A "distillation" mechanism for intracrustal differentiation in arcs

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Eruption rates, proportions of erupted lava types, phenocryst assemblages, phase equilibria, and seismic profiles from several arcs can be used as evidence that the primary mechanism driving intracrustal differentiation at subduction zones is one of repeated episodes of magma emplacement, rapid solidification, and subsequent partial melting. At a typical arc, most basalt is frozen into the deep crust, some is emplaced at shallower levels, and only a small fraction erupts. New injections of hydrous arc basalt into the lower crust drives partial melting of previous gabbroic intrusions, leading to a spectrum of liquid compositions ranging from basaltic andesite to andesite/dacite, depending on the local degree of partial melting. These partial melts ascend through the crust along fractures, with the more felsic compositions having a statistically greater chance of reaching higher crustal levels than the more mafic compositions, owing to their lower crystallization temperatures as they ascend through a crustal column that is hundreds of degrees colder than their liquidi. This process of repeated episodes of partial melting is not restricted to the lower crust, but occurs throughout the crustal column at all depth levels. Three critical features control this differentiation process: (1) the relatively low volumes of arc basalt emplaced into the crust per unit time compared to other magmatic tectonic settings, which promotes rapid solidification, (2) the hydrous character of arc basalts, causing water to be released when they solidify, which lowers the solidus of adjacent rock bodies and produces hydrous partial melts throughout the crustal column, and (3) the $>10^6$ year time scale for arc magmatism along the strike of the arc, allowing the process of partial melting in the crustal column to be repeated over and over.

Hydrous components in the mantle

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Water can be recycled through many inputs in the solid Earth system, e.g. altered ocean crust, sediments, serpentinites. All of these components have different ratios of H_2O to Ce and other incompatible elements. The same holds for many incompatible element ratios. Much subducted ocean crust is depleted, some is enriched, sediments have distinctive ratios, serpentinites are unique. Outputs coming off the slab are also variable. Ratios of H_2O to Ce and other incompatible elements ratios can vary by an order of magnitude. Some components are low T slab fluids, others are high T fluids, and others may be melts of sediment or subducted crust. Variations in these components should be systematic with subduction parameters, composition of the slab, and distance from the trench. Global arcs and back-arcs provide the necessary data to test this hypothesis. While some convergent margins are well explained by the "slab-fluid" and "sediment-melt" paradigm, others are not. Slab components in the Lau back-arc for each segment reflect a single local subduction component that combines with an E-MORB-like component that can be ascribed to low degree melts before mixing with the ambient depleted mantle. The subduction component in Mexico has both fluid characteristics (e.g. high Pb/La, U/La) and sediment characteristics (e.g. high Th/Nd), and also sees a low degree melt component. Low degree melt components are also ubiquitous in the back-arc setting, with isotope ratios that suggest young formation ages. Despite the diversity of inputs and output at convergent margins, "enriched components" in the mantle as observed in E-MORB and ocean island basalts are remarkably uniform in H_2O /Ce and in other incompatible element ratios. This may result from mantle equilibration with high H_2O fluids in the wedge, and migration of low F melts that ultimately leads to a partition coefficient control on enriched components.