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Traveltime and waveform tomography analysis of synthetic borehole seismic data based on the CO2SINK project site, Germany

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Time lapse analysis of seismic data is very important for CO2 storage projects. Therefore, we have tested traveltime and waveform tomography methods to detect velocity changes in a CO2 injection reservoir using synthetic time lapse data. The structural model tested is based on the CO2SINK injection site at Ketzin, Germany where CO2 is being injected at about 630-650 m into a saline aquifer. First, we created synthetic time lapse moving source profiling (MSP) data, also known as walkaway profiling. The velocity model used for modeling was based on well logging and lithological information in the injection borehole. Gassmann fluid substitution was used to calculate the reservoir velocity after injection. In this substitution, we assumed a saturation of CO2 of 30%. The model velocity of the reservoir changed from 2750 m/s (before injection) to 2150 m/s (after injection). A 2D finite difference code available in Seismic Unix (www.cwp.mines.edu) was used. 60 source points were distributed along a surface line. The distance from the injection well was between 150m and 858m, with an interval of 12m. We recorded 21 channels at receiver depths from 470m to 670m, with an interval of 10m. The injection layer was assumed to be between 629m and 650m depth. The wavelet used for the synthetic data was a Gaussian derivative with an average frequency of 60Hz. Then first arrivals were picked on both data sets and used as input data for traveltime tomography. For traveltime tomography, the PS_tomo program was used. Since no data were recorded above 470m, the initial velocity model used above this depth was the true velocity model. Below 470m, the initial velocity model increases linearly from 3000m/s to 3250m/s. After inversion, the reservoir velocity and an anhydrite layer (high velocity layer) can be seen clearly in the final inverted velocity models. Using these velocity models as starting models, we performed waveform tomography in the frequency domain using a program supplied by Pratt. We started at 10HZ, then moved up in frequency in steps of 5HZ. A taper window of 50ms following the first arrivals was applied on the data. Finally, we obtained the velocity difference between the models before injection and after injection. The reservoir velocity before injection is around 2700m/s, and after injection is around 2100m/s in the inverted models. The result is very close to the true model. Our study shows that tomographic methods can potentially be used to monitor velocity changes in CO2 storage projects if high quality data are available. Compared with surface seismic data, MSP data allow more velocity information to be obtained near the borehole. For optimum results, some receivers should be located under the layer of interest, to ensure that first arrivals pass through it.