Non-stationary shear wave statics in the radial trace domain

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ABSTRACT

Due to very low velocity values the magnitude of S-wave statics is several times larger than P-wave statics, producing a very destructive effect when stacking traces. In this paper it is shown how S-wave statics may also show a non-stationary behaviour. This effect was studied in terms of variations in the transmission angle through the low velocity layer (LVL) due to changes in offset and as a result of the structure of the LVL. An analytic expression for computing deviated travel times through the LVL in terms of its dip, thickness and velocity is proposed here. This expression may be used as the engine for an iterative non-linear inversion algorithm that will allow us to compute velocity models for the near surface given a set of delay times and the ray-path angles associated with them.

Traveltime analysis

- Surface-consistent statics assume vertical raypaths in the LVL
- When velocity contrasts are smooth this assumption is not valid and traveltimes start to increase significantly as is shown in Figure 1.

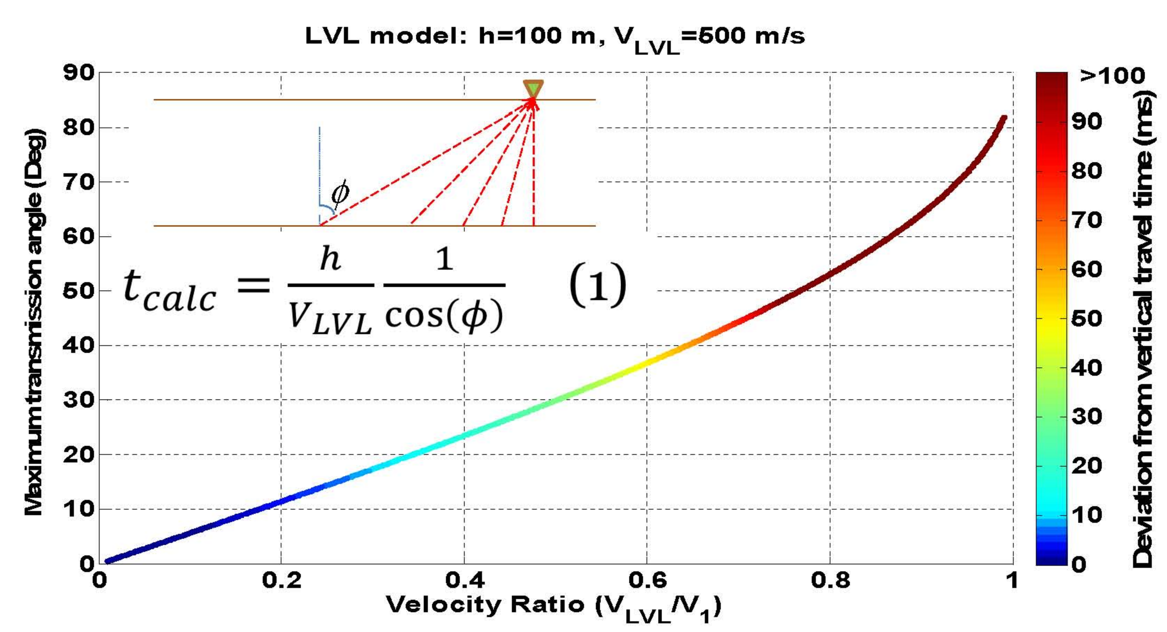
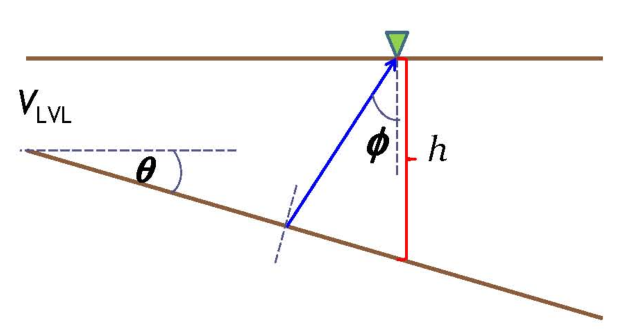


FIG. 1. Crossplot showing the increase in travel times due to changes in the raypath direction. Control of the velocity contrast on the transmission angle in the LVL , following Snell's Law, is considered here.

- Even if the velocity contrast is not large the presence of a dipping LVL may impose a raypath-dependency on the traveltimes.



$$t_{calc} = \frac{h}{V_{LVL}} \frac{\cos(\theta)}{\cos(\phi-\theta)} \quad (2)$$

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

FIG. 2. Geometry of the problem of a dipping LVL and analytical formula for computing traveltimes under this conditions

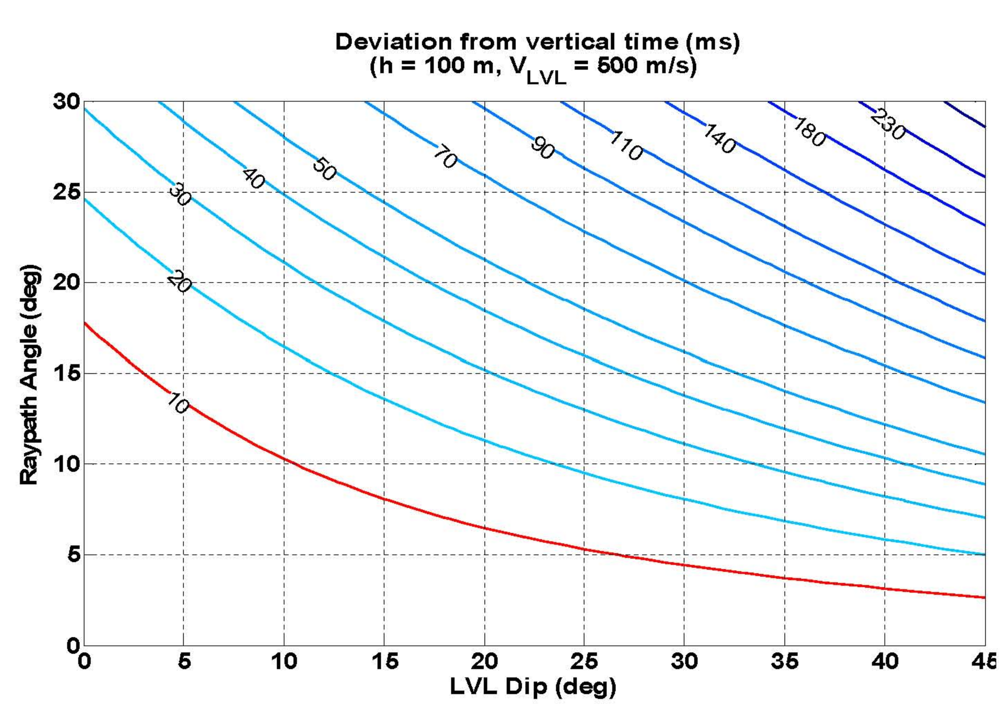


FIG. 3. Contour plot showing the change in traveltimes due to the presence of a dipping LVL and variations in the raypath angles.

Ray-tracing analysis

- PS ray-tracing results show that reflection times that arrived at the receiver location with the same raypath angle are recorded at different offset
- Reflections recorded at different offsets and times need different static corrections

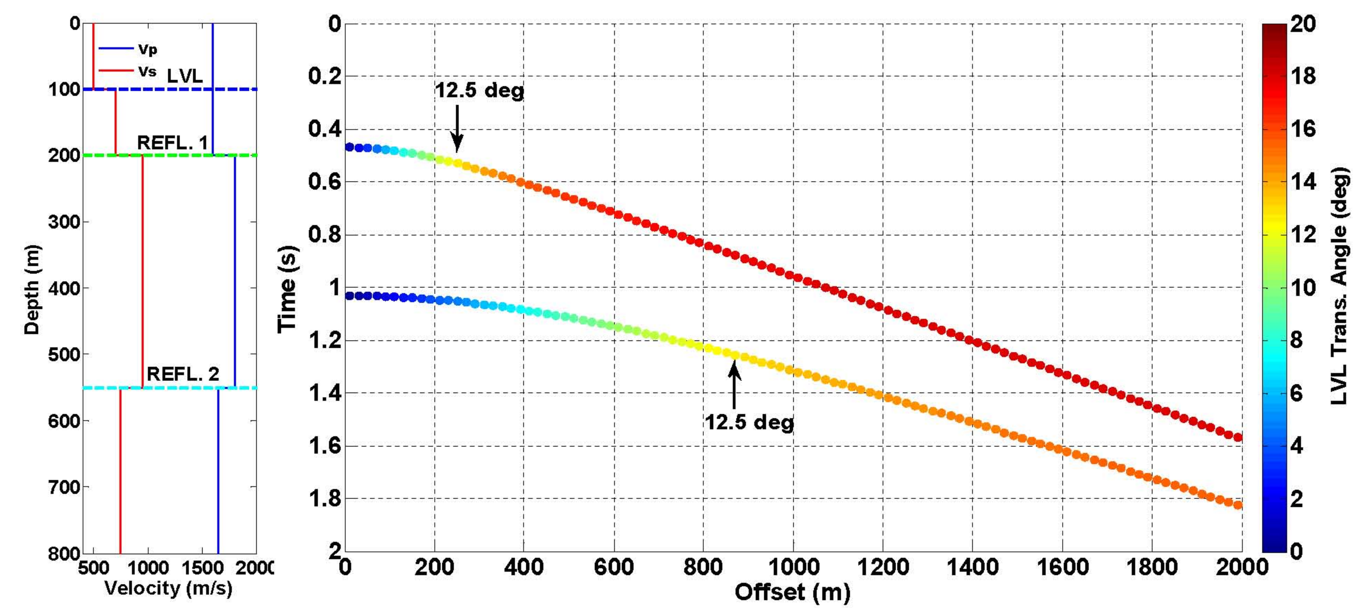


FIG. 4. PS reflection travel times for the velocity model on the left. Note how reflections arrive at the receiver location with different raypath angles

- 2D raytraced traveltimes for a dipping LVL matched very well with computed travel times using equation (2).
- Equation (2) may be used as the forward modeling operator in an iterative inversion algorith in order to retrieve the dip, thickness and velocity of the LVL from a given set of raypath-dependent traveltimes

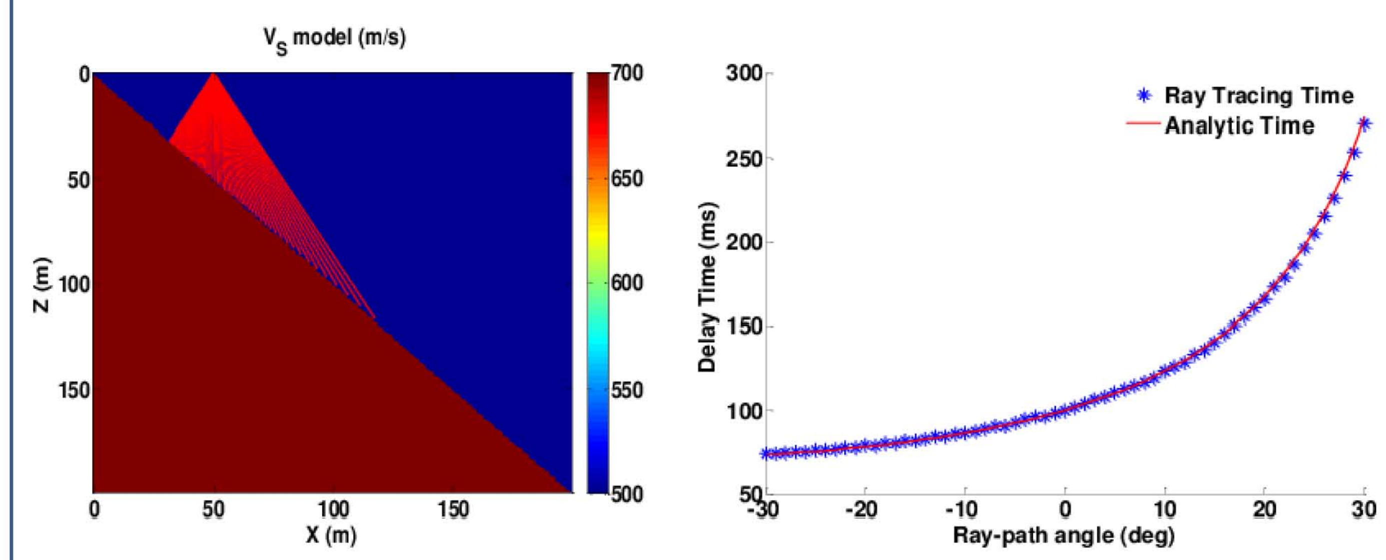


FIG. 5. (left) Raytracing over a dipping LVL layer. (right) Raytracing and analytic traveltimes for a dipping LVL.

Finite difference modelling

- PS synthetic data were created using elastic finite difference modelling. No LVL was included in the P-wave velocity model

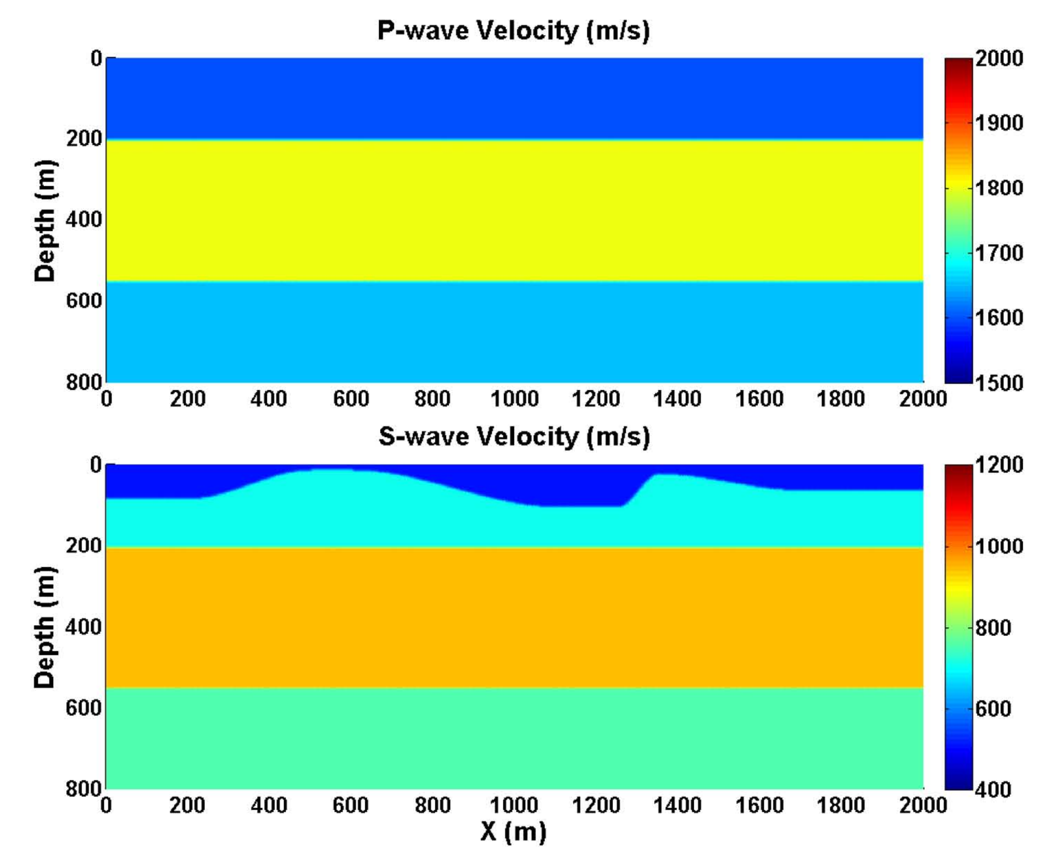


FIG. 6. Velocity models used for elastic finite difference modelling

Synthetic data analysis

- The Effect of the S-wave statics was clearly seen on synthetic data.
- For a fixed receiver location traces at positive and negative offset displayed different delays making it impossible to flatten the gathers.

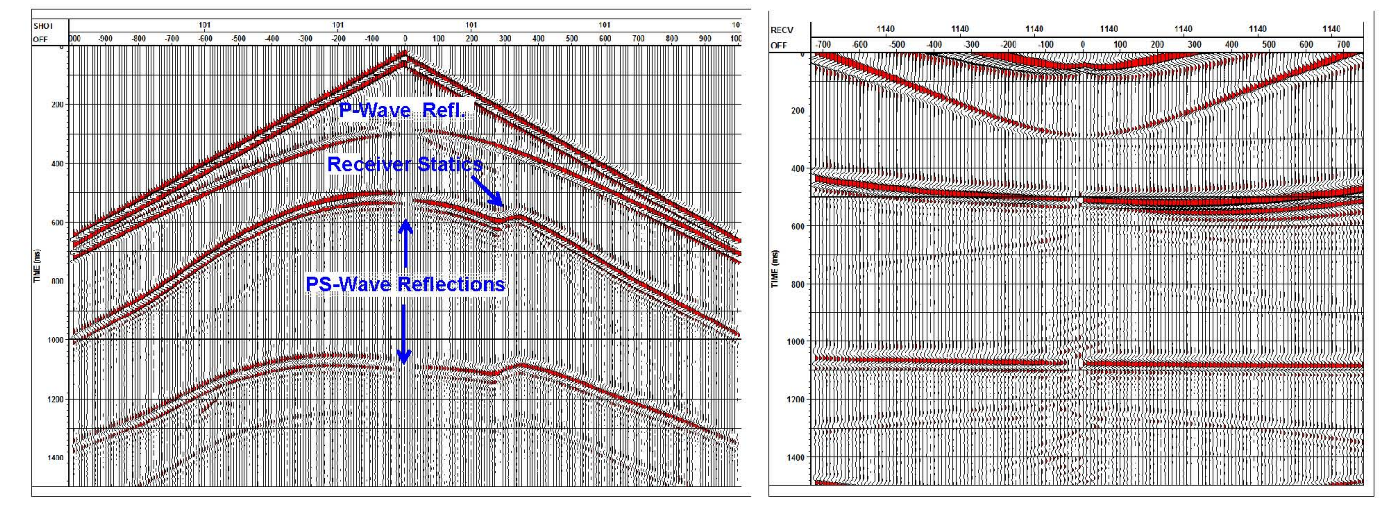


FIG. 7. (left) Raw radial-component shot gather. (right) PS-NMO corrected receiver gather.

- The radial-trace (R-T) transform was used for simulating seismic data recorded approximately along straight ray-paths.

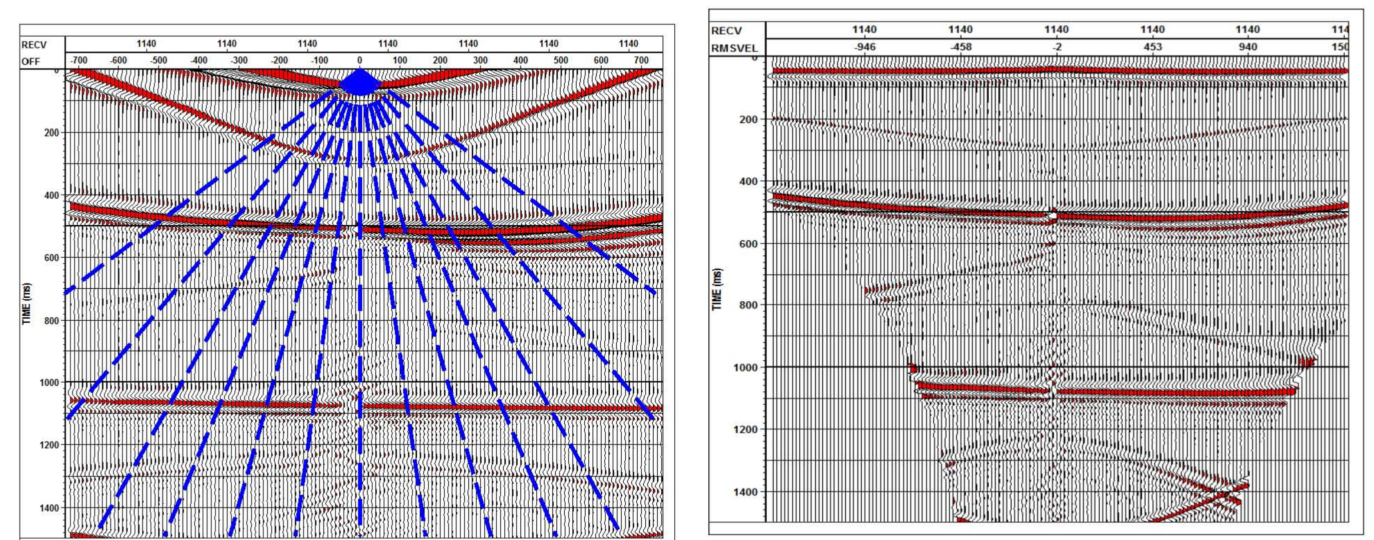


FIG. 8. (left) Schematic representation of the R-T transform. (right) Receiver gather in the R-T domain

- Results showed that in the R-T domain the delay time between traces in the same receiver gather were approximately stationary.

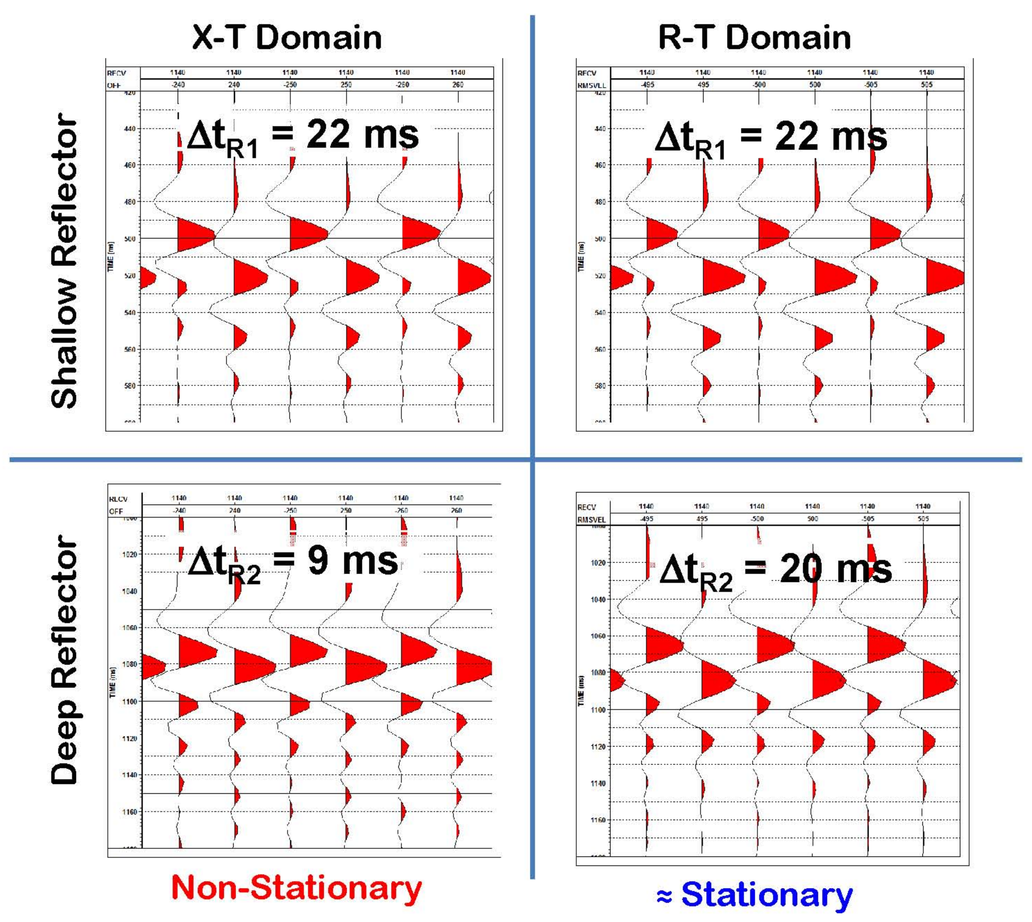


FIG. 9. Delay times analysis in the X-T and R-T domains.

CONCLUSIONS

- Since the R-T transform used here assumes constant ray parameter values, stationarity is not fully achieved. Snell's ray transform may be used to improve these condition
- Further work is needed to establish a clear relationship between the radial traces and raypath angles. This will allow us to use these delay times for inverting a S-wave velocity model for the LVL using equation 2.