FWI schemes on high-resolution 3D seismic data, using Born and Rytov wave-equation tomography

Sasha Ziramov, Stanislav Glubokovskikh, Milovan Urosevic

Curtin University, Australia

In this work, we describe a gradient-based Full Waveform Inversion (FWI) applied on a high-resolution and high-density 3D seismic data, with limited source-receiver offsets. The back projections of Born and Rytov approximations are able to provide velocity updates beyond penetration depth of the diving waves. To illustrate how our gradient successfully recovers the velocity from pre-critical reflections, we use recorded 3D seismic data from a CO_2 controlled release experiment, CO2CRC Otway Project in Australia.

There have been many successful case histories of conventional Ray-based tomography from refracted and turning waves recorded in high-resolution 3D surveys. In these scenarios recorded diving waves allow tomography to resolve geological features down to the deepest turning point, defined by the maximum source-receiver offset. As our high-density “Mini” Otway 3D survey has useable offsets up to 200m, the maximum depth we can recover using diving waves is down to 45m. For deeper targets tomography needs to rely on reflected energy to updated initial model.

Our approach to FWI is to separate the wavefileds of observed and syntetic data into a frequency ranges, and then compute differential wavefield in two stages. First, we use Rytov approximation that creates a linear relation between velocity and phase perturbations. This velocity update will be used to compute new synthetic data and then compute new differential wavefield, this time using Born wavepaths. Born approximation gives a relation between velocity and amplitude perturbations. The process is repeated for all frequency ranges, ending at 200 Hz.

Our FWI scheme provides a high-resolution velocity updates without migration imprint into final velocity model. The method uses reflected and transmitted waves, enabling velocity updates beyond the penetration depth of diving waves and reduces the dependency on long offsets. The application of this innovative FWI approach on “Mini” 3D Otway has been most successful. The CO2 controlled release study now has a detailed velocity model down to 130m of depth. The high-resolution velocity model will improve our understanding of the CO_2 migration behavior in shallow faults and help us to assess monitoring strategies.

REFERENCES

Ramos-Martinez, J., Chemingui, N., Crawley, S., Zou, Z., Valenciano, A., and Klochikhina, E., 2016, A robust FWI gradient for high-resolution velocity model building: SEG Technical Program Expanded Abstracts,1258-1262.

Tarantola, A., 1984, Inversion of seismic reflection data in the acoustic approximation: GEOPHYSICS, 49, 1259–1266, http://dx.doi.org/10.1190/1.1441754.

Woodward M. J., 1992, Wave-equation tomography: GEOPHYSICS, VOL. 57, P15-26.