FWI Using Reflections in Shallow Waters Offshore Abu Dhabi

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Abstract

The Arabian Gulf near-surface geology is complex, with extremely shallow waters and a hard water bottom generating high amplitude short period multiples, and thinly bedded high and low velocity layers creating high apparent anisotropy in the bandwidth of seismic surveys. Obtaining an accurate description of the velocity variations in the near-surface and at intermediate depths is a necessity for reliable imaging and positioning of the reservoir layers located underneath. We propose a two-step full-waveform inversion (FWI) of ocean-bottom node (OBN) seismic data from offshore Abu Dhabi. For the first step we update the velocity model using diving waves only, whilst for the second step we use both diving waves and reflected waves to reach the required depth of penetration.Due to the oscillatory nature of seismic data, FWI can be subject to cycle-skipping, where the inversion process falls into a local minimum. This risk is mitigated by using a good initial model and starting the inversion from low frequencies. A further challenge we have to deal with in the shallow waters of offshore Abu Dhabi is that, near-offset data suffer from strong mud-roll and guided-wave energy that are not properly modeled with acoustic FWI. We propose to exclude these offsets from the input data and use diving waves, starting at 3.5Hz, to update the near surface.As the diving waves penetration is limited to approximately one kilometer in this area and corresponds to the base of a shallow high velocity layer, for deeper updates, the data are processed to remove the mud-roll and guided wave energy. This allows for the inclusion of reflections and near offsets. The FWI update is performed to 10Hz and penetrates about 3km into the sub-surface.Furthermore, we need an accurate estimation of the anisotropy to reconcile the kinematics of reflected waves, travelling mostly vertically and used for imaging, and diving waves, travelling mostly horizontally, and used in the velocity update. This is obtained using Backus averaging from available well logs.We applied this FWI workflow to a recent node survey acquired offshore Abu Dhabi. The velocity model obtained follows the main geological structures and accurately describes the velocity variations in the shallow sub-surface. The estimation of anisotropy is important to ensure good convergence of the FWI and for imaging and vertical positioning of the migrated events. The reverse-time migration (RTM) image obtained with the updated model shows improved focusing and simplified depth structures compared to the RTM image obtained with the smooth initial model.