An electrical resistivity distribution model beneath Zao volcano, NE Japan, explored by audio-frequency magnetotelluric method

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1. Introduction

Phreatic eruption potentials of active volcanoes in Japan have been evaluated since the 2014 phreatic eruption of Ontake Volcano, central Japan. Zao Volcano, NE Japan, had phreatic eruptions at the crater lake Okama during prehistoric times, while the most recent eruption in 1940 was at a new fumarole located about 2 km northeast of Okama. Recent studies suggest that the spatial relation between subsurface impermeable layer representing smectite and seismicity is useful to evaluate the phreatic eruption potential (Gresse et al., 2021; Tseng et al., 2020; Tsukamoto et al., 2018). The purpose of this study is to extend the audio-frequency magnetotelluric (AMT) exploration after those done around Okama, Zao Volcano in 2014 (Ichiki et al., 2016), and to reanalyze the resistivity structure down to 2 km depth below sea level. After analyzing the detailed distribution of electrically conductive zones, we will discuss the spatial relationship between the conductive zone and the hypothenters occuring beneath Zao Volcano.

2. Data and Method

AMT frequency response functions and geomagnetic transformation functions of 1-10k Hz were obtained at 22 stations around Okama on September 17-20, 2014, and at 40 stations in a 1 km×1 km area around Goshikidake on the east side of Okama on September 28-October 22, 2020. From the obtained AMT frequency response functions and geomagnetic transfer functions, the three-dimensional resistivity model was estimated using the WSINV3D-MT code (Siripunvaraporn & Egbert, 2009). The reference model of 30, 100, 300 and 1000 Ωm uniform models were used in the inversion analysis.

3. Results and Discussion

The spatial distribution of the phase tensor determinant calculated from the AMT frequency response function shows a spatial pattern with a maximum at Goshikidake between 3 and 5k Hz. The in-phase Parkinson vectors of the 2020 data point towards Okama at all frequencies. The in-phase Parkinson vectors of the 2014 data have small amplitudes and random directions. Note that there are no Parkinson vectors pointing toward Shin'funkiko located in the northeast of the observation network. The phase tensor nature suggests that resistivity beneath Okama and Goshikidake is more conductive than those beneath Shin'funkiko. The most optimal 3D resistivity model at this time has the normalized root mean squared (RMS) misfit of 3.63. Regardless of using any of the four reference models, the following common features robustly appear in the obtained models.

(1) The conductive layer (~1 Ωm), which is interpreted as a smectite layer, lies from surface to 1000 m depth above sea level (asl) within ±1 km NS and EW of Goshikidake. Most conductive zone in the layer is located 200 m north of Goshikidake and 300 m northeast of the center of Okama, about 300 m depth below surface.

(2) There is almost no distinctive resistivity feature at depths from 1000 m asl to 1.5 km below sea level (bsl). However, a moderately conductive (30-100 Ωm) body with a few meters on each side is modeled at 1.5 km depth bsl below Goshikidake.

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(3) The mechanism solution explaining the long-period earthquakes shows that the almost vertical open crack are located in the region with no resistivity feature in (2) just below the conductive layer in (1). The moderately conductive body at 1.5 km depth bsl lies at the greater end of the depth of the vertical open crack. The hypocenters of the A-type earthquakes are located near the conductive body at the same depths.

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