Building a Reliable Near-surface Model for Depth Imaging using Wave-equation Traveltime Inversion: A Case Study from a Transition Zone 3d Seismic Survey in Saudi Arabia

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Abstract

Objectives/Scope: Due to the complexity of the near-surface in the arid environment of Saudi Arabia, building reliable shallow velocity models for accurate depth imaging is challenging. Using full-waveform inversion (FWI) might be the key. Nevertheless, low S/N ratio, lack of low frequencies and adequate initial models limit the applicability of such methods. The objective of this study is to demonstrate that detailed velocity variations in the near-surface can be obtained with wave-equation traveltime inversion (WTI) technique.

Methods, Procedures, Process: In WTI methodology, synthetic seismograms are modeled with the initial velocity model by full waveform modeling and first-breaks are picked on the synthetic gathers. The velocity model is perturbed until the first-breaks from the synthetic seismograms are best fitted to the observed first-breaks in a least squares sense with a gradient optimization techniques. The perturbation of travel-times with respect to velocity is derived directly from the wave equation. Higher details on the velocity models can be obtained by increasing the frequencies used in the forward modeling.

Results, Observations, Conclusions: Here, we show a case from a challenging transition zone 3D survey in Saudi Arabia where low-velocity zones and layers are present in the near surface with velocity reversal resulting in shingling of first arrivals. The lack of low frequencies and the S/N ratio prevented us from inverting for the velocity model using FWI. However, Wave-equation traveltime inversion (WTI) could reconstruct a velocity model with inversion resulting in accurate depth images. Since the only input to WTI is traveltime picks (1st breaks), the picks should be as accurate as possible. Our first-breaks picking strategy was based on array stacking in the CDP domain and will be shown. While WTI models seem to have less detailed velocity model than FWI, it can provide a good initial velocity model for FWI. Thus, For more complex models with stronger velocity inversions, a hybrid approach is suggested where WTI model serves as a starting model for FWI at higher frequencies.

Novel/Additive Information: The complexity of the near-surface in Saudi Arabia is characterized by large lateral heterogeneities, large-impedance contrasts and velocity inversions. Such complexity cannot be obtained with turning ray tomographic inversions and FWI would be the optimum technique. However, applying FWI is challenged by poor data quality and lacking low frequencies and good starting models. WTI has advantages such that it is insensitive to the starting model and does not suffer from cycle skipping.