Evidence for a role of slab fluids in the oxidized nature of arc basalts

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The oxidized nature of arc basalts is plausibly due to the subduction of oxidized species and their delivery to the source of arc volcanism. Here, we provide observations and model results that constrain the process driving arc basalts to be more oxidized than mid-ocean ridge basalts.

We measured $Fe^{3+}/\Sigma Fe$ ratios in submarine glass and olivine-hosted melt inclusions from the Mariana arc and back-arc, and find this ratio is positively correlated with enrichments in fluid-mobile trace elements, e.g., $Fe^{3+}/\Sigma Fe$ ratios rise from ~0.16 in MORB lavas with Ba/La ratio ~5, to ratios >0.19 when Ba/La >10 in subduction related lavas. Because Ba is fluid mobile, this trend suggests that fluids released from subducting slabs are oxidizing, causing oxidation to take place in the mantle sources of arc lavas. Rapid secular evolution of both $Fe^{3+}/\Sigma Fe$ and Ba/La ratios early in the history of the Mariana subduction system suggest this process begins at the very onset of subduction.

These observations constrain the identity and abundance of oxidized species in the aqueous slab fluids that appear to drive oxidation of the sources of arc lavas. Our initial efforts to model this process focus on sulfate as a potential oxidant. Our models describe the products of melting peridotite (resembling the NMORB-source) in response to fluxing by fluids with variable concentrations of S^{6+}, Fe^{3+}, Fe^{2+}, Ba, La, and H_2O. These fluids mix with the mantle rock to produce hybrid mantle compositions, which then melt. The compositions of melts and solid residues are calculated using the simultaneous solution of mass balance constraints, a wet melting function, melt/solid partition coefficients, and a function linking Fe^{+3}/Fe^{+2} to S^{+6}/S^{-2} in the resultant melt. By exploring the parameter space of this model that can simultaneously explain the observed range in $Fe^{3+}/\Sigma Fe$ and Ba/La using plausible mantle wedge and slab-derived fluid compositions, we are able to set constraints on the nature of coupled mantle oxidation and melting in the sources of arc magmas.