# Temporal and spatial variations of helium isotope ratios in volcanic gases at Kirishima volcanic group

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In Kirishima volcanic group in Kyushu, Southwest Japan, Shinmoe-dake erupted in 2008, 2011, 2017 and 2018, and Iwo-yama also erupted in 2018. For volcanic disaster prevention, forecasting volcanic eruption is required. It is known that temporal variations in chemical and isotopic compositions of volcanic gases are useful to evaluate the present state of volcanic activity [1]. Among them, helium isotope ratio ($^3He/^4He$) has a great potential as a good indicator of volcanic activity, because it exhibits unique values corresponding to the origin (e.g., 7-8 Ra in the mantle and about 0.02 Ra in the crust, where 1 Ra denotes atmospheric $^3He/^4He$ ratio of $1.4\times10^{-6}$ [2]). Some studies have reported pre-eruptive $^3He/^4He$ anomalies, suggesting the increase of the magmatic helium supply into the hydrothermal system preceding eruption [1,3,4].

We report spatial and temporal variations of $^3He/^4He$ ratios of fumaroles and hot spring gases collected from 10 sites in Kirishima volcanic group during 2016 to 2020. The measured $^3He/^4He$ ratios were corrected for atmospheric contamination based on $^4He/^{20}Ne$ ratios. The air-corrected $^3He/^4He$ ratios (6.8 to 7.7 Ra) observed in and around the central craters of the active volcanos (i.e., Iwo-yama, Shinmoe-dake, and Ohata-ike) are higher than those (3.5 to 5.8 Ra) at the other sites. The $^3He/^4He$ ratios of non-crater sites decrease with the increase of their distances to each sampling site from a magma reservoir, location of which is estimated as pressure source of crustal deformation associated with the 2011 Shinmoe-dake eruption. This can be accounted for by an increase of contribution of radiogenic $^4He$ in old groundwater to the magmatic helium with migration distance of the fluid from the magma to the site [7]. On the other hand, former or present active craters show constant and high $^3He/^4He$ ratios irrespective of the distance from the magma reservoir, indicating there would be pathways of magmatic gas from the magma without or less interaction with the old groundwater.

The $^3He/^4He$ ratios of fumaroles in Iwo-yama slightly increase before Shinmoe-dake eruptions, and decrease after each eruption. This variation cannot be accounted for by the contribution of the radiogenic $^4He$ relative to total helium in the fumaroles before and after the eruptions, because it is estimated that the amount of radiogenic $^4He$ which volcanic gas can acquire during its migration from magma to the surface is negligible. Alternatively, the variation results from the change in mixing ratio of gases derived from two reservoirs having high and low $^3He/^4He$ ratios. Assuming that the magma reservoir has high $^3He/^4He$ ratio, the increase of $^3He/^4He$ ratios of the fumaroles before the eruption would result from increase of the supply of the gas from the magma reservoir to the Iwo-yama fumaroles. Once an eruption occurs at Shinmoe-dake, magmatic gas is effectively released through the volcanic vent, resulting in decrease of its supply to the Iwo-yama fumaroles. Thus, the temporal variation of $^3He/^4He$ ratios in volcanic gases may reflect the pressure variation of the magma reservoir. Since the last eruption at Shinmoe-dake in June 2019, the $^3He/^4He$ ratios of Iwo-yama fumaroles have been constant at high values (7.2–7.6 Ra), suggesting magmatic gas has been continuously supplied to Iwo-yama fumaroles at constant rate.

References:

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