Investigation of Geothermal Energy Potential Using the Magnetotelluric Method and 3-D Inversion: A Case Study from a Geothermal Field in Japan

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SUMMARY

With the growing interest in geothermal potential investigations in Japan, the demand for magnetotelluric (MT) surveys is increasing. For most of the developable geothermal fields in Japan, complex subsurface structures and topographic irregularities present significant challenges to improving accuracy. At a geothermal field in Japan, we conducted a high-density MT survey with a high-resolution topography-considered 3-D inversion using the finite-element modeling code FEMTIC to address these issues.

Furthermore, the surveyed area faces significant cultural noise challenges that could influence our success. To mitigate this, we extended the acquisition time and applied additional technical processes. We analyzed the data using the short-time Fourier transform to identify time-related noise conditions, enabling us to select the cross-power more strictly on dead-band frequencies. The processed sounding curves were further smoothed to serve as more reasonable modeling inputs.

After addressing the noise issues, we utilized the full components of impedances and tippers in the inversion. The modeling employed unstructured tetrahedral elements to produce high-resolution topography, minimizing the influence of topographic distortions on MT transfer functions. The distortion tensor was also considered a variable in the objective function. We used 1-D Occam's inversion results to set the value of the uniform half-space in the prior model. The optimal model was defined using the L-curve method by adjusting the trade-off parameters.

Overall, the inverted resistivity model fits the observed data well, both in the sounding curves and the induction arrow map. We compared the resultant resistivity model with resistivity logs and density profiles from 2-D inverted gravity data. The resistivity distribution extracted from our model aligns with the logging data, and the deeper resistivity structure and the buried body shape in density profiles are similar. This case demonstrates progress in commercial investigations with the 3-D inversion of the MT survey and its prospects in Japan.

Keywords: Magnetotelluric method; Geothermal field; FEMTIC; Geophysical exploration; 3D inversion