Three-dimensional resistivity structure and magma plumbing system of Meakandake volcano inferred from broadband magnetotelluric survey

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Meakandake is one of the active volcanoes in the southwestern part of the Akan caldera in eastern Hokkaido. Recently, a remarkable ground inflation occurred on the northeastern foot of the volcano. In this study we conducted a magnetotelluric survey in 2018 and 2019 to investigate the electrical structure to cover both Meakandake and the deformation source. We inverted the MT data into 3D resistivity model to discuss the magma plumbing system beneath Meakandake.

At Meakandake, small-scale phreatic eruptions repeatedly occurred in recent years. Some of these phreatic eruptions were seemingly associated with elevated number of deep low-frequency earthquakes (DLFE), so it was possible that magma or fluid was supplied from deep underground prior to these eruptions. In recent years, a remarkable ground inflation was reported on the northeastern flank from 2016 to 2017. The main pressure source was modeled as an opening of a sill-like crack at a depth of about 3 km from Meakandake to Lake Akan hot spring area (about 7 km long and 2 km wide) (Hokkaido Univ, 2019). However, relationship between the ground deformation and the volcanic activity of Meakandake was unknown. Neither of the previous resistivity surveys (NEDO, 1992; Takahashi et al., 2018) did not cover the inflation region.

Therefore, in this study, we newly deployed 26 broadband MT sites by using the MTU-5/5A system (Phoenix Geophysics Ltd) around Meakandake. Then, we performed an inversion based on the ModEM (Egbert and Kelbert, 2012; Kelbert et al., 2014) to obtain a 3D resistivity model. We started from the initial model that was meshed in 48 ×48 ×85 blocks (horizontal 250 to 128,000 m, vertical 25 to 256,000 m) with a uniform resistivity at 100 Ωm. The atmosphere and sea water were fixed at 108 Ωm and 0.3 Ωm, respectively.

Our modeling by the 3D inversion has revealed the low resistivity body C1 (about 1-10 Ωm) extending from 0.5 km BSL to deeper part of Meakandake, as well as another low resistivity body C2 (about 0.1-10 Ωm) around Mt. Fuppshidake. On the other hand, no remarkable low resistivity anomalies appeared in the area where the above-mentioned pressure source was assumed. We performed some sensitivity tests, in which the deeper extension of the low resistivity bodies (C1 and C2) was varied. As the result, C1 was found to be meaningful down to about 6 km BSL, and C2 was to 5 km BSL. In addition, a low resistivity slab of 1 to 10 Ωm that imitated a sill-like intrusion of magma or hydrothermal water was placed at the presumed inflation source area with a fixed upper depth of the slab at 1.5 km BSL and a varying thickness in order to examine its effect on the MT response. Then, we confirmed that the effect of the low resistivity slab was insignificant when it had a bulk resistivity above 10 Ωm, or when it was thinner than 200 m. In other words, our MT data did not exclude the possibility that there was an intrusion event at the location of the pressure source in 2016-2017.

We considered that the low resistivity body C1 was a part of the volcanic vent, since it underlay the lower limit of the micro-seismic hypocenters in the shallow part of Meakandake. Considering the focal region of the DLFE (about 30 km deep) as a deep magma chamber of Meakandake, C1 was likely to be the shallow extension of the plumbing system. If this is the case, the uppermost part of C1 was probably connected to the active vents of Meakandake through quasi-vertical conduits. Meanwhile, the sill-like inflation in 2016-2017 was suspected to be a lateral intrusion that branched at a certain depth from C1.

As a next step, we plan to refine our model by combining with the AMT/MT data that was obtained by another previous survey in 2010, where the hot spring area of Lake Akan in the north of the sill-like inflation source was previously explored.

Keywords: Magnetotelluric, Meakandake, resistivity