CREWES

An interferometric solution for raypath-consistent shear wave statics

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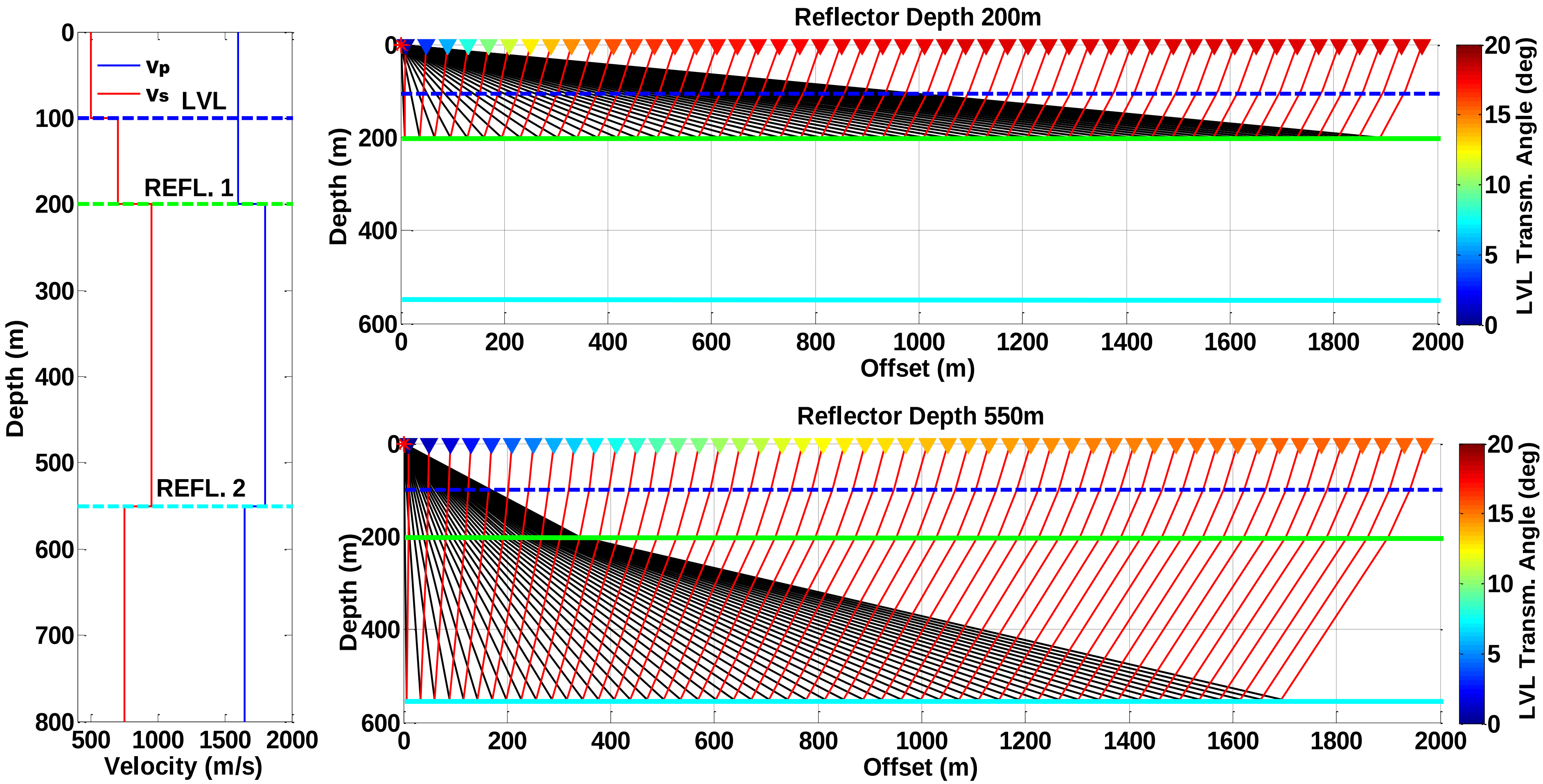
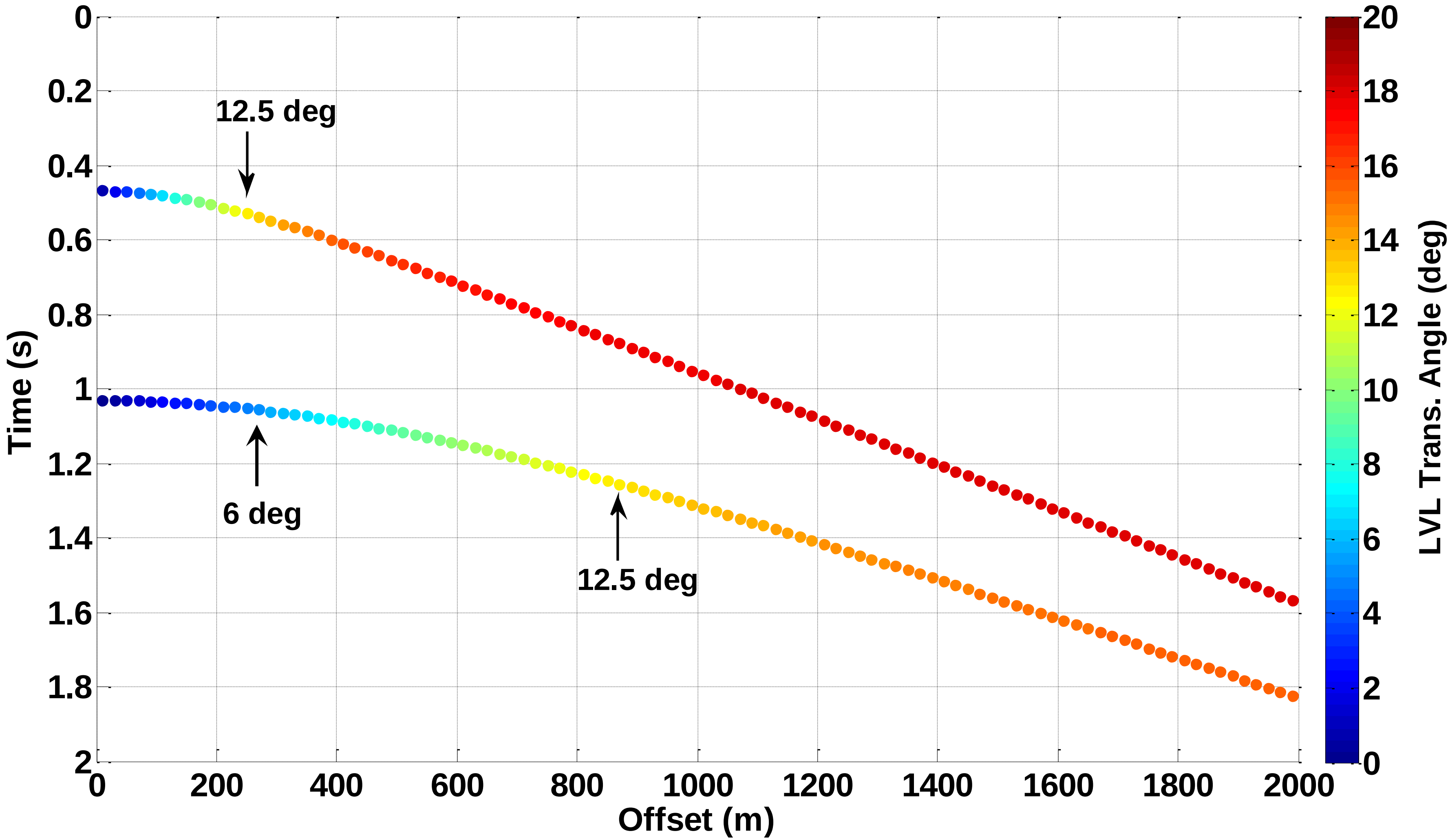
Introduction

- The S-wave statics problem:
  - The near surface "seen" by S-waves is different than the one seen by P-waves (e.g. water table depth).
  - S-wave statics solutions may be independent of P-wave statics.
  - Slow velocities magnify the effect of small changes in the propagation.
  - Non-Stationarity? Why? How to correct them?

PS Ray-Tracing



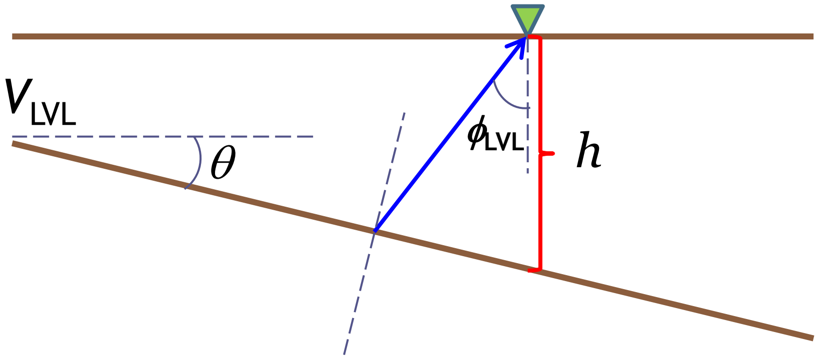
Ray-Tracing



✓ Reflection times with the same transmission angle are recorded at different offsets

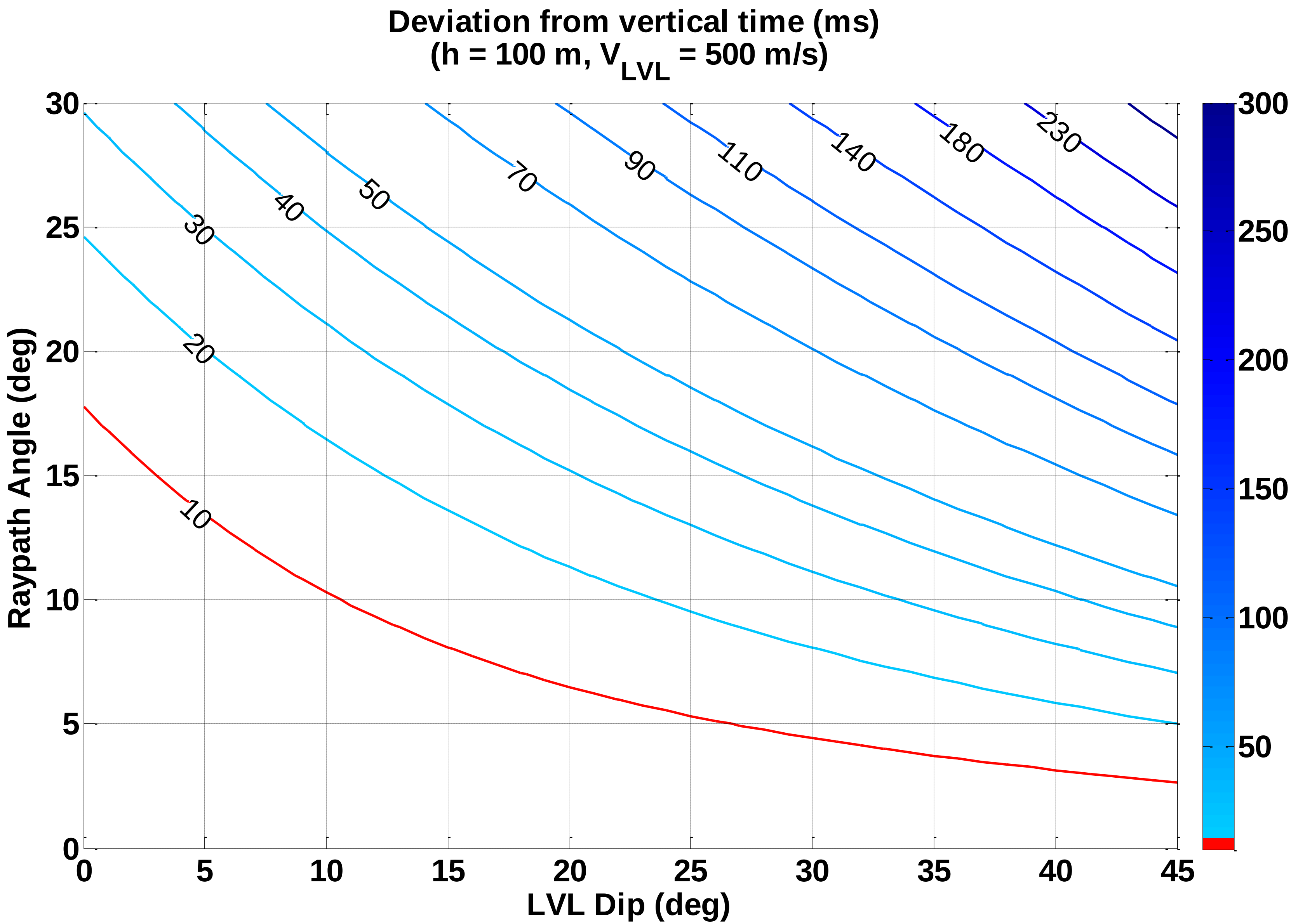
Geometry of the problem

Travel times for a dipping LVL:

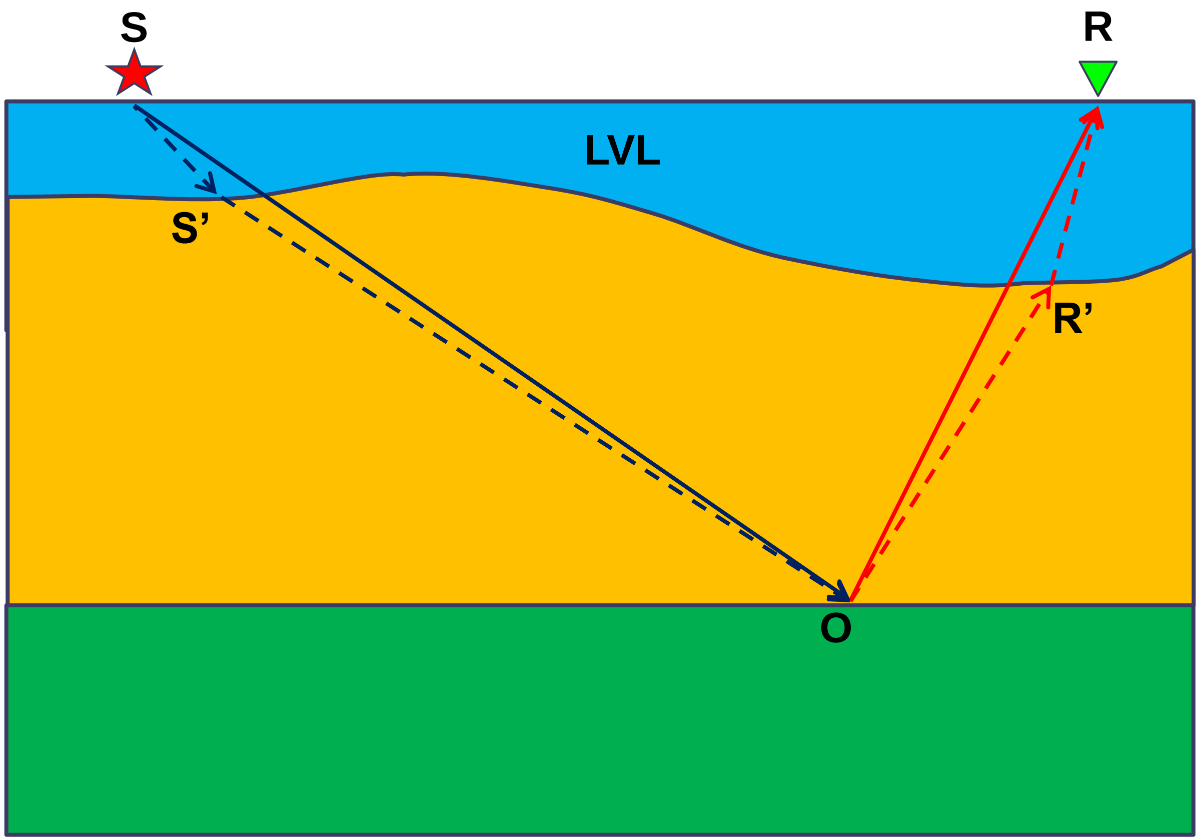


h : Vertical thickness
V : Shear wave velocity
ϕ : Dip of the base of the LVL
θ : Raypath angle

$$t_{calc} = \frac{h}{V_{LVL}} \frac{\cos(\theta)}{\cos(\phi_{LVL} - \theta)}$$


Deviation from vertical time (ms)
(h = 100 m, V_LVL = 500 m/s)
Raypath Angle (deg)
LVL Dip (deg)
0
5
10
15
20
25
30
35
40
45
10
20
30
40
50
70
90
110
140
180
230
300
250
200
150
100
50

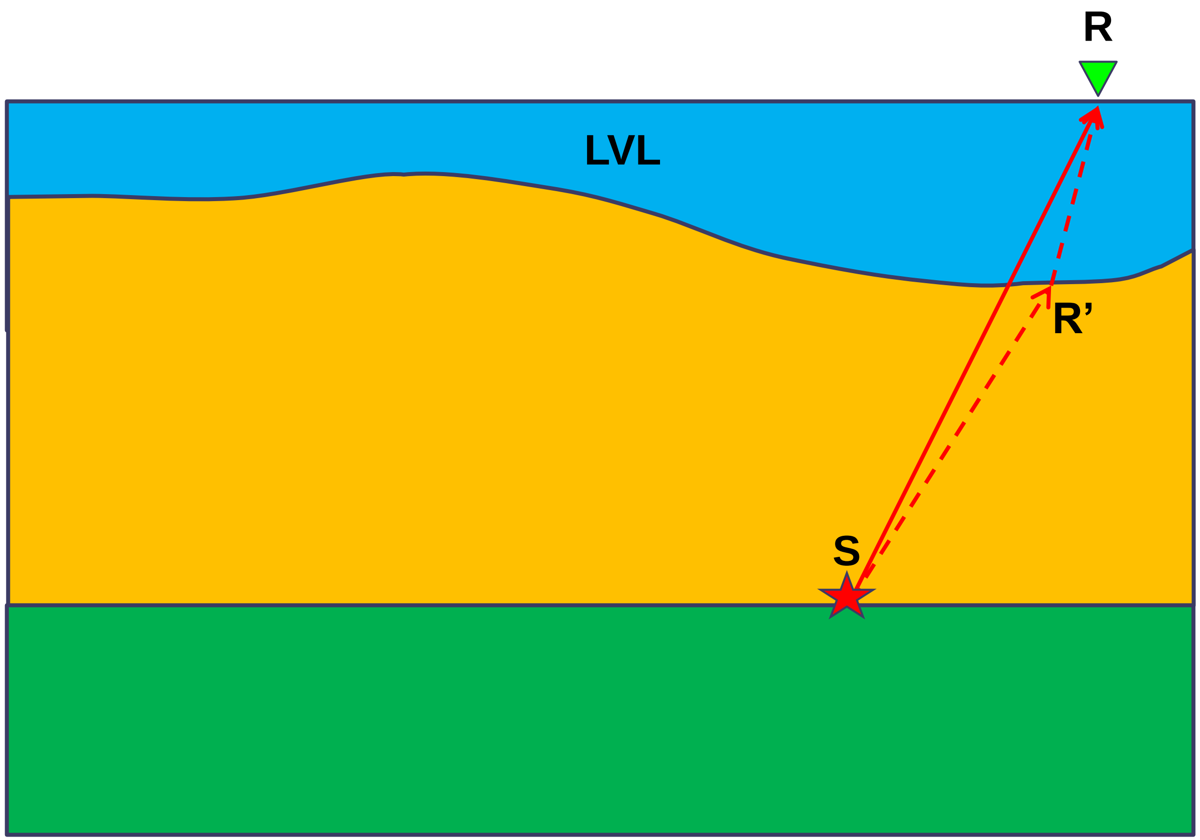
Traveltime Interferometry



Total static time $\Delta t = \tau'_{SOR} - \tau_{SOR}$

Receiver side static time $\Delta t_R = \tau'_{OR} - \tau_{OR}$

Traveltime Interferometry



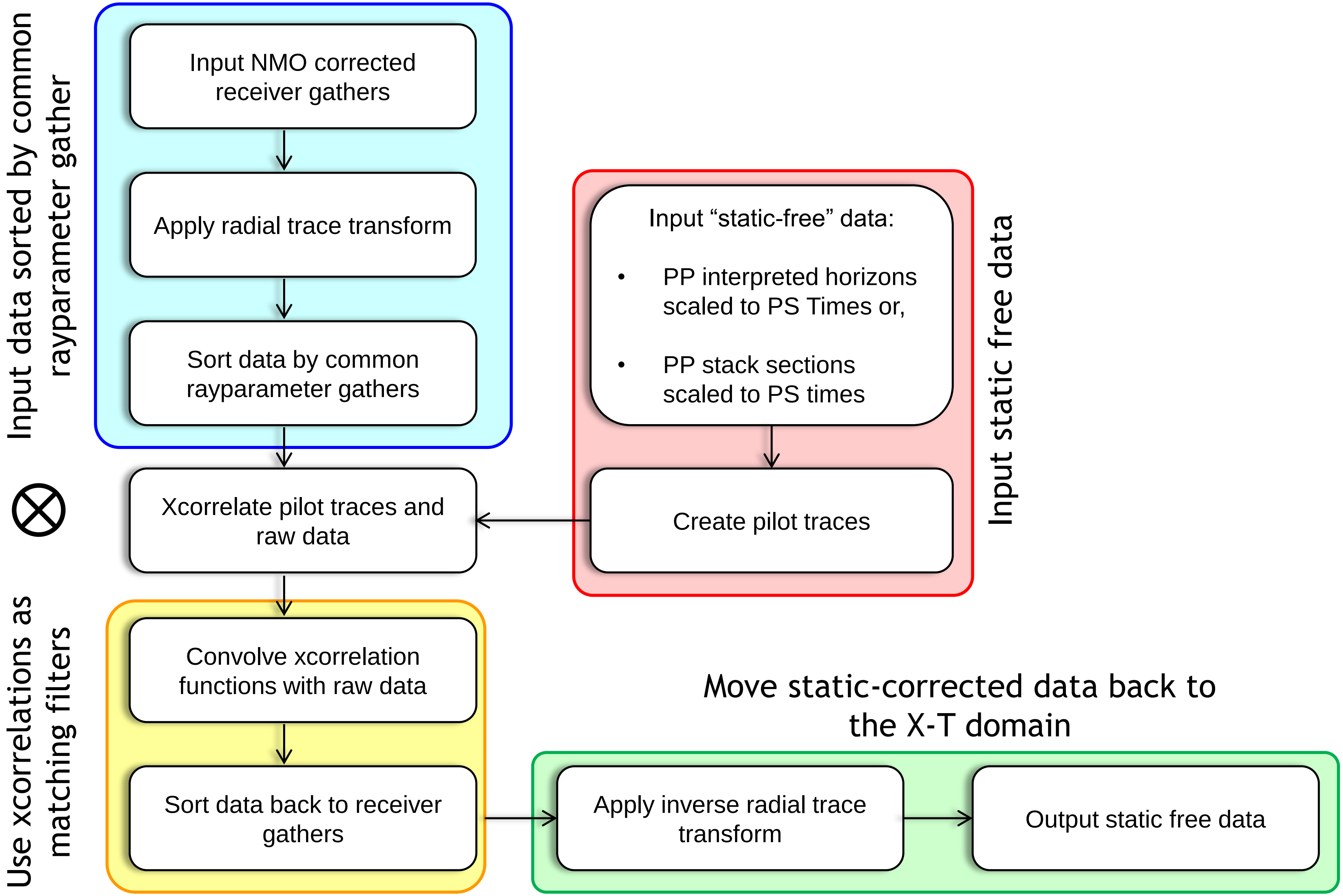
Static time

Delayed path $s'(t) = \delta(t - (\tau + \Delta t))$

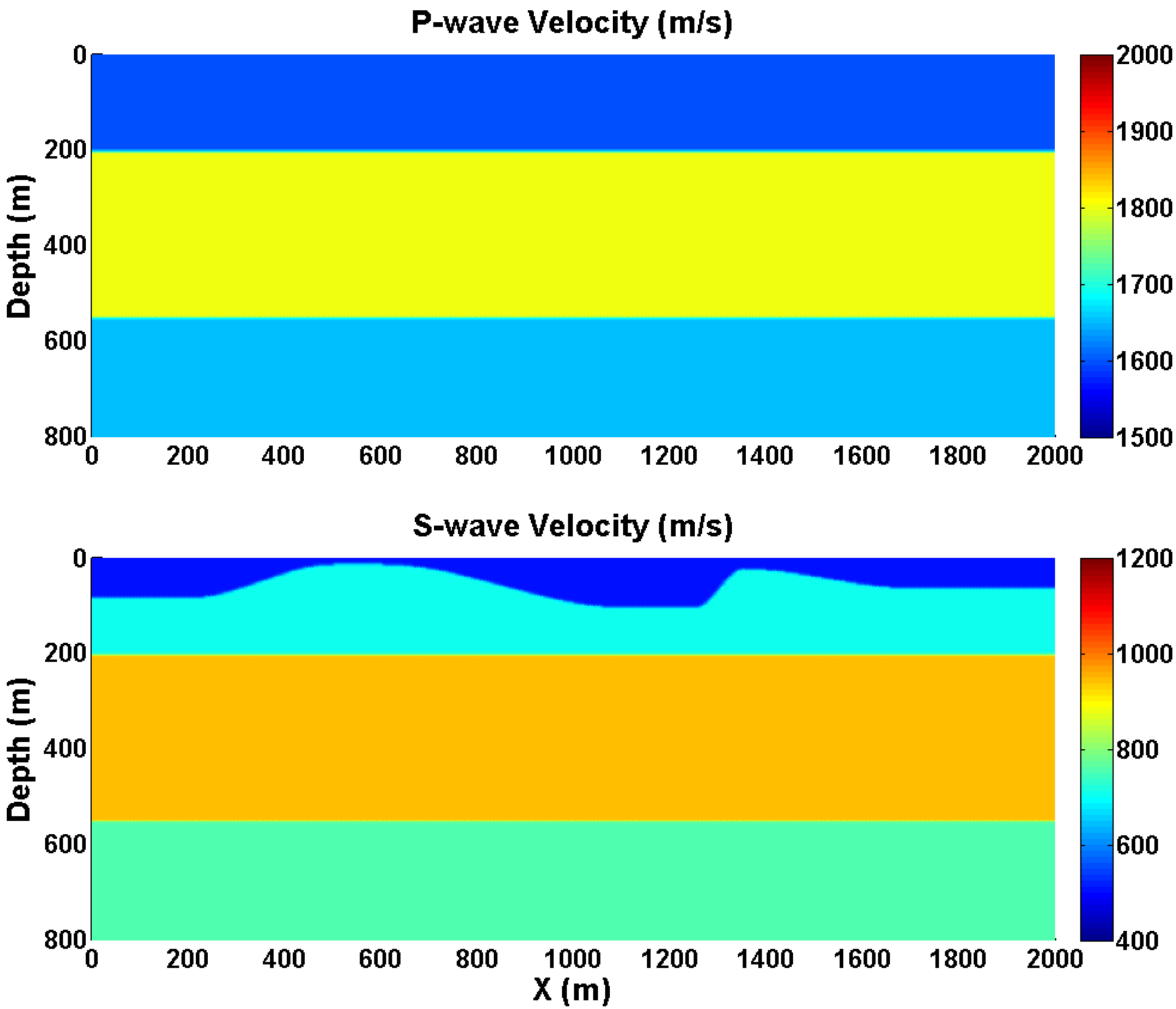
Static-free path $s(t) = \delta(t - \tau)$

$$\otimes \quad = \delta(t + \Delta t)$$

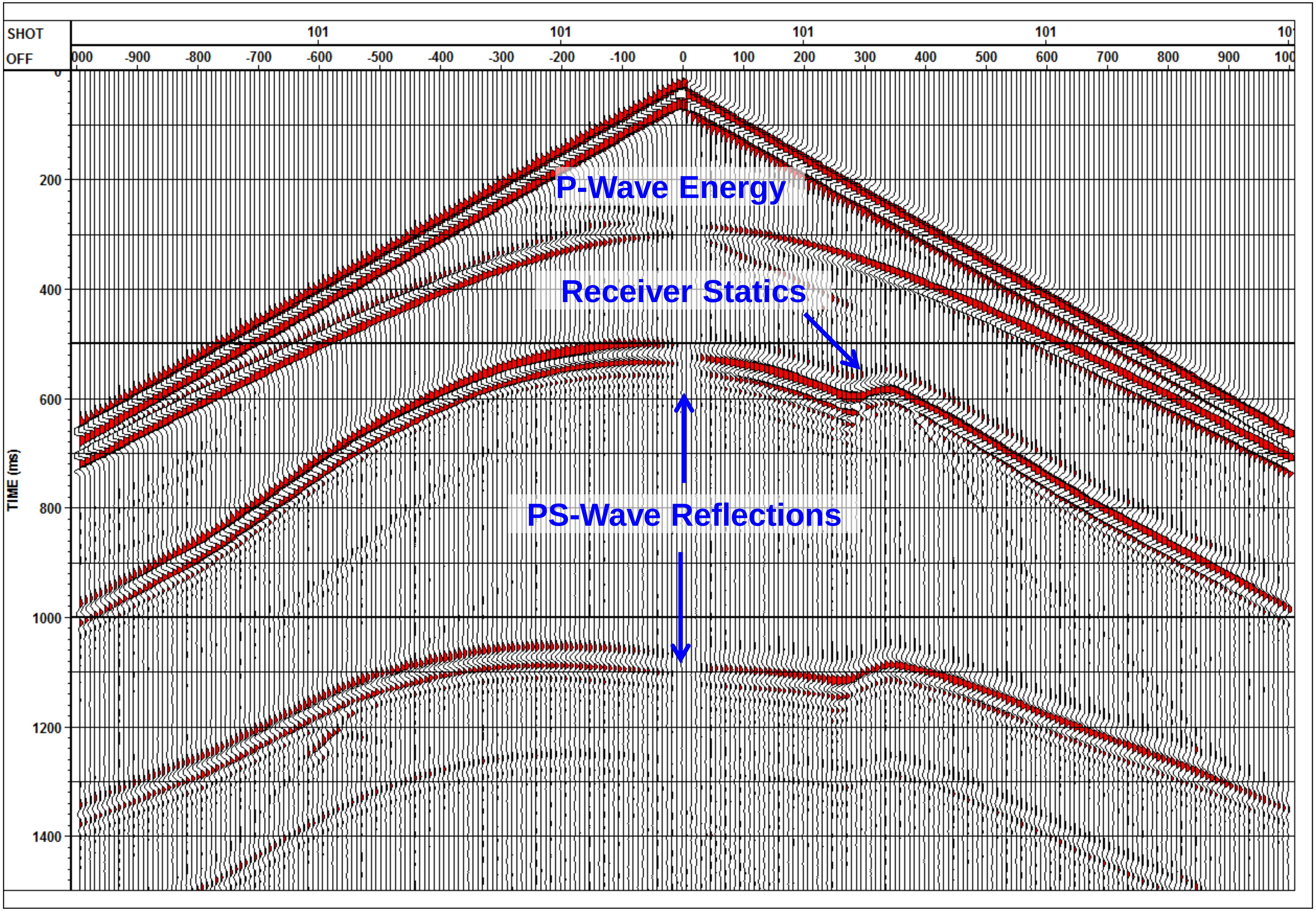
Statics processing workflow



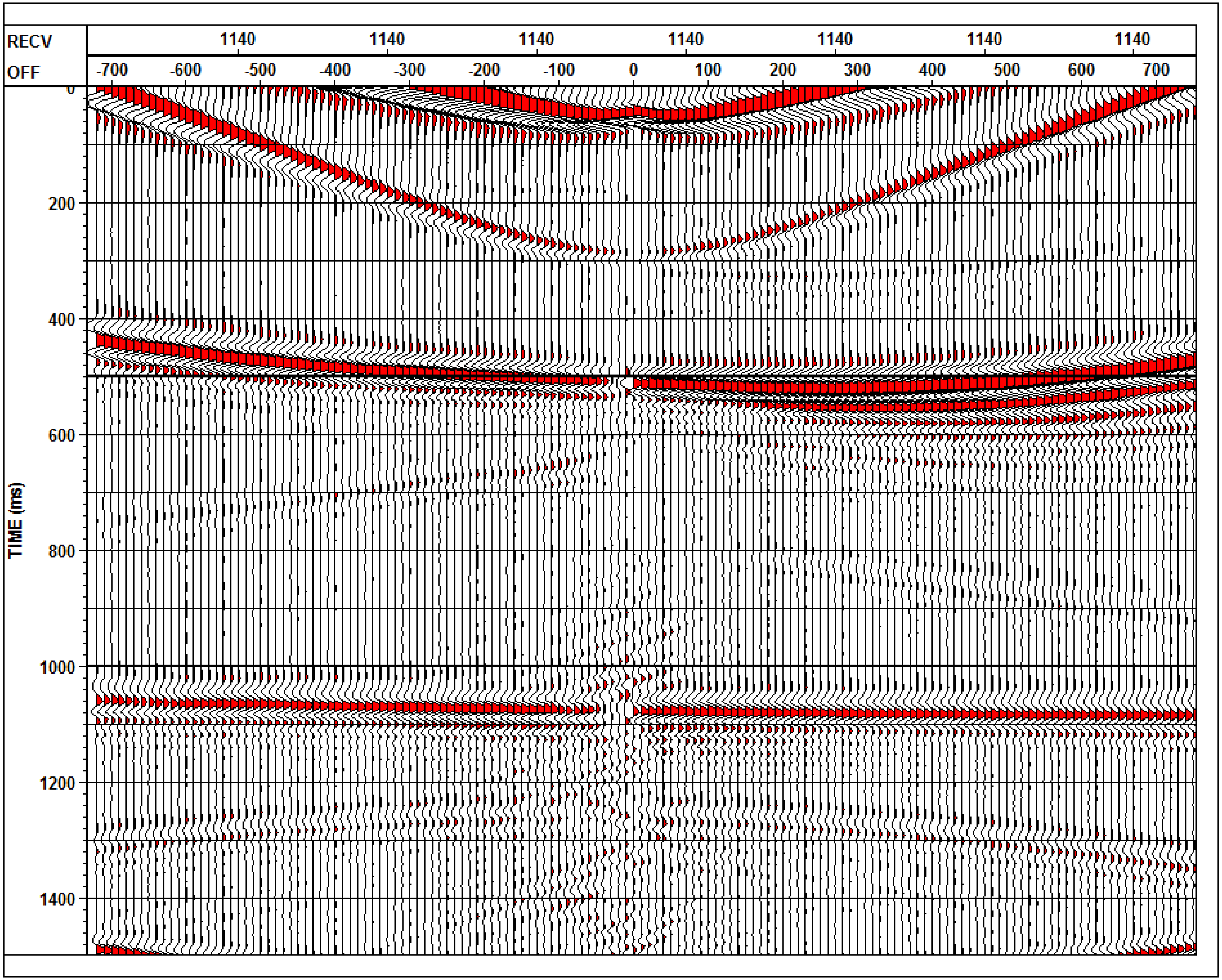
Finite-Difference Modeling



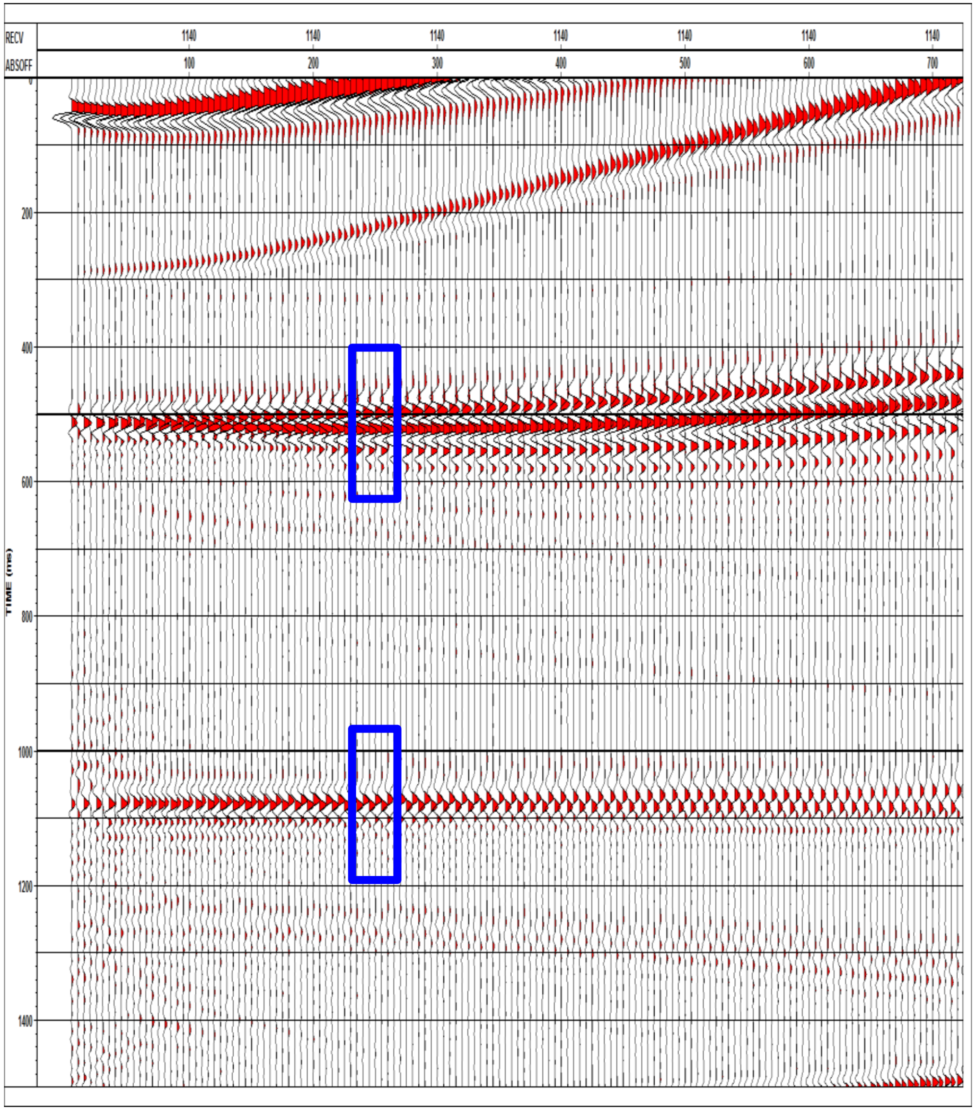
Raw X-component Shot Gather

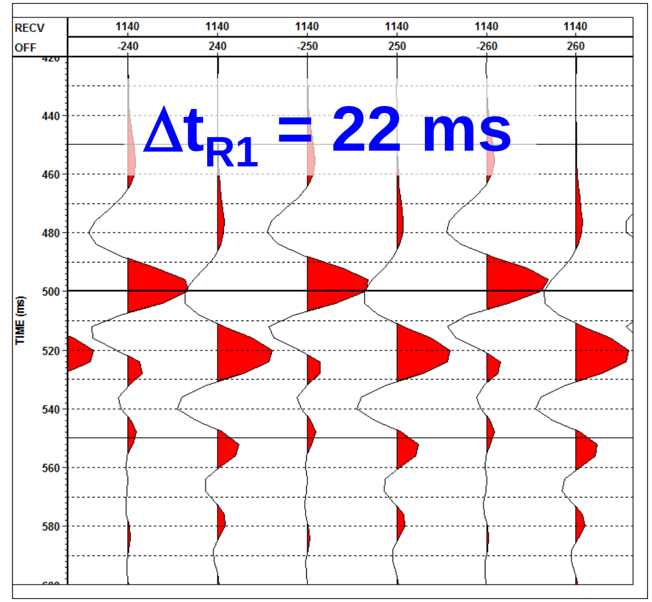


Receiver Gather

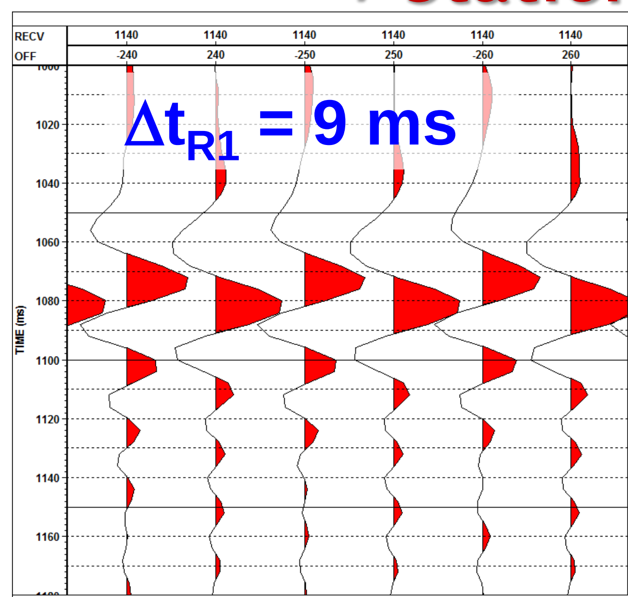


Receiver Gather (Zoom at offset 250m)

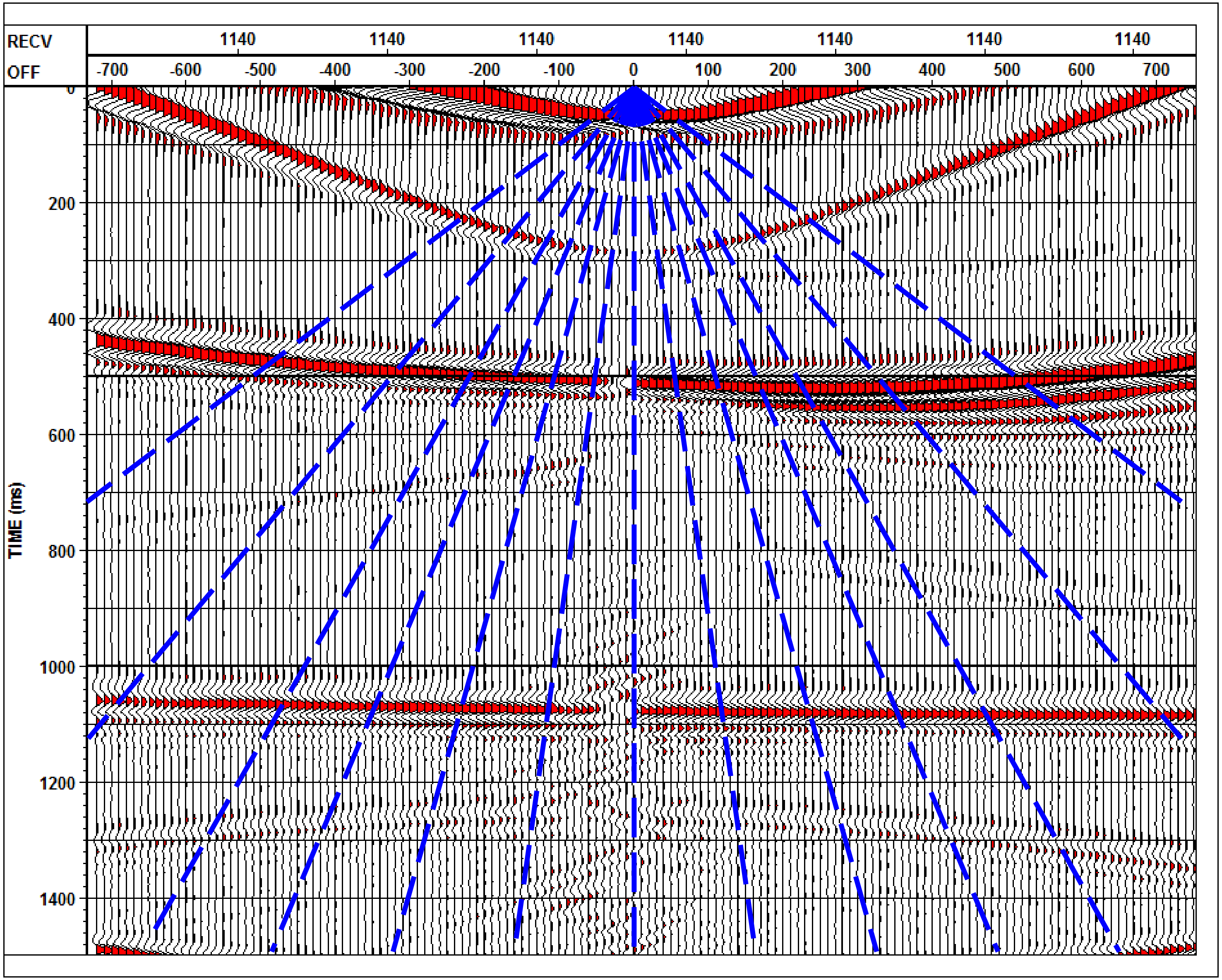




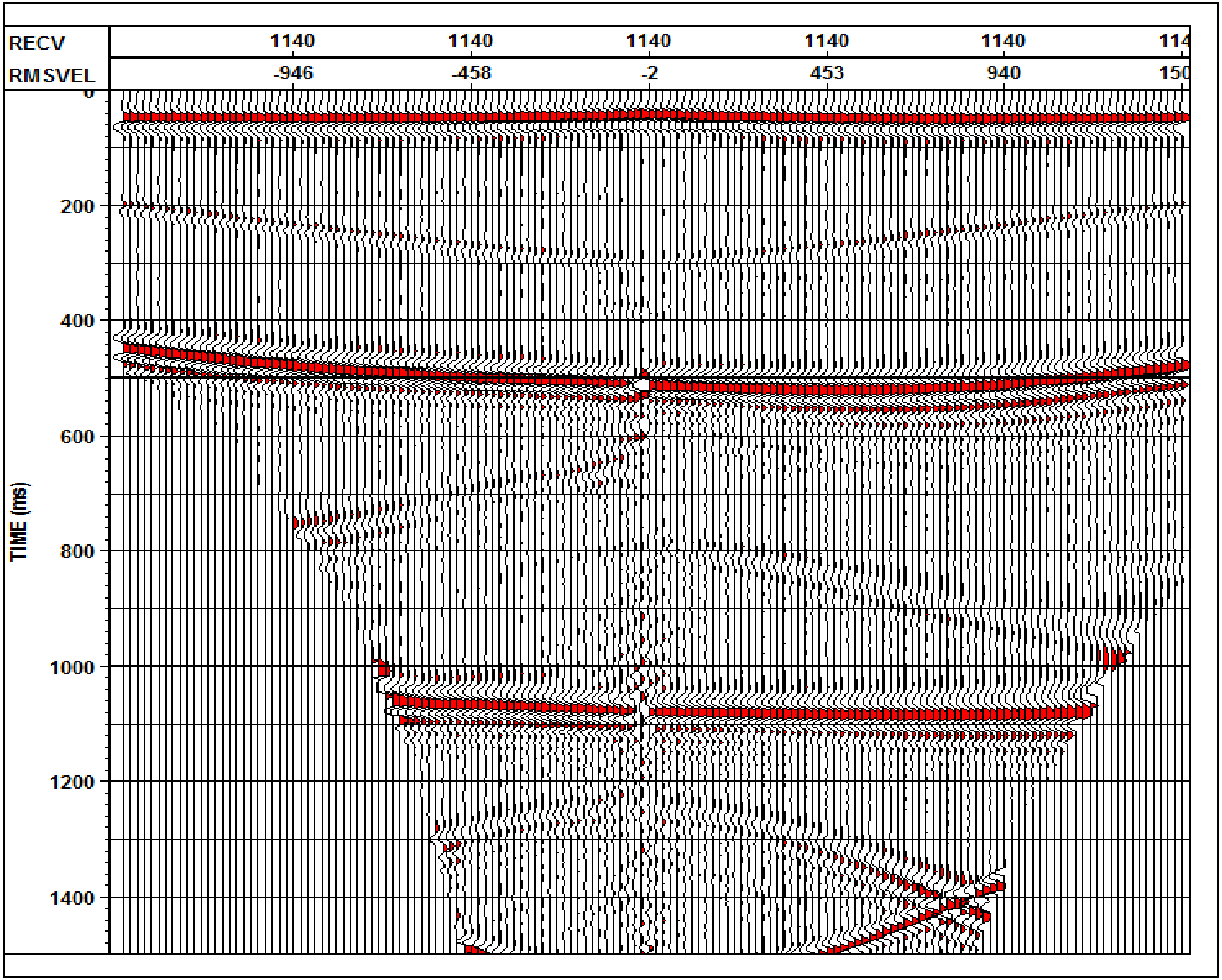
≠ Stationary



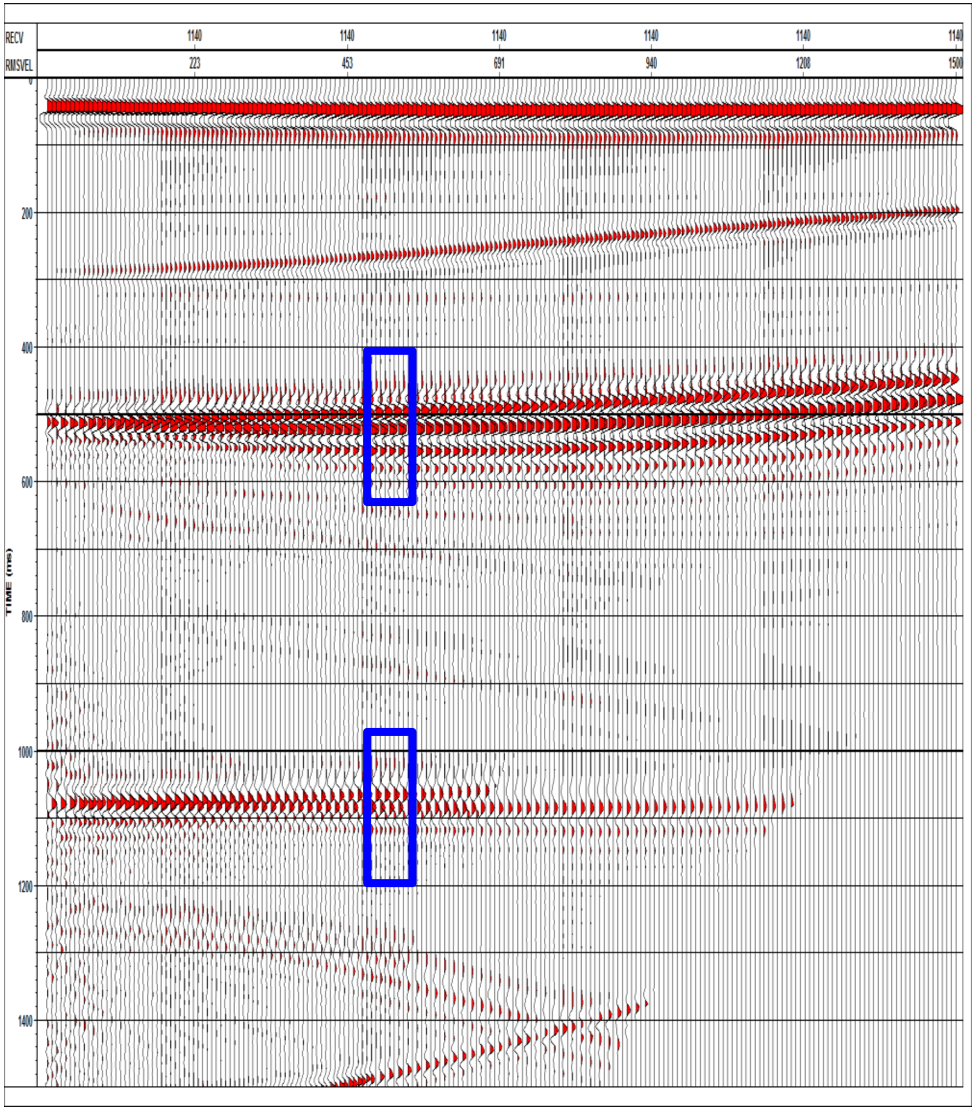
Receiver Gather

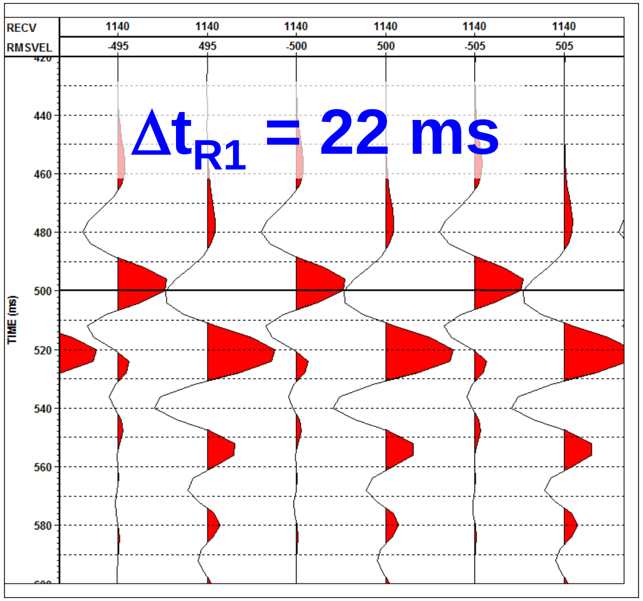


Radial-Trace Gather

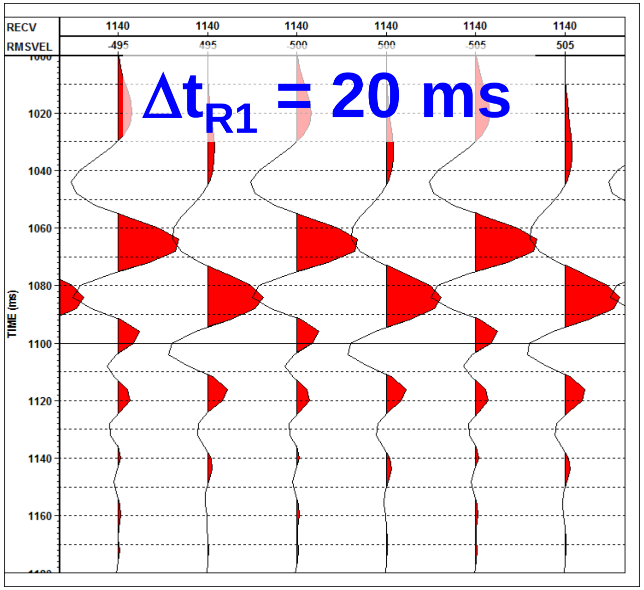


RT Gather (zoom at 500 m/s radial trace)

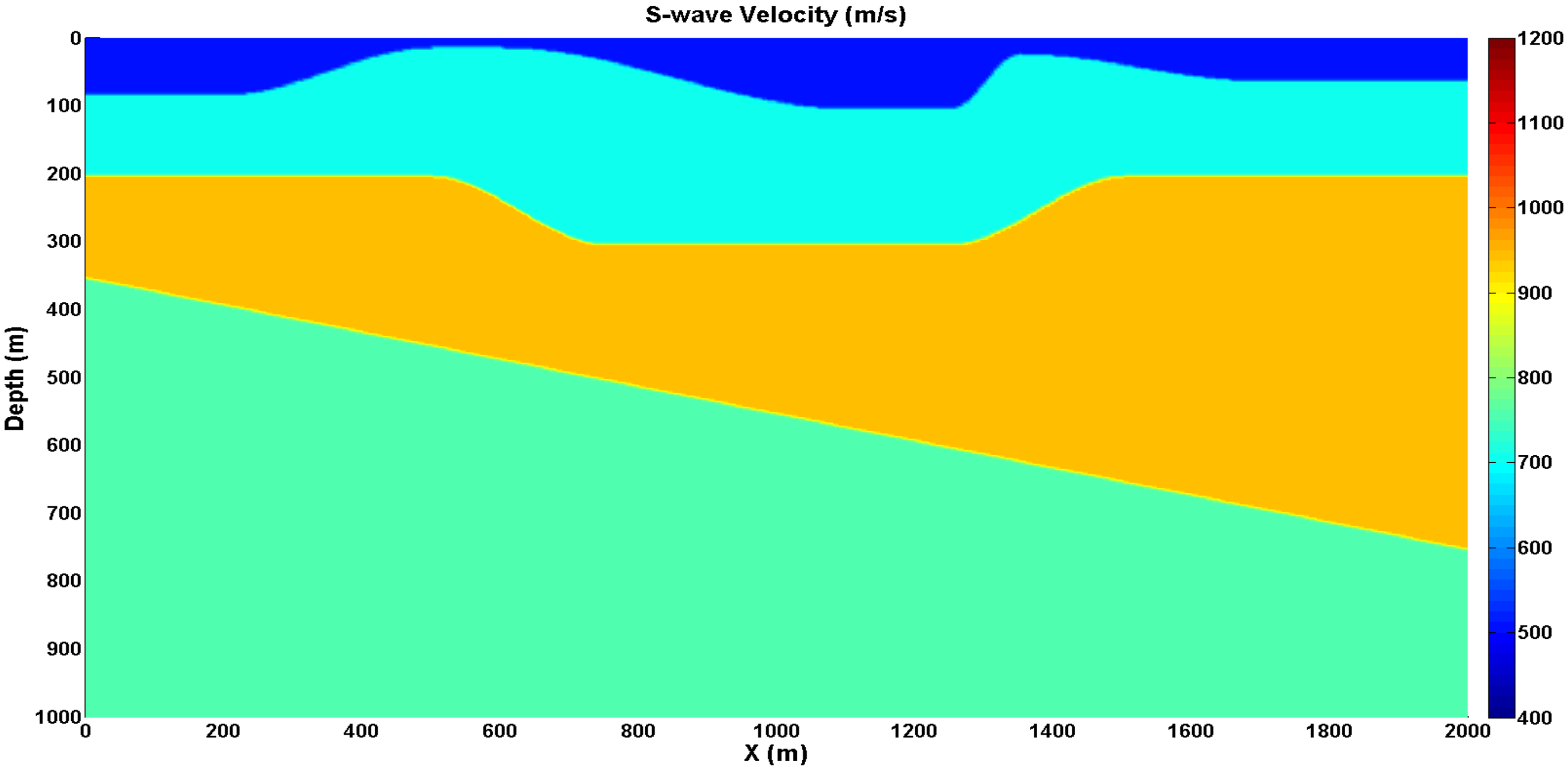




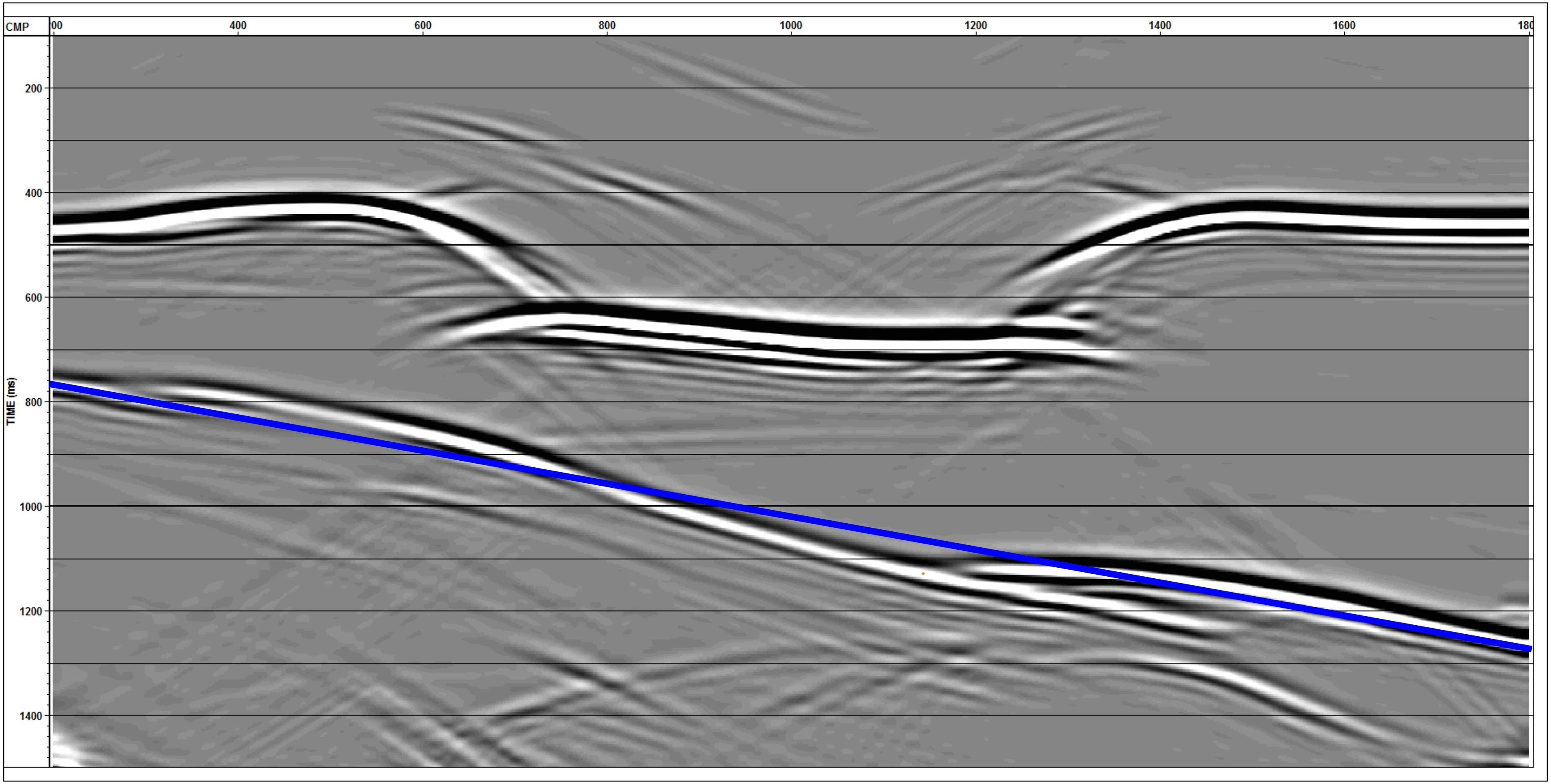
≈ Stationary



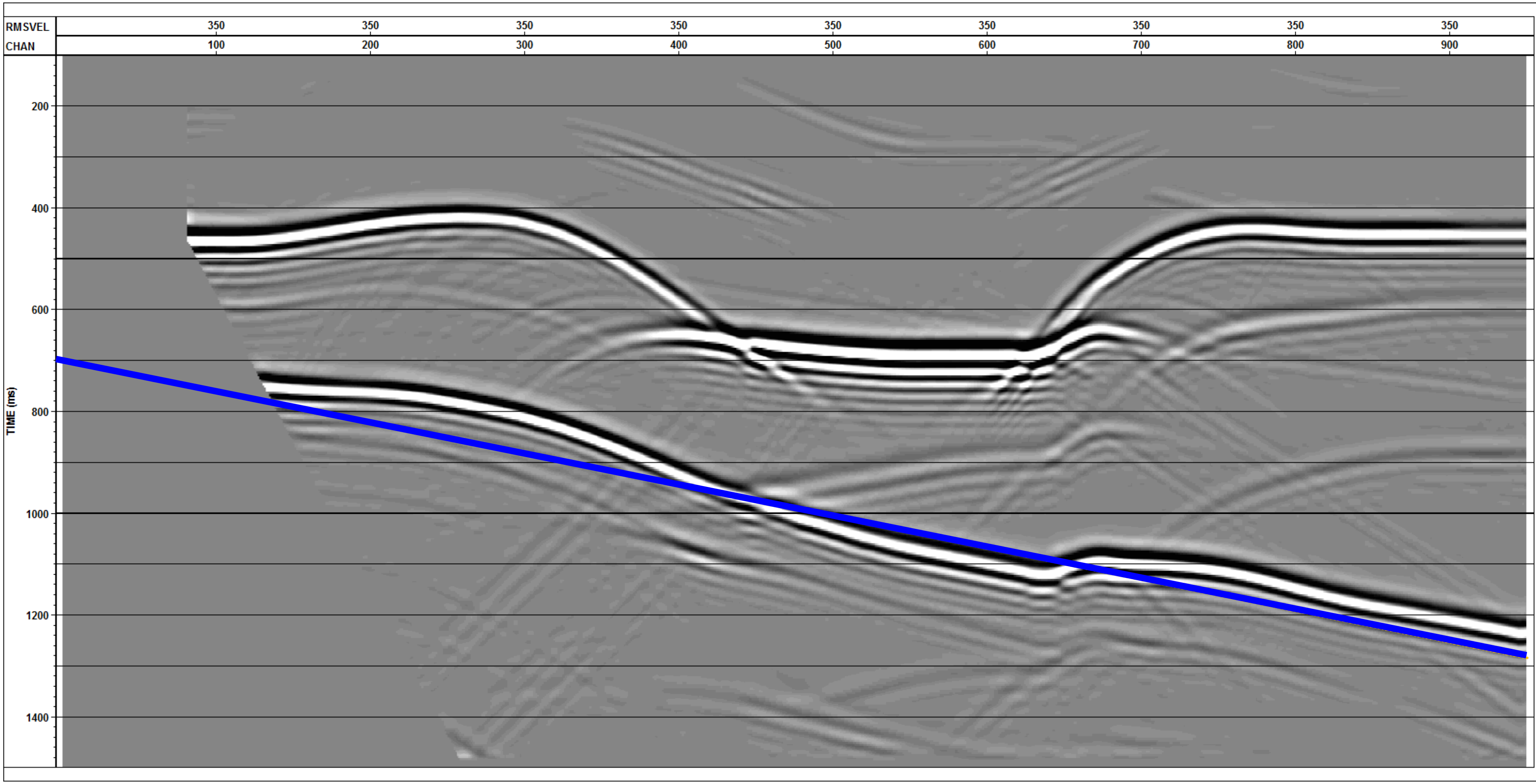
Finite-difference modeling



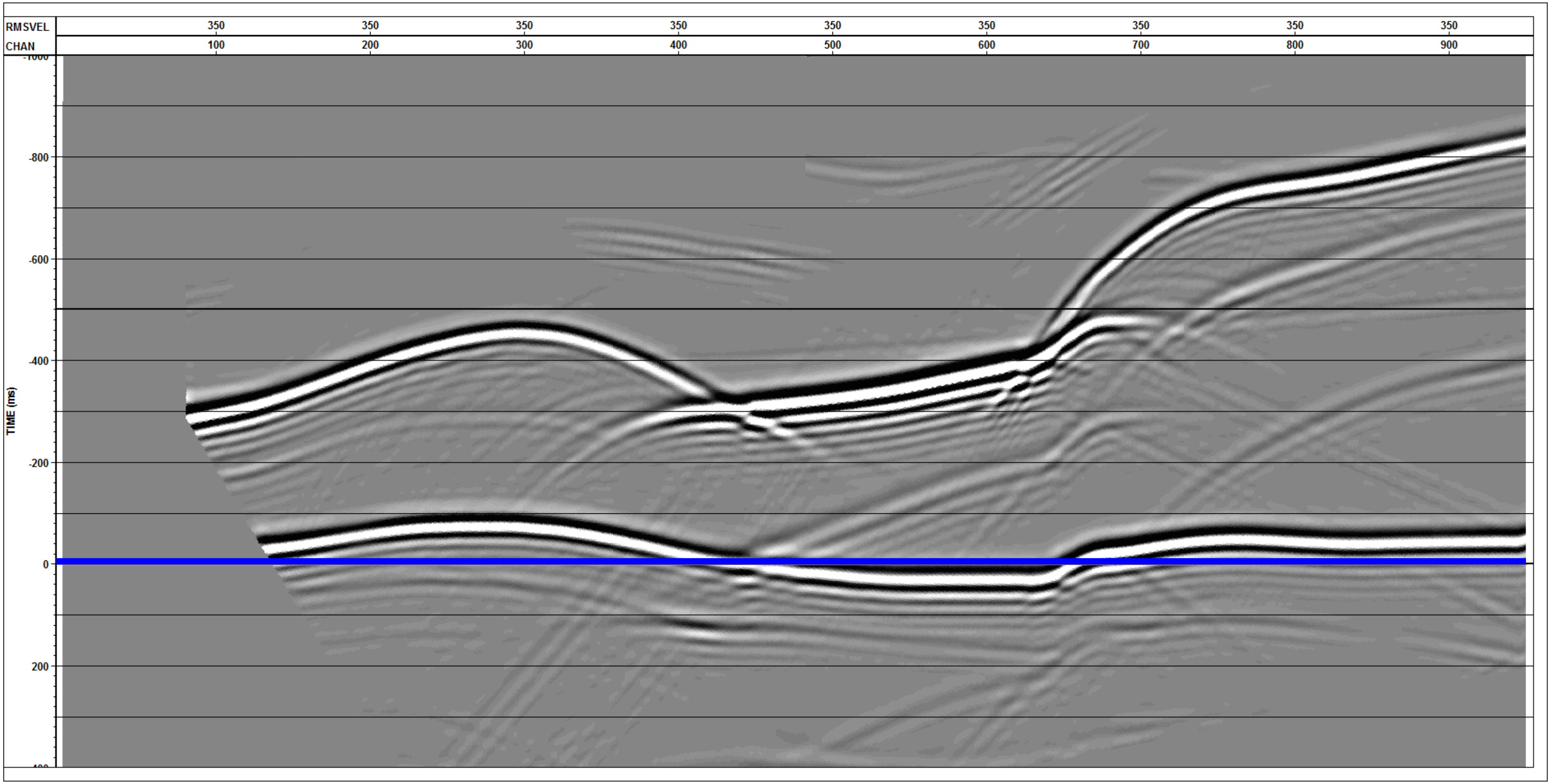
ACP Stack w/o statics



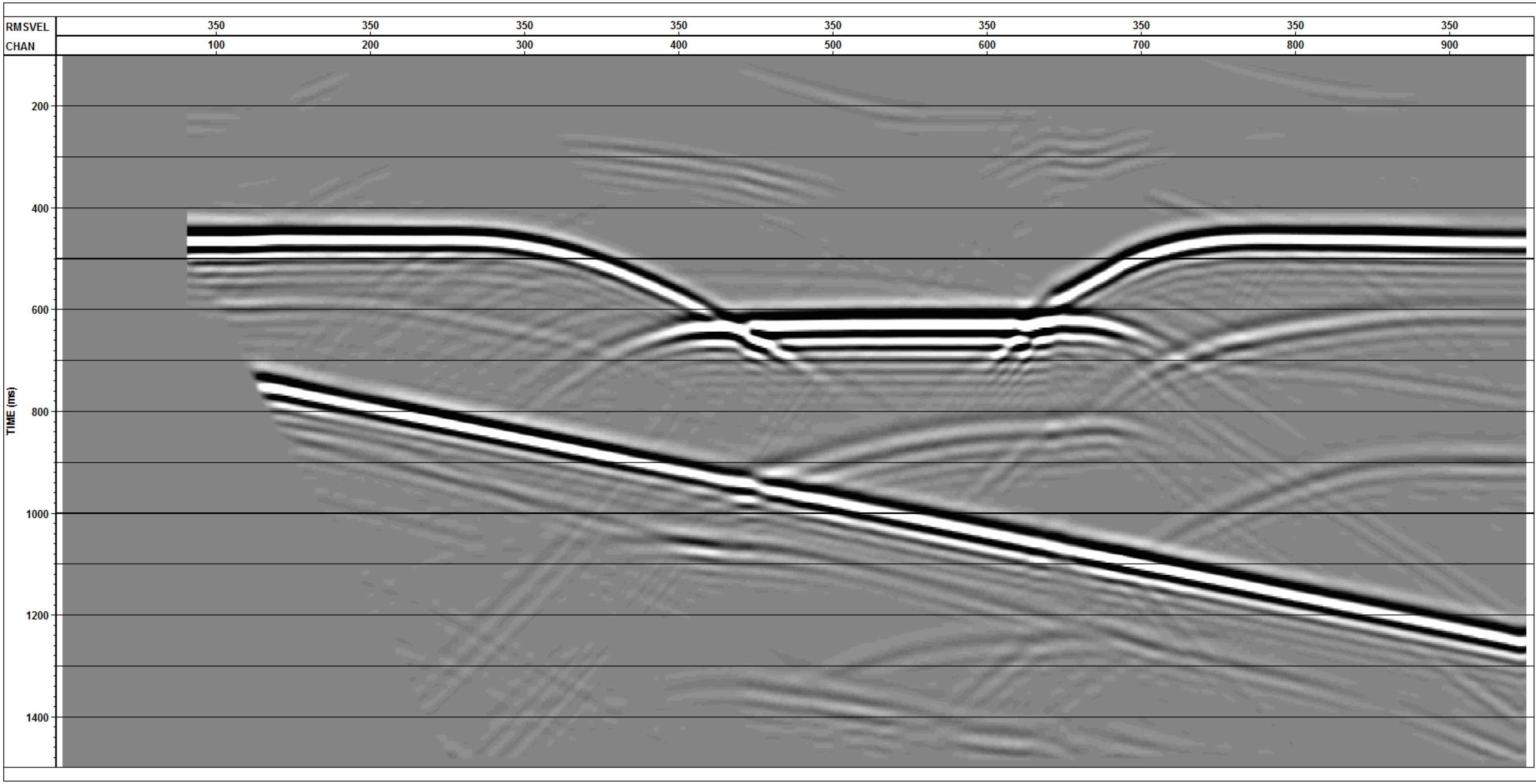
Common rayparameter gather (350 m/s)



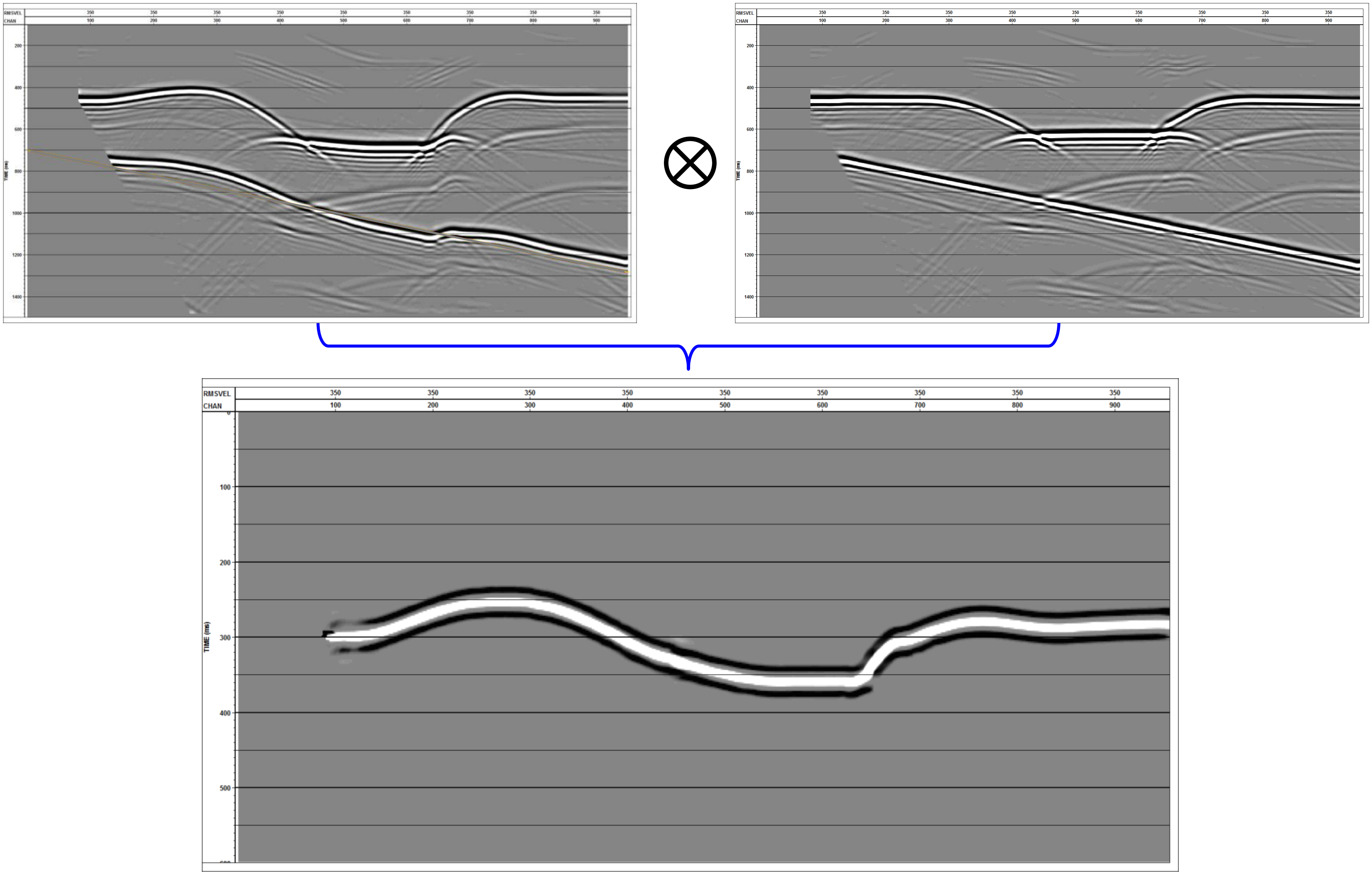
De-structured rayparameter gather



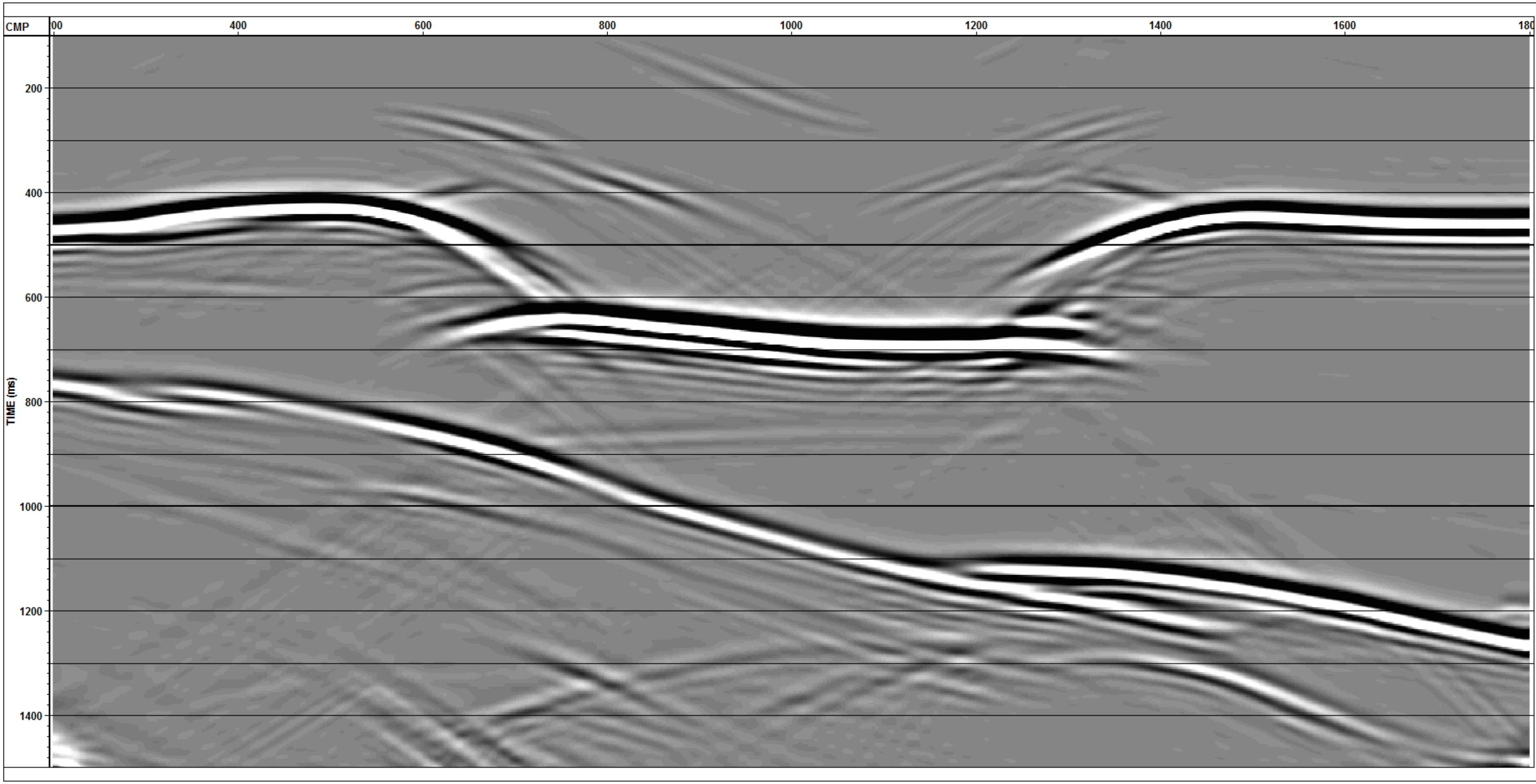
Pilot rayparameter gather



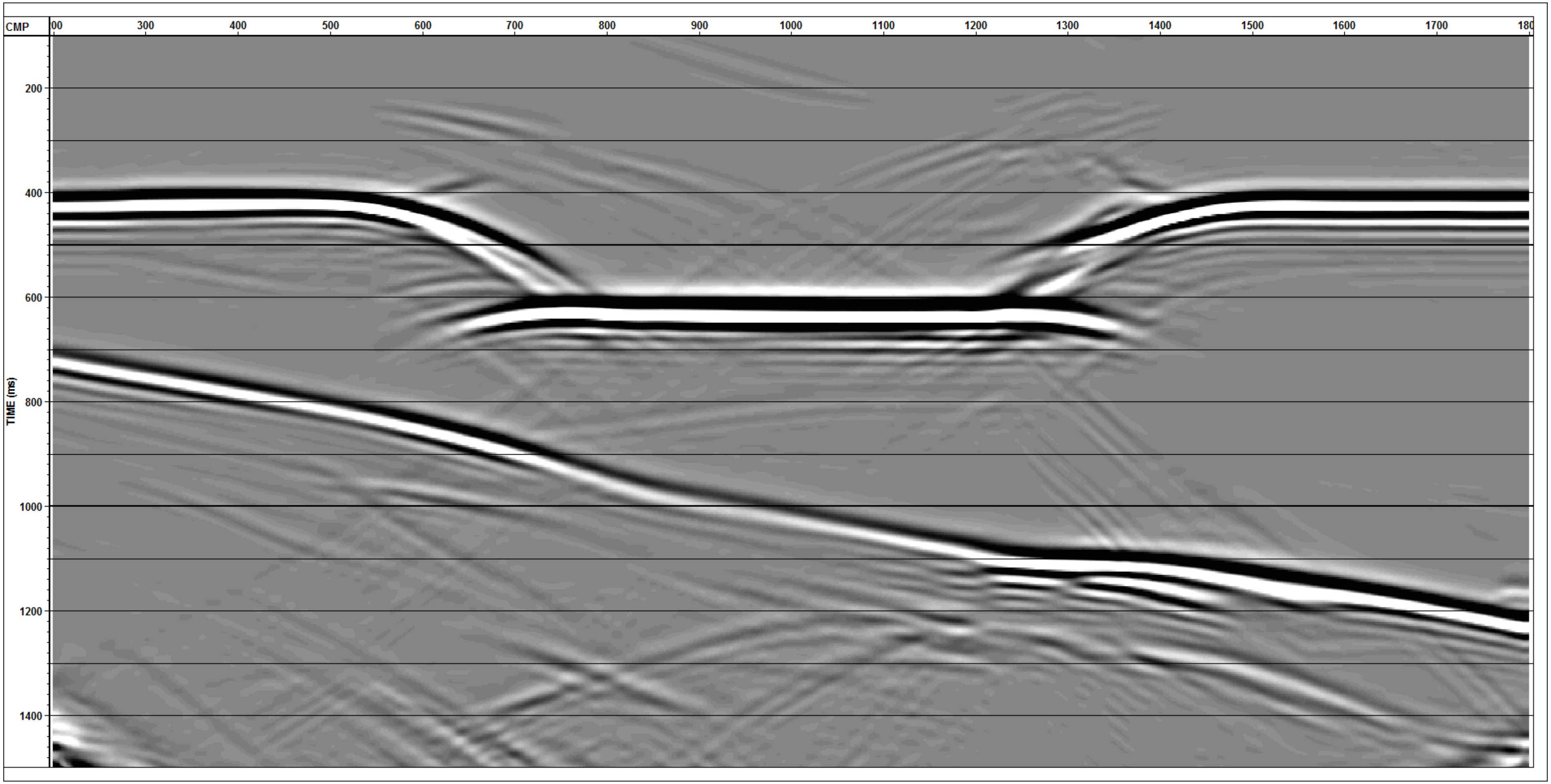
Cross-correlation functions



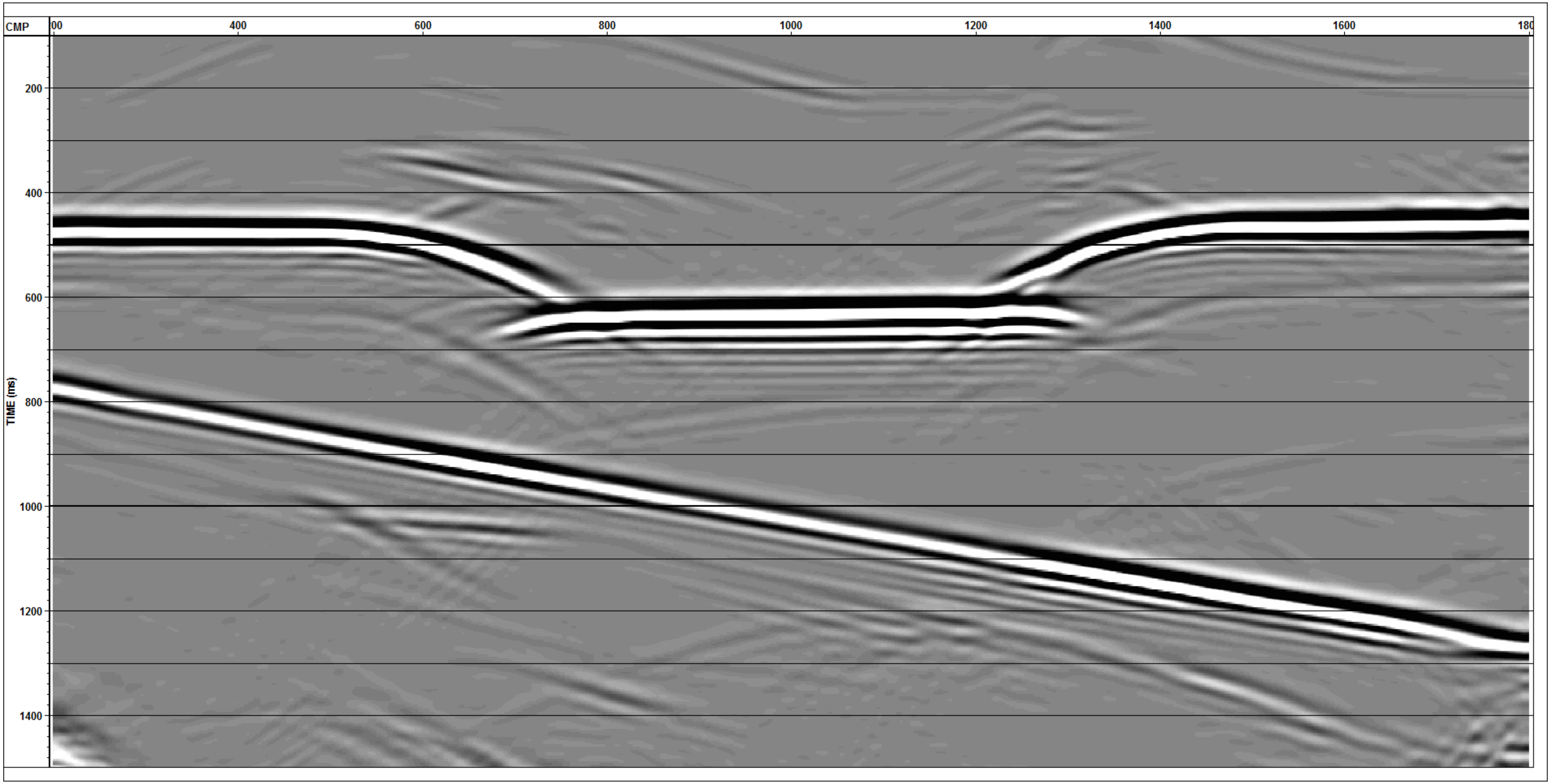
ACP Stack w/o statics

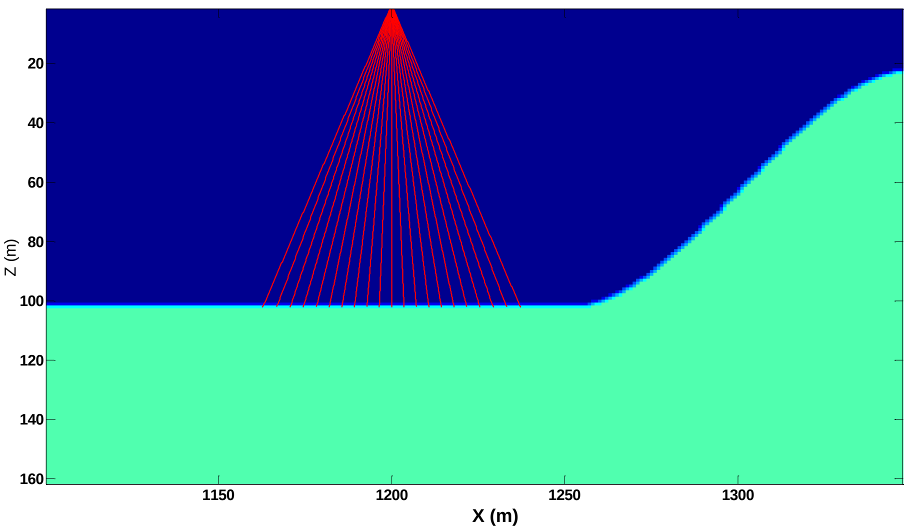


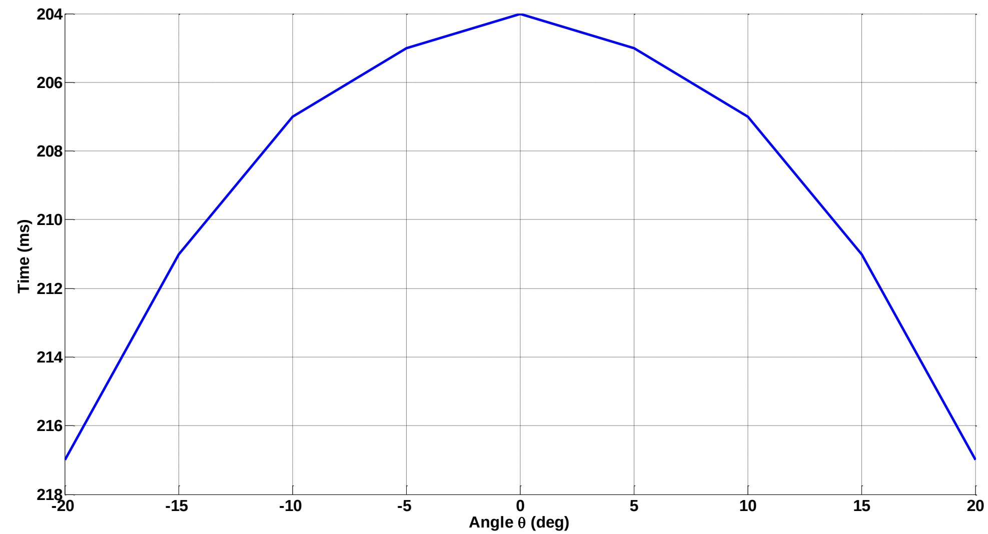
ACP Stack w surface consistent statics



ACP Stack w ray-path consistent statics

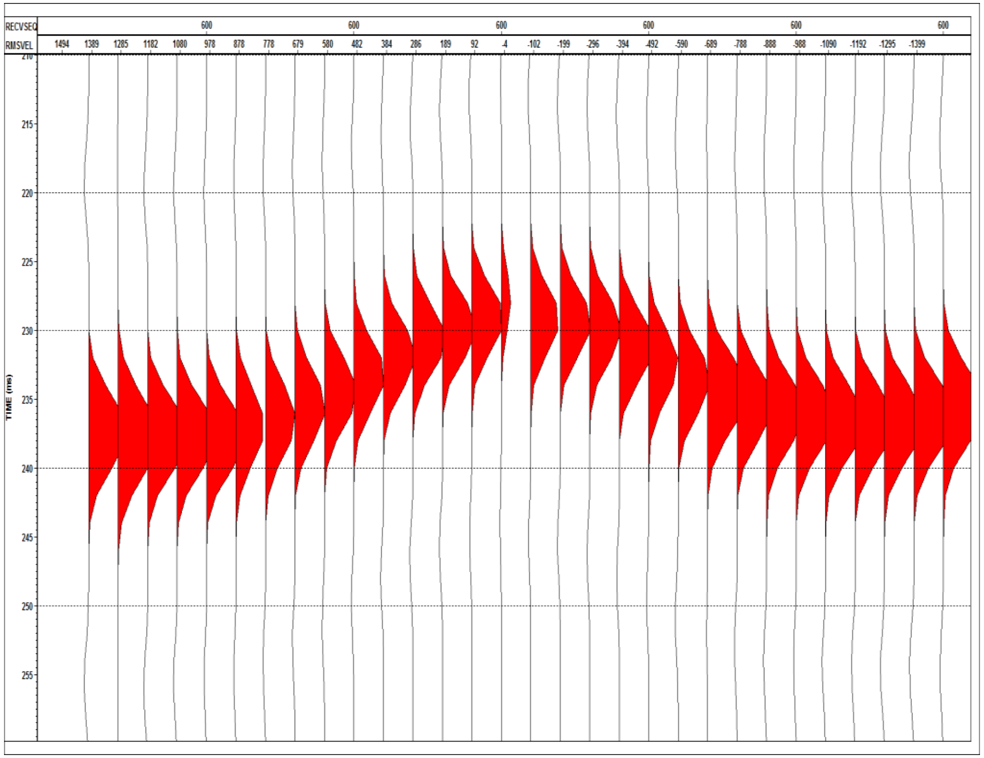


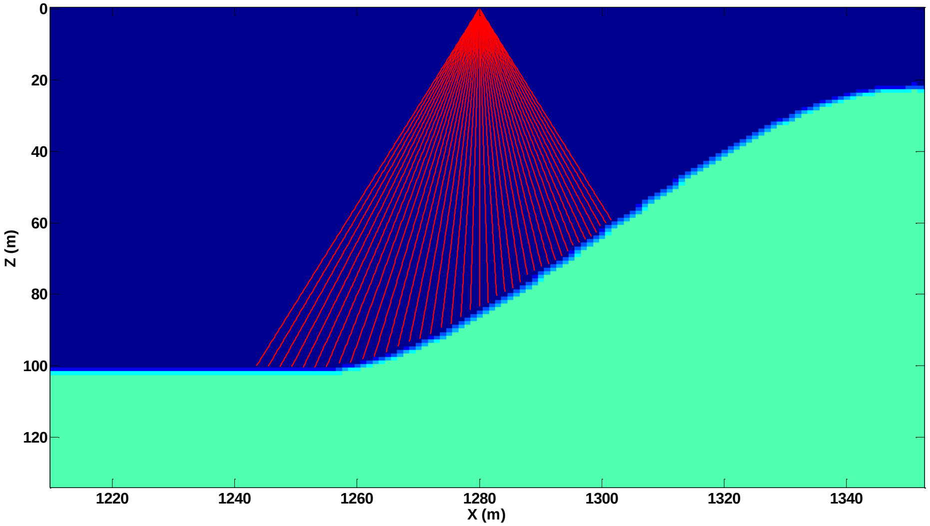


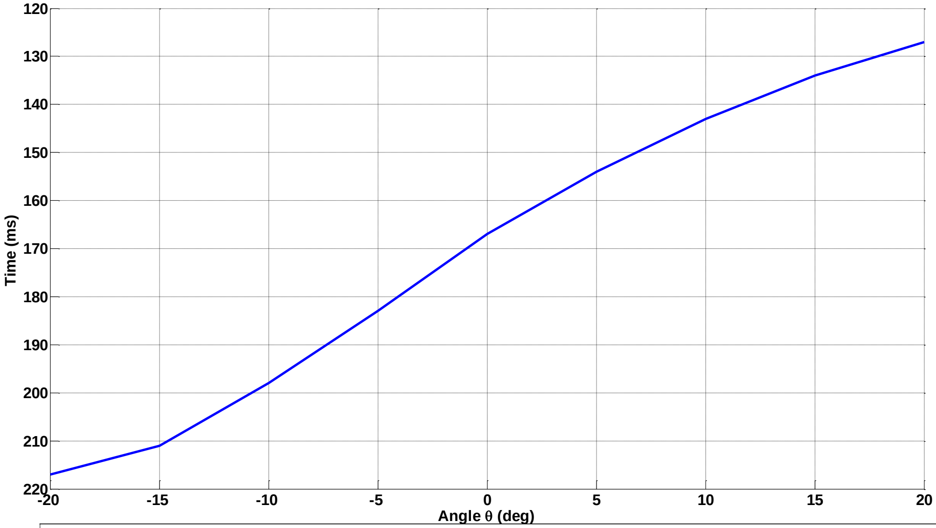


$$t_{calc} = \frac{h}{V}\frac{1}{\cos(\theta)}$$

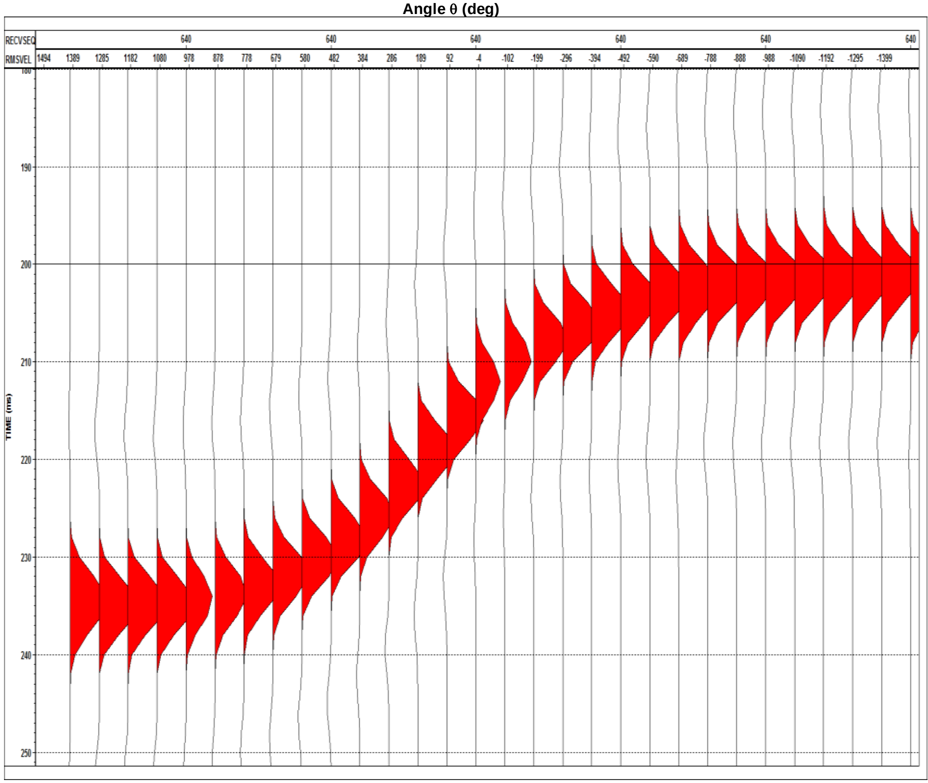
h : Vertical thickness
V : LVL velocity
θ : Transmission angle







$$t_{calc} = \frac{h}{V_{LVL}} \frac{\cos(\theta)}{\cos(\phi_{LVL} - \theta)}$$



h : Vertical thickness
V : LVL velocity
ϕ : Dip of the base of the LVL
θ : Transmission angle

Summary

- If velocity contrasts at the near surface are not large, S-wave statics may show ray-path dependency
- Ray-path dependency implies a non-stationary behavior in time domain.
- Interferometric statics applied in the R-T domain showed to solved the problem.
- Straight ray-path assumptions for applying the radial transform may not be enough. Snell ray transform can be the next step.
- Inversion of the cross-correlations peaks time may be used for computing a velocity model for the near surface.

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- Kris Innanen.
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… THANKS!!!