Time-lapse imaging of supercritical geothermal drilling and production using full waveform inversion method

*笠原 順三[1,3,4]、羽佐田 葉子[2,1]、山口 隆志[1]
*Junzo Kasahara[1,3,4], Yoko Hasada[2,1], Takashi Yamaguchi[1]

1. エンジニアリング協会、2. 大和探査(株）、3. 東京海洋大、4. 静岡大学
1. ENAA, 2. Daiwa Exploration and Consulting Co. Ltd., 3. Tokyo University of Marine Science and Technology, 4. Shizuoka Univ.

Introduction

Due to increase of the energy consumption in Japan, the geothermal energy is getting one of the most important energy sources. In particular, the supercritical water is attracting world geothermal people as a future important renewable energy. The critical point of pure water is 374˚C and 22 MPa. In Kakkonda geothermal field, a scientific drilling showed the temperature was >500˚C at 3,800 m depth. There are several leading countries such as Iceland, USA, Mexico, Italy and Japan for this supercritical energy source. In Japan, NEDO is promoting the supercritical geothermal source

Method of imaging of time lapse

In geophysical exploration, the migration method is frequently used. Recently the full waveform inversion technique has been applied to the imaging of subsurface. The waveform inversion is like the time reversal technique or backpropagation based on reciprocal principle of Green’s function. This method has been applied to the 3D seismic data, not the time-lapse method. We have used backpropagation technique of residual waveforms to image the temporal changing zone (Kasahara and Hasada, 2016). Although the backpropagation of residual waveforms good image of temporal changing zone, it does not give the temporal change of physical properties. To estimate the physical properties at the target zone, we applied the full waveform inversion for the investigation of supercritical water. Among many methods for the full waveform inversion, we used the method by Tromp *et al* (2005). The sensitivity kernels for compressibility, rigidity and density can be obtained by the adjoint method using backpropagation. Because the waveforms at receivers are considered to be new seismic sources by the reciprocity principle of Green’s function, we propose to use fiber optical DAS receivers along the borehole. We carried out a simulation with a seismic source placed in the downhole at 2 km depth. In the simulation, we tested three different locations of source and reconstructed the image. We used 1 km long x 200 m thick supercritical reservoir at 4 km depth. We assumed the physical property change of ΔVp=5% ΔVs=5% and Δdensity =2.5%.

Result

The reconstructed images assuming three source locations of 5 km, 3 km and 1 km from the drilling borehole show satisfactory retrieval of the assumed zone. The 3 km location test gave the best results. After several iterations in the inversion, the Vp, Vs and density were retrieved as 4%, 4% and 2% at the almost exact location and thickness, respectively. The satisfactory results obtained by our seismic time-lapse approach suggest that the proposed technique is very promising for the supercritical heat energy investigation.

Discussion and Conclusions

The quality of DAS data has been tested in field, and it can be comparable to seismometers (Kasahara *et al.*, 2018). The DAS can be used at high temperature circumstances as ~500°C. This simulation does not include noise test. However, if we use ACROSS (Accurately Controlled and Routinely Operated Signal System) described in Kasahara and Hasada (2016), background noise can be separated from source signal using spectral comb method. In addition, stacking of data for long duration enhances the S/N drastically. We could use several weeks data for imaging. In the true situation, distribution of supercritical zone or low-velocity zone might cause the scattering of seismic waves.

Acknowledgements

This presentation is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO)We also express our great thank to NEDO and officers in NEDO.

キーワード：超臨界水、地熱エネルギー、フルウエーブインバージョン、タイムラプス、DAS
Keywords: super critical water, geothermal energy, full waveform inversion, time lapse, DAS

