Noble gas isotope compositions of mafic phenocrysts in Holocene lavas of Kusatsu-Shirane Volcano

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Kusatsu-Shirane Volcano is an active volcano, composed of two composite pyroclastic cones (Mt. Shirane and Mt. Motoshirane). Typical eruptions at Kusatsu-Shirane during the last 140 years were phreatic eruptions, and the first historic phreatic eruption at Mt. Motoshirane occurred on 23 January 2018. The chemical and isotopic compositions of volcanic gases can be useful indicators of volcanic activity because they can be a geochemical tracer for the contributions of various components (magma, crust, and atmosphere) and the degree of magma degassing. The air-corrected $^{3}He/^{4}He$ ratio of Sessho-gawara fumarole, located 2 km east of the 2018 vent, had been constant at 7.0–7.5 Ra during 2014 and 24 January 2018 and dropped to 6.5 Ra on 13 February 2018 [1]. Therefore, Toyama et al. [1] inferred that the low $^{3}He/^{4}He$ ratios observed after the 2018 eruption may reflect the relative increase of the contribution of gas supplied from Mt. Motoshirane hydrothermal reservoir which may have low $^{3}He/^{4}He$ ratio. However, the relationship of noble gas isotopic compositions between possible end-member components (volcanic gas, evolved felsic magma, mantle-derived mafic magma, etc.) that are the possible source of hydrothermal fluid is poorly understood. To obtain information on the noble gas isotopic ratios of mafic and evolved felsic magmas, we analyzed mafic phenocrysts in lavas that erupted during the relatively recent activities (after 7 ka [2]).

We measured noble gas (He, Ne, Ar) isotopic ratios of mafic phenocrysts (olivines: ol, pyroxenes: px) in the andesitic lavas of Kusatsu-Shirane Volcano. The lavas analyzed in this study were Kagusa Lava erupted from Mt. Shirane, and Sessho Lava and Furikozawa Lava both erupted from Mt. Motoshirane. Noble gas isotope analysis was conducted using a mass spectrometer installed at the University of Tokyo. The methods used for the extraction of noble gases from separated phenocrysts were in-vacuo crushing, and in-vacuo heating of the original grains and of powder recovered after crushing [3]. In contrast to that noble gases are selectively extracted from fluid inclusions by the crushing, noble gases not only in the fluid inclusions but also in melt inclusions and mineral lattice are simultaneously extracted by the heating. We also analyzed Green Tuff distributed around Kusatsu-Shirane as a basement rock that may contaminate magma using an in-vacuo heating method.

The $^{3}He/^{4}He$ ratios of ol in the three lavas obtained with the crushing were in the range of MORB-source mantle (8 ±1 Ra). Comparing with these ratios, the $^{3}He/^{4}He$ ratios obtained by the powder heating of ol from Sessho Lava was higher, clearly indicating the effect of cosmic ray irradiation. In contrast, the values obtained by the powder heating were lower than those obtained by the crushing for the Furikozawa and Kagusa Lavas, indicating the addition of radiogenic ^{4}He from U and Th. The $^{3}He/^{4}He$ ratios of px by the crushing show systematically lower values than ol, suggesting contamination of ^{4}He from the basement rock to the magma when px were crystallized.

The $^{4}He/^{40}Ar^{*}$ ratios ($^{40}Ar^{*}$ denotes non-atmospheric ^{40}Ar) of phenocrysts ranged from 0.1 to 1.1, which

are lower than those of current fumaroles (4–9, [1]). Because He is more soluble than Ar within silicate melt, the $^{4}He/^{40}Ar^{*}$ ratio of magma would increase as it degasses. Using the $^{4}He/^{40}Ar^{*}$ ratios as the index for the degree of magma degassing, the values observed in current fumaroles suggest that volcanic gas is derived from magma that is significantly degassed compared to magmas that have crystallized mafic phenocrysts. This implies that the current magma does not contain enough volatiles to ascend compared to past magmas, which is consistent with the fact that only phreatic eruptions have occurred in historical times.

References: [1] Toyama *et al.* (2019) JpGU2019, SVC38-P07. [2] Hayakawa (1989) *Quat. Res.*, 28, 1–17. [3] Sumino *et al.* (2001) *J. Mass Spectrom. Soc. Jpn.* 49, 61–68.

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