

# Helium, Oxygen and Hydrogen Isotope Constraints on Magmatic Degassing and Melt Evolution of the 2022 Hunga Eruption

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The Hunga Tonga-Hunga Ha'apai volcano (Hunga volcano) in the Tonga-Kermadec Arc experienced a powerful explosive eruption (VEI = 5) on January 15, 2022. The eruption column reached a height of ~57 km, extending into the mesosphere and injecting vast amounts of water vapor and volcanic ash into the stratosphere. To investigate the eruption mechanism, we analyzed volatiles and stable isotopes in volcanic rocks from the caldera interior and the southern seamount (Volcano A). Here, we report helium, oxygen, and hydrogen isotope compositions along with volatile contents. Olivine-hosted melt inclusions exhibit basaltic andesite compositions with high water contents ( $\text{H}_2\text{O} = 1.88$  to  $4.95$  wt.%). Helium and oxygen isotopes ( $^3\text{He}/^4\text{He} = 2.27$  to  $6.54$  Ra;  $\delta^{18}\text{O} = 5.49$  to  $6.37$ ‰) in mineral grains and glass fragments indicate that the primary melt and volatiles originated from a hydrated mantle wedge and subsequently interacted with thick crust beneath the Tonga-Kermadec Arc. Hydrogen isotope compositions ( $\delta\text{D} = -97$  to  $+25$ ‰) and volatiles ( $\text{H}_2\text{O} = 0.20$  to  $4.95$  wt.%;  $\text{CO}_2 = 1$  to  $87$  ppm;  $\text{S} = 0$  to  $857$  ppm) from melt inclusions to erupted lavas suggest extensive degassing before the eruption. Considering the degassed water content and estimates of erupted magma volume ( $\sim 6.3$  km<sup>3</sup> [1];  $\sim 9.5$  km<sup>3</sup> [2]), we estimate that the total water vapor released was  $\sim 474$  to  $714$  Tg, significantly exceeding the  $\sim 146$  Tg recorded by the Aura Microwave Limb Sounder (MLS) [3]. Our findings indicate that extended degassing since December 2021 contributed to a much greater total water release than that observed during the 2022 eruption.

[1] Henley, R. W. *et al.* (2024), *J. Volcanol. Geotherm. Res.* **451**, 108077.

[2] Le Mével, H., Miller, C. A., Ribó, M., Cronin, S., & Kula, T. (2023), *Sci. Adv.* **9**(50), eadh3156.

[3] Millan, L. *et al.* (2022), *Geophys. Res. Lett.* **49**(13), e2022GL099381.