Impact of TTI Anisotropy on Elastic Reverse Time Migration

R. Lu* (ExxonMobil Upstream Research Company), P. Traynin (ExxonMobil Upstream Research Company), T. Dickens (ExxonMobil Upstream Research Company) & J.E. Anderson (ExxonMobil Upstream Research Company)

SUMMARY

Studies have been conducted to demonstrate the impact of correct TTI parameterization on acoustic RTM (reverse time migration) imaging results. In this study, we extend the study to investigate the TTI effect on the elastic reverse time migration. We expect to see improvement in terms of better kinematics positioning as well as better focusing by including proper TTI parameterization.
Impact of TTI anisotropy on elastic reverse time migration

Rongrong Lu*, Peter Traynin, Tom Dickens, and John E. Anderson, ExxonMobil Upstream Research Company

Studies have been conducted to demonstrate the impact of correct TTI parameterization on acoustic RTM (reverse time migration) imaging results (Zhang and Zhang, 2008). In this study, we extend the study to investigate the TTI effect on the elastic reverse time migration. We expect to see improvement in terms of better kinematics positioning as well as better focusing by including proper TTI parameterization.

Elastic RTM uses the elastic wave equation to propagate source and receiver wave fields and has potential advantages over acoustic RTM for migrating multi-component data. The conventional approximation for multi-component data has been to migrate individual particle-velocity components using an acoustic RTM scheme making the assumption that the vertical geophone records only P waves and that the horizontal geophones only record S waves. Although acoustic RTM is faster than its elastic counterpart, it has the intrinsic liability that the actual wave propagation in the earth is elastic. By migrating the elastic wave field using acoustic approximations, inevitably artifacts due to the coupling and conversion between P-wave and S-wave components bring uncertainty to the migrated results. On the other hand, elastic RTM has the correct physics to handle multi-component data and accurate source and receiver features such as radiation patterns, and it can migrate different wave types to their correct subsurface position. Meanwhile, our computational capability has increased dramatically, which makes full elastic RTM more practical for real applications. We developed a new 3D RTM tool which incorporates multiple levels of physics ranging from isotropic constant-density scalar acoustic simulation to fully anisotropic variable-density visco-elastic simulation. The elastic simulations are conducted via a time-domain velocity-stress set of coupled equations on a rotated staggered grid (RSG) as described by Saenger (2000) or a standard staggered grid (SSG) as described by Virieux (1984).

We create a synthetic 2D elastic anisotropic version of the current SEAM (SEG Advanced Modeling) model (Fehler and Larner, 2008). In our modified model, the P-wave velocity (Figure 1a) and the density (Figure 1b) are taken from the original model. The S-wave velocity is computed assuming a Vp/Vs ratio (Figure 1c). The anisotropy model consists of four arbitrary layers that follow the sediment trend line with the ε and δ values ranging from 0.1 to 0.25, as shown in Figure 1d and 1e. The local tilt angles of the sediments are obtained from the P-wave velocity model using plane-wave destruction, as shown in Figure 1f. The maximum tilt angle in this 2D model is about 43 degrees. This tilt model is used to compute the TTI Cij coefficients for both forward simulation and RTM.

Shot gathers are simulated using the elastic TTI model depicted above assuming an OBC acquisition geometry, where the pressure sources are fired near the water surface and the receivers are laid out along the ocean bottom. These shot gathers are then migrated in three different cases – migrating assuming an isotropic model, migrating assuming anisotropic model but only account for VTI, and correct TTI anisotropic model. Figure 2 shows a zoomed-in initial comparison between the VTI image and TTI image. Kinematically, there is variation between 30 and 70 meters in position of the same events between TTI and VTI images. The uplift associated with elastic RTM with TTI vs. with VTI increases with tilt and is most obvious when comparing the deep section of the image, where significant improvements in terms of location and focusing can be observed.

Reference
Zhang, H. and Y. Zhang, 2008, Reverse time migration in 3D heterogeneous TTI media, SEG Expanded Abstract, 27, 2196-2130

Figure 1. Anisotropic elastic SEAM 2D model with (a) P-wave velocity along the local symmetry axis, (b) density, (c) S-wave velocity along the local symmetry axis, (d) ε, (e) δ, and (f) local tilt angle.

Figure 2. Initial comparison between (a) TTI RTM result, and (b) VTI RTM result. Red line on top of RTM image is the VTI position of the same event.