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More Mantle, More Melt: Modeling the Mantle-Derived Causes of Heterogeneity in Volumetric Magmatic Flux at Arcs

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Estimates of volumetric magmatic flux vary significantly between arc volcanoes, both globally and between volcanoes in a given arc. A recent case study of the Cascades arc suggested that a root cause of heterogeneity in surface volcanic flux is variations in mantle magma flux entering the crust, which could relate to along-arc variations in fluid flux from the subducting oceanic lithosphere, changes in mantle thermal structure or composition, or subduction geometry.

In this study, we model the volumetric flux of magma from the mantle using a simplified 3-D box model of a subduction zone in order to constrain the physical factors with the greatest influence on the volume of magma produced in the mantle over time. In the model, we evaluate the relative importance the physical parameters of subduction (i.e., dip, convergence rate, thermal structure, lateral range of melting, and mantle grain size) have in controlling mantle magma flux, compared to the extent and type of melting (i.e., flux and decompression) in a Monte Carlo calculation.

Our results suggest that the lateral span of melting exerts the largest control on mantle magma flux calculated in our model. Although mantle thermal structure and flux of volatiles from the subducting plate exert first order controls on the degree of melting, they have relatively minor influence on total volumetric flux. In cases where calculated volumetric magmatic flux closely approximates published estimates, the average size of the melting footprint significantly exceeds the main edifice radius of volcanoes, suggesting that volcanoes likely harvest magma from larger regions.

The results of our modeling could explain volcanic features like monogenetic fields proximal to larger volcanic edifices. Our results may also help in the interpretation of geochemical features like similarity of primitive magmas at adjacent volcanoes and support the idea that mantle magma supply may control volcano spacing.