A subsurface electrical resistivity model beneath Zao Volcano, NE Japan, and interpretation of the shallow conductive zone caused by hydrothermal alteration

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SUMMARY

Studies of the electrical resistivity structures beneath active volcanoes that experience phreatic eruptions reveal that a shallow impermeable layer, resulting from hydrothermal alteration, controls the upwelling of hydrothermal fluids. This determines whether phreatic eruptions occur or not. This study aims to achieve two objectives: 1) to evaluate the resistivity structure down to a depth of 2 km below sea level by expanding the audio-frequency magnetotelluric (AMT) observations at Zao Volcano, one of the active volcano, NE Japan, and 2) to assess a volume fraction of the clay mineral, in particular smectite, causing the impermeable layer based on the resistivity confidence interval for estimating permeability.

The AMT impedance and geomagnetic transfer functions in 1-10k Hz were acquired at 60 stations in a 1 km ×1 km area centered on the crater lake, Okama, Zao Volcano, and inverted into a three-dimensional resistivity model using WSINV3D-MT code (Siripunvaraporn & Egbert, 2009). The resultant three-dimensional resistivity model represents a conductive zone within ±1 km from east to west, north to south, centered on Okama, down to 500 m depth above sea level. The shallow conductive zone is interpreted as a hydrothermal alteration or smectite-rich layer. The confidence interval resistivity with a 99 % level of the shallow conductive zone less than 3 Ohm-m was estimated to be 1.5-2.5 Ohm-m using Welch's t-test. Using the confidence interval of resistivity and the smectite surface conduction experimental data (Levy et al., 2018; Revil et al., 2019), a smectite volume fraction was calculated to be less than 9.5 % at 150 degrees C. The 9.5 % volume fraction of smectite is enough to prevent the hydrothermal fluid from upwelling. Our next aim is to estimate a permeability reduction depending on smectite transformation into illite by increasing temperature.

Keywords: electrical resistivity, confidence interval of resistivity, smectite, permeability, phreatic eruption, hydrothermal fluid