Applications of full-waveform inversion to long offset Vibroseis data

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We show two case studies of full-waveform inversion (FWI) application to regional deep reflection seismic profiles recently acquired in Poland. In the first example, we use data from a 240-km long seismic profile (called POLCRUST-01) located in southeast Poland. This experiment is unique as it portrays different tectonic deformation styles over a relatively short distance (from Paleozoic platform to Carpathian Mts.). It was designed for deep reflection imaging, but we decided to use FWI to provide a high-resolution P-wave velocity model of the shallow (down to 3 km) subsurface. The acquisition parameters, namely the use of 10-Hz geophones and Vibroseis sweeps starting at 6 Hz, made it necessary to design a non-standard data preconditioning workflow for enhancing low frequencies including match-filtering and curvelet denoising. Final model was validated using multiple procedures, such as comparison with borehole data and independently processed Kirchhoff pre-stack depth migration (PSDM). Although in some deeper areas of the model we identified artefacts that are most likely a result of cycle skip, the velocity profiles from our model match the borehole check-shot data and the velocity anomalies coincide very well with the reflectivity in the migrated data. The resolution of the model allows us to delineate the internal structure of the Carpathian thrust system and presumably small natural gas reservoirs in the Miocene sediments of the Carpathian Foredeep. In the second example, we used data from a 100-km long profile from the PolandSPAN™ survey located in Central Poland. In this case, a broadband Vibroseis sweep starting at 2 Hz was used, but the 10-Hz geophones used for recording the signal damped the lowest frequencies and we started the inversion at 3.5 Hz. This however, was enough to resign from a conventional method for building the starting model, namely first arrival travel time tomography, that in this case study would be extremely laborious and inefficient. We show that purely heuristic models of anisotropy are a functioning alternative when it comes to conditioning the PSDM velocities for use in calculation of first-arrival travel times and as the initial model for FWI. The initial velocity model that we obtained by conditioning the smoothed PSDM velocities allowed us to provide high-resolution FWI model that we managed to verify using the results of reflection imaging and vintage well-log data.

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