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Across-arc K isotope variations reveal deep dehydration of subducted lower oceanic crust

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Plate subduction governs water cycling in subduction zones [1, 2]. Dehydration of altered upper oceanic crust and slab serpentinite is widely regarded as the principal source of slab-derived fluids beneath volcanic arcs [3, 4]. In contrast, the role of the lower oceanic crust—situated between the altered upper crust and underlying serpentinite—has received far less attention. This gabbroic layer can store appreciable amounts of structurally bound water [5], yet its contribution to fluid release, particularly at depths beyond the sub-arc region, remains poorly constrained. Potassium (K) isotopes provide a powerful tracer of slab inputs because the upper oceanic crust and lower oceanic crust exhibit distinct $\delta^{41}K$ signatures, whereas serpentinite contains negligible K and thus contributes little to the slab K budget [6, 7].

Here we report $\delta^{41}K$ data for basalts from the Guguan cross-chain arc and back-arc basin in the Mariana subduction zone. Across-arc lavas are systematically enriched in heavy K isotopes relative to MORB. Notably, rear-arc and back-arc basin basalts display heavier $\delta^{41}K$ values than volcanic-front lavas. Overall, $\delta^{41}K$ shows a positive correlation with slab depth and negative correlations with slab-fluid proxies (e.g., Ba/Th, Ba/La, and K/Nb). These systematics cannot be explained solely by fluids derived from the altered upper oceanic crust. Instead, they indicate an increasing contribution from fluids released during dehydration of the gabbroic lower oceanic crust at depths beyond the sub-arc region. Our results highlight the importance of deep slab dehydration and call for a reassessment of the lower oceanic crust's role in regulating the water budget of subduction zones.

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