Temporal and spatial variations of helium isotope ratios in volcanic gases in Kirishima volcanic group, Japan

*Kotaro Toyama[1], Hirochika Sumino[1], Kaori Kawana[1], Takeshi Ohba[2], Muga Yaguchi[3], Yoshihide Akiyama[1], Koki Aizawa[4], Kaori Tsukamoto[4]

1. Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, 2. Department of chemistry, School of Science, Tokia University, 3. Meteorological Research Institute, 4. Institute of Seismology and Volcanology, Faculty of Science, Kyushu University

In Kirishima volcanic group in Kyushu, Southwest Japan, Shinmoe-dake is an active volcano and erupted in 2008, 2011, 2017 and 2018, and Iwo-yama also erupted in 2018. For the volcanic disaster preservation, forecasting the timing of the volcanic eruption is required. It is known that the temporal variations in chemical and isotopic compositions of volcanic gases are useful to evaluate the present state of volcanic activity [1]. Especially, helium isotope ratio ($^3He/^4He$) 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 1.4×10^{-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 2018. 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) of the central craters in the active volcanos (i.e., Iwo-yama and Shinmoe-dake) are higher than those (4.3 to 5.3 Ra) of the other sites. These $^3He/^4He$ ratios decrease with the increase of the distance from the magma reservoir, location of which is estimated as pressure source of crustal deformation associated with the 2011 Shinmoe-dake eruption, to each sampling site. This trend reflects that the contribution of radiogenic ^4He in old groundwater increases with migration distance of the gas from the magma to the site [5].

The $^3He/^4He$ ratios of fumaroles in Iwo-yama slightly increase before Shinmoe-dake eruptions, and decrease after the 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 chamber has high $^3He/^4He$ ratio, the increase of $^3He/^4He$ ratios of the fumaroles before the eruption would be resulted from increase of the supply of the gas from the chamber 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 chamber.

References: [1]Paonita et al. (2016) Geol.; [2] Ozima and Podosek (2002) Noble Gas Geochemistry.; [3] Padrón et al. (2013) Geol.; [4] Sano et al. (2015) Sci. Rep.; [5] Sano et al. (1994) Appl. Geochem.

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