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A Practical Approach for Estimating Temporal Resistivity Changes in Volcanoes Using Broadband Magnetotelluric Data

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Broadband magnetotelluric (MT) surveys have been widely conducted on volcanoes worldwide, often revealing a shallow conductive layer underlain by a column-shaped conductor. While imaging resistivity structure is a common application of MT, detecting temporal resistivity changes is more challenging due to surficial distortion and limited repeated measurements. In this study, we show a practical approach for estimating temporal resistivity changes using broadband MT data from two volcanoes. The first case involves repeated MT observations at 26 sites on Iwo-yama, Kirishima volcanic complex (2015 – 2017 and 2024), where a small phreatic eruption occurred in April 2018. The second case uses five months of MT recording (February – June 2010) at six sites on Sakurajima volcano.

MT response functions were estimated from electric and magnetic field time series using remote-reference processing. The most significant temporal changes appeared in vertical magnetic transfer functions (VTFs), emphasizing the importance of measuring vertical geomagnetic fields for resistivity monitoring. Changes in the phase tensor (Caldwell et al., 2004) were also detected, indicating that these variations reflect subsurface resistivity changes rather than surficial distortion.

We estimated 3-D resistivity changes using the FEMTIC code on a hexahedral mesh (Usui, 2015, 2024), incorporating two VTF components, four phase tensor components, and four impedance tensor components as input data. Galvanic distortion on the 2 × 2 impedance tensor was also considered. Although impedance data are susceptible to distortion, they remain necessary for constraining resistivity values. Phase tensor data help improve constraints, particularly in shallow regions. In the first step of the inversion, we determined a reference resistivity structure and corresponding galvanic distortion parameters using reference datasets (Iwo-yama: 2015 – 2016; Sakurajima: entire observation period). In the second step, these reference models were used as initial models for subsequent inversions (Iwo-yama: 2024 data; Sakurajima: monthly averaged data), enabling estimation of temporal 3-D resistivity changes.

At Iwo-yama, we found a substantial decrease in resistivity from the surface to ~200 m depth, coinciding with the area of post-eruption geothermal activation. This change likely reflects mixing of high-temperature volcanic fluids with shallow groundwater. The clay-rich cap layer expanded in an ENE – WSW direction and evolved into a more bell-shaped structure, potentially enhancing fluid storage. In contrast, the uppermost part locally increased in resistivity, possibly due to capping degradation from heating or acidification. These changes suggest an elevated potential for larger-scale phreatic eruptions. Interpretation of the Sakurajima results is ongoing, with volatile-rich fluids from magma interacting with groundwater as a possible mechanism.