Simulation and field studies of the seismic time lapse by ACROSS methodology

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Introduction

The temporal change of seismogenic zone and the volcanic evolution are the typical examples of time progression problems in earth sciences. The seismic time-lapse technology is used to estimate the change of subsurface in such cases. ACROSS (Accurately Controlled and Routinely Operated Signal System) methodology has been developed by Kumazawa and others since 1994. According to this methodology, the ACROSS seismic sources were built and has been tested by the groups of JAEA, Nagoya University and JMA. We tested the application of ACROSS technology by simulations and the field tests in Japan and Saudi Arabia.

The authors have applied this methodology for the monitoring of CCS (Carbon Capture and Storage), and EOR (Enhance Oil Recovery). We tried to image the changing zone by the backpropagation of residual waveforms before and after some temporal change in subsurface (Kasahara and Hasada, 2016). In this presentation, we introduce the recent advances of the ACROSS application.

ACROSS methodology

The typical signal used by the ACROSS seismic source is chirp signal within the desired frequency range. By the deconvolution of observed waveforms by the source signature in frequency domain, the transfer function can be calculated. Enhancement of S/N can be obtained by stacking of data during long duration owing to the steady control and the strict synchronization of the source and recording devices.

Detection and imaging of temporal changes

We carried out the field experiment in Awaji Island in 2011 using an ACROSS seismic source with air injection to the 100 m depth during 5 days (Kasahara et al., 2012). Because of excellent repeatability of source signature of the source, the residual waveforms before and after the injection show almost no temporal change before injection and large waveform changes after the injection. We attempted the imaging of the temporal change by backpropagation or reverse-time migration using the residual waveforms.

Another field experiment using the ACROSS seismic source was held in Saudi Arabia. We detected temporal changes possibly due to water movement in the aquifers. We discussed the repeatability of observed system and concluded that the repeatability using ACROSS seismic source was the excellent (Kasahara et al., 2016),

We also carried out several simulation in some cases to investigate the effective source and receiver arrangement for subsurface imaging (see figure).

Conclusions

We examined the time-lapse study using the ACROSS seismic source by field tests and simulations assuming a few source and a dense seismic array (Kasahara and Hasada, 2016). Through field studies and simulations, we showed the temporal changing zone by the backpropagation of residual waveforms. Although we studied the time lapse in a few km scales, this technology can be applied to many cases such as seismogenic zones, volcanic region, civil engineering such as road, river levees, bridges, tunnels and buildings.

Keywords: time lapse, ACROSS, residual waveform, backpropagation, imaging, temporal change

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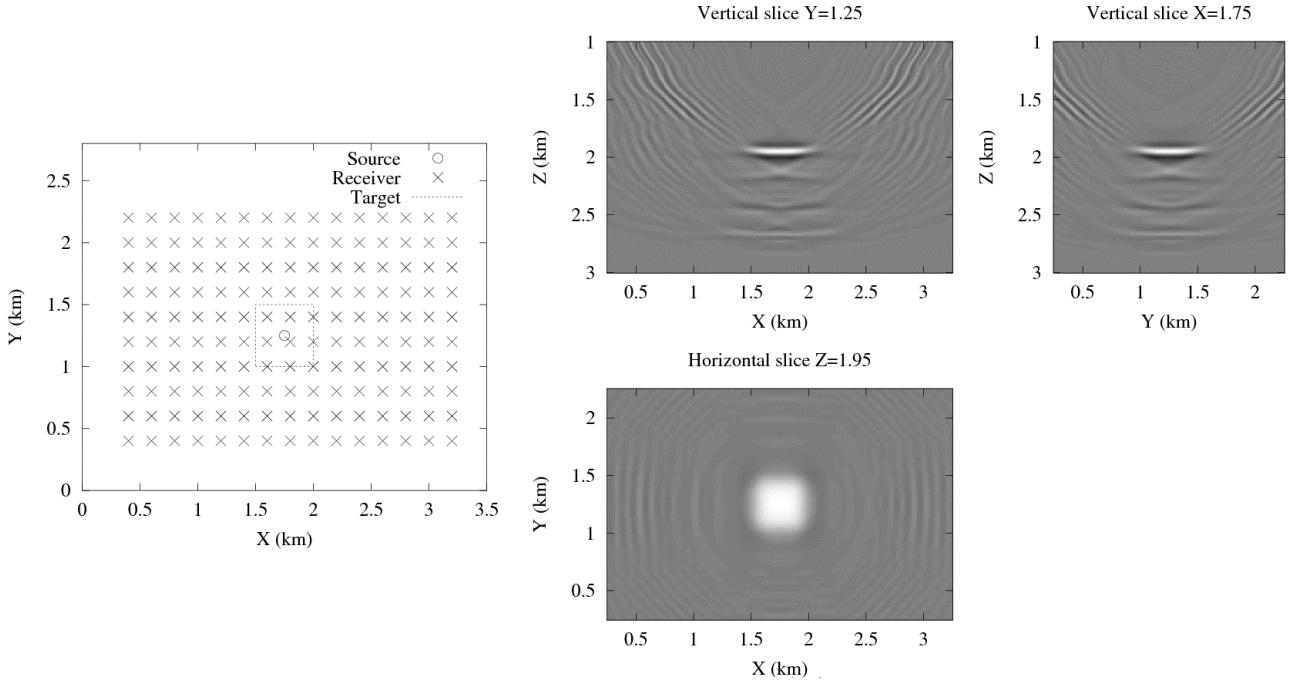

The model setting (left) and the result (right) of the simulation assuming a 2 km deep reservoir.

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