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Tracing Progressive Slab Devolatilization across the Mariana Forearc via Nitrogen Isotope Signatures of Forearc Serpentinites

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Subduction-zone nitrogen (N) recycling plays a critical role in regulating the long-term evolution of Earth's N reservoirs. As oceanic plates subduct into the mantle, slab-derived fluids are released and interact with the mantle wedge to generate arc magmatism, returning volatiles to the surface. While volatile recycling via arc magmatism is relatively well understood, the transfer of volatiles from the slab to the forearc at shallow depths and the role of the serpentinized forearc mantle wedge in the subduction-zone N cycle remains poorly constrained. Here, we report N contents and isotope compositions ($\delta^{15}N$) of mantle serpentinites from five forearc mud volcanoes (Yinazao, Fantangisña, Asùt Tesoru, South Chamorro, and Conical), with corresponding slab depths of ~13 to ~19 km. Nitrogen was analyzed using both crushing (releasing N from grain boundaries and/or fluid inclusions) and combustion (releasing lattice-bound N from the mineral matrix) methods. These forearc serpentinites show ubiquitous N enrichment with N contents of 2.4×10^{-10} mol·g^{-1} to 3.5×10^{-8} mol·g^{-1} and $\delta^{15}N$ values of -3.2‰ to +3.1‰ from crushing analysis, while combustion methods yield higher and relatively smaller ranges in both N contents (2.5×10^{-7} mol·g^{-1} to 9.9×10^{-7} mol·g^{-1}) and $\delta^{15}N$ values (-1.3‰ to +3.6‰). We observe first-order positive correlations of N contents between crushing and combustion methods, particularly in serpentinites from Conical. Nitrogen contents from both methods also positively correlate with loss on ignition (LOI), suggesting that N was incorporated during serpentinization processes. Combined with the behavior of other slab-derived fluid-mobile elements (e.g., Cs and Rb/Cs ratios), our results show progressive N devolatilization of distinct slab components during subduction. Serpentinites from Yinazao (~13 km) record opal dehydration from subducting chert and radiolarite at shallow depths, with possible contributions from pore fluids. Serpentinites from Fantangisña and Asùt Tesoru (~14–18 km), and some from Conical (~19 km) reflect clay dehydration at intermediate depths. At greater depths (~18–19 km), serpentinites from South Chamorro and Conical record dehydration of altered oceanic crust. Together, these data reveal a dynamic process of slab dehydration coupled with forearc mantle serpentinization as the subducting slab descends, highlighting the critical role of the forearc mantle wedge in modulating subduction-zone N cycle.