The isotopic composition of subduction fluid: High-, low-, or normal $\delta^{18}O$?

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The oxygen isotopic composition of subduction zone fluids has been hypothesized to have high-$\delta^{18}O$ derived from the high-$\delta^{18}O$ upper portions of the slab's top and sediments. We report oxygen isotope analyses of olivine and other phenocrysts from four arcs that appear to have unusually large fluid contributions (ca >5-10wt%): Mt. Shasta, California, Kluchevskoy, Kamchatka, ten samples of high-^{226}Ra lavas from the Tonga Kermadec arc, and lavas from Central American arc. Other fluid-sensitive trace element ratios (Ba/La) and mass balance approaches were used to constrain the amount of fluid added.

Basalts and mantle-derived high-Mg andesites from Mt. Shasta have olivine $\delta^{18}O$ values ranging from 5.06-5.83‰ only moderately elevated above mantle values. The $\delta^{18}O$ values of phenocrysts from the Tonga-Kermadec arc, the fastest and most variable modern convergent margin (20 to 2 cm/y) is mantle-like, regardless of measured ^{226}Ra excesses (2-6) [1]. Olivine phenocrysts from primitive basalts from Klyuchevskoy volcano have the highest-$\delta^{18}O$ (6.5-7.3‰), but exhibit a negative correlation with water and B, and a positive with K,Ba, Th, Nb, LREE and require either high-$\delta^{18}O$ slab or lower crustal melt contributions [2, 3]. In contrast, Central American volcanics have low-$\delta^{18}O$ol values (ca. 4.8‰), and are interpreted to reflect addition of low to normal-$\delta^{18}O$ fluids from the slab interior [4].

The $\delta^{18}O$ value of subduction zone fluids may not be universally high as evidenced by these end-member examples. Where fluid signature is strong, it can also be variable but have $\delta^{18}O$ not much higher or lower (i.e. ±2-3 ‰) than the mantle. This result corroborates our recent result that slab-derived melt components also cluster around mantle $\delta^{18}O$ values. Examples of significant departures from this rule: high $\delta^{18}O$ olivines in Trans-Mexican volcanic belt and Kamchatka, and low-$\delta^{18}O$ (e.g. Kamchatka, Fisher and Okmok calderas, Aleutians) are explained by crustal contribution.

References

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Distribution of water in the mantle wedge of subduction zones

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Water plays a critical role in the operation of global subduction zones as a primary driver of melting within the mantle wedge. Excess H_2O in the wedge is presumably derived from the subducting slab, but questions of the magnitude of the H_2O flux, the effect of progressive slab dehydration, and the fluid pathways from the slab through the mantle wedge are dynamic uncertainties that remain largely unknown. The H_2O concentrations of arc and back-arc lavas are elevated relative to the concentrations measured at mid-ocean ridges (0.01-0.05 wt.%), and arc basaltic magmas range to much higher H_2O concentrations (0.1-6.2 wt%) than back-arc basalts (0.1–2.5 wt%) We employ new measurements of melt inclusions from the Mariana Arc, along with existing data, to determine the integrated H_2O concentrations in the mantle sources of subduction zones. We use TiO_2 as a proxy for melt fraction (*F*), which we then use to invert measured melt H_2O concentrations to mantle source concentrations (i.e. H_2O_o). Water concentrations of mantle beneath back-arc basins and arcs range more than an order of magnitude and vary systematically as a function of the distance between the eruptive center and the trench. Most back-arc basin segments are 250-400 km from their trenches, with the wettest spreading segments (up to 0.35 wt.% H_2O_o) residing ~300 km or less from the trench. This trenchward increase continues beneath arc volcanic fronts, which occupy positions 250-180 km from the trench and record mantle H_2O concentrations up to 1.6 wt. %. Mantle H_2O in excess of average MORB is present up to 400 km from the trench, but H_2O_o concentrations increase exponentially as trench distance decreases from 300 to 200 km. These relationships clearly implicate the subducting slab as the global source of elevated H_2O in arc and back-arc magmas, but on a smaller scale, progressive slab dehydration and lateral fluid transport across the wedge must both play significant but variable roles in region-specific trends in the distribution of H_2O across the mantle wedge.