An improved conceptual model for hydrothermal system at Kusatsu-Shirane volcano, inferred from chloride and water stable isotope ratios of hot springs

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Kusatsu-Shirane volcano, Japan, is one of the most active volcano in terms of repeated phreatic eruptions at around the Shirane pyroclastic cone in historic times. The latest eruption occurred on 23 January 2018 at the Kagami-ike-kita pyroclastic cone, 1.2 km south of the Shirane pyroclastic cone, which results in the death of a skier. Kusatsu-Shirane volcano exhibits thermal features such as emissions of acid thermal waters on its eastern flank as well as Yugama crater lake at the summit of Shirane pyroclastic cone. Because phreatic eruptions are likely caused by breaching of an impermeable layer covering shallow hydrothermal reservoir, it is one of the critical issue to understand origins of hot springs associated with underlying hydrothermal system.

To understand physics and chemistry of hydrothermal processing, investigations such as geochemical, geophysical and geological approaches have been conducted at Kusatsu-Shirane volcano. Ohba et al. (2000) proposes a simple model of a two-phase hydrothermal reservoir beneath Yugama crater lake. Analyses of stable isotope ratios of hot springs suggest the hydrothermal water is derived from a mixture of magmatic high-temperature volcanic gasses (HTVG) and meteoric water. Nurhasan et al. (2006) discusses smectite-rich layers play an important role to control fluid flows within the volcanic edifice. However, spatial distributions of geochemical characteristic of hot springs are still open to discussion. In this study, we sampled most of hot springs emitting at the eastern flank of Kusatsu-Shirane volcano. In addition, we found thermal water which is emitting from the bottom of a stream located at the foot of the Shirane pyroclastic cone. On the basis of geochemical analyses of hot springs such as chloride and stable isotope ratios, we propose an improved conceptual model for hydrothermal system at Kusatsu-Shirane volcano.

We sampled water in total 35 of hot springs in 2017. Localities of sampling sites are around Shirane pyroclastic cone and the eastern flank of Kusatsu-Shirane volcano. Kusatsu Yubatake is at 6 km south-southeast of Yugama crater lake, which is the most far site from the summit of Kurasut-Shirane volcano. The concentrations of Cl and SO_4 ions were determined with an ion chromatograph. The pH and EC were measured using a handheld pH/EC meter. The δD and δ^{18}O values were determined by Cavity Ringdown Spectroscopy (Picarro, L2120-i).

According to analyses of stable isotope ratios, the thermal water emitting from the bottom of a stream located at the foot of the Shirane pyroclastic cone (Ye) has relatively high contribution of HTVG compared to other hot springs. Such characteristic is similar to that of Kagusa hot springs (Kg), however, Ye shows higher Cl/SO_4 ratio than that of Kg. Geochemical characteristics of Ye are similar to the fluid injected from the bottom of Yugama crater lake (Kuwahara et al., 2017). In addition, geochemical features of previous hot spring of Kusatsu Yubatake are almost same as Ye (note that chemical concentrations of Kusatsu Yubatake have been modified since Bandaiko hot spring was developed in 1970s).

These results indicate an existence of “Yugama group”. Thermal waters which supply to the area of the Shirane pyroclastic cone such as Yugama crater lake and Ye flow down to south-southeast direction. We believe that hot waters emitting from Kusatsu Yubatake are essentially derived from the Yugama group and have been modified by Bandaiko hot spring since 1970s. The hot springs of Hse (Ohba et al., 2000) are referred to as “Kagusa group” in this study. The hot water flows down from around Kagusa hot spring, 2 km east of the Shirane pyroclastic cone, to Jyoufu and Gunma-Tetsuzan.

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