Multiscale SRT of NGU synthetic fault zone model using a laterally averaged 1D-gradient starting model

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Summary

Using Norwegian Geological Survey (NGU) synthetic travel time data obtained from NGU fault zone models, we show improved Seismic Refraction Tomography (SRT) results and model interpretation. Our approach is based on the Wavepath Eikonal Traveltime inversion (WET) method (Schuster 1993). We obtain a 1D-gradient starting model by laterally averaging pseudo-2D DeltatV velocity vs. depth profiles obtained below each Common Mid-Point (CMP) to remove DeltatV artefacts (Sheehan 2005). We then implement a multiscale Conjugate-Gradient WET inversion approach. This approach improves the resolution of P-wave velocity tomograms by iteratively decreasing the WET wavepath width. Decreasing the wavepath width, i.e. Fresnel volume, corresponds to increasing the effective frequency in our tomographic method. We use Wavelength-Dependent Velocity Smoothing (WDVS; Zelt 2016) and WET to partially model finite-frequency signal propagation effects. Our results show considerable improvement in imaging of lateral velocity variation and of modeled fault zones compared to our default Smooth inversion method. We obtain a final tomogram with a lateral resolution similar to the lateral resolution reached using the Plus-Minus layered refraction method starting model. We also show that our default 1D-gradient starting model can work even with steep topography. The not laterally averaged pseudo-2D DeltatV starting model (Gebrande 1985, 1986) shows strong velocity artefacts with strong refractor curvature (Sheehan 2005) or strongly undulating topography (Tassis 2018).

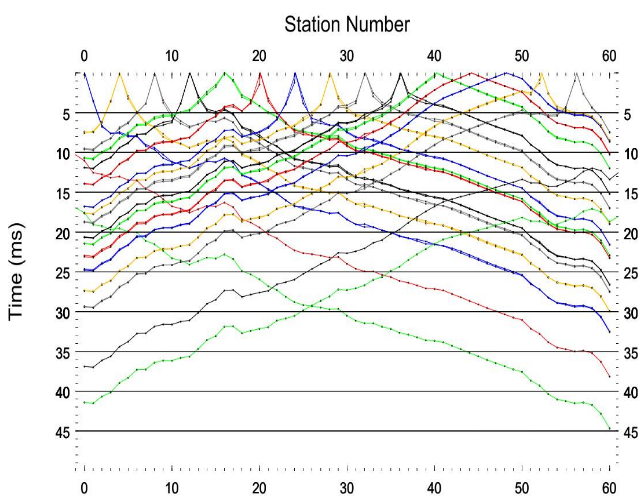

Fig. 1: Forward-modeled traveltime curves (solid) obtained using NGU fault zone model (Fig. 3). Inverted curves (dashed) obtained by multiscale WET inversion (Fig. 4).

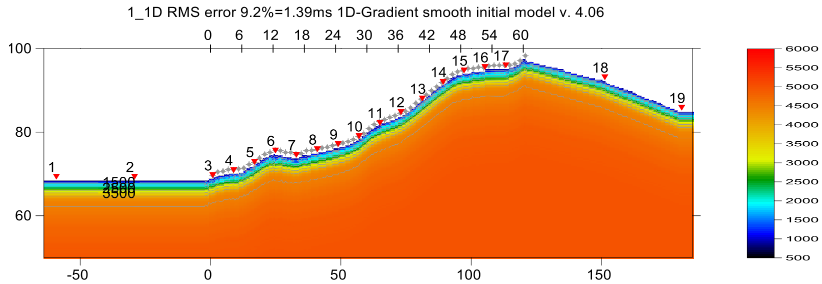

Fig. 2: 1D-gradient starting model used for Fig. 4. We laterally average the pseudo-2D DeltatV velocity vs. depth profiles obtained below each CMP (Sheehan 2005) to suppress DeltatV artefacts.

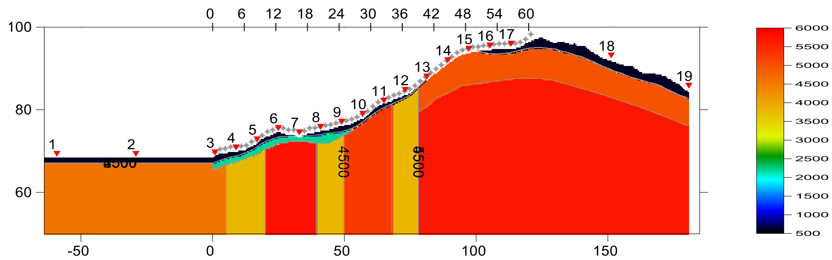

Fig. 3: The true model built and made available by NGU (Tassis 2018). The red triangles are the shot points. The grey dots are the receivers. The unit is meters per second.

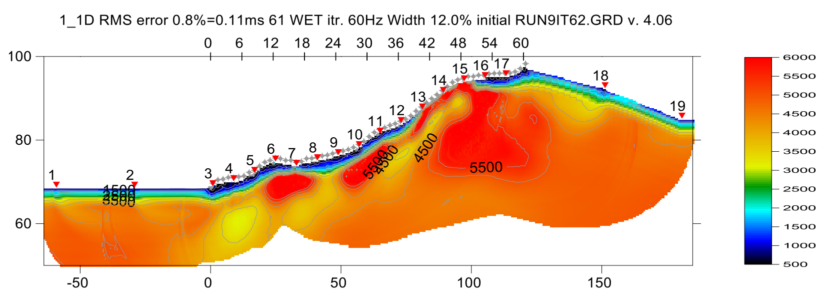

Fig. 4: Multiscale Conjugate-Gradient WET inversion using 1D-gradient starting model (Fig. 2). Wavelength-Dependent Velocity Smoothing (WDVS; Zelt 2016) enabled at 1200Hz.

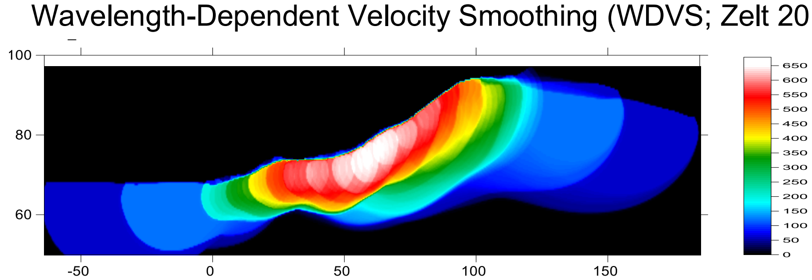

Fig. 5: WET wavepath coverage plot obtained with Fig. 4. Unit is wavepaths per grid cell.

Results

Our results (Rohdewald 2024a) show considerable improvement in imaging of lateral velocity variation and of modeled fault zones when using a multiscale Conjugate-Gradient WET inversion approach compared to our default Smooth inversion method. Using our default laterally averaged 1D-gradient starting model and WDVS smoothing, we obtained a final tomogram with a lateral resolution similar to the lateral resolution reached using the Plus-Minus layered refraction method starting model (Tassis 2018). We also show that our 1D-gradient starting model can work even with steep topography. The not laterally averaged pseudo-2D DeltatV starting model (Gebrande 1985, 1986) shows strong velocity artefacts with strong refractor curvature (Sheehan 2005) or strongly undulating topography (Tassis 2018).

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