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Characteristics of hydrothermal system causing phreatic eruptions inferred from resistivity and geochemical structures

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Thesis outline

Phreatic eruption is one of the volcanic explosion styles, occurring frequently all over the world. The ejecta of phreatic eruptions do not contain juvenile materials but often contain hydrothermally altered minerals, suggesting that explosions occur in the shallow hydrothermal system. Forecasting this type of eruption is still difficult because the precursory events are often too small for current observation techniques to detect and because the eruption mechanism is not fully understood. The cap layer is a key structure for causing phreatic eruptions. It is formed by precipitation of minerals from hydrothermal fluids and/or alteration of surrounding rocks, and prevents hydrothermal fluids from upwelling to the surface. Accordingly, hydrothermal fluids could be confined beneath the cap layer to form a reservoir of vapor and/or superheated water, where the pressure and temperature are considered to be in relatively high state. However, there are various images of cap layers for each field of study from the viewpoint of constituent minerals, thickness, depth and so on. In this thesis, the shallow hydrothermal systems of two geothermal areas where phreatic eruptions could occur are investigated from high-resolution resistivity structure model and the geochemical analysis of the fumarolic gas and hot-spring water, and then a general image of the cap layer and the accompanying reservoir beneath it is shown. Previous studies on resistivity structures have often found thick cap layers composed of smectite-rich rocks widely distributed over the volcanic edifices. However, it is doubtful whether the regional smectite cap layer could directly control the occurrence of phreatic eruption, since analysis of the ejecta indicates that the eruption initiates in a shallow depth. The thin surface cap layer inferred from this study has developed just below the phreatic eruption crater or the active fumarolic zone, and is different from the regional smectite cap layer in terms of constituent minerals. The resistivity is relatively high beneath this surface cap layer, where the presence of hydrothermal fluids rich in the vapor phase is inferred from the chemical analyses of the fumarolic gas and hot-spring water. Furthermore, in the two surveyed geothermal areas, the source locations of localized surface deformation were estimated around the boundary between the surface cap layer and the underlying reservoir. I conclude that the thin surface cap layer plays an important role in the occurrence of phreatic eruptions. In other words, in order for phreatic eruption to occur, it is required to destroy and blow away this surface cap layer.

In forecasting phreatic eruptions, it is essential to know the position and shape of the shallow thin cap layer and the temperature/pressure state of hydrothermal reservoir beneath it. As a result, it would be possible to monitor the physical and chemical state of the shallow hydrothermal system as a preparation zone of phreatic eruption, and to lead to clarification of the eruption mechanism.