MONITORING CO2 INJECTION WITH CROSS-BOREHOLE SEISMIC TRAVELTIME AND WAVEFORM TOMOGRAPHY AT THE SVELVIK CO2 FIELD LABORATORY, NORWAY.

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In September 2021, a series of cross-borehole seismic surveys were acquired at the Svelvik CO_2 field laboratory before and during a period of active CO_2 injection. The Svelvik CO_2 field laboratory, which is part of the European Union DIGIMON project, was established in 2010 to study and develop systems to monitor CO_2 storage. The laboratory is located on a sand ridge at the mouth of the Drammensfjord, approximately 50km southwest of Oslo, Norway. A clay content log extracted from the CO_2 injection well shows that sediments in the ridge transition from sand-dominated to more clay-dominated deposits at a depth of about 35m. The primary goal of this work is to show how first-arrival traveltime tomography and early-arrival waveform tomography can be used to track the movement of injected CO_2 within the survey area by monitoring changes in compressional velocity with time.

The cross-borehole seismic data was acquired in two monitoring wells that are cased with PVC to a depth of approximately 100m and are in-line and equidistant from a 90m deep well that is screened for CO_2 injection between a depth of 64m and 65m. The receiver well contained two, 24-channel strings of hydrophones (BHC5 from Geotomographie GmbH) that were clamped to the cased borehole at 1m intervals from 30m to 77m. In the source well, a P-wave sparker source (SBS42 from Geotomographie GmbH) was fired at 1m intervals from 30m to 77m. A baseline survey was acquired before the injection of any CO_2, followed by repeat surveys for 6 days during which CO_2 was injected at a rate of $8m^3$/day.

We applied first-arrival traveltime tomography and early-arrival waveform tomography to the baseline survey and a survey that was acquired after four full days of CO_2 injection. The first arrival tomograms for each survey display a prominent, high-velocity clay layer at a depth of about 36m. The difference between the day four traveltime tomogram and the baseline tomogram shows a localized decrease in velocity immediately below the clay layer of approximately 6%. The early-arrival waveform tomograms reveal additional high-velocity layers beneath the clay layer, and these layers display a good correlation with the clay content log extracted from the injection well. The difference between the day four waveform tomogram and the baseline waveform tomogram shows a more laterally continuous decrease in compressional wave velocity immediately beneath the clay layer with changes as large as 18%. The decrease in velocity below the clay layer at 36m after four full days of CO_2 injection indicates that a portion of the CO_2 injected at a depth of 64m has migrated, and been trapped, beneath the clay at a depth of about 36m.