貯留層中の超臨界CO_2影響評価のための繰り返し音波検層における振幅減少情報の利用

Utilization of wave attenuation in time-lapse sonic logging data to evaluate the effect of super-critical CO_2 in the reservoir

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This paper discusses seismic wave attenuation by injected CO_2 in the formation. Seismic methods have been broadly used for the monitoring of injected CO_2 at many CCS sites. Concerning the velocity change by the existence of CO_2, the relationship between P-wave velocity and CO_2 saturation in rock samples and formation have been studied well. Some laboratory experiments studied amplitude of P-wave as well as the velocity change by the invasion of CO_2, and the change in amplitude was larger than that of time delay (e.g. Muller et al., 2010). Meanwhile investigations on amplitude attenuation were rather limited. In this paper, we investigated P-wave data in the results of time-lapse sonic logging at the Nagaoka site.
At the Nagaoka site, time-lapse well loggings have been conducted during the injection period and post injection period at observation wells, which are 40 m and 60 m apart from the injection well. The sonic logging was conducted 45 times during 12 years using Halliburton’s LFDL (Low Frequency Dipole-Sonic Logging Tool). Since it is not ascertain that the monopole transmitter has emitted the same energy at every logging, we chose a reference point in the cap rock 10 m above the target zone. At this depth, the formation was highly cemented with very small slowness, so the position was easily recognized in wave data and its wave field would not change during the CO_2 injection. We took the amplitude of the first P-wave arrival as the reference. We also assume that the emitted energy from the transmitter would not change at the reservoir within 15 m interval from the reference point.
Firstly, we compared the wave data at the depth where the largest change observed by CO_2 injected. We can see that the first arrival of P-wave at the nearest observation logging was shifted from 1.64 to 1.8 micro-sec at 14-th run. Amplitude of the peak was also gradually decreased after the CO_2 breakthrough, and the amplitude at 21-st run was clearly small. Next we calculated spectrum around the first P-wave arrivals, and found that high frequency components decreased much than the lower frequency components. This frequency shift looked like to be recovered during the imbibition process. These could be an evidence of wave-induced flow of two phase liquid.
From these analyses, amplitude attenuation can be observed in the sonic logging at geological storage site. The combination of seismic wave amplitude and time-delay could be applied for more reliable evaluation of CO_2 saturation as Azuma et al. (2014) pointed out. The amplitude change might be effective in the early detection of CO_2 leakage along the well, if results as the laboratory experiments were obtained in the field. An effective measurement for this purpose could be realized with the use of DAS-VSP.

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