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Time-lapse field experiment using seismic ACROSS at the air injection into the shallow ground in Awaji Island-II

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1. Introduction

Seismic ACROSS has been developed in Japan as one the time-lapse (4D) methodology to monitor a change of transfer function along the propagating ray paths by transmitting accurately-controlled signals and repeatedly receiving the steady continuous signals (Kumazawa et al., 2000; Kasahara et al., 2010).

Time-lapse observation is very useful for monitoring some changes in the seismic characteristics of the particular phases propagating through the time-variant target regions such as oil-gas/CO2 and magma reservoirs. We expect to detect the small changes by using both accurate-and-steady repeated seismic signals and high-quality multi-receiver's data.

In this paper, we show the preliminary but impressive results of the time-lapse experiment with an air injection into the shallow ground in Awaji Island, Japan, by using ACROSS system.

2. Outline of the Air-injection and Seismic ACROSS Observation

We conducted thefield experiment near the active Nojima fault in Awaji Island from Feb. 11 to Mar. 10, 2011, using two seismic ACROSS sources and temporal 32 three-component geophone sets installed at the sedimentary-rock surface and a stationary 800-m borehole site (operated by Kyoto Univ.) located at the hard-rock site.

During five days (Feb.26-Mar.3), 81 tons air in total amount were injected with 21 atoms in pressure into the 100-m depth point of the Osaka formation (Kasahara et al., 2012).

We used two different mass-rotation-type ACROSS sources, Source-A and Source-B. The Source-A (operated by Nagoya Univ.) locates in a southern east area has a vertical rotational axis (Yamaoka et al., 2001). Source-A and B transmitted the seismic signals in a frequency range of 10-30 Hz in a horizontal plane and 10-35 Hz in a vertical plane, respectively.

3. Data and Results

The combination of clockwise and anti-clockwise rotation signals provide us the linear vibration (Kunitomo and Kumazawa, 2004). We obtained the transfer function, H, as a second order tensor with 9 elements from U = H F, where U and F represent the observed displacement and the transmitted single force. Subscripts, r, t and z, denote the radial, transverse and vertical directional components, respectively.

We here show the transfer functions related to the Source-A. We found that a small P-wave arrival appeared with a relatively larger S-wave in the Hzr component while a large S-wave arrival revealed with an unclear P-wave in the Htt components. The apparent velocity of P and S waves (Vp and Vs) were evaluated to be about 2.3 and 0.7 km/s, respectively. In the northern area, the apparent Vp were about 1.6, 2.5 or 4.5 km/s, and Vs was less than 0.5 km/s (Kasahara et al., 2011).

The transfer function obtained at the receiver-#7 showed the small first P-wave arrival appeared around 0.2-sec in travel time and S-wave and its later phases appeared after 0.4-sec. The waveform differences between the reference trace recorded at Feb. 24, 00:00 before the air injection and each trace at every hour. We found that the remarkable changes of the waveforms, particularly of the S-wave and its later phases, appeared about one day after the start time of air injection. The travel time of the later phase mostly delayed during the air injection. However such changes disappeared after the stop time of the injection.

4. Conclusions

We conducted the time-lapse experiments in the Awaji island, Japan, by using an ACROSS methodology. As preliminary results, we found that the waveforms, particularly of the S-wave and its later phases, remarkably changed in time and space after the air injection into the shallow ground. We conclude that ACROSS methodology is useful enough to detect and monitor the changes of the seismic properties relating with geophysical changes around the reservoir accompanying with the air/gas injection into the subsurface.

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Keywords: CCS, time lapse, ACROSS