

Helium isotope ratios of fumaroles and hot-spring gases at Kusatsu-Shirane volcano

*角野 浩史¹、川名 華織¹、山根 康平²、秋山 良秀¹、大場 武³、谷口 無我⁴、寺田 暁彦⁵

*Hirochika Sumino¹, Kaori Kawana¹, Kohei Yamane², Yoshihide Akiyama¹, Takeshi Ohba³, Muga Yaguchi⁴, Akihiko Terada⁵

1. 東京大学大学院総合文化研究科広域科学専攻基礎科学系、2. 東京大学教養学部統合自然科学科、3. 東海大学理学部化学科、4. 気象庁気象研究所、5. 東京工業大学理学院火山流体研究センター

1. Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, 2. Department of Integrated Science, College of Arts and Science, University of Tokyo, 3. Department of Chemistry, School of Science, Tokai University, 4. Meteorological Research Institute, Japan Meteorological Agency, 5. Volcanic Fluid Research Center, Tokyo Institute of Technology

Mount Kusatsu-Shirane, an active composite stratovolcano consisting of three pyroclastic cones (from north to south, Mt. Shirane, Mt. Ainomine, and Mt. Motoshirane) erupted on 23 January 2018 at Mt. Motoshirane although active discharges of fumaroles have been observed and the historic eruptions have occurred around the summit of Mt. Shirane. The 2018 eruption was a phreatic eruption, which often occur without magma movement, hence there is no or very small precursor geophysical signals. In contrast, geochemical signatures of volcanic gases could have changed reflecting pressure rise of a gas reservoir which caused the phreatic eruption. Among noble gases, helium is regarded as an useful tracer for the volcanic activity because isotope ratio of helium ($^3\text{He}/^4\text{He}$) exhibits unique values corresponding to the origin (e.g., 7–8 R_A in the mantle where 1 R_A denotes atmospheric $^3\text{He}/^4\text{He}$ ratio of 1.4×10^{-6} [1]). Few studies have reported pre-eruptive $^3\text{He}/^4\text{He}$ anomalies [2,3], suggesting the increase of supply of the magmatic helium into the hydrothermal system preceding eruption.

We have conducted biannual monitoring of $^3\text{He}/^4\text{He}$ ratios of fumaroles and hot-spring gases in Kusatsu-Shirane volcano since 2014. $^3\text{He}/^4\text{He}$ ratios until November 2017 of Kitagawa fumaroles, which are active fumaroles north of Yugama crater lake, the largest of the three crater lakes within Mt. Shirane, have been high as 7.3–7.8 R_A after the correction of atmospheric contamination based on $^4\text{He}/^{20}\text{Ne}$ ratios. On the contrary, hot-spring gases located relatively far from the summit of Mt. Shirane were also constant but lower, around 6.5 R_A at Yubatake and 4.8 R_A at Shiryaki which are 6 km and 9 km away from the summit, respectively. This tendency has been observed by a previous study [4] and explained as that high $^3\text{He}/^4\text{He}$ magmatic gas is mixed with and/or diluted by low $^3\text{He}/^4\text{He}$ crustal gas with increasing distance from the summit. At the Sessyogawara fumarole, located on the southeastern flank of Mt. Shirane and 2 km east of the 2018 phreatic vent, $^3\text{He}/^4\text{He}$ ratio had been almost constant at 7.0–7.5 R_A . However, $^3\text{He}/^4\text{He}$ ratio of fumarole collected at 13 February 2018 was 6.5 R_A , which is significantly lower than the previous values. There was no change in $^3\text{He}/^4\text{He}$ ratio of Yubatake hot-spring gas after the eruption, and unfortunately we have no sample from the Kitagawa fumaroles after the eruption until now. If the decrease in $^3\text{He}/^4\text{He}$ ratio of Sessyogawara fumarole is related to the phreatic eruption on January 23, it could imply the following scenarios. (1) contribution of magmatic helium with high $^3\text{He}/^4\text{He}$ ratio similar to the Kitagawa fumaroles decreased due to sealing of gas pathway from magma to its source gas reservoir resulting in dilution by low $^3\text{He}/^4\text{He}$ crustal gas. The sealing could cause increase of gas supply to another gas source, which possibly caused the phreatic eruption. (2) The Sessyogawara fumarole is a mixture of two gases from reservoirs having different $^3\text{He}/^4\text{He}$ ratios, the one is 7.3–7.8 R_A represented by the Kitagawa fumaroles and the other is 6.5 R_A represented by the Yubatake hot-spring. The low $^3\text{He}/^4\text{He}$ ratio of the Sessyogawara fumarole after the eruption suggests drastic change in mixing ratio of the two gases,

implying hydrothermal system beneath the Kisatsu-Shirane volcano complex could change and resulted in the phreatic eruption at unexpected location. Further monitoring is necessary to see what happened with reservoir(s) supplying gas to the Sessyogawara fumarole.

[1] Ozima & Pososek (2002), Noble Gas Geochemistry. [2] Padrón et al. (2013), Geol. [3] Sano et al. (2015), Sci. Rep. [4] Sano et al. (1994), Appl. Geochem.

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