Towards Assessing the Causes of Volcanic Diversity at the Arc Scale

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After many decades of research we have successfully identified and constrained the overarching processes that give rise to subduction zone volcanism, as well as the processes that produce specific chemical signatures at a given volcano. However, variations in erupted compositions, volumes and morphology between individual volcanoes and sub-arc segments have been noted in many arcs and the drivers of this diversity are poorly constrained, particularly in regards to the relative importance of crustal vs. mantle processes. To this end, we explore the thermal effects of magmatism on the geophysical state of the crust by utilizing arc-scale geophysical data sets (seismic velocities & surface heat flow) and statistically-treated geochemical (volcanic rock volumes & geochemistry) for the Cascades. We calculate the heat released to the crust in order to produce the observed Quaternary volcanic fluxes via differentiation and crustal melting and find that the heat from the production of silicic volcanism is the dominant signal in the geophysical observations. Overall, Quaternary volcanism in the Cascades necessitates magmatic heat release of 0.1-7x10^{20} J/degree latitude and a flux of mantle-derived basalt of ~60-1900 km^3/myr/degree latitude, with the average volcanic heat budget and mantle flux south of 45°N being more than twice that to the north. We compare these results to seismic velocities using a 1D steady-state thermal model. Shear wave velocities predict a heat input into the crust of 6-12x10^{21}J within each ~100 km along strike, also increasing to the south. The difference between the seismic and petrologic magmatic heat estimates can be accounted for by a modest intrusive magmatic input and imply that there is little to no variation in the intrusive: extrusive ratio along strike, a result that suggests crustal stresses are not the primary control on the intra-arc volcanic behavior. We conclude that a 2-fold variability in the volume of mantle-derived magmas regulates the observed Quaternary volcanic activity in the Cascades, and that crustal heating from magmatic differentiation is the predominant signal evident in the geophysical observations.