The origin of magmatic volatiles and the current state of the hydrothermal system of Ioto volcano inferred from helium and carbon isotope ratios of fumaroles and hot spring gases

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The magma of Ioto volcano, located on the southernmost part of the Izu-Ogasawara arc, is characterized by magma chemistry, which differs from that of the other volcanoes in the arc, suggesting a larger contribution of a subducted component. The island is also known for significant crustal deformation resulting in continuous uplift, and for active geothermal activity throughout the island with frequent phreatic eruptions. To elucidate the unusual magma genesis and the behavior of volatiles in vigorous hydrothermal activity, fumaroles and hot spring gases were sampled from 1997 to 2001 and in August 2017 and November 2022, and noble gases and carbon isotope ratios were measured.

Noble gas and carbon isotopic characteristics of Ioto magma are quit distinct from other volcanoes in the Izu-Ogasawara-Mariana arc system: (1) a low $^{3}He/^{4}He$ ratio of 5.6 R_A, (2) enrichment in heavy noble gases, and (3) a heavy carbon isotope ratio (+1.5‰) almost equivalent to the highest value for marine carbonates. These unusual features strongly suggest an involvement of slab-derived volatiles in the magma. Based on a mixing calculation using helium-carbon isotope systematics, an extremely large contribution of slab-derived components (31% for ^{4}He and more than 95% for ^{12}C) is required to explain the unusual features of helium and carbon isotopes (Sumino et al., Chem. Geol. 2004). Enhanced slab-derived carbon and helium emissions (3.5×10^{9} mol/year and 4.0×10^{3} mol/year) estimated from carbon dioxide emissions at the island (Notsu et al., JVGR 2005) indicate a large input of slab component to the mantle wedge and/or effective devolatilization of slab materials. As for its origin, we consider that the unusual tectonic setting around Ioto may be responsible: (1) subduction of the Ogasawara Plateau, which brings a significant volume of thick crustal blocks into the mantle wedge beneath Ioto, (2) flattened subduction as a consequence of the buoyancy of the subducted Ogasawara Plateau, and (3) the extension of the back-arc basin in the Mariana Trough has migrated northward into the back-arc region of this island (Sumino et al. Chem. Geol. 2004).

The phreatic eruptions on the island have continued for the past 1,000 years, but the submarine eruption that occurred in August 2022 on the southeast marine caldera margin of the island turned out to be a magmatic eruption, suggesting that the volcanic activity may be moving to a different stage. The $^{3}He/^{4}He$ ratios of fumaroles and hot spring gases sampled in November 2022 on the north side of the island, where phreatic eruptions have frequently occurred since August 2022, showed no significant changes from the previous observations. However, an unprecedentedly high value of 6.0 R_A was observed at Iogaoka in the center of Motoyama. Based on the distribution of epicenters and observations of the ejecta of previous phreatic eruptions, the center of the hydrothermal system is thought to be located beneath the north of the island. Therefore, even if the magma-derived helium that ascent to the shallow depth in 2011 has a high $^{3}He/^{4}He$ ratio, its contribution has not yet been observed in the hydrothermal reservoir, where the 3He/4He ratio would be low due to the contamination by ^{4}He derived from surrounding rock. On the other hand, the magmatic contribution may have been more significant at Iogaoka, where the influence of the hydrothermal reservoir is relatively small, implying future changes in the $^{3}He/^{4}He$ ratio of

fumarolic and hot spring gases should be monitored with caution.

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