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

KASAHARA, Junzo[1*], Shinji Ito[2], Tomohiro Fujiwara[2], TSURUGA, Kayoko[3], HASADA, Yoko[4], IKUTA, Ryoya[1], FUJII, Naoyuki[1], YAMAOKA, Koshun[5], NISHIGAMI, Kin'ya[6], ITO, Kiyoshi[6]

[1]Faculty of Science, Shizuoka Univesity, [2]NTTdataCCS Co. Ltd., [3]Tokyo University of Marine Scienc and Technology, [4]Daiwa Exploration and Consulting, Co. Ltd., [5]Enviromental Sciences, Nagoya University, [6]EPRI, Kyoto University

1.Introduction

In the monitoring of physical states of CO2 storage zones in CCS, oil-gas reservoirs, fluid flow along subduction zones and migration of magma bodies, the development of time lapse or 4D observation methods are very important. However, any effective methods for the above objectives have not been established yet. We have developed an effective method for time-lapse measurements using seismic ACROSS (Accurately Controlled and Routinely Operated Signal System) and seismic arrays. We showed nice imaging results by simulation using a few seismic sources assuming ACROSSs and seismic array (Kasahara et al., 2011; Hasada et al. 2011).

Although temporal changes have been reported in the past ACROSS observations, the separation of true changes in the deeper ground from near-surface changes are not enough. In order to prove the usefulness of our method, we carried out a field test using air injection into the ground as the artificial cause, ACROSS seismic sources and multi-receiver array.

2.Field experiment and processing

We carried out field experiment near the Nojima Fault System in Awaji Island, Japan from February 20 to March 10, 2011. We simultaneously used two seismic ACROSS; ACROSS-V with vertical rotational axis for the eccentric weight mass owned by Nagoya University and a newly built seismic ACROSS-H having the horizontal rotational axis to generate vertical and horizontal vibrations. The ACROSS-H generated 10-30Hz and the ACROSS-V generated 10-35Hz, though the latter unit has a potential up to 50Hz.

The one hour unit of each ACROSS signal comprised of 32 repetitions of 10-35Hz (or 10-30Hz) sweep and 400-seconds transition. The rotational directions were switched every one hour. By division of observed data by designed source spectrum, the transfer functions between the source and each receiver were obtained.

The geophones are placed in the 1km square region near the Nojima fault system. The injection point was at the center and two ACROSSs were at NE and SE of the region, respectively. 80ton air in total with 21MPa was injected into the Osaka formation at 100m depth between February 26 and March 3. 32 3-components and one 800m-borehole geophones were used. Although we used four different types of geophones, it does not matter because the frequency bands used in this experiment are $>$10Hz. In this presentation, we show only the results obtained by the ACROSS-H. For the ACROSS-H, we can synthesize vertical and horizontal forces by combining the clockwise and anticlockwise rotations (Kasahara et al. 2011b). Vertical and horizontal vibrations efficiently generate P and S waves, respectively.

In order to image the disturbed zone, we carried out time-reversal method (Kahahara et al.,2011a).

3.Results

Except for one malfunctioned unit, all surface and borehole geophones showed very large travel time and waveform changes. The largest changes were observed at stations #6 and #7 after one day.

The later phases change more than the first arrivals of P and S. Despite major P and S phases seen in travel-time vs. distance diagram, the interpretation for details appeared on each component is difficult. The change at 800m borehole is not easily interpreted because the borehole is away from the direct path from the source to the injection point. The results of time-reversal method to image disturbances zone due to the injection shows centralized during 8 hours after the start of injecting air and gradually migrates toward eastward.

4.Conclusions

By the injection experiment in Awaji Island using seismic ACROSS, we confirmed the effectiveness of our time-lapse method to image the disturbed zone. Although the behavior of air is not the same as supercritical CO2, the first step for the CCS and CO2-EOR can be obtained by the combination of seismic ACROSS and multi-receivers. This method is also applicable to monitor of seismogenic zones and volcanic areas.

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Keywords: CCS, Global Climate Change, Time Lapse, Back propagation, CO2-EOR, 4D