3-D multiphase flow modeling: a method to constrain electrical conductivity structure of volcanoes

Marceau Gresse[1]; Takao Koyama[2]; Makoto Uyeshima[3]; Tsuneo Ishido[4]; Yuichi Morita[5]; Yoichi Sasai[6]; Jacques Zlotnicki[7]; Hideaki Hase[8]; Wataru Kanda[9]; Yasuo Matsunaga[10]; Koki Aizawa[11]; Hideki Ueda[12]; Tawat Rung-Arunwan[13]; Maki HATA[14]; Yusuke Yamaya[15]
[1] ERI; [2] ERI, University of Tokyo; [3] ERI, Univ. Tokyo; [4] AIST; [5] ERI, UTokyo; [6] EPRC, IORD, Tokai Univ.; [7] CNRS (France); [8] KSVO, Tokyo Tech; [9] KSVO, Tokyo Inst. Tech.; [10] Tokyo Tech; [11] SEVO, Kyushu Univ.; [12] NIED; [13] Mahidol Univ., Thailand; [14] ERI, the University of Tokyo; [15] FREA, AIST

Measuring the electrical conductivity of rocks is a classical approach used to investigate volcanic edifices at depth. The electrical conductivity of rocks has two main contributions: (1) the conduction in the bulk pore fluid, induced by fluids saturation, ionic strength, and temperature of pore water, and (2) the surface conductivity, related to secondary minerals. These two contributions are controlled by complex interactions between hydrology, geology, tectonic settings and magmatic forcing. As a consequence, the interpretation of electrical conductivity images is strongly non-unique and thus, remains poorly constrained on volcanoes.

Here, we demonstrate that extracting accurate physical information (e.g. temperature, gas saturation, pressure) from an electrical conductivity distribution is achievable using multi-phase flow modeling. Indeed, multiphase flow modeling represents the coupled transport of fluids (liquid, gas), and heat through porous and fractured rocks. Therefore, such simulation can be directly connected to electrical conductivity of rocks.

We applied this technique to characterize the electrical conductivity structure of Miyake-jima volcano obtained from a Magnetotellurics survey. Results of the 3-D multiphase flow model successfully explain the electrical conductivity structure of the volcano in term of temperature, fluids saturation and their distributions. We reveal a deep conductive body (1-5 ohm⋅m) formed by a high-temperature, liquid-dominated plume connected to the fumarolic area inside the Oyama crater. In addition, we explicate the shallow resistive layers (500-1000 ohm⋅m) as unsaturated and low-temperature deposits. These results are consistent with surface observables (soil temperature, direct and diffuse degassing) and the distribution of hypocenters. This multidisciplinary approach brings new insights into a better understanding of volcanic edifices and their structures.