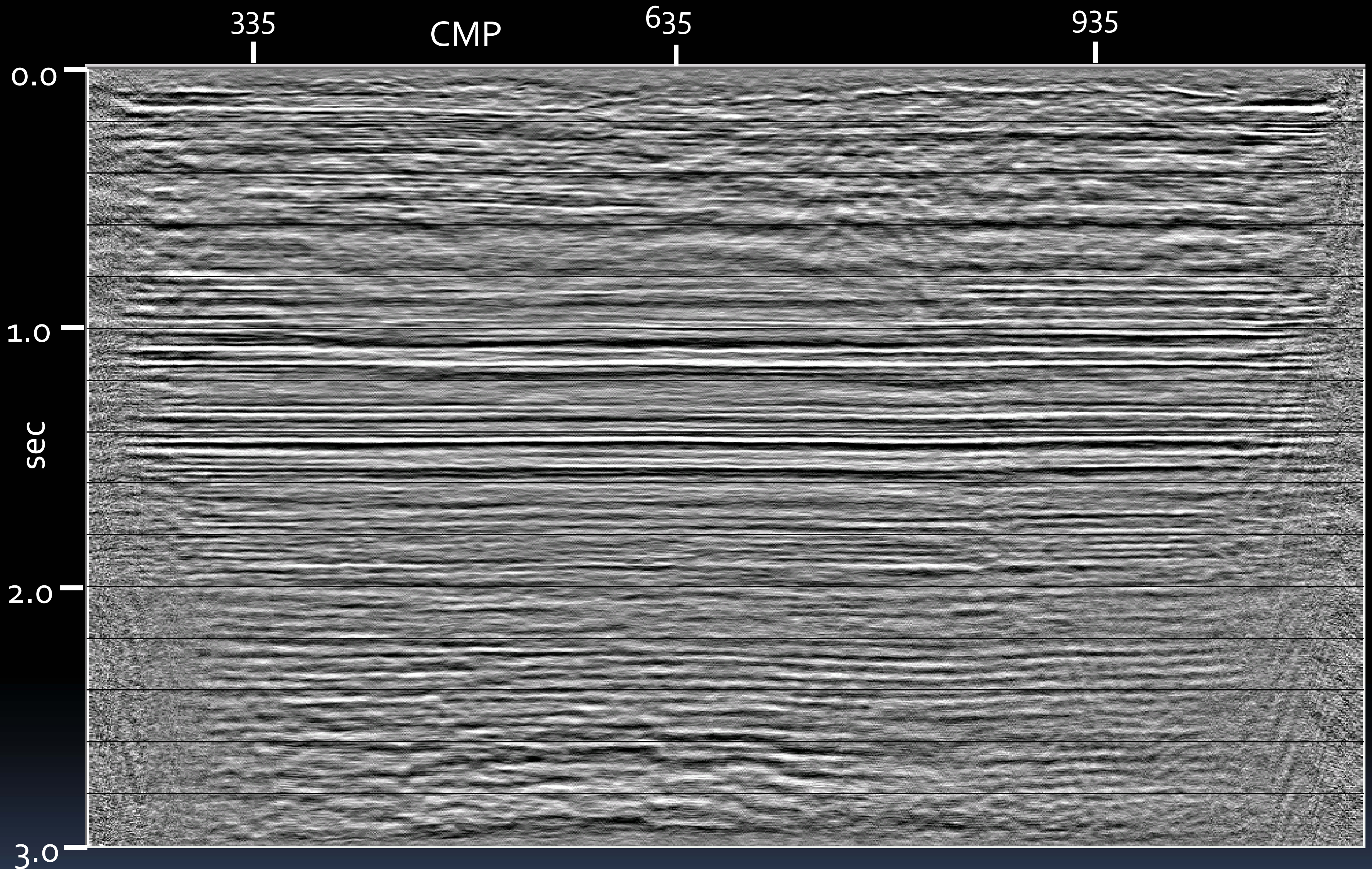
Radial Trace Transform—approximate raypath domain



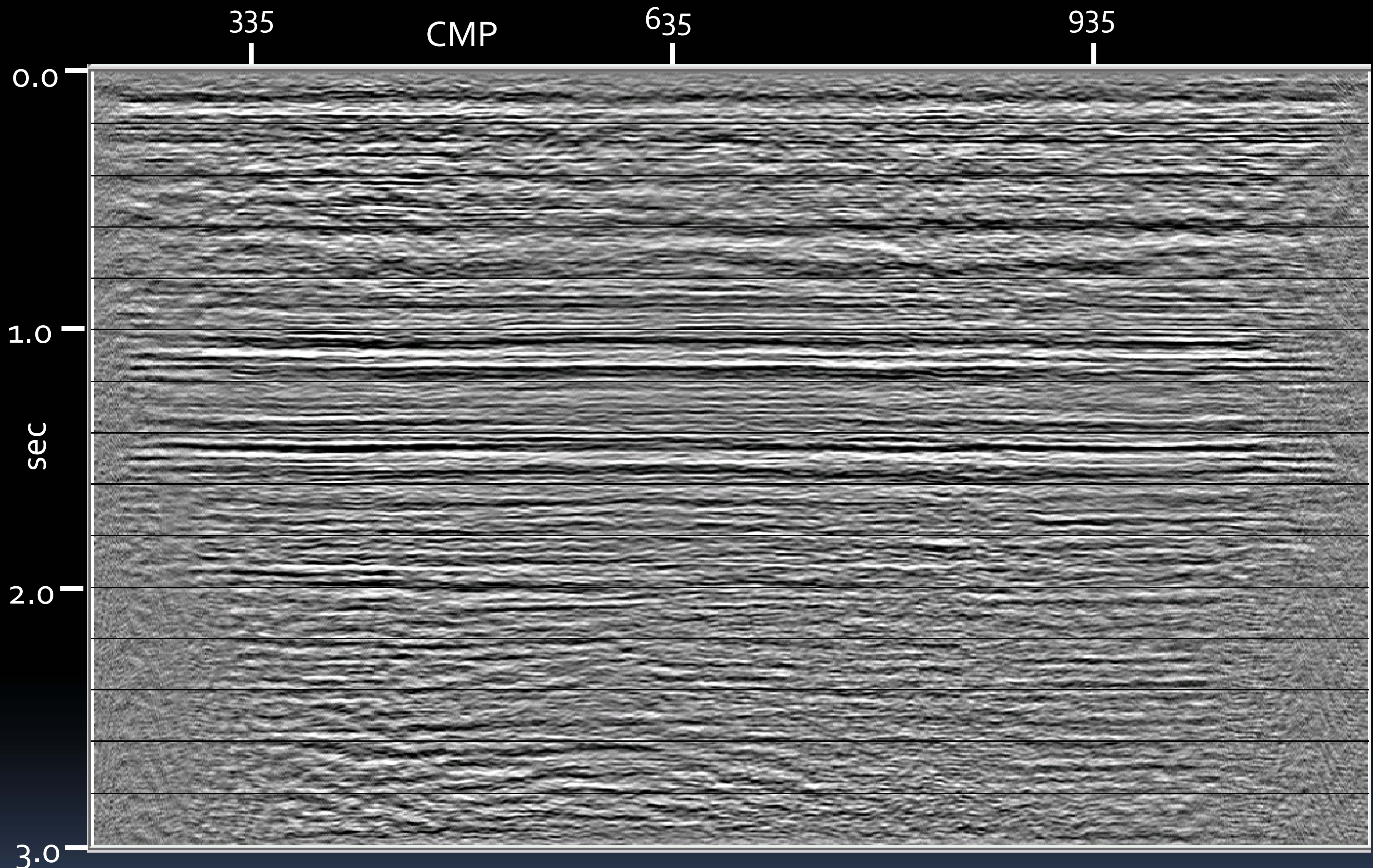
Snell Ray Transform option 1—improved raypath domain



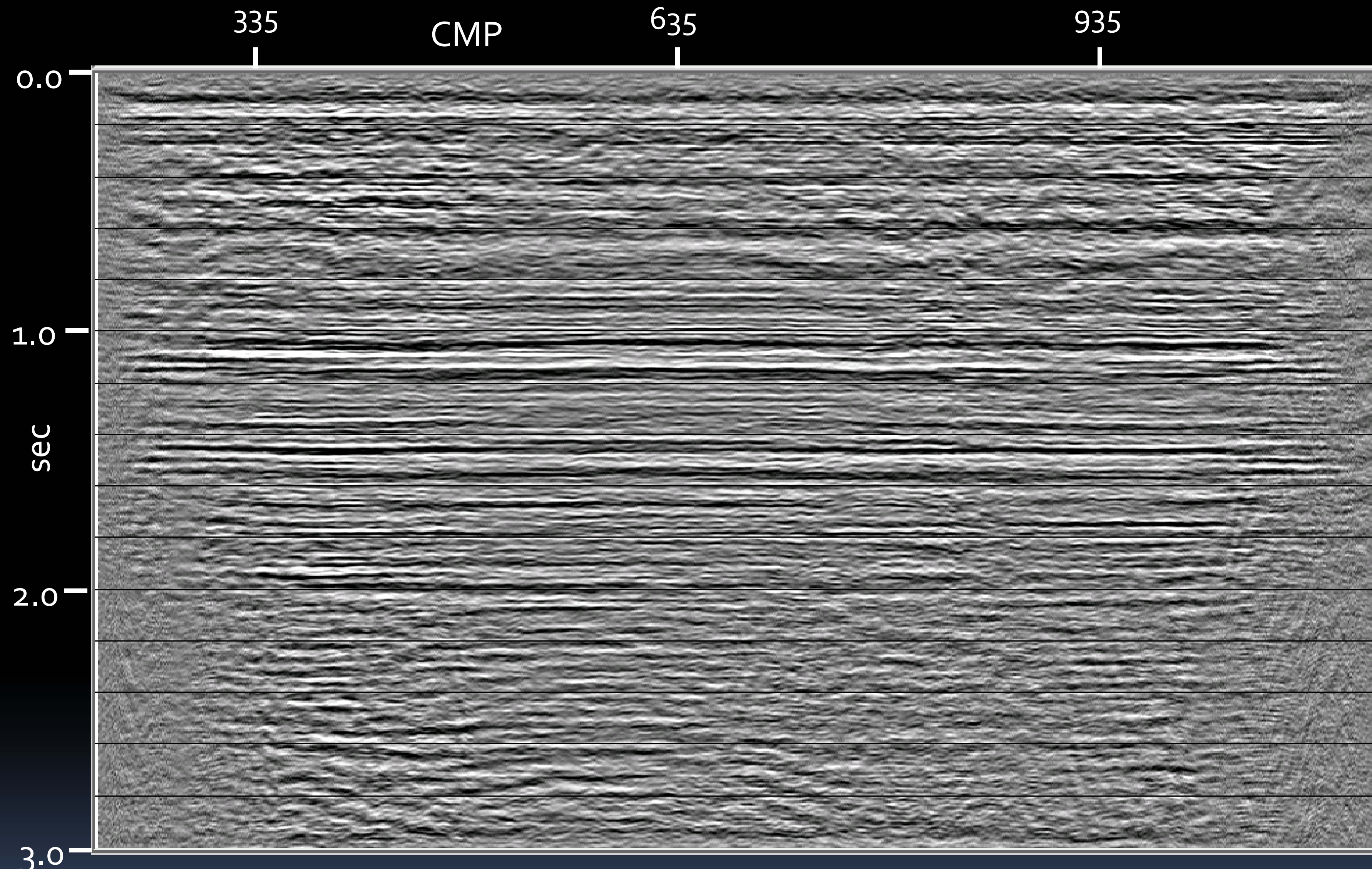
Snell Ray Transform option 2—improved raypath domain



Radial Trace Transform—***straight raypaths***



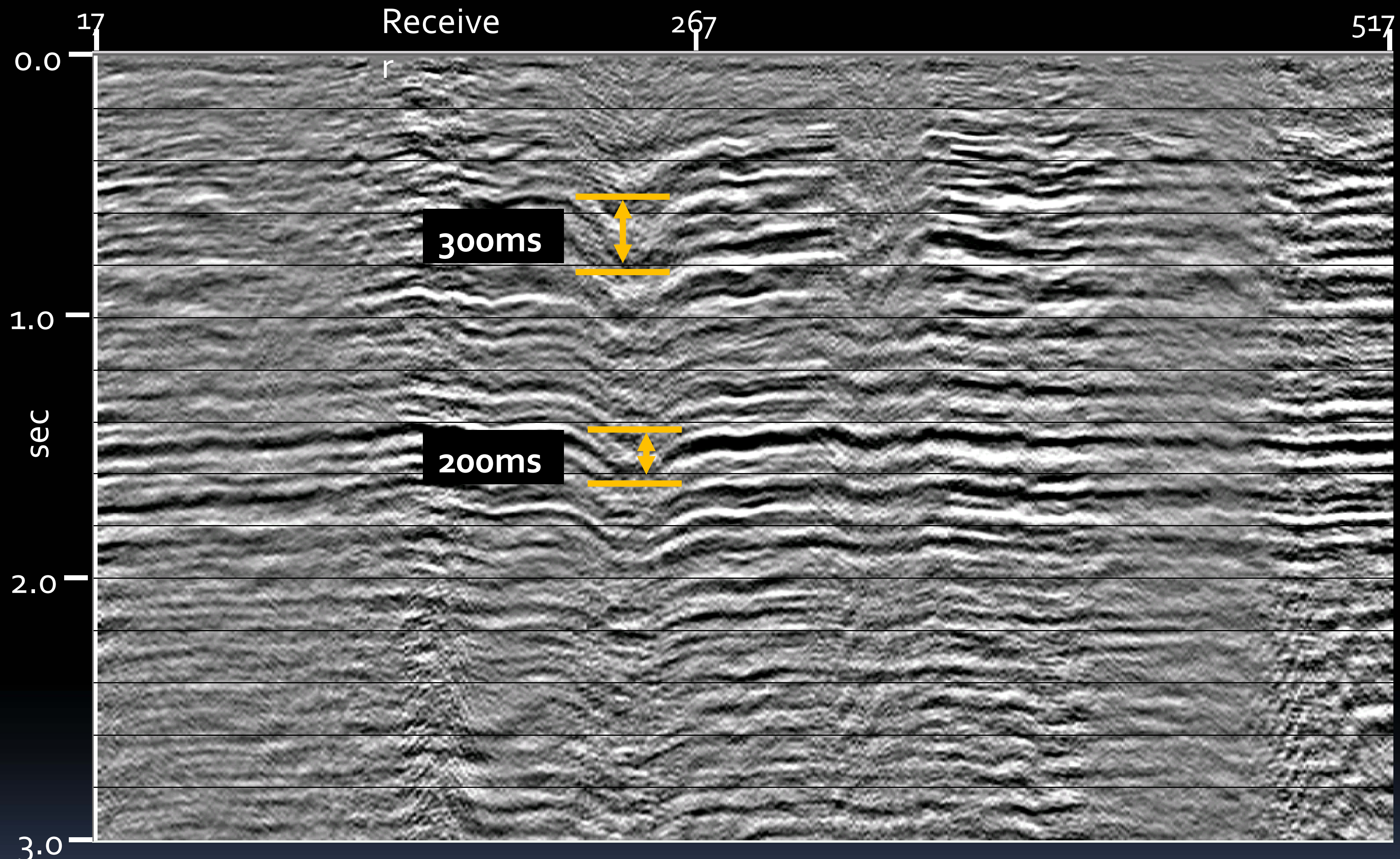
Snell RayTransform—***velocity function raypaths***



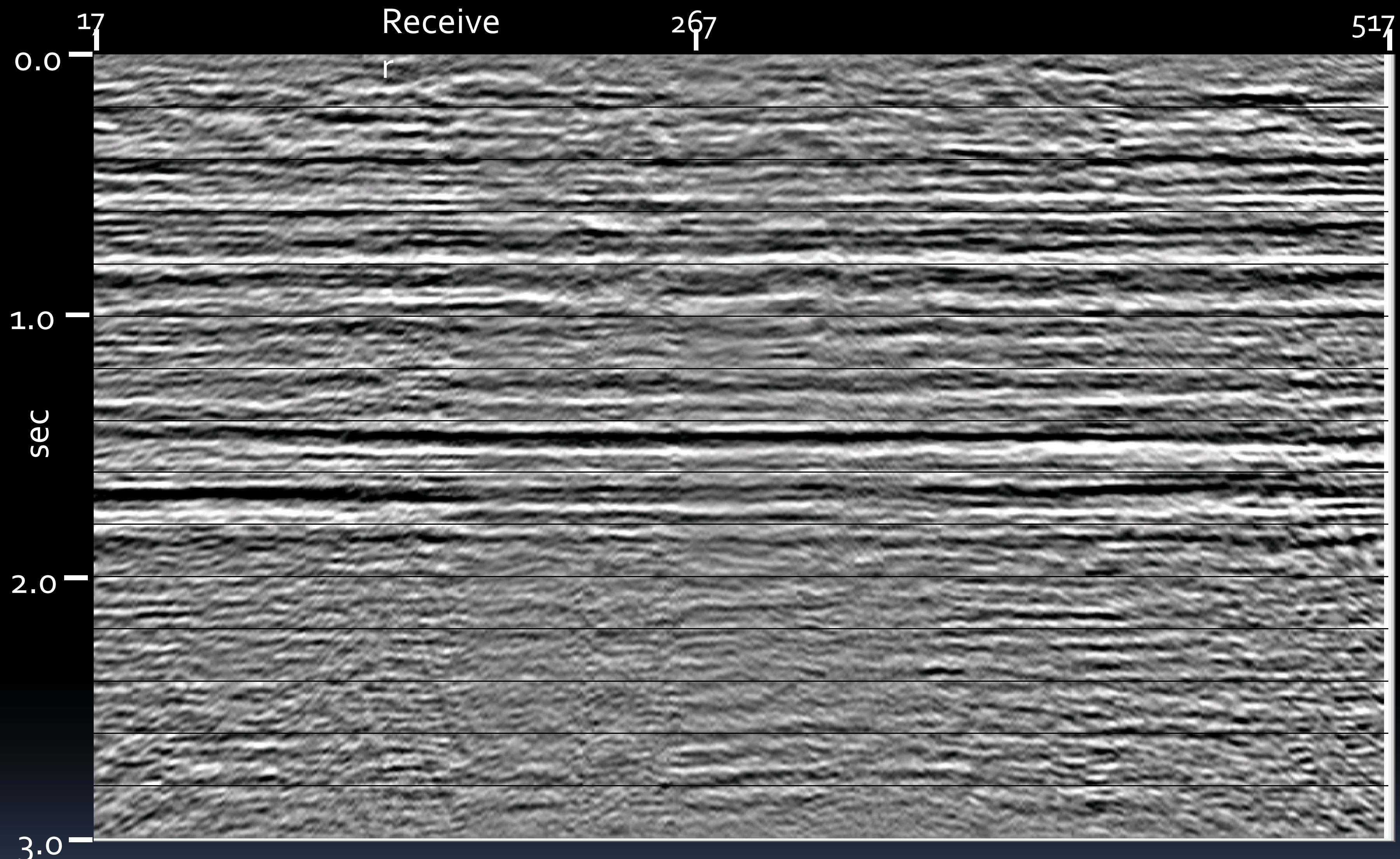
Snell Ray Transform—***curved raypaths***

Hussar PS

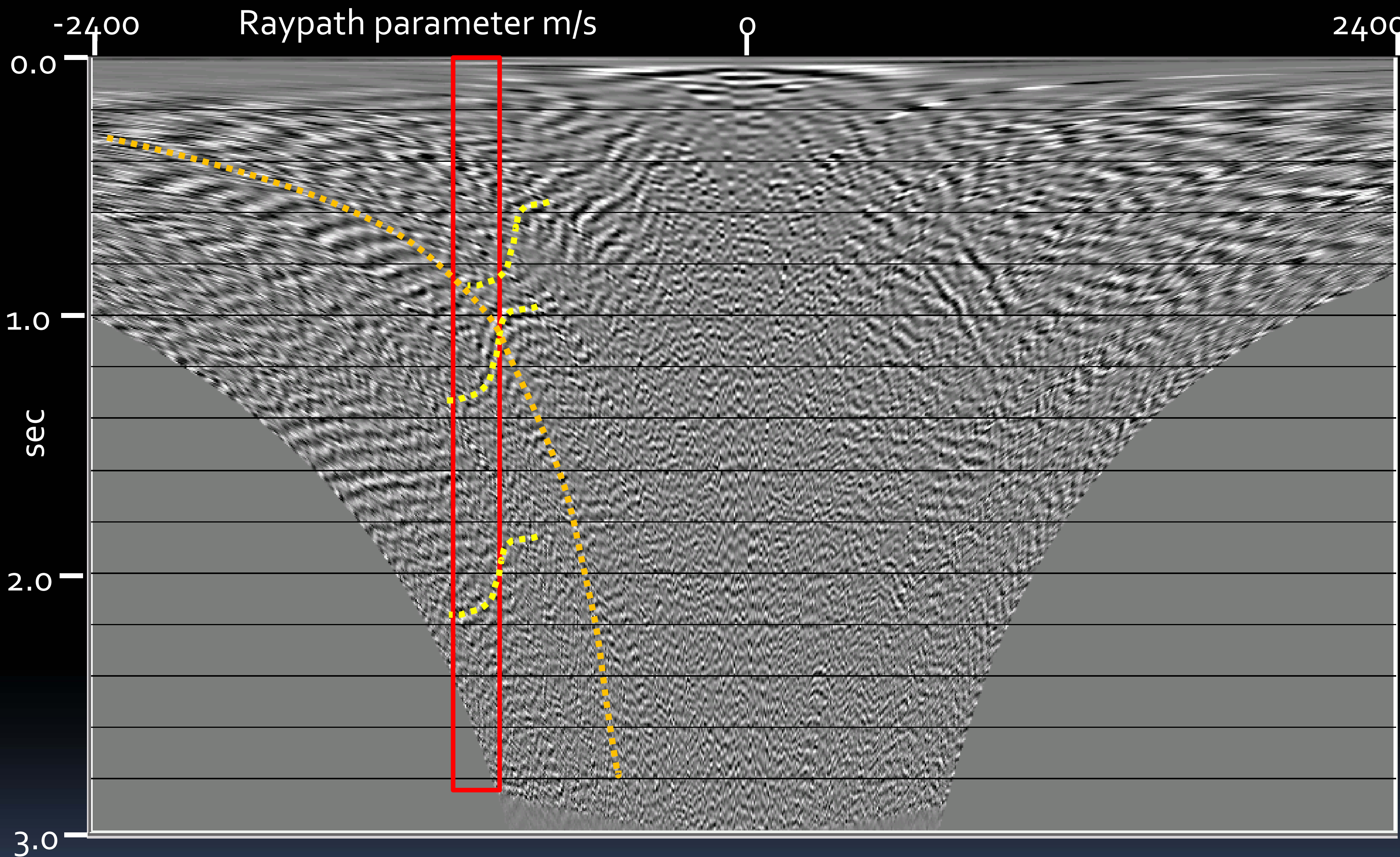
- ***Conventional statics*** and ***NMO*** analysis provide ***adequate*** solution for ***deeper reflections***
- Statics appear to be ***nonstationary***
- ***Raypath domain*** provides ***increased redundancy*** and better statics estimates due to ***'common-raypath'***



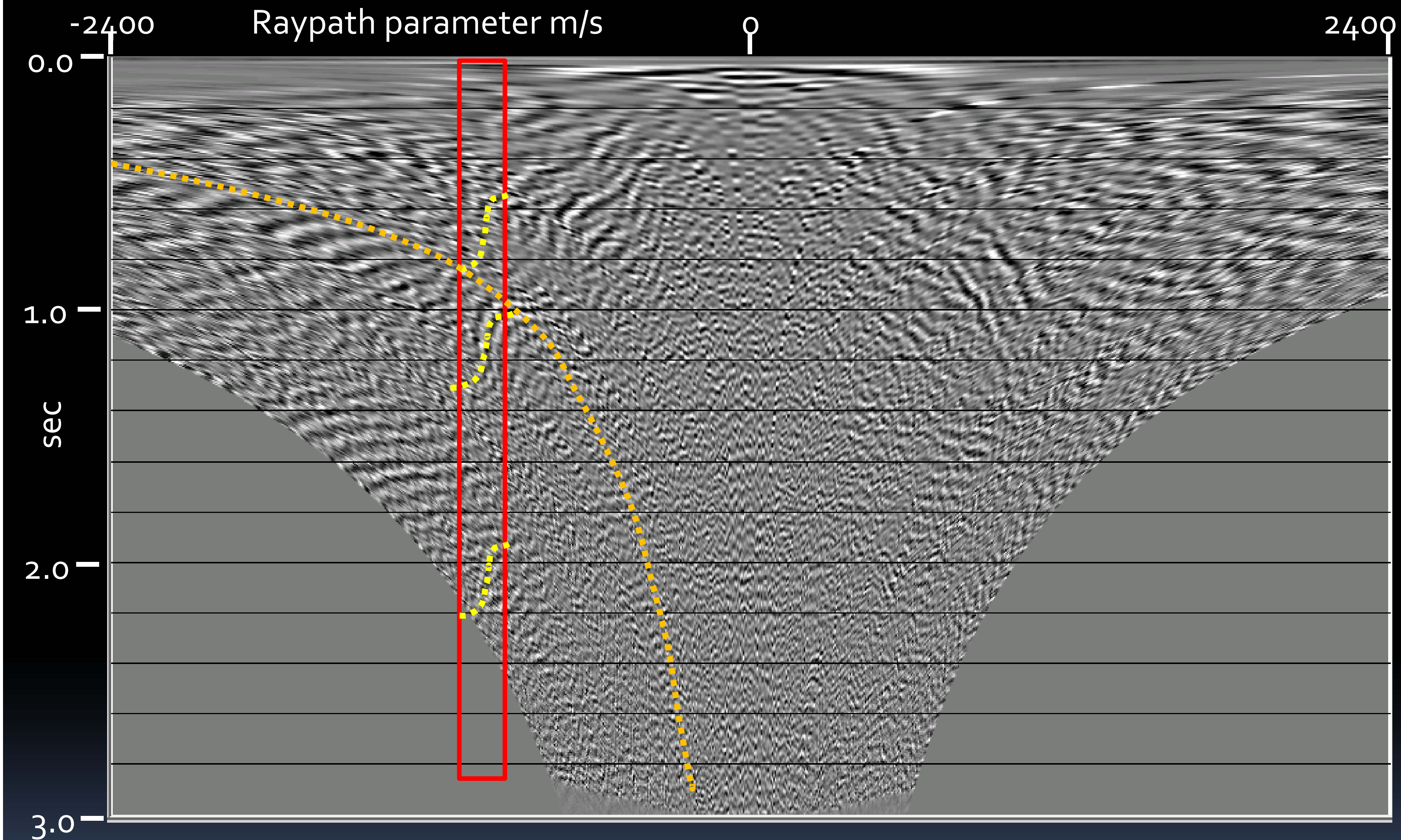
Common-receiver stack—evidence of ***nonstationary statics*** on Hussar PS data



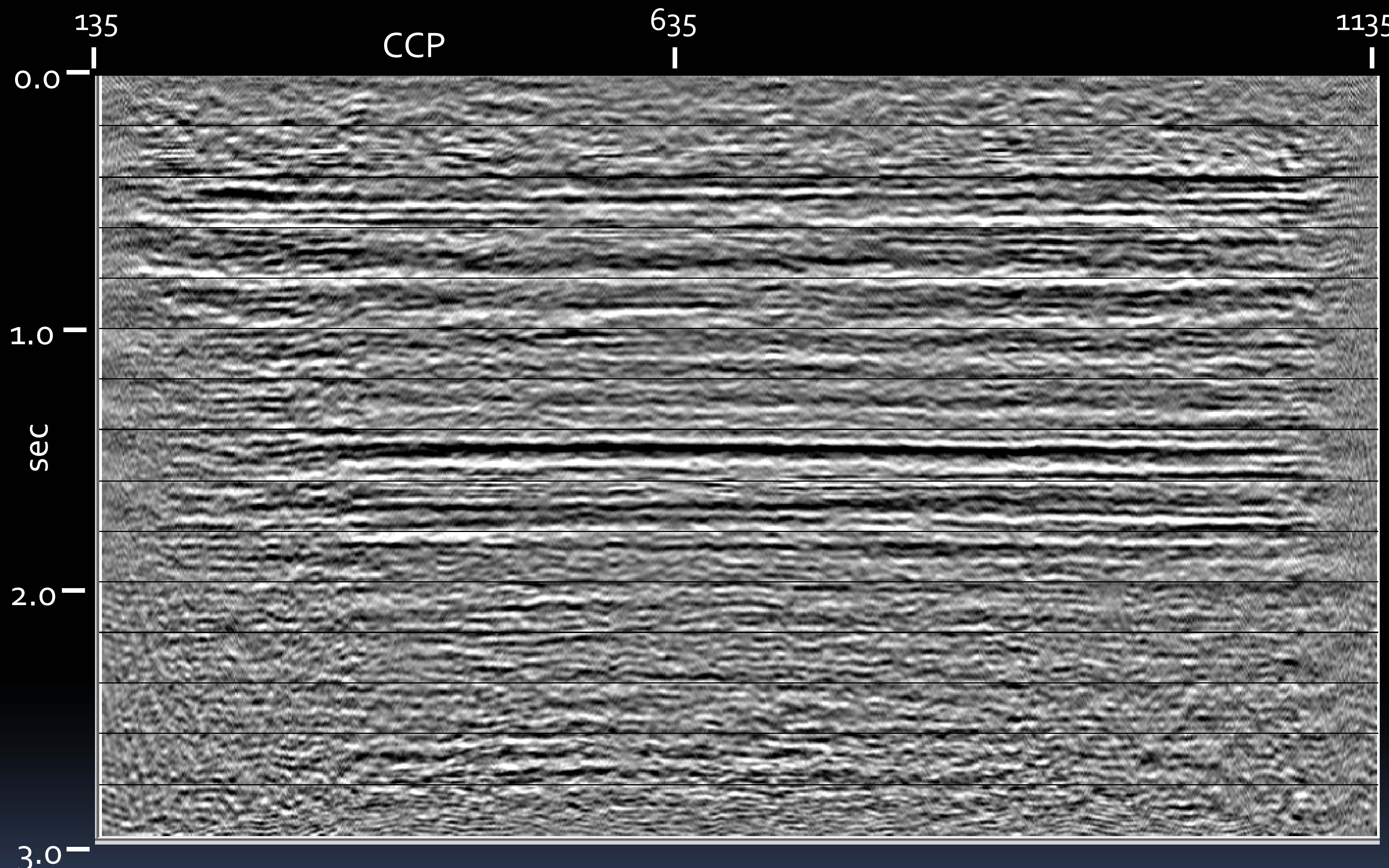
Common-receiver stack after raypath interferometry—
no NMO adjustment required



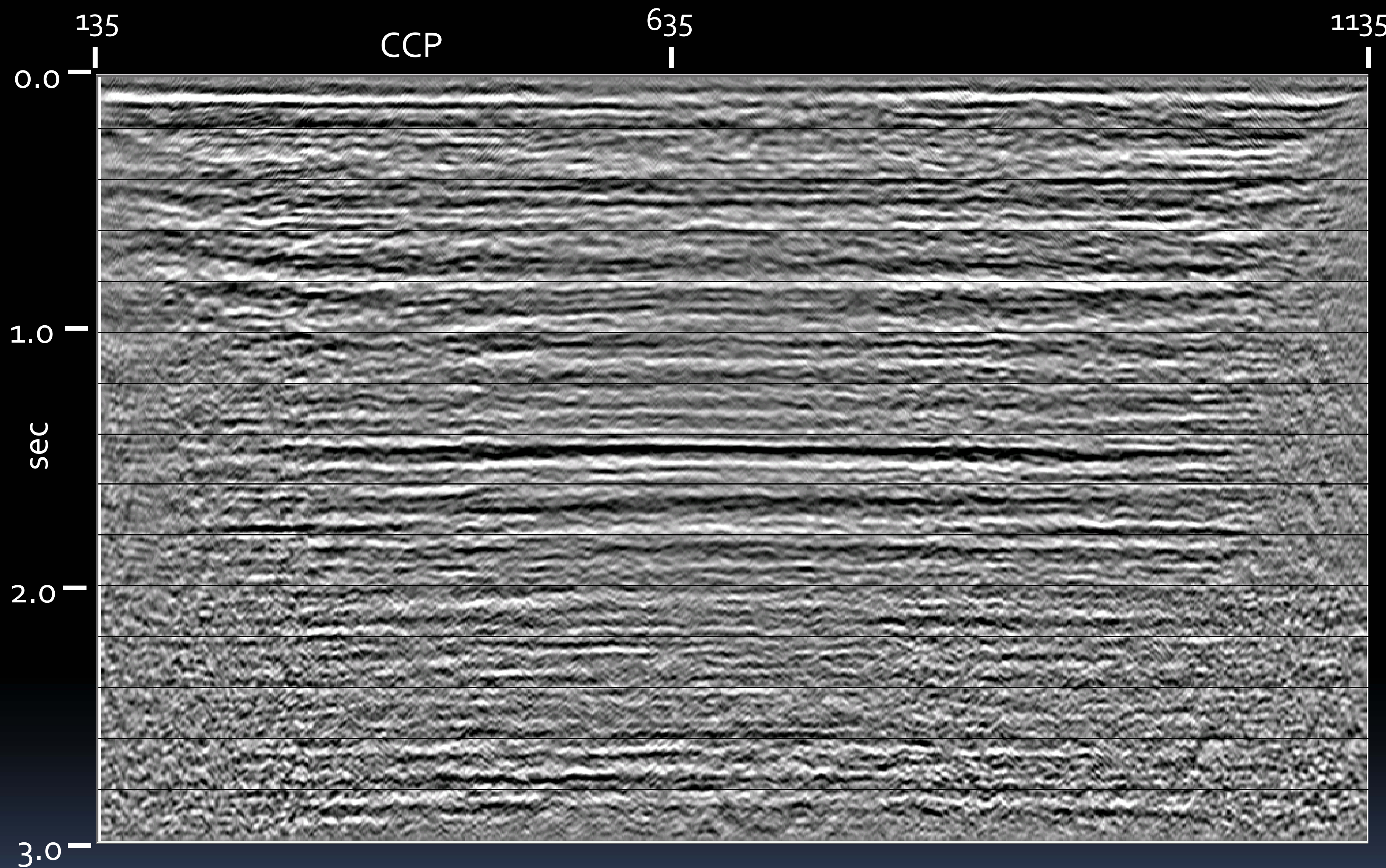
Radial Trace Transform—*straight raypaths*



Snell Ray Transform—***curved raypaths***



CCP stack of Hussar PS—***Radial Trace Transform***:
straight raypaths



CCP stack of Hussar PS—***Snell Ray Transform***:
curved raypaths

Conclusions

- ***Reference wavefield*** can be estimated using ***trace mixing*** or ***SVD***
  - Horizon ***flattening needed*** for either method
  - ***Trim statics*** can speed convergence
- ***Raypath domain*** can be entered using ***Radial Trace Transform***, ***Snell Ray Transform***, or ***Tau-P Transform*** ***(See Cova et al, following)***
  - ***Snell Ray transform*** seems to improve performance
  - ***Tau-P Transform*** demonstrated by Cova et al

Acknowledgements

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- Funding—NSERC
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