Arc sulfur budgets, isotopic compositions, and oxidation of the arc mantle

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We present sulfur (S) isotope data for magmatic gases emitted along the Southern Central American (SCA) Arc. The results are interpreted through mass balance calculations to characterize the S cycle through subduction zones with implications for the redox conditions of arc magmas.

Voluminous gas emissions from Masaya and Turrialba volcanoes together represent ~50% of the SO_2 flux from the SCA arc [1]. The Masaya plume has an isotopic composition of $\delta^{34}S$ + 4.8 ± 0.4 ‰ whereas the Turrialba plume has + 3.6 ± 1.7 ‰. Degassing fractionation modeling and assessment of differentiation processes at Masaya suggest that the plume value is close to that of the source composition. High T gas samples from other SCA volcanoes (Momotombo, Cerro Negro, Poás, Turrialba) range from + 1.7 ‰ (Poás) to + 6.0 ‰ (Momotombo). The average $\delta^{34}S$ of the bulk SCA gas emissions, weighted according to the SO_2 flux from each volcano, is calculated at + 4.2 ‰. The high $\delta^{34}S$ values relative to upper mantle are attributed to recycling of subducted oxidized sulfur (sulfate ~ + 21 ‰) through the SCA arc.

The subduction of oxidized material at arcs presents a likely explanation for the oxidized nature of arc magmas relative to magmas from spreading centers. Mass balance calculations suggests that subducted crust (sediments, altered oceanic crust, and serpentinized lithospheric mantle) delivers ~3.1 x 10^{10} mols of S with $\delta^{34}S$ of ~-1.4 ‰ per year into the subduction zone. The total S output from the arc is ~ 2.4 x 10^{10} mols/yr. Constraints on $\delta^{34}S$ values for ambient upper mantle (~0 ‰ [2]) and slab-derived fluids (~+14 ‰ [3]) allow calculation of the flux of S released from the slab into the mantle wedge: ~7.0 x 10^9 mols of S per year. If slab-derived S is in the S^{6+} oxidation state, this flux is enough to oxidize the entire mantle wedge to the Fe^{3+}/Fe^{2+} observed in typical arc rocks in ~ 20 million years.

[1] de Moor et al. (2017) G-cubed, DOI: 10.1002/2017GC007141
[2] Sakai et al. (1984) J. Petrol., 52: 1307-1331
[3] Alt et al. (2012) Earth Plan. Sci. Lett., 327: 50-60