Water, fO_2, and the creation of continental crust signatures in Aleutian arc magmas

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Early Fe depletion of arc magmas (i.e., calc-alkaline affinity) drives them towards the composition of bulk continental crust. Arc magmas may develop early Fe depletion due to high magmatic H_2O, which suppresses silicates, high oxygen fugacity (fO_2), which promotes early Fe-oxide crystallization, or primary Fe-poor magmas may emerge via slab melting and mix with Fe-rich basaltic magmas, causing an apparent Fe-depletion trend that is unrelated to differentiation of a single parent magma. Yet, the relative importance of these key factors in generating calc-alkaline trends in natural arc magmas remains under-constrained.

In the oceanic Aleutian island arc, magmas become strongly calc-alkaline towards the west, where convergence is highly oblique. This unique setting provides an ideal locale to test the effects of H_2O, fO_2, and parental magma composition on the development of Fe-depletion in arc magmas. Here, we present new measurements of western Aleutian whole-rock lavas paired with $Fe^{3+}/\sum Fe$ ratios (a proxy for magmatic fO_2; acquired by XANES), dissolved volatile contents, and major elements of olivine-hosted melt inclusions from western and central Alaska-Aleutian arc volcanoes. The Tholeiitic Index (THI; [1]) quantifies Fe depletion in the magma series at each volcano (<1 is Fe-depleted, >1 is Fe-enriched). Over a range of THI, from 0.9-0.65, the $Fe^{3+}/\sum Fe$ ratios of Aleutian basalts, referenced to 6 wt.% MgO (i.e., $Fe^{3+}/\sum Fe_{6.0}$) range from 0.22-0.31 and correlate strongly with THI, such that more Fe-depleted magmas contain proportionally more oxidized Fe. Maximum dissolved H_2O contents of these volcanoes also negatively correlate with THI and with $Fe^{3+}/\sum Fe_{6.0}$ ratios, suggesting Fe-depletion originates by differentiation rather than by mixing. The effects of H_2O and fO_2 on arc magmatic differentiation are challenging to isolate in nature, but experimental data suggest that fO_2 exhibits stronger control than H_2O on the relative appearance of magnetite vs. silicates on the liquidus, thus exerting greater leverage on the THI.

[1] Zimmer, M.M., et al., 2010, *J. Pet.* 51, 2411-2444, doi:10.1093/petrology/egq062.