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Crustal thickening drives arc front migration

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The location of volcanic arcs, relative to the trench evolves over time. Arc front migration has been observed in relic (Sierra Nevada, Andes) as well as active (Cascades) arcs, sometimes with cycles of retreat and return of the front towards the trench over millions of years. Other arcs, particularly where back-arc extension dominates, migrate more slowly, if at all. Coupled with arc migration there are systematic changes in the geochemistry of magmas such as the ratio of trace elements La/Yb and 87Sr/86Sr isotopes (e.g., Haschke et al., 2002).

The position of active volcanic arcs relative to the trench is controlled by the location where melt is generated in the mantle wedge, in turn controlled by the geometry of subduction, and the processes that focus rising melt. Arc front migration is commonly attributed to variation in dip angle of the downgoing slab, delamination of overthickened crust, or to subduction erosion. Here we present an alternative hypothesis. Assuming mantle wedge melting is a largely temperature-dependant process, the maximum isotherm in the wedge sets arc front location. Isotherm location depends on slab angle, subduction velocity and wedge thermal diffusivity (England and Katz, 2010). It also depends on crustal thickness, which evolves as melt is transferred from the wedge to the crust. Arc front migration can thus occur purely through magmatic thickening of crust and lithosphere. Thickening rate is determined by the mantle melt flux into the crust, modulated by tectonics and surface erosion. It is not steady in time, as crustal thickening progressively truncates the mantle melt column and eventually shuts it off. Thus slab angle need not change, and in the absence of other contribution processes front location and crustal thickness have long-time steady state values.

We develop a quantitative model for arc front migration that is consistent with published arc front data, and explains why arc fronts do not move when there is extension, such as intra-oceanic arcs. We also present new geochemical and age data from the Peninsular Ranges Batholith that are consistent with this model. The evolution of crustal thickness sets front location, while the ratio of intrusive to extrusive magmatism (reflected in eruptive output but also crustal geochemical indices) increases with thickness and duration of magmatic accretion.