論文 / 著書情報
Article / Book Information

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Title(English)	Development of three-dimensional magnetotelluric inversion scheme using the unstructured tetrahedral element
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

A three-dimensional magnetotelluric inversion scheme using tetrahedral elements has been developed so as to precisely incorporate topography into computational mesh. The undulations of the Earth's surface as well as the land-ocean boundaries can distort electromagnetic fields and response functions. Without correcting the distortion, the subterranean resistivity structure can be misinterpreted. Among the approaches to simulate the electromagnetic field on the survey area with complex topography, the finite element method using the unstructured tetrahedral mesh is considered to be the most effective one because it can represent complicated objects precisely and robustly with a moderate number of elements. Therefore, the present study developed an original three-dimensional magnetotelluric inversion scheme using tetrahedral elements as an effective method to prevent the misinterpretation of the subsurface resistivity structure due to topography.

The developed inversion scheme calculates the electromagnetic field on the Earth using the edge-based tetrahedral elements, and searches subsurface resistivities and distortion tensors of observation sites. The forward modelling part of the scheme was verified using three test models: a benchmark model with a flat surface (Dublin Test Model 1), a trapezoidal-hill model and a model with steep bathymetry slope. For all of the models, the calculated response functions were in good agreement with the reference solutions, and thus the forward part was confirmed to calculate responses functions with sufficient accuracy. In addition, as the verification of the model-update part, the developed scheme was applied to a synthetic data set (Dublin Secret Model 2), and it was confirmed that the developed scheme can recover the original resistivity structure with the same accuracy as those of other schemes. Then, the author compared the data-space method to the model-space method by performing synthetic inversions, showing that the calculation time was reduced significantly by transformation from the model-space to the data-space whereas the resulting resistivity structure remained unchanged.

The developed scheme was then applied to a model with two overlapping mountains to confirm its applicability to the data affected by topography. Inversions were performed using the synthetic data of the impedance tensor, the vertical magnetic transfer function and the phase tensor, respectively, as well as the joint inversion of the former two data. In each of these cases, by incorporating the topography into computational mesh, the original resistivity structure was estimated more accurately than when a flat-surface mesh was used. Furthermore, by performing a synthetic inversion for the model with a Gaussian seamount, the developed scheme was also verified to give more accurate resistivity structure by using the mesh with the seafloor topography than by using a mesh with a flat seafloor. From these results of the synthetic inversions, it was confirmed that the influences of topography can be sufficiently reduced by representing topography in tetrahedral mesh, and more reliable resistivity structure can be obtained in magnetotelluric modelling. In addition, it was also shown that by inverting distortion tensors as the model parameters, the influences of galvanic distortion were reduced effectively and the resistivity structures were prevented from departing from the true values.

Finally, in order to demonstrate that the inversion scheme can give sensible results even when the measured data is used, it was applied to the two field-observed data sets. The first one is the data observed by a dense magnetotelluric survey around Asama Volcano. In the estimated resistivity structure under the volcano, there is a widespread conductive layer below the resistive surface layer and resistive bodies located under the old eruption centres. In addition, the subsurface resistivity appears to be changed in the east-west direction beyond the volcanic conduit below the present active crater. To the west of the conduit, a spherical resistive body is found to exist under the 24 ka collapse caldera, which would

consist of unfractured rocks and prevent the volcanic gases and hydrothermal water beneath the active crater from flowing to the southwest of the conduit. Furthermore, it may contribute to the higher concentrations of SO_4^{2-} and Cl^- in the spring water discharged at the northern and eastern feet, and may cause a diffuse CO_2 flux anomaly to appear only to the east of the present crater.

The second data set is a marine magnetotelluric data surveyed around a knoll in the middle Okinawa Trough. With the aid of the three-dimensional modelling using the mesh with precise bathymetry around the knoll, it was revealed that the anisotropic off-diagonals of the impedance tensor as well as the trends of the induction arrows can approximately be reproduced by a simple two-layer structure and the bathymetry. The estimated resistivity structure under the knoll is characterized by a conductive surface layer and the underlying resistive layer. The former conductive layer is consistent with the pelagic/hemi-pelagic sediments and the highly permeable zones within the upper crust, in which the hydrothermal fluid system was inferred to exist.