

Seismic study using optical fiber and surface seismometers in the Medipolis geothermal field located in southern Kyushu

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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. The New Energy and Industrial Technology Development Organization (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 sensing spacing is a few meters (e.g., Hartog, 2017). We evaluated the usefulness of DAS technology on land and concluded that it is comparable to using geophones (Kasahara *et al.*, 2018). In order to study supercritical water reservoirs, we carried out a simulation using full-waveform inversion (FWI) (Kasahara *et al.*, 2019). It was found that physical properties such as V_p , V_s , and density in the reservoir were well retrieved.

Field study

To evaluate 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) temperature and DAS seismic measurements in the borehole using the same fiber-optic cable. We also installed 20 sets of seismometers along the 2 km long EW line at approximately 100 m spacing.

Results

The maximum temperature in the IK-4 borehole was measured as 264 °C at 914 m. The DAS data were obtained continuously at every 1 m for 4.5 days. We observed seven natural earthquakes between $M = 0.8$ and $M = 5.2$ by the DAS mode. The P first arrivals of the M5.2 earthquake was observed at a hole depth of 977 m to 0 m for every 1 m location. Although the temperature at the 914 m depth was 264 °C, any evident seismic attenuation was not observed. In some earthquake records, some surface seismometers showed large amplitudes on horizontal components at 0.8 seconds after the P first arrivals in the vertical component. Using the DAS waveforms, we estimated the apparent P interval-velocity surrounding the borehole. The apparent P interval-velocities for northern and southern incident earthquakes show 4.5-3.0 km/s and 3.0 km/s, respectively. Considering the well deviation, the P interval-velocity was estimated to be approximately 3.0 km/s between 800–977 m.

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. 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 evaluated well deviation and it can explain the difference of apparent P interval-velocity between norther and souther incidents. The P interval-velocity in the borehole shows approximately 3.0 km/s between 800 m and 977 m.

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. The conversion can be explained by the presence of low S velocity layer below the Medipolis geothermal field.

Although further studies are needed, the DAS system could supply a very dense vertical seismic array, and with the DAS seismic system and the FWI method, we could image the deep-seated supercritical geothermal reservoirs if they exist.

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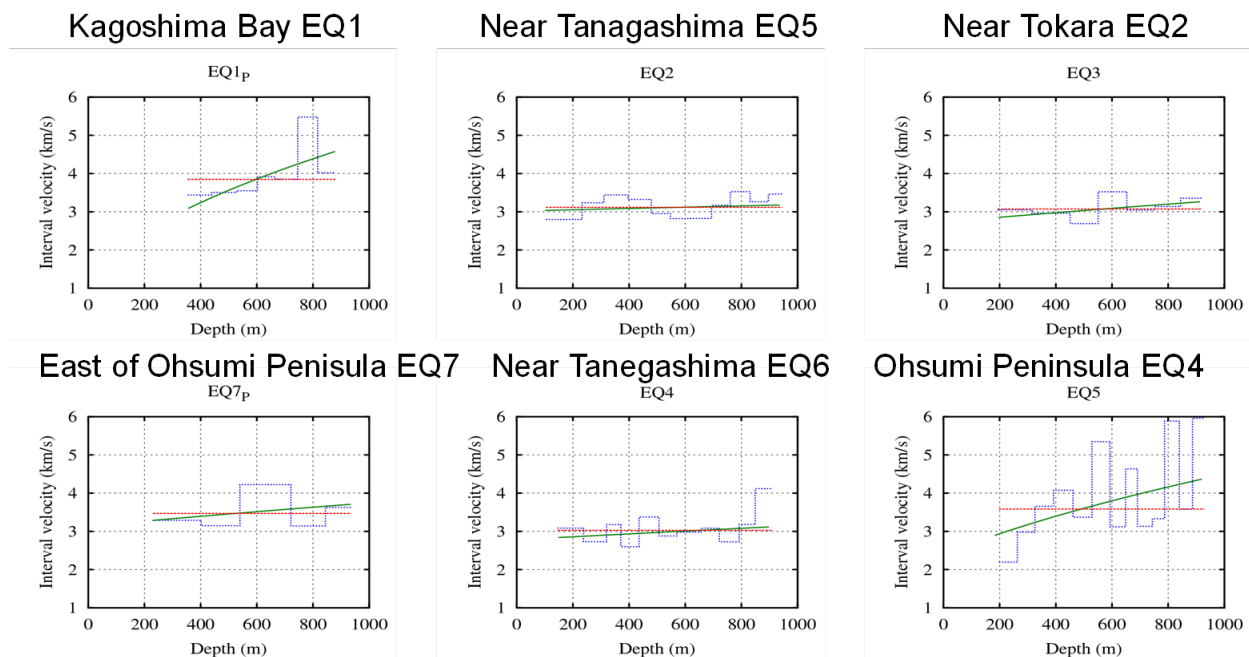


Figure : Results of apparent interval Vp profile for six earthquakes. The vertical and the horizontal axes of each figure are apparent interval Vp in km/s and depth in meter, respectively. Green line: Vp obtained by the first arrivals fitted by smooth curves, Red line: mean Vp from the bottom to the shallowest depth. Blue line: Vp obtained by the picking of arrival times. EQ1 and EQ4 came from the north and EQ2, EQ5, and EQ6 came from the south.