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Review of tomographic methods

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Abstract

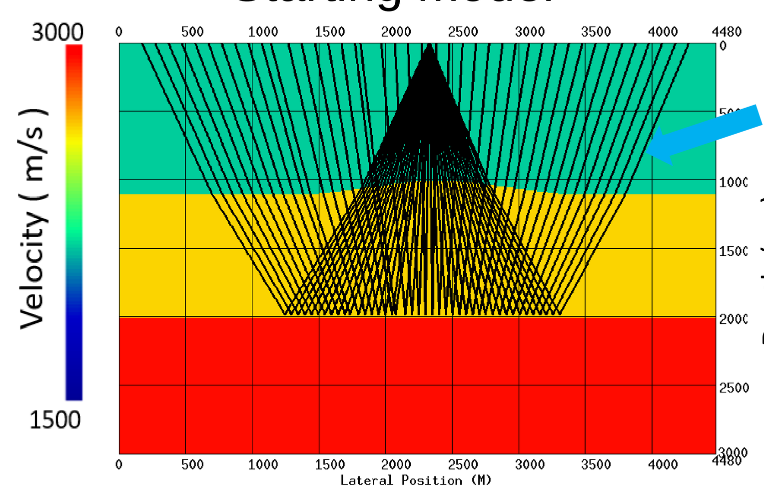
Classical reflection tomography (Bishop 1985) can accurately estimate the subsurface velocity; however, the difficulties in picking reflection arrival times on continuous reflection events on CDP stack and prestack gathers make it an undesirable approach. PSDM tomography (Stork 1992, Wang 1995, Gray 2000 and Etgen 2002) improves the picking efficiency by automatic scanning of the residual moveout within a common image gather (Al-Yahya 1989). Residual moveout picks can be back projected to the velocity model along ray paths or converted to Δt as input to reflection tomography. Stereotomography (Sword 1987, Billette 1998, Tavakoli 2017) uses automatically picked shot and receiver ray parameters and two way traveltimes to estimate the macro velocity model.

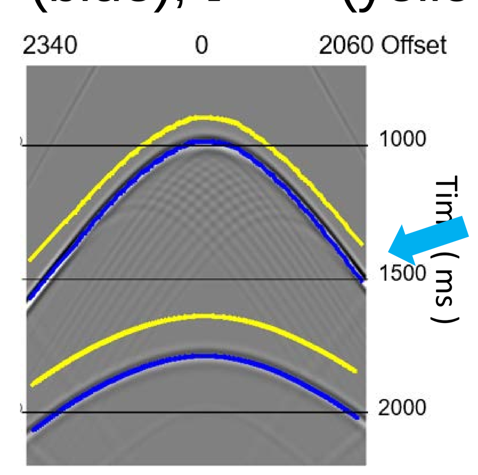
Classical Reflection Tomography

$$t_{raypath} = \int_{raypath} s(x,z)dl, \quad \Delta T = L\,\Delta S$$

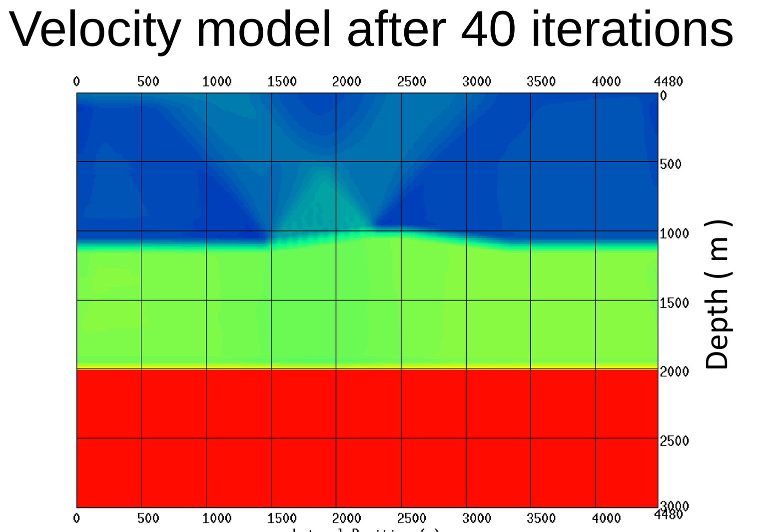
Starting model

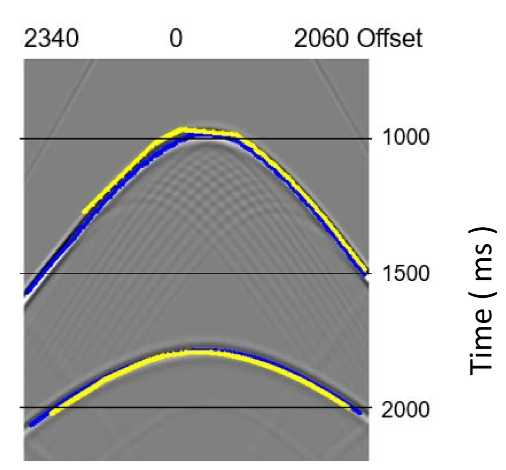
T^{obs}(blue), T^{pred}(yellow)



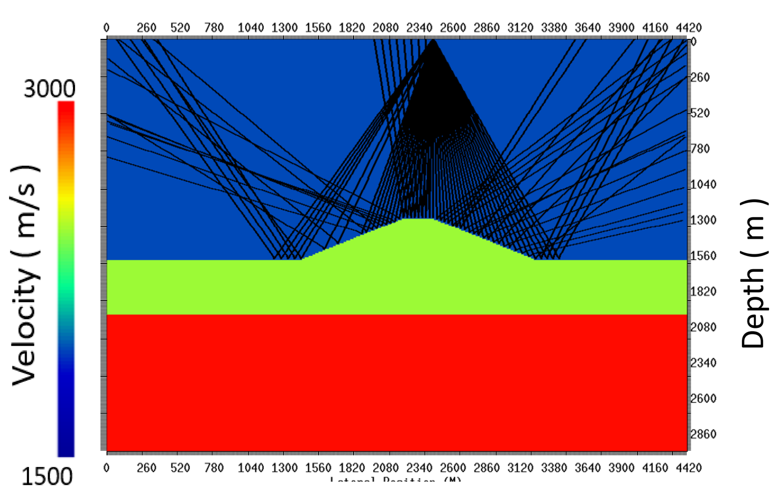


Velocity model after 40 iterations

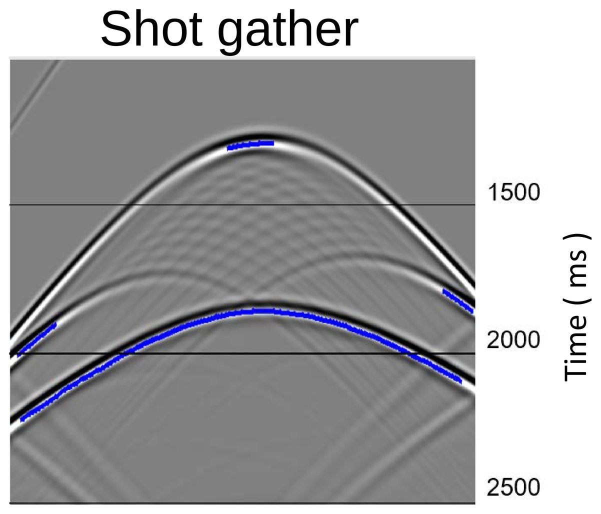




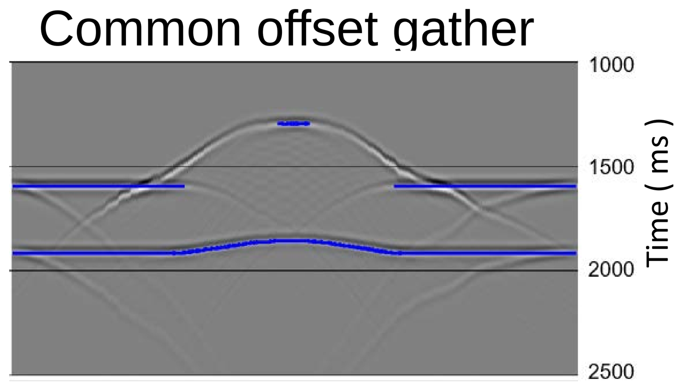
Problems with classical reflection tomography



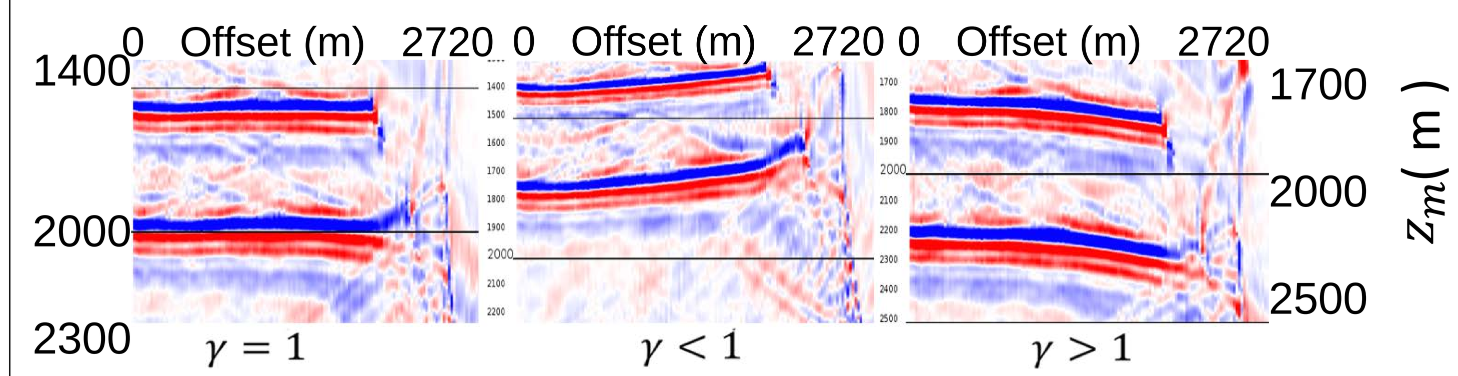
Shot gather



Common offset gather

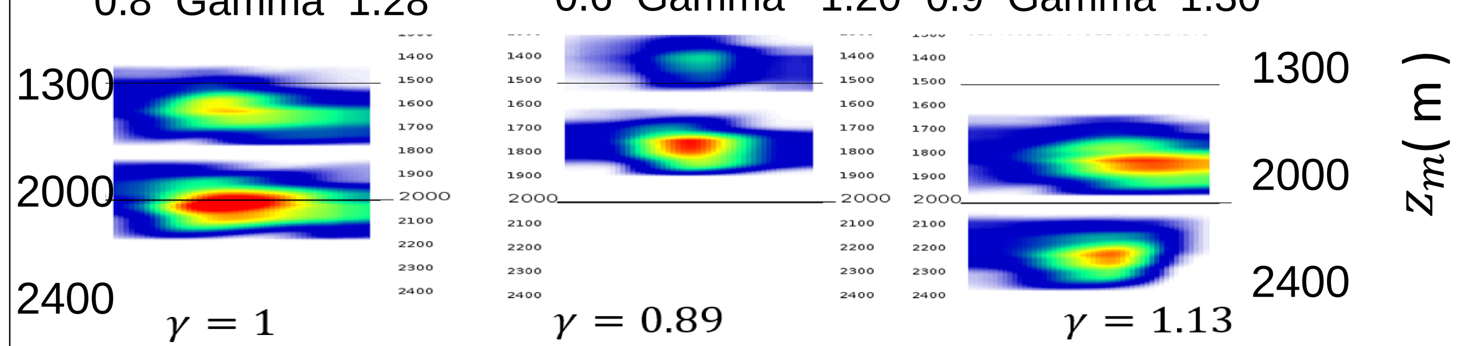


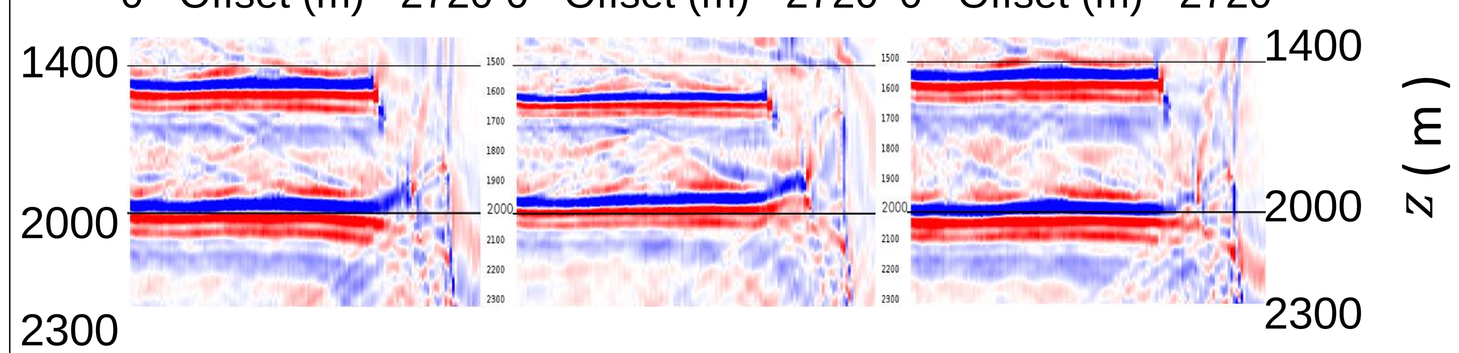
PSDM Tomography



$$\gamma = \tilde{V}_m / \tilde{V}, \quad z_m = \sqrt{\gamma^2 z^2 + (\gamma^2 - 1)x^2}$$,Al-Yahya (1989)

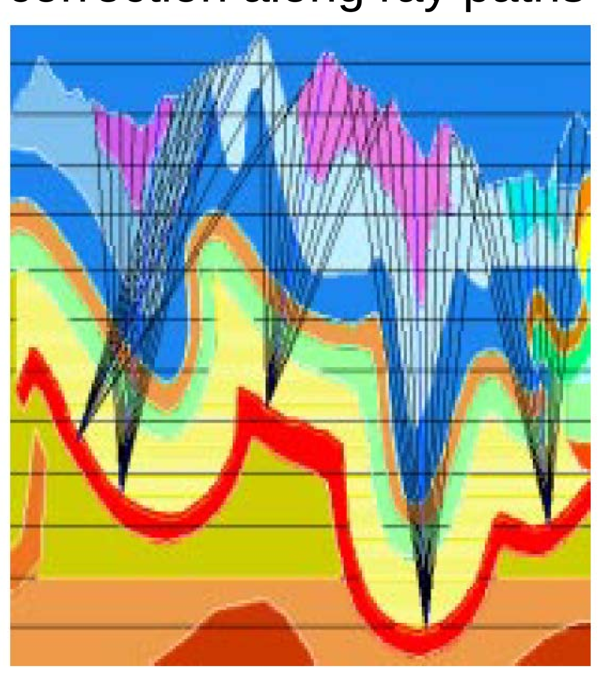
γ scan





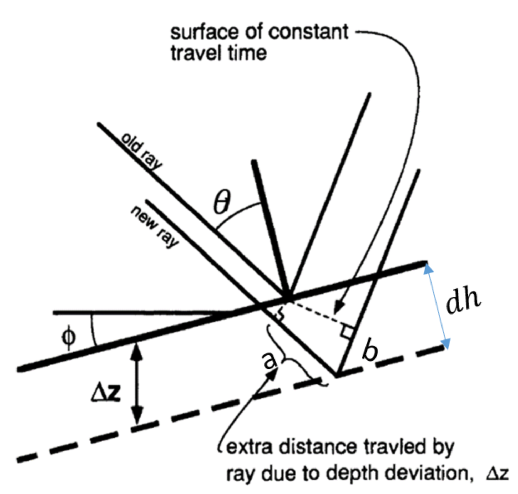
Velocity model update

Back project velocity correction along ray paths



Gray (2000)

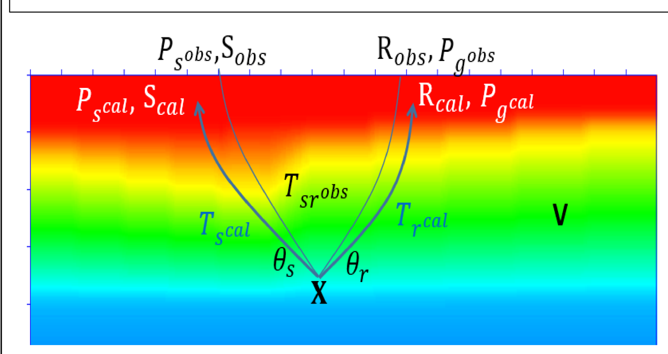
Convert residual moveout to residual time and perform reflection tomography



$$\Delta t = 2 \cdot s \cdot \Delta z \cdot cos(\phi) \cdot cos(\theta)$$
$$L\Delta S = 2 \cdot s \cdot \Delta z \cdot cos(\phi) \cdot cos(\theta)$$

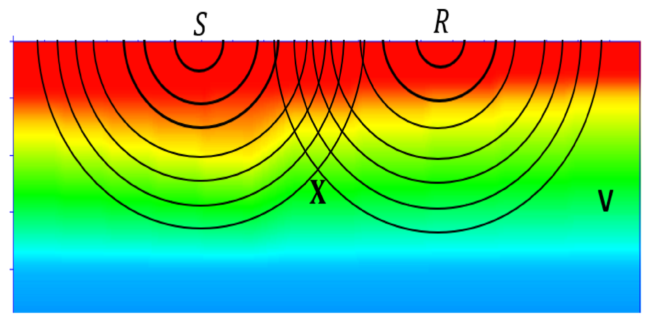
Stork (1991,1992)

Stereotomography



Classical stereotomography

$$m = [(X, \Theta_s, \Theta_r, T_s, T_r)_{i1=1,N}], [V]_{i2=1,M}]$$
$$d = \left[S, R, P_s, P_g, T_{sr} \right]_{j=1,N}$$

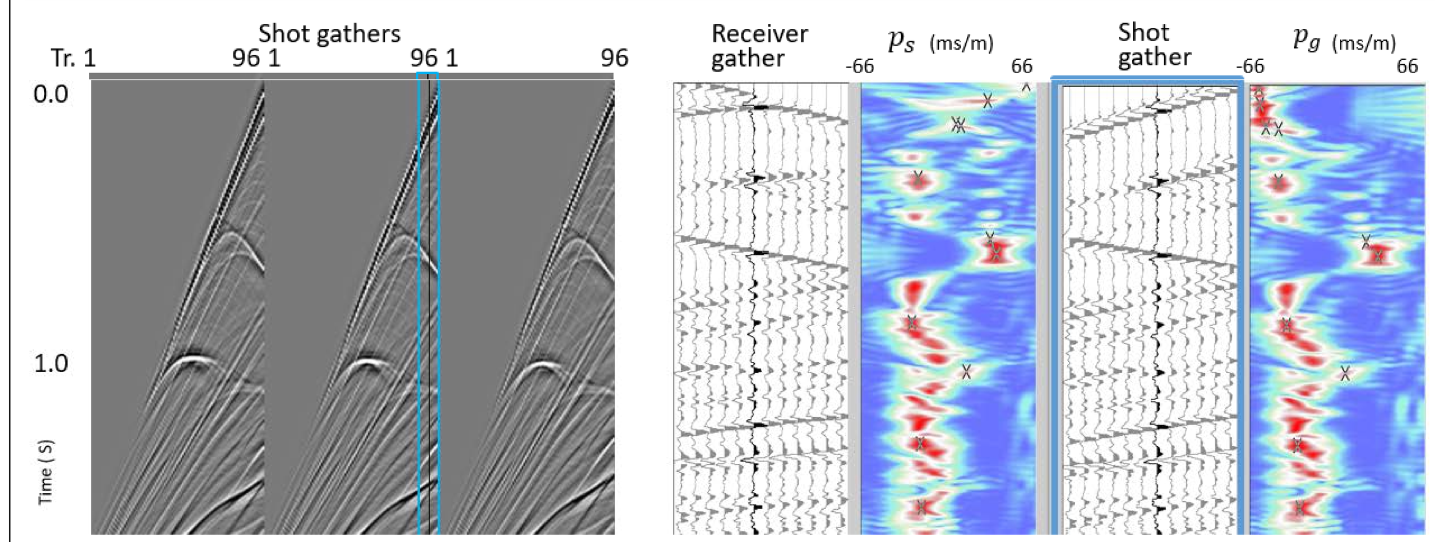


Adjoint stereotomography

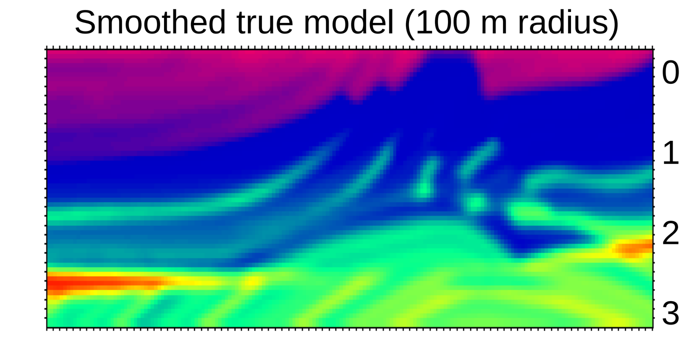
$$m = [X_{j=1,N}], [V]_{i=1,M}]$$
$$d = \left[P_s, P_g, T_{sr} \right]_{j=1,N}$$

Stereotomography updates the model parameters by minimizing the differences between the observed and predicted data. Adjoint stereotomography reduces the data and model space by ray tracing from the surface. Adjoint state method provides a matrix free approach to the solution.

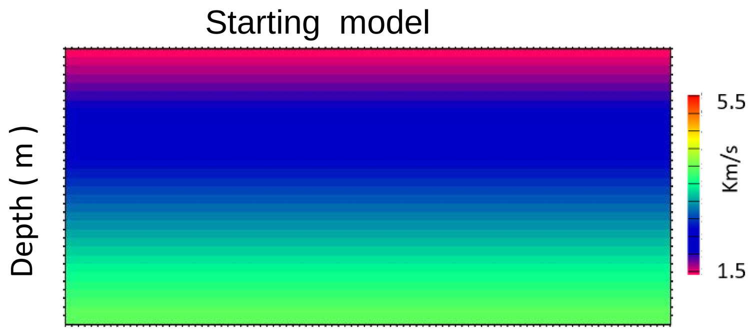
Synthetic test for adjoint stereotomography



Smoothed true model (100 m radius)

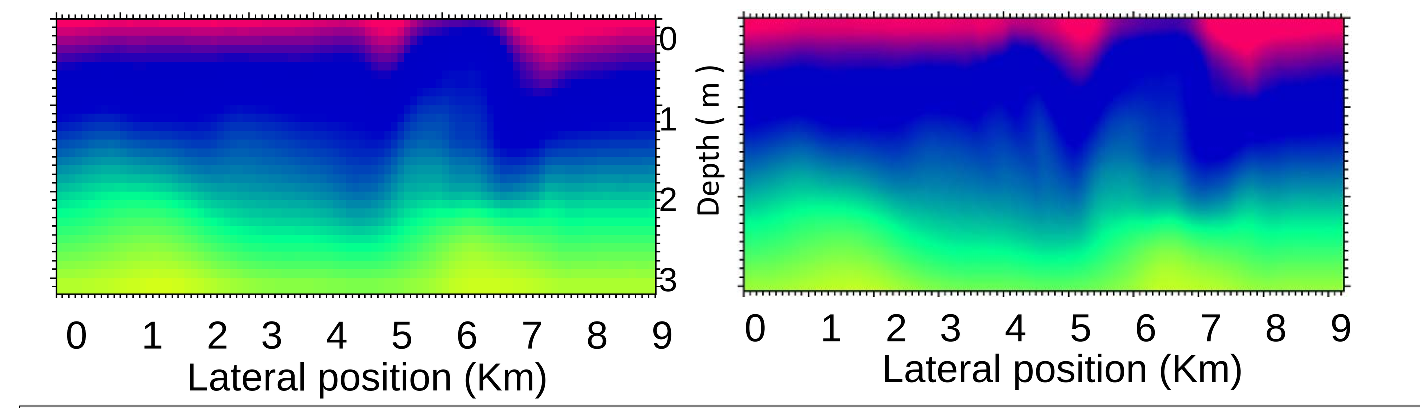


Starting model

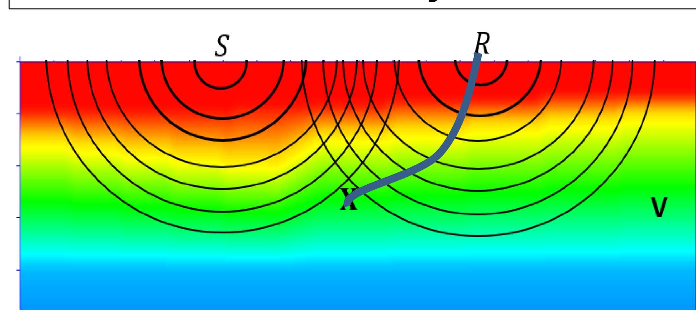


Final model at 100m grid after 23 iterations

After 7 additional iterations at 25m grid



Parsimonious adjoint stereotomography (Sambolian 2019)



Using focusing equations (Chauris 2002), $P_r^{pred} = P_r^{obs}$, and X is computed directly from receiver ray path and T_{sr}. This reduces the model and data space and avoids the cross talk between X and V.

$$m = [V]_{i=1,M}]$$
$$d = \left[P_s, T_{sr} \right]_{j=1,N}$$

Conclusions and future work

- PSDM tomography and stereotomography has picking advantage over classical reflection tomography.
- Adjoint stereotomography test result captures the long wavelength components of the true model. Our implementation of the multi-scaling approach does not improve the resolution of the velocity model.
- Future work includes further investigation of the accuracy in the estimation of scatter position and multi-scaling, and investigating the parsimonious adjoint stereotomography method.

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