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AVO attributes analysis of time-lapse 3D surface seismic data from CO2SINK project site, Ketzin, Germany

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CO2 storage is becoming an increasingly important option to mitigate atmospheric CO2 release into the atmosphere and reduce the potential global warming problem. The CO2SINK project is the first European onshore CO2 storage study in this respect and started in April 2004. A major objective of the project has been to provide operational field experience for CO2 geologic storage. The research site for this project is located west of Berlin, near the town of Ketzin, Germany. Three boreholes were drilled in 2006, one for injection and two for observations. In 2005, a baseline 3D seismic survey was acquired. On 30th June 2008, the GFZ German Research Centre for Geosciences began to inject CO2 into an underground saline aquifer layer at depth of about 630-650 m. In 2009 a smaller size 3D monitor seismic survey was acquired. In this study we apply Amplitude Variation with Offset (AVO) analysis to investigate the AVO signature of the injected CO2. This method is now routinely applied in gas detection, lithology identification and fluid parameter analysis. First, we did seismic modeling for different situations like no gas, 30% gas saturation and 60% gas saturation in the reservoir based on well logging data and Gassmann fluid substitution. We found the reservoir shows a class Three AVO anomaly, the amplitude of the top of the reservoir increase with offset (incidence angle) after CO2 injection. For the real data, CDP gathers after NMO correction were loaded into a software package for AVO analysis. After correlation with well logging data, we extracted super gathers from both data sets to increase reflection clarity and remove noise. Aki and Richard's three term equation was used to calculate intercept (A) and gradient (B) attributes since we had incidence angles greater than 30°. We focused on two time intervals in both data sets. The first one was the CO2 injection layer which is around 510-530 ms in the seismic cube. The second interval was a shallower layer (around 200-300 ms in the seismic cube). This region was used to store natural gas until 2000, and still contains some residual gas. From the A*B plots, we did not see much difference between two data sets. However, in the cross plots between A and B, we observe a clear class Three AVO anomaly at injection layer near the injection borehole on the repeat data. There is no AVO anomaly at the reservoir level on the baseline data since it corresponds to a water saturated sand layer. An anhydrite layer above the injection reservoir shows no difference between two data sets, implying that the injected CO2 is not migrating upwards. For the shallower part corresponding to the residual gas zone (200-300 ms), we observe almost the same AVO anomaly on both data sets, with just a few ms difference, indicating no significant changes in the residual gas conditions. This time difference may be due to that the statics are different between the two data sets. Our study shows that AVO analysis can be used to monitor CO2 in the CO2SINK project, and the injected CO2 at the time of the repeat survey is trapped in the reservoir.