Temporal variations in helium and carbon isotopic compositions of fumarolic gases from Ioyama volcano, Kirishima volcanic group

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In Kirishima volcanic group in Kyushu, Southwest Japan, Mt. Shinmoedake recently erupted in 2011, 2017, and 2018, and Mt. Ioyama also erupted in 2018. Some fumaroles are continuously discharging volcanic gases at Mt. Ioyama. Volcanic gases are also emitted from the Shin-yu fumaroles at ~2 km west of Mt. Shinmoedake. Chemical and isotopic compositions of volcanic gases may reflect volcanic activity related to the eruption such as increase in magmatic gas flux. Helium ($^3He/^4He$) and carbon ($\delta^{13}C = [(^{13}C/^{12}C)_{gas}/(^{13}C/^{12}C)_{PDB} - 1)] \times 1000$ (‰)) isotope ratios are potential tracers of volcanic activity as they exhibit unique values corresponding to the origins. For example, $^3He/^4He$ ratios are ~8 Ra in the mantle (1 Ra is equal to the atmospheric $^3He/^4He$) and <0.02 Ra in the crust. Similarly, $\delta^{13}C$ values are −6.5±2.5‰ in the mantle, ~0‰ for marine carbonate, and <−20‰ for organic carbon. Pre-eruptive $^3He/^4He$ rises have been reported in some volcanoes, suggesting increase in magmatic He supply preceding the eruptions [e.g., 1]. Here we report temporal variations in $^3He/^4He$, $\delta^{13}C\text{-}CO_2$, and $^3He/CO_2$ of volcanic gases from five fumaroles (a, b, c, h, V2) at the Ioyama volcano and those from a Shin-yu fumarole, which is located 4 km south of the volcano, between August 2016 and June 2021.

The $^3He/^4He$ ratios (corrected for atmospheric He contamination by $^4He/^{20}Ne$) of the five Ioyama fumaroles (6.8–7.7 Ra) roughly synchronized each other, indicating that volcanic gases are supplied from a single gas reservoir. The average $^3He/^4He$ value increased and decreased before and after the Mt. Shinmoedake eruptions, respectively. This pattern probably reflects the variation in magmatic gas supply to the Ioyama fumaroles due to the pressure variation of the magma reservoir [2]. The average $^3He/^4He$ value increased again since July 2018 and has been stable until June 2021 (7.4–7.6 Ra). The $^3He/CO_2$ variations at the Ioyama fumaroles ($(0.6–2.1) \times 10^{-10}$) were less synchronized and did not correlate with $^3He/^4He$ ratios. This indicates that $^3He/CO_2$ cannot be explained by a simple mixing of magmatic gas and crustal CO_2. Alternatively, the results suggest that a significant amount of CO_2 is chemically removed from the volcanic gases before reaching the surface, or presence of more than two magmatic gas components with different $^3He/CO_2$ ratios. On the other hand, the variations of $\delta^{13}C\text{-}CO_2$ (−5.1 to −2.5‰) roughly synchronized each other. The average $\delta^{13}C\text{-}CO_2$ increased ~1‰ after the 2018 eruption and decreased ~1‰ since July 2020. The former may reflect CO_2 contribution from a newly supplied magma, and the latter may indicate that $\delta^{13}C\text{-}CO_2$ of the magma became lower due to continuous degassing. Occurrences of magmatic $\delta^{13}C\text{-}CO_2$ shifts to the lighter values over time have been reported in some field studies. This is probably induced by progressive loss of CO_2 relatively enriched in ^{13}C compared that in the magma, resulting in the CO_2 in the residual melt being isotopically lighter with time [3].

The Shin-yu fumarole shows low $^3He/^4He$ ratios (4.3–5.8 Ra) relative to the Ioyama fumaroles, reflecting larger contribution of crustal He probably incorporated during transportation of hydrothermal fluid from the Shinmoedake volcano. The $^3He/^4He$ gradually decreased from one month after the 2017 eruption and started to increase in August 2018. The decrease in $^3He/^4He$ after volcanic eruption was also observed at some fumaroles around the Kusatsu-Shirane volcano [4]. Both may reflect decrease in hydrothermal fluid supply after the eruptions, resulting in larger contribution of crustal He.

References

[1] Padrón *et al.* (2013) *Geology* **41(5)**, 539–542. [2] Sumino et al. (2020) JpGU, SVC45-P29, abstract. [3] Bergfeld et al. (2017) *J. Volcanol. Geotherm. Res.* **343**, 109–121. [4] Obase et al. (2021) JpGU, SVC29-P03, abstract.

Keywords: Helium isotopes, Carbon isotopes, Volcanic gas, Kirishima volcanoes

