Numerical model of temporal changes in magnetic total field and ground deformation due to hydrothermal system in volcanoes (1). - A case study on Tokachi-dake volcano, Japan –

*Ryo Tanaka[1], Takeshi Hashimoto[1], Tsuneo Ishido[2], Nobuo Matsushima[2]

1.Hokkaido University, 2.AIST

Localized temporal changes in the magnetic total field and ground deformation are often observed at volcanoes that have hydrothermal system within. At Tokcahi-dake volcano, one of such volcanoes in central Hokkaido, Japan, continuous magnetic field changes accompanying ground inflation at a shallow depth have been observed. At this volcano, small phreatic explosions took place commonly among major magmatic/phreatomagmatic eruptions in recorded history (JMA, 2013). Repeated magnetic total field surveys since 2008 revealed demagnetization beneath 62-2 crater between 2008 and 2009 (Hashimoto et al., 2010). Besides, the baseline changes by GPS suggested a localized inflation beneath the crater after 2007 (JMA, 2015). Assuming the thermomagnetic effect, Hashimoto et al. (2010) proposed a possible mechanism for such changes. They suspected that steam ascending along the conduit experienced phase change at a shallow depth, releasing latent heat and flowing back as liquid to form a hydrothermal reservoir. They also suggested that increase in heat supply from depth is not essential for the demagnetization in case that heat discharge rate from the crater has been reduced for some reasons. In this study, we verify such a conceptual model by using a numerical simulation of hydrothermal system.

In general, phreatic explosions need substantial amount of water, cap-rock structure that confines pressure, heat supply and increase in pressure for a hydrothermal reservoir to flush through an abrupt phase change. However, it remains an open question whether such structure and processes bring about observable magnetic changes and/or ground deformation preceding to a phreatic eruption. We addressed the following working hypothesis to model Tokachi-dake as a case study. (1) There is a cap-rock structure with a narrow crack below 62-2 crater. (2) Gases through the crack are discharged as plumes from the crater. (3) Decreasing permeability of the crack causes increase in temperature and pressure around the cap-rock structure. We tried to examine the hypothesis using the numerical code “STAR” with the equation-of-state “HOTH2O” (Pritchett, 1995). It enabled us to calculate the heat and mass flow rate of H_2O (gas, liquid and two-phase) in porous media. The calculation region was set as approximately the cross-section passing the summit of Tokachi-dake, 62-2 crater and hot spring located on halfway up the mountain. Firstly, we estimated the background permeability of rock constituting the volcano, which gives a plausible water table. As boundary conditions, constant temperature and pressure conditions were applied to the ground surface and downstream vertical boundary, thermally-insulating and impermeable conditions were applied to the bottom and upstream vertical boundaries. A constant rate of precipitation was injected from the ground surface. A constant heat flow was supplied from the bottom. Subsequently, we reproduced the fumarolic discharge from the crater and the hot spring located in the middle of the slope by providing thermal water from the bottom just beneath the crater. We also introduced a high permeability column as a vertical conduit connected from the volcanic input at the bottom to the crater, as well as a horizontal channel connected to the hot spring. In addition, the low permeability cap-rock with a narrow crack was introduced below the crater. Finally, we changed the crack permeability to observe changes in temperature and pressure of the system. We confirmed that the decrease of the crack permeability caused the increase in temperature and pressure around the cap-rock structure. These results suggested that the working hypothesis was at least self-consistent. In the next step, we will quantitatively investigate the system's responses by comparing the changes in temperature and pressure beneath the crater from the numerical simulation

to the observed temporal change in the magnetic total field and ground deformation.

Keywords: numerical simulation, hydrothermal system, phreatic explosion, magnetic total field, ground deformation

