

CHARACTERIZING VELOCITY ANOMALIES THROUGH FULL WAVEFORM INVERSION OF CROSSWELL SEISMIC DATA

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Seismic imaging of injected CO₂ (or any anomalous volume) in the cross well geometry can be challenging especially when the target reservoir is encased by layers with higher velocities. Travel-time tomography, for example, may not be able to resolve the velocity anomaly caused by fluids or fractures in such a layer or waveguide. But the waveforms of later arrivals can contain adequate information to characterize the anomalies. Hence, full waveform inversion (FWI) shows promise for reservoir characterization and monitoring. Layered waveguide models, with velocity contrasts of up to 30% and elliptical velocity anomalies inside the waveguide, are used to test the capability of time-lapse FWI. Frequency-domain FWI for synthetic data from transmissions in a cross well survey with a single receiver array shows that frequencies even up to 300 Hz don't fully resolve velocity anomalies and create a shadow of the anomaly on the source side. Adding another receiver array on the source side allows FWI to take advantage of backscattered waves. FWI from this dual receiver array acquisition better resolves the background velocity structure and the shape of anomalies within the waveguide. The differences between before-and-after FWI for the synthetic time-lapse data clearly delineate anomalies. The error of the inverted velocity up to 300 Hz is small (less than 1%). The error is most pronounced at sharp velocity contrasts created by layer interfaces and the elliptical anomaly. We have also acquired a number of ultrasonic lab measurements on a physical waveguide model in a cross well geometry. The data are quite coherent with numerical modeling and can be used for FWI. Using FWI in the cross well geometry with receivers in both wells may substantially enhance imaging for reservoir characterization and monitoring.