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The effect of slab-derived sulfate on the sulfur content and oxygen fugacity of basaltic magmas in the southern Cascade arc

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Arc magmas often contain more sulfur and are more oxidized than mid-ocean ridge basalts. Some evidence indicates that arc magmas develop these traits during crustal differentiation, while other evidence points toward the influence of oxidizing slab-derived material in the mantle source. Slab-derived sulfate has the potential to be a powerful means of oxidizing and transferring sulfur into the sub-arc mantle, but the cycling of sulfur through subduction zones is poorly understood.

Here we track the influence of slab-derived sulfur on the sulfur content and redox state of arc magmas using high-Mg olivine-hosted melt inclusions from cinder cones in Lassen volcanic area within the southern Cascade arc. We combine measurements of major and trace elements, $S^{6+}/\sigma S$, $Fe^{3+}/\sigma Fe$, $\delta^{34}S$, and volatile contents to create a model of sulfur cycling in the southern Cascade arc and characterize its relationship to arc magma redox state. Estimated primary magma sulfur contents from cinder cones range from 790 to 1940 ppm. $S^{6+}/\sigma S$ ranges from 0.41 to 1.00 and estimated primary magma $Fe^{3+}/\sigma Fe$ ranges from 0.17 (QFM + 0.8) to 0.28 (QFM + 2.0). Average measured $\delta^{34}S$ ranges from 1.8 to 5.2‰. Each of these parameters increases with Sr/Nd, a proxy for slab material added to the mantle source. These correlations demonstrate that sulfur in Lassen magmas is partially sourced from the subducting slab and that the influence of slab-derived sulfur is tied to arc magma redox state.

To quantify the relationship between slab-derived sulfur and arc magma redox state, we combine pMELTS models, trace element partitioning, coupled sulfur and iron redox equilibrium, and sulfur isotope mass balance calculations to model the effect of oxidized sulfur on magma generation in the mantle wedge. We find that addition of slab-derived sulfur can explain the variably oxidized primitive melts in the Lassen region, but oxidation caused by sulfur enrichment requires an unusually sulfur-rich slab melt and/or multiple stages of melt or fluid fluxing in the mantle source. These modelling results are strong evidence for a causal link between slab-derived sulfur and the sulfur content and oxidation state of arc magmas in the southern Cascades.