Numerical investigation of temporal changes in field observations associated with volcanic hydrothermal systems during inter-eruptive stages

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Localized temporal changes in the magnetic field and coincident ground deformation are often observed at volcanoes that have fumarolic activities (Mt. Tokachidake, Mt. Meakandake, Mt. Tarumae, Kuchinoerabujima volcano, etc.). This study focuses on two mechanisms that may bring about some changes in hydrothermal system during inter-eruptive stages: (1) permeability reduction at the shallow part of the conduit, and (2) fluctuation of hydrothermal fluid flux from a deeper part. Numerical calculation serves as a platform for systematic investigation of the surface responses to these mechanisms. We classify the pattern of temperature and pore pressure changes as well as the resulting magnetic total field, fumarolic heat discharge, and possible ground deformation that are associated with the conduit constriction and/or fluctuating flux of hydrothermal fluid by means of hydrothermal numerical simulation.

We used the numerical code "STAR" with the equation-of-state "BRNGAS" (Pritchett, 1995). It enabled us to calculate the heat and mass flow rate of H_2O (vapor, liquid and two-phase) and Air in porous media over a temperature range 0–350 ºC. The calculation region was set as axisymmetric 2D to represent a simplified conical edifice. The edifice (host rock) had a uniform porosity and permeability. Temperature and pressure were maintained constant at the ground surface and on the vertical boundary of the downstream side. Thermally insulating and hydraulically impermeable conditions were imposed at the bottom boundary. Meteoric recharge was injected at the land surface at a constant rate and a constant heat flow was supplied at the base of the model. The high-permeability conduit was introduced at the axis of symmetry, hydrothermal fluid is injected at the bottom of the conduit to reproduce fumarolic heat discharge of about 100 MW, after reaching a quasi-steady condition. Thereafter, an abrupt reduction of permeability at a particular depth (PCB) in the conduit (conduit obstruction) and/or an increase in the flux of hydrothermal fluid at the bottom of conduit (increase in hydrothermal-fluid-flux) were imposed, and the system response is observed.

Conduit obstruction caused reduction in temperature and pore pressure above PCB, and increase in temperature and pore pressure below PCB. Meanwhile, increase in hydrothermal-fluid-flux induced heat accumulation and pore pressure increase around the conduit. When conduit obstruction and increase in hydrothermal-fluid-flux are introduced at the same time, whether temperature and pore pressure above PCB increase was influenced by the balance between the amount of permeability reduction of PCB and the amount of increase in flux of hydrothermal fluid. However, when the permeability of PCB after reduction was smaller than the permeability of host rock, temperature and pore pressure decrease above PCB regardless of the amount of increase in hydrothermal-fluid-flux.

In the presentation, we will discuss the change in total magnetic field, ground deformation, and fumarolic heat discharge by using these changes in temperature and pore pressure. In addition, we will try to investigate the influence of parameters such as host-rock-permeability, depth of PCB, the construction of permeability and porosity in the edifice.

Keywords: hydrothermal system, hydrothermal sealing, numerical simulation

