Hydrothermal system of Tokachidake volcano, Japan: Examination from multi-disciplinary surveys

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Tokachidake volcano, located in central Hokkaido, Japan, has had intermittent magmatic eruptions during the 20th century. Recently, increases in seismic activity, ground inflation around the active craters and chemical changes of thermal waters are observed, and hence, a magmatic eruption in the near future is of concern. The 1926 eruption induced a large-scale lahar (Taisho lahar). Uesawa (2014) proposed that large amounts of thermal water were released as a hydrothermal surge from the interior of the volcanic edifice, expanding the scale of the Taisho lahar. In addition, chemical and thermal changes related to volcanic activity were observed in thermal waters around the volcano (Takahashi et al., 2015). These phenomena are deeply related to hydrothermal systems. Therefore, to detect precursor activities precisely at Tokachidake volcano, we should understand the subvolcanic hydrothermal systems. In this study, we performed multi-disciplinary surveys, such as magnetotelluric (MT) survey, geological investigations and thermal water and fumarolic gas observations, to examine the subvolcanic hydrothermal systems.

We performed MT survey at 13 stations along an NW-SE survey line across the volcano, and detected several conductive zones in the edifice. A conductive zone was detected at more than 3–4 km depth beneath the summit crater area (deep conductive zone). Volcanic earthquakes did not occur in this conductive zone, but their hypocenters were distributed surrounding the zone. This would indicate that the outer margin of the conductive zone is coincident with the brittle-ductile transition zone. Another conductive zone is distributed at 300–1,500 m depth beneath the summit crater area (shallow conductive zone).

In order to discuss the shallow hydrothermal system, we investigated phreatic ejecta, the 1926 debris avalanche deposits and accessory ejecta, all of which record subsurface hydrothermal environments. As a result, we revealed that an alteration zone with a pyrophyllite+quartz assemblage occurs at depths of >500 m beneath the crater area (Takahashi & Yahata, 2018). This zone reflects a high-temperature environment (200–300 ˚C). Also, fumarolic gas observations suggest that high-temperature (200–300 ˚C) hydrothermal systems exist the shallow subsurface. We can consider that the shallow hydrothermal system inferred from these investigations is coincident with the shallow conductive zone detected by MT survey.

We have observed the thermal waters around Tokachidake volcano over a period of more than three decades. At Fukiage spa area, thermal waters caused chemical and thermal changes by the supply of the magmatic NaCl-type thermal water associated with the increase in volcanic activity (Takahashi et al., 2015). A distribution area of the NaCl-type thermal water around magma would be detected as a conductive zone because thermal waters with high temperature and high NaCl concentration show high conductivity. Thus, we can consider that the deep conductive zone is interpreted as a distribution area of the NaCl-type thermal water.
In consequence of multi-disciplinary surveys at Tokachidake volcano, we revealed the subvolcanic hydrothermal systems. We should continue careful observations and revise the model to understand more precisely the volcanic activity of the volcano.

Keywords: Tokachidake volcano, hydrothermal system, magnetotelluric survey

