Highly oxidized, near-primary arc magmas influenced by slab melting

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The distinct lithologies of oceanic lithosphere likely experience different fates at depth within subduction zones. The serpentinized lithospheric mantle mostly dehydrates, the sediments often partially melt, and the altered basaltic crust may either dehydrate or partially melt. Arc basalts are more oxidized than those from mid-ocean ridges, and broad relationships exist between arc magmatic H_2O content, the Ba/La ratio (a signature of slab-derived aqueous fluids), and magmatic oxygen fugacity. Yet, explicit links between contributions of discrete slab lithologies and the oxygen fugacity of arc magmas have yet to be established. Here, we show that arc magmas bearing clear signatures of partial melts of subducted oceanic crust are significantly more oxidized than those with signatures of only fluid or sediment melt addition to the mantle source.

One dredge of Evita seamount, southern Vanuatu arc (cruise SS07/2008), recovered submarine lavas of two geochemical affinities. Group 1 has low Sr/Y (13-18) and Dy/Yb (1.4-1.9) whereas group 2 is elevated in both ratios (Sr/Y=32-59; Dy/Yb=2.3-3.4), which are common indices of slab melting. We measured major elements (EMP), trace elements (LAICPMS), dissolved volatiles (FTIR), and $Fe^{3+}/\sum Fe$ ratios (XANES) in olivine-hosted melt inclusions from both groups. Both contain Fo_{86-93} olivine, and glass inclusions are near-primary melts with Mg#=66-79. Group 1 inclusions are typical of arc magmas, with H_2O up to 5 wt.%, H_2O/Ce=6000, and $Fe^{3+}/\sum Fe$=0.17-0.22. Group 2 inclusions contain lower H_2O (up to 2.7 wt.%) and have low H_2O/Ce ratios (130-250) suggesting a hot slab surface (~1100°C) that has enabled melting. These melts are also significantly more oxidized, with $Fe^{3+}/\sum Fe$ ratios up to 0.3, among the highest yet measured in natural glasses by XANES.

Our results show that arc magmas are oxidized from their origin in the mantle, requiring no differentiation process to elevate oxygen fugacity. The more oxidized condition of slab melt-influenced magma may arise because 1) the subducted altered basalt is highly oxidized over MORB and (2) melts may more efficiently transport certain oxidized species (e.g., Fe^{3+}) from the slab to the mantle wedge.