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Constrained 3D VTI Full Waveform Inversion of Wide Azimuth Data from the Red Sea, Saudi Arabia

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ABSTRACT

Full waveform inversion (FWI) is one of several techniques used to estimate high resolution velocity fields by employing an optimization approach. This methodology is based on the minimization of an objective function between the recorded data and the modeled full waveform seismic wavefields. The derived velocity field has been used as the background velocity depth model for subsequent depth migrations to provide a cleared depth images and mitigate drilling risks.

In this research, we employed a 3D pseudo-acoustic vertically transverse isotropic (VTI) operator with zero shear wave vertical velocity in the time domain (2^{nd} order in time and 8^{th} order in space) for the computation of forward and backward propagated wavefields. In addition to the modeling operator, the gradient vector and pseudo-Hessian, which are necessary for parameter estimation and updating were calculated in the frequency domain. The source wavelet was estimated by using l2-norm between frequency-domain modeled and observed wavefields at every shot independently.

Although this methodology allows us to invert for δ and ε, we have decided to update only the P-wave velocity to reduce the risk of falling into local minima. In addition, we added the total variation term in the objective function calculation to constrain parameter updates, preserve model discontinuous edges and resolve sharp interfaces.

A 3D wide azimuth marine dataset acquired in the northern part of the Red Sea was employed to demonstrate the effectiveness of the proposed VTI FWI methodology. It was confirmed that the inverted P-wave velocity models showed higher resolution of the layered evaporate sequence while the boundaries of salt bodies were preserved. In addition, the VTI reverse time migration (RTM) was implemented with the initial and inverted models to verify the VTI FWI results and produce depth images and common angle-azimuth gathers. The 3D common azimuth-angle image gathers were computed by using vector fields computed by optical flow methodology and the inverted velocity model was verified by examining the flatness of these image gathers.

Future work will be focused on the inversion of all three anisotropic parameters to properly evaluate the benefits of VTI FWI in mitigating drilling risks in such geologically challenging environments.