Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.4013

Secular variations in helium isotope ratios in Izu Oshima volcano

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Helium isotope ratios ($^3He/^4He$) differ significantly in geochemical reservoirs such as air, the crust, and the mantle. Therefore, helium in volcanic gases can be used as a sensitive tracer of magma activity. In Izu-Oshima volcano, $^3He/^4He$ of a steam well increased immediately after the 1986 eruption from a low value of 1.7 Ra, peaked in 1988 at 5.5 Ra, and has been decreasing until now (Sano et al., EPSL 1991). The $^3He/^4He$ corrected for atmospheric contamination using $^4He/^{20}Ne$ was about 6.2 Ra throughout the last 1986-1990 eruptive activity. On the other hand, air-corrected $^3He/^4He$ of hot spring gases collected from other wells have been constant at 6.2 Ra since 2001. These results suggest that the supply of magma-derived helium to the steam well has been decreasing, while the $^3He/^4He$ of magmatic gas itself has been constant over the past 30 years.

The lower $^3He/^4He$ of the present magma than the mantle value of 8 Ra suggests the significant contribution of crustal helium in the magma reservoir. On the other hand, $^3He/^4He$ of olivines in 19-40 ka volcanic rocks are around 7 Ra, suggesting that $^3He/^4He$ of the magma at these stages were more similar to that of the mantle. However, $^3He/^4He$ of olivines in 1.3 ka scoria is 4.6 Ra, indicating that crustal helium significantly contaminated the magma.

Based on these observations, two scenarios can be expected for the next eruption: first, if the old magma reservoir is reactivated, the $^3He/^4He$ of hot spring gases will remain unchanged at about 6 Ra, and only the contribution of magma-derived helium in the steam well will increase, similarly to the previous eruptive activity. In the second scenario, in which the reactivation of the magma is caused by a supply of primitive magma with a high $^3He/^4He$, not only the contribution of magmatic helium in the steam well increases, but also the air-corrected $^3He/^4He$ of the steam and hot-spring gases will be higher than 6 Ra. Namely, whether the next eruption results from new magma supply from greater depths or just reactivation of the old magma can be constrained by $^3He/^4He$.