

## On the relationship between Vp and CO<sub>2</sub> saturation in the logging data at the Nagaoka site

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This paper discusses the relationship between seismic P-wave velocity (Vp) and CO<sub>2</sub> saturation in the field scale observation at the Nagaoka site. This dependency is important to evaluate the stored CO<sub>2</sub> in the ground using seismic exploration methods. There are many reports which examined and modeled the relationship. However, most of the reports studied drainage processes, where pore water is replaced by injected CO<sub>2</sub>. In this paper, we investigate the relationships during drainage and imbibition processes using the time-lapse logging data at the Nagaoka site. Nagaoka site is the first CO<sub>2</sub> injection site in Japan, and CO<sub>2</sub> was injected between July 2003 and January 2005. Time-lapse loggings have been conducted at the observation wells in order to monitor the injected CO<sub>2</sub>. The period of the post-injection monitoring is almost 15 years, so the monitoring data provide information on the imbibition process.

The monitoring data at a down-dip direction showed that CO<sub>2</sub> saturation increased at the injection period, became maximum one year after the end of the injection, and was gradually approaching a certain value. The latest data is thought to be the residual saturation state. Vp change in the sonic logging data represented that the Vp decreased uniformly during the drainage process but the trajectories during the imbibition process have facies dependencies. This facies dependency means that there is hysteresis in the relationship between Vp and CO<sub>2</sub> saturation, the hysteresis is stronger in the silty stone than the sandy stone at the Nagaoka site.

Physical meanings of these behaviors were considered. The relationship at the drainage process is thought to be modified patchy saturation as Azuma et al., (2013) pointed out. However, during the imbibition process, it became more uniform relationship. The reason of this difference is thought to be come from that injected CO<sub>2</sub> would be invading from the large pore space, while the residual CO<sub>2</sub> would exist only in small pore space, which is thought to be uniformly spread out than large pore space. This supports that the silty layer worked like a uniform medium at the imbibition process.

The results of these analyses indicate that the evaluation of CO<sub>2</sub> saturation from seismic methods needs to be more careful at the post-injection period.

Keywords: Geological CO<sub>2</sub> storage, Sonic logging, P-wave velocity, Hysteresis, Nagaoka site