

# Time-lapse approach for monitoring of change in the supercritical water zone during drilling operation and production

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## Introduction

Due to increase of the energy consumption in Japan, the geothermal energy is getting one of the most important energy sources. The supercritical water is attracting world geothermal people as the future important renewable energy in the world. The critical point of pure water is 374 degree C and 22 MPa. In Kakkonda geothermal field, the scientific drilling WD-1a in 1995 showed the temperature was  $>500^{\circ}\text{C}$  at 3,800 m depth. Other areas in the world, there are many geothermal fields showing the circumstances close to supercritical point of water or above the critical point. There are several leading countries including Japan for this supercritical energy source. In Japan, NEDO is promoting the supercritical geothermal exploration as the future important energy source. The current technologies to know the physical status of deep geothermal zone are not many. We propose the seismic time lapse technology to monitor the temporal change of supercritical water zone.

## Method of monitoring

The authors have worked on the time-lapse method for the monitoring of temporal changes in oil and gas reservoirs and  $\text{CO}_2$  storage (Kasahara and Hasada, 2016). In this approach, we used a stable seismic source and array of geophones. According to the supercritical  $\text{CO}_2$  or high temperature water injection in the reservoirs or production of oil or gas, the physical properties and locations of reservoirs could change, and they could change the nature of scattering of seismic waves from the reservoirs, and the change of scattering seismic waves could make the change of waveforms at receivers. Using reciprocity principle of Green's function for the residual waveforms before and after the injection or production we can image the temporal change of reservoirs by the waveform inversion. We will use this approach to the temporal change of supercritical water caused by drilling and production. We propose to use downhole seismic source(s) and high temperature fiber optic DAS (Distributed Acoustic Sensors). DAS technology uses the backscattering of an input laser light due to strain caused by seismic waves. The DAS could provide huge sensor array at a few m spacing. The reciprocal principle suggests the trade of source(s) and receivers. By use of fiber optic receiver array provided by DAS technology, we could have extremely dense source array in the borehole(s).

## Efforts toward time-lapse method for the supercritical geothermal exploration

To evaluate the quality of data provided by DAS, we carried out a comparison of geophone and 3C seismometer and DAS in the campus of the CRIEPI. We used fiber optic DAS equipment's provided by Schlumberger hDVS technology. Because hDVS measures the strain rate cause by seismic waves, we calculated the strain rate from seismometer records and compared to DAS data for natural earthquakes in Japan. The results showed nearly identical waveforms between two (Kasahara *et al.*, 2018a). For reconstruction of supercritical water zone, we developed the full-wave inversion technique (Kasahara *et al.*, 2018b). By this method, the physical properties of  $V_p$ ,  $V_s$  and density for the model at 4 km depth was

nicely recovered.

### **Discussion and Conclusions**

The combination of stable downhole seismic source, DAS technology and full-wave inversion will give new feature in the geothermal exploration, in particular supercritical water development. If we obtain information of physical property change during the drilling, we could the most appropriate decision for the next stop.

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