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Temporal and spatial variations of helium and carbon isotope ratios at Kirishima volcanic group, Japan

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In assessing volcanic activity, helium isotopic ratios in volcanic gases serve as a useful indicator for the quantitative evaluation of magmatic fluid contributions. We investigate temporal variations and spatial distribution of helium isotopic ratios in volcanic gases from the Kirishima volcanic group in southern Kyushu Japan, examining their relationship with volcanic activity.

The Kirishima volcanic group experienced multiple eruptions. Shinmoe-dake Volcano had small-scale eruptions from 2008 to 2010, followed by a sub-plinian eruption with lava effusion in January 2011. Shinmoe-dake Volcano resumed activity in October 2017, experiencing lava effusion and intermittent eruptions in March 2018. Subsequently, a phreatic eruption occurred at Ebinokogen Iwo-yama Volcano (hereafter, Iwo-yama) in April 2018.

To monitor temporal variations, we collected volcanic gas samples every few months from 2016 to 2024 from the fumaroles of Iwo-yama Volcano and the *Shinyu* fumarole, located approximately 5 km south of Iwo-yama. The air-corrected $^{3}He/^{4}He$ ratios of Iwo-yama (monitored throughout the study period) and of Shinmoe-dake Volcanoes (sampled in 2017) generally ranged from 6.8 to 8.0 Ra (where Ra is the atmospheric $^{3}He/^{4}He$ ratio), roughly consistent with the mantle value. These values suggest that volcanic gases at both sites originated from sources with minimal interaction with low-$^{3}He/^{4}He$ crustal fluids. In contrast, the Shinyu fumarole exhibited relatively lower values of 2.1-5.9 Ra, indicating the contribution of crustal fluids during the migration from the hydrothermal system beneath Shinmoe-dake Volcano.

Notably, significant temporal variations in the $^{3}He/^{4}He$ ratios were observed at Iwo-yama Volcano before and after the eruptions in 2017 and 2018. Specifically, the $^{3}He/^{4}He$ ratio increased prior to the October 2017 eruption, decreased afterward, and then increased again during the 2018 eruption. The helium isotope ratios have remained high through the end of 2024, with slight fluctuations since then.

The spatial distribution survey revealed high values exceeding 7 Ra around active volcanic centers, including Iwo-yama and Shinmoe-dake Volcanoes, with values gradually decreasing toward peripheral areas. This distribution pattern is consistent with the 3-D resistivity structure [1] and may reflect the mixing ratios of magmatic and crustal fluids decreasing with distance from the magma reservoir.

[1] Aizawa et al. (2014) JGR: Solid Earth