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The role of mid- to deep crustal processes for sulfur isotope fractionation in arc magmas

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Representing one of the most abundant volatiles within contemporary subduction systems, sulfur displays a complex behavior that arises from its ability to partition between various phases (i.e., solid, immiscible liquid, gas and dissolved ions) and from its redox-dependent speciation (S^{2-} to S^{6+}). While sulfur isotopes (expressed as $\delta^{34}S$) represent useful tracers of provenance, magmatic redox conditions, sulfide immiscibility and degassing, the origin of the wide range of $\delta^{34}S$ values captured by arc-sourced rocks remains the subject of active debate [1-5]. One set of hypotheses attribute the observed $\delta^{34}S$ variability to recycling, with slab-related fluids and organic-rich sediments supplying sulfur sourced from ^{34}S-enriched sulfate or ^{34}S-depleted sulfide, respectively. Alternatively, others argue that primitive arc magmas inherit mantle-like $\delta^{34}S$ values (~0‰), which are subsequently overprinted by some combination of magmatic differentiation, country rock assimilation, and/or degassing. To discriminate between these competing hypotheses, herein we present the whole rock sulfur isotope systematics of two well-studied crustal arc sections - the Early–Middle Jurassic Talkeetna Arc in south-central Alaska, and the Late Cretaceous Bear Valley Intrusive Suite (BVIS) in southern Sierra Nevada. Our results reveal that primitive arc basalts inherit mantle-like $\delta^{34}S$ values, with melt differentiation promoting a –1.3 to +5.6‰ $\delta^{34}S$ increase in the Talkeetna Arc and a –1.3 to –4.8‰ $\delta^{34}S$ decrease in the BVIS. These opposing trends are explained by the crystallization of immiscible magmatic sulfides, and possibly upper crustal magma degassing, in the presence of dissolved oxidized and reduced sulfur species, respectively. The BVIS features clear evidence implicating the assimilation of graphite-bearing metasediments (–11.5 to –4.1‰) in the mid–lower crust, while crustal assimilation in Talkeetna is limited. While our findings advocate $\delta^{34}S$ values as faithful redox tracers, it is clear that crustal processes severely influence the $\delta^{34}S$ evolution of arc magmas thereby compromising their utility to track source processes.

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