Time-lapse crosswell seismic tomography for monitoring CO2 geological sequestration in Nagaoka pilot-scale project

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Japan's first pilot-scale CO2 geological sequestration experiment has been conducted in Nagaoka, where 10400 t of CO2 have been injected in an onshore saline aquifer at a depth of about 1100 m. Among various measurements conducted at the site for monitoring the injected CO2, we conducted time-lapse crosswell seismic tomography between two observation wells to determine the distribution of CO2 in the aquifer as the change of P-wave velocities.

The crosswell seismic tomography measurements were carried out seven times; once before the injection as a baseline survey, three times during the injection and three times after injection as monitoring surveys. The velocity tomograms resulting from the monitoring surveys were compared to the baseline survey tomogram, and velocity difference tomograms were obtained. The velocity difference tomograms showed that velocity had decreased in a part of the aquifer around the injection well, where the injected CO2 was supposed to be distributed. We also found that the area in which velocity had decreased was expanding in the formation up-dip direction, as increasing amounts of CO2 were injected.

Seismic tomography successfully delineated the injected CO2 distribution as a velocity reduction area even when only 3200 t of CO2 was injected. The maximum velocity reductions observed were 3.5%. However, it was much smaller than that observed by sonic logging (more than 20%). One of the reasons why the velocity reduction by tomography was so small was the occurrence of low velocity artifacts. In order to estimate more accurate velocity reduction values, we tried to apply a restriction to the tomographic reconstruction algorithm, in which velocity update was allowed only in a fixed area. As the result, maximum velocity reduction value became 13.4% which is still smaller than that obtained by sonic logging, but is reasonable value.