Crosswell seismic tomography for the monitoring CO2 geological sequestration

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1. Introduction

Recently, many research works on reducing carbon dioxide in the air have been conducted as a technology for the prevention of global warming. One of the effective methods is the geological sequestration technology. In Japan, the first pilot scale experiment of the CO2 geological sequestration started in July 2003 at the Minami-Nagaoka oil and gas field, in which CO2 had been injected in a deep saline aquifer. Total 10400 t-CO2 were injected into the aquifer at the depth of about 1100 m during the period between July 2003 and January 2005. The basic data such as the temperature and pressure were acquired, and some geophysical measurements were conducted to monitor the injected CO2 movements in the aquifer. We conducted time-lapse crosswell seismic tomography as a part of the monitoring surveys. In this paper, we describe the results of the seismic tomography conducted before, during and after CO2 injection.

2. Crosswell seismic tomography

Crosswell seismic tomography was conducted between two observation wells OB-2 and OB-3. The well spacing was about 160 m at the CO2 injection depth, about 1100 m. The seismic sources were located at the depth between 900 and 1284 m, while the receivers were located between 900 and 1228 m, both in 4 m intervals. The energy source used in the experiment was called OWS source, which can generate high frequency seismic waves and shows good repeatability. A 24-level hydrophone array cable was used as the receivers, and the maximum 24 times stacking was conducted. The dominant frequency of the first arrival waves was about 500 Hz.

The velocity model used in the tomography was expressed by assigning a constant velocity in each cell having 4 m height and 8 m width. The first arrival traveltimes were picked manually from the waveform data, and the traveltime curves were carefully checked and adjusted. Tomography algorithm used was SIRT with ray tracing in order to take account of ray bending. Although the wells used in the tomography were not on a plane, the deviation from the vertical plane was so small that the two dimensional reconstruction was considered to be applicable.

3. Time-lapse results

The baseline survey tomogram was used to generate velocity difference tomogram for every monitoring survey, these are MS1 (after 3200 t-CO2 injected), MS2 (after 6900 t-CO2 injected), MS3 (after 8900 t-CO2 injected), and MS4 (after 10400 t-CO2 injected). As the results, a velocity reduction area was found around the CO2 injection point. In addition, the velocity reduction area was expanded as the amount of injected CO2 increased.

4. Discussions

We examined if the velocity reduction area detected by tomography was really produced by the traveltime delays of the rays passing through the area. The waveforms showed the traveltime delays whose ray paths passed through the velocity reduction area.

In addition, we examined if the velocity reduction area extending to outside of the aquifer was actual velocity change due to CO2 injection. We conducted some numerical experiments simulating the field conditions. As the results, we found that the apparent velocity reduction was artifacts due to the source-receiver geometry for this particular site.

5. Conclusions

We have successfully applied crosswell seismic tomography to image the distribution of injected CO2 during the Japan's first pilot scale project of CO2 geological sequestration. The time-lapse tomography results showed the expanding velocity reduction area as the amount of injected CO2 increased. Since the monitoring technology is very important for the geological sequestration project, these successful results are significant.

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