A feasibility study to identify supercritical geothermal reservoirs on southern Kyushu Island using DTS and DAS systems

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Introduction: Supercritical water is drawing the attention of members of the global geothermal community as an important future renewable energy source for the world (*e.g.*, Dobson *et al.*, 2017). NEDO is promoting supercritical geothermal exploration as an important future energy source. There have been several efforts to use the fiber-optic distributed acoustic sensor (DAS). The DAS method is sensing strain or strain rate caused by seismic waves and the spatial resolution is a few meters. Because the temperature at the supercritical point is higher than 374 ˚C, ordinary geophones cannot be used in such supercritical conditions. In contrast, the optical fiber can be used at ~500 ˚C. We evaluated the usefulness of DAS technology on land and concluded that it is comparable to using geophones (Kasahara *et al.*, 2018a). In order to study supercritical water reservoirs, we carried out a simulation using full-waveform inversion (Kasahara *et al.*, 2018b). It was found that physical properties such as Vp, Vs, and density in the reservoir were well retrieved.

Field study: To evaluate the feasibility of our approach in a real geothermal field, we carried out a field study in the Medipolis geothermal field in Kyushu, Japan in fall, 2018. The fiber-optic cable was deployed down to a 977 m depth in the IK-4 borehole. We conducted the distributed temperature sensor (DTS) and DAS seismic measurements in the borehole using the same fiber-optic cable. We also installed 20 sets of three-component geophones along the 2 km long EW line at approximately 100 m spacing.

Results: The maximum temperature was measured as 264 ˚C at 914 m. The DAS data were obtained continuously at every 1 m for 4.5 days. Using the DAS system, we observed seven natural earthquakes between M0.8 and M5.2. The P-wave first arrival of the M5.2 earthquake was observed at the whole depth of 977 m to 0 m. Although the temperature at the 914 m depth was 264 ˚C, any evident seismic attenuation was not observed. In some earthquake records, some surface geophones show large amplitudes on horizontal components at 0.8 seconds after the P first arrivals in the vertical component. To estimate the vertical Vp profile of the surrounding area, we conducted a semblance analysis and obtained the Vp for every 100 m depth interval along the borehole. The Vp is estimated to be approximately 4 km/s and 3.3 km/s between 800–977 m, and between 500–800 m, respectively.

Discussion and conclusions: Although the temperature at a 914 m depth was as high as 264 ˚C, no significant attenuation of P arrivals was observed. The Vp profile in the borehole shows approximately 4 km/s between 800 m and 977 m. It seems no effects by the high-temperature zone. The reason for these measurements might be explained by the wavelengths of natural earthquakes being longer than the thickness of the high-temperature zone.

We observed seven natural earthquakes, but we did not see reflected phases from the deep reflectors. Surface geophones suggest the presence of P-to-S converted waves, and the conversion could be happening just below the study field. Although further studies are needed, the DAS system could supply a very dense vertical seismic array, and with the DAS seismic system and full-waveform inversion method, we could image the deep-seated supercritical geothermal reservoirs if they exist.

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Keywords: DAS, Geothermal field, Geothermal reservoir, Seismic monotoring, DTS, Passive seismic source

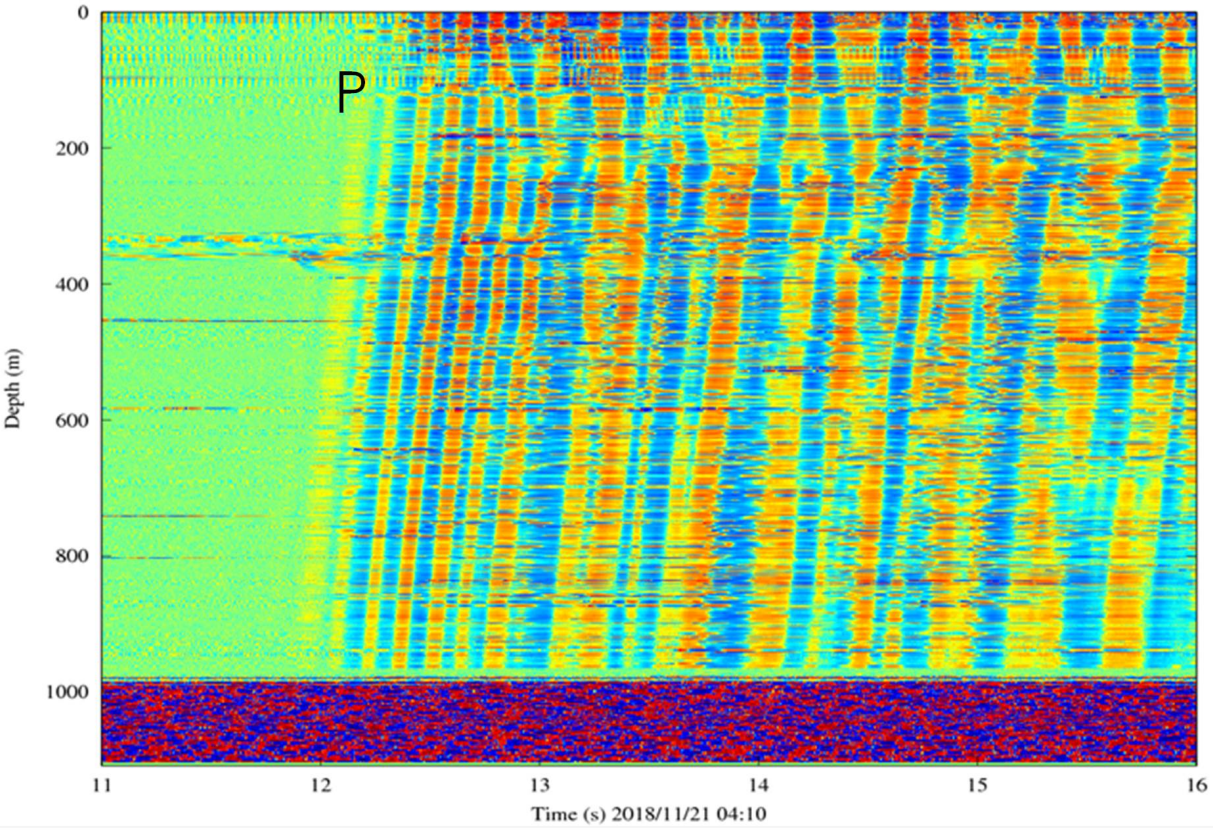

Figure : An M5.2 natural earthquake occurring 100 km focal distance and 123km focal depth recorded by the DAS. The vertical axis is depth from 0 m (top) to 977 m (bottom). The horizonal axis is the arrival time in seconds.

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