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Hot and Cold Slabs: Effects on Hf and Nd

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A burst of new Hf and Nd isotopic data on marine sediments [1-3] motivates a fresh look at mixing relationships in the source of arc magmas. Most arcs plot above the εNd-εHf isotopic terrestrial array, as do many subducting sediments, potentially linking the two. Alternatively, compositions above the terrestrial array could derive from preferential addition of Nd over Hf, creating strongly hyperbolic mixing trajectories. Resolving source mixing (sediment and basalt in the subducting plate) from elemental fractionation (partitioning into slab fluids and melts) is an outstanding goal in unraveling the processes that occur in subduction zones. A greater goal is to link geochemical systematics to physical parameters such as slab temperature, and dynamic processes such as fluid and solid flow.

Here we explore isotopic mixing and elemental fractionation together by examining the systematics of arc volcanics and subducting sediments on Hf/Nd vs. εNd diagrams. Mixing on these diagrams is linear and therefore less ambiguous to interpret. Many arcs form linear arrays that are consistent with depleted mantle (high Hf/Nd and εNd) and sediment (low Hf/Nd and εNd) as end-members. New estimates of bulk sedimentary compositions subducting at each margin [4] allow quantitative testing of this prediction. Surprisingly, arc mixing arrays project to a low-εNd component that fails in every case to intersect the local bulk sediment. Highly fractionated sediment compositions (i.e. even taking Hf/Nd to zero) also fail as end-members. A simple solution to this dilemma is to add varying amounts of MORB εNd and εHf from the subducting plate, as low Hf/Nd fluids. We find that the proportion of Nd that is slab MORB vs. sediment increases with slab surface temperature, as estimated from H_2O/Ce [5]: from 0-20% MORB Nd (i.e. 100-80% sediment Nd) for central Tongan volcanoes and Seguam (Aleutians) to 79-90% MORB Nd for Shishaldin (Aleutians) and Adams (Cascades). Cold slabs may barely intersect the water-saturated sediment solidus at the slab surface, thus liberating only sediment Nd and Hf, while MORB in the deeper portion of the slab remains too cold for Nd-Hf to partition into fluids. Hot slabs may drive both slab sediment and MORB above their solidi, so liberating Nd-Hf from both. Thus, slab thermal structure may be the primary control on the Nd and Hf isotopic composition of arc basalts.

[1] Chauvel et al. (2008) G3. [2] Carpentier et al. (2009) EPSL. [3] Vervoort et al. (2011) GCA. [4] Plank (2012) Treastise on Geochem. [5] Plank et al. (2009) Nature Geosci.