Magmatic Processes in Island Arcs – a tour of the crust from the bottom on up

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Comparison of exposed sections of four ancient magmatic arcs reveals a pattern of depth-specific processes that may be typical of arcs worldwide. These processes include (1) crystallization of mafic and ultramafic cumulates by fractionation from a highly mafic parental magma (mantle derived) in the uppermost mantle and lowermost crust, (2) subsolidus transformation of mafic plutonic rocks into very dense garnet-bearing assemblages in the region of the Moho in thick arc sections (>30 km depth) by isobaric cooling and/or partial melting, (3) extensive dehydration melting of amphibolitized basalt and gabbro (including pre-existing oceanic basement) in the deep to mid crust to produce felsic tonalite/trondhjemite (15-25 km depth), (4) mingling/mixing/homogenization of these felsic crustal melts with mafic mantle-derived magmas in the mid crust (15-25 km depth), (5) increasing homogenization of magmas in mid to upper crustal levels (<20 km depth) to produce intermediate composition magmas.

Individual arcs will vary given their unique tectonic settings and petrogenesis. But these processes may be a general framework that can be used as an overlay for interpretation of geophysical observations in active arcs and for petrogenetic studies of arc volcanic rocks.

The four sections used in the study (correlated to observed processes as listed in the first paragraph) include the Jurassic Talkeetna arc exposed in the Tonsina-Nelchina area of Alaska processes 1,2,4,5), the Cretaceous Kohistan arc of northern Pakistan (processes 1,2,3,4), the Jurassic Bonanza arc exposed on the west coast of Vancouver Island (processes 3,4,5), and Cretaceous arc basement of the North Cascades crystalline core (southern Coast Plutonic Complex) (processes 3,4,5). Comparable levels of each of these arcs are strikingly and remarkably similar, both physically and geochemically.

The broader issues of density and geochemical stratification of arcs, as well as their bulk composition, are critical to an understanding of the growth and compositional evolution of continental crust. An obvious speculation given the observed densification of the Moho region in thickened arcs is the role of delamination in removing the most mafic, lowermost section of arcs during accretion. This would result in a more felsic residuum comparable to continental crust.