

## The isotopic ratios of the hot springs in the Jigokudani Valley, Tateyama Volcano

\*Kaori Seki<sup>1</sup>, Takeshi Ohba<sup>2</sup>, Shinnosuke Aoyama<sup>1</sup>, Yuichiro Ueno<sup>1</sup>, Wataru Kanda<sup>1</sup>, Toshiya Tanbo<sup>3</sup>

1. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2. Department of chemistry, School of Science, Tokia University, 3. Tateyama Caldera Sabo Museum, Toyama Prefecture

Tateyama Volcano in the Hida Mountains has an active solfatara field called Jigokudani Valley (JV). The JV is formed by repeated phreatic eruptions about 40,000 years ago. These situations are suggestive of the presence of a well-developed hydrothermal system beneath the JV because phreatic eruptions mostly occur within the hydrothermal system. Recently, the JV showed the increased volcanic activity such as the sulfur outflow and the changes in the composition of fumarolic gases. We conducted resistivity surveys and geochemical analyses of the hot-spring water in order to reveal the hydrothermal system beneath the JV.

Hot-spring waters were sampled from 2014 to 2016, and we measured anion concentrations and isotopic ratios of them ( $\delta^{18}\text{O}_{\text{water}}$ ,  $\delta\text{D}_{\text{water}}$ ,  $\delta^{34}\text{S}_{\text{sulfate}}$  and  $\delta^{33}\text{S}_{\text{sulfate}}$ ). The results of the isotopic ratio of water and the anion concentration suggested that the hot springs of the JV were classified into the following three groups. (1) Hot springs characterized by high anion concentration and the isotopic ratio of water close to the magmatic vapor (MV). In addition, the  $\text{Cl}^-/\text{SO}_4^{2-}$  concentration ratio showed the value near 1. (2) Hot springs which showed large time variations of  $\text{Cl}^-/\text{SO}_4^{2-}$  concentration ratios because of decrease of  $\text{Cl}^-$  concentration. The isotopic ratios of water were plotted between MV and local meteoric water (LMW). (3) Hot springs which were mainly composed of  $\text{SO}_4^{2-}$  without  $\text{Cl}^-$  and showed low anion concentrations and the low isotopic ratios near LMW.

We also measured the  $\delta^{34}\text{S}$  value of sulfate in the hot-spring waters. Generally, primary sulfates (derived from  $\text{SO}_2$  disproportionation) in hot springs show higher  $\delta^{34}\text{S}$  values than secondary sulfates (formed by the  $\text{H}_2\text{S}$  oxidation). The  $\delta^{34}\text{S}$  of hot springs in the JV showed the values from -0.81‰ to 19.93‰. The sulfate of (3) is considered to be derived from the oxidation of  $\text{H}_2\text{S}$  because  $\delta^{34}\text{S}$  showed low values. On the other hand,  $\delta^{34}\text{S}$  values of (1) and (2) were distributed over a wide range regardless of the ion concentration and the isotopic ratio of water. A linear relationship between  $\delta^{34}\text{S}$  and  $\delta^{33}\text{S}$  is known because isotopic fractionation depends on the mass difference, which is called the mass dependent fractionation (MDF). The deviation from MDF (defined as  $\Delta^{33}\text{S}$ ) of samples in the JV was not zero, which is considered to be affected by kinetic isotope effects. The intersection point ( $\delta^{34}\text{S} \sim 9\text{‰}$ ) between the regression line of samples and the  $\Delta^{33}\text{S} = 0$  line might indicate the sulfate value of the primitive magmatic gases.

These results indicate the following formation processes of hot springs of JV; (1) Hot springs derived from the condensation of volcanic gases. (2) Hot springs formed by the mixing of the vapor phase of two-phase fluid and meteoric water at shallow depth. (3) Hot springs formed by the surface water in which  $\text{H}_2\text{S}$  in volcanic gases were dissolved.

We compared the results of the geochemical analysis with the resistivity structure (Seki et al., 2016), which indicates that all hot springs of the JV are formed within the depth of 500 m. In particular, we found that the hot-spring water of (2) was formed directly beneath the cap rock that is a key structure of the occurrence of phreatic eruptions. It is important to monitor the chemical and isotopic compositions of the hot-spring water in order to detect the changes in the volcanic activity because the hot spring of JV is formed in the shallow depth and affected by the conditions of temperature and pressure.

Keywords: Hydrothermal system, Hot spring, Water isotopic ratio, Sulfur isotopic ratio