Chapter 5

Conclusions

In this dissertation, I present an integrated technique to build an anisotropic Earth model that satisfies seismic, geological, and rock physics constraints. In order to achieve this goal, I develop three key novel algorithms and one workflow for anisotropic model building.

First, I extend the isotropic wave-equation migration velocity analysis scheme to the anisotropic medium. I utilize the defocused energy to evaluate the accuracy of the background model and to provide meaningful updates in all parameters. I use a combined DSO operator and stacking power operator, which shares the merits of the global convergence of the DSO operator and the high resolution of the stacking power operator. Using an optimized finite differencing one-way wavefield extrapolation, the cost of the anisotropic WEMVA is on the same order as the isotropic WEMVA.

Second, I develop a new rock physics model for shale anisotropy that models both sand-shale lamination and sand as inclusions in the shale background material. This new model allows testing of multiple geological settings and rock physics scenarios. As a result, the uncertainties and the correlations in the anisotropic models are better captured.

Third, I develop a new regularization scheme to integrate geological and rock physics information to better constrain the seismic inversion. I summarize both types of information into the covariance matrix. The spatial component, defined by the geological knowledge, and the cross-parameter component, defined by the rock physics modeling, are considered independent of each other. This formulation allows me to modify the unconstrained anisotropic WEMVA workflow by gradient preconditioning, a process whose cost is negligible.

Finally, I develop a workflow to best utilize all the available information. Start an anisotropic model building process by translating the well log and/or other available lithological information into anisotropic models using stochastic rock physics modeling. Obtain the average anisotropic model and the cross-parameter covariance matrix. Estimate the spatial covariance matrix using the initial migration image. Set up the surface seismic data inversion using the average anisotropic model as the initial solution and the covariance matrix as the constraints.

I test the algorithms and the workflow developed in this dissertation extensively on synthetic, 2-D field, and 3-D field datasets. The inversion yields models that simultaneously explain the seismic data and satisfy the geological and rock physics constraints. The corresponding migration images show faults with higher resolution, better defined depths, and better imaged steeply dipping reflectors.