Water storage and amphibole control in arc magma differentiation

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Arc magmas are distinguished from those of other tectonic settings by several first order characteristics; 1) they tend to be realtively differentiated with even the most mafic rocks in a suite typically $\geq$50% SiO_2, 2) they typically contain high H_2O contents and 3) they have distinctive trace element signatures. The "standard" model for arc petrogenesis involves melting of a mantle wedge, preconditioned by the ingress of fluids ± melts from the subducted slab (oceanic crust ± sediments). This produces primitive hydrous basalts with a distinct trace element signature reflecting a combination of process and inheritance from source components. The subsequent differentiation path is critical in defining the compositions of rocks ultimately formed through eruption or emplacement, and also for dictating practical criteria such as eruptive behavior. A petrographic survey of volcanic arc rocks show that they are typically in equilibrium with a shallow pressure gabbroic assemblage. On the other hand, indications of open system processes along with thermal modeling argue for processing in the deep crust.

We have collated data from single volcanic suites from a representative global sample of arcs, and found compelling evidence for the involvement of amphibole during differentiation. Preferential sequestration of middle REE (e.g. Dy) over heavy and light REE can only reasonably be explained by the involvement of amphibole, which has middle REE partition coefficients higher than both light and heavy. Amphibole also, by virtue of its low SiO_2, has the capacity to leverage liquid SiO_2 towards higher values, and may also lower TiO_2 as seen in arc magmas. The amphibole could be directly fractionated from liquids in which it is stable, or residual in partial melts of amphibolite. In either case differentiation is dominantly in the mid-deep crust.

The signature of amphibole indicates that a significant H_2O-bearing reservoir exists in the arc crust, which may be tapped to produce silicic, explosive magmas or ore-forming fluids. Furthermore, amphibole has the capability of rotating REE patterns to obtain the characteristic light REE enrichment of the continental crust.