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Potassium isotope evidence for slab-derived fluids in the sub-arc mantle

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Subduction processes recycle water and other volatiles into Earth's mantle and play an important role in chemical and mass exchange between Earth's surface and its interior. Recently, the emerging K stable isotope system has been proposed as a new tracer to study subduction processes, particularly to distinguish the contributions from different subducting materials, since marine sediments and altered oceanic crust exhibit distinct isotopic signatures. However, it is still unknown whether these K isotopic signatures would remain unchanged and be preserved during the subduction dehydration and metamorphism. Fluid-mobile element K tends to be enriched in the water expelled from dehydrating slabs into the mantle wedge. Sub-arc mantle samples (i.e., peridotite xenoliths) could potentially retain components of this fluid including K. To investigate the nature of the slab-derived fluids as well as their roles in metasomatizing the sub-arc mantle, here we study high-precision K isotope systematics of peridotite xenoliths and related host rocks from an active arc volcano, Avacha, Kamchatka. These peridotite xenoliths are unaltered spinel harzburgites derived from the lithospheric mantle above a subduction zone. We found that their host lavas show a limited range of K isotopic variation and no difference from values for the bulk silicate Earth and the upper continental crust. In contrast, the peridotite xenoliths show an extreme variation range and are mostly enriched in heavy K isotopes compared to the BSE and UCC values. In addition, when compared to a global database of non-subduction zone mantle peridotites, there are no known mantle peridotites with K isotopic composition as heavy as these Avacha xenoliths studied here. Consistent with previous K isotope data on arc lavas and eclogites, the Avacha xenoliths suggest that slab-derived fluids have a uniquely heavy K isotopic signature, which is different from the K isotopic composition of the source subducting materials (e.g., the marine sediments and altered oceanic crusts). These new data provide direct evidence that slab-derived fluids have infiltrated the sub-arc mantle wedge. Due to the large K concentration difference between the depleted mantle and slab-derived fluids, K isotopes would be a very sensitive tracer to fluid activity in the sub-arc mantle.