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What can sulfur isotope ratios measured in melt inclusions tell us about the subduction zone sulfur cycle?

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Subduction zones are a critical part of the global volatile cycle, where surface environments, the mantle, and the crust interact. Magmas formed at subduction zones are more oxidised and volatile-rich compared to magmas in other tectonic settings. Water and chlorine are particularly notable, given seawater inputs into the mantle during subduction. Sulfur concentrations are also elevated, although the cause is more enigmatic: is this due to net transfer of slab sulfur or due to the oxidation potential of slab fluids/melts? Using melt inclusions, we determine the sulfur contents and sulfur isotope ratio ($\delta^{34}S$) of undegassed melts at multiple arcs (Aleutians, Central America, Marianas, Tonga), which provide new constraints on the transfer of sulfur from the subducting slab to the mantle wedge. We find that undegassed melts contain between 1790 (Agrigan) to 5340 ppm (Shishaldin) sulfur at these locations. $\delta^{34}S$ ratios in Aleutian and Central American melt inclusions are positive relative to depleted mantle (DM), varying from +0.9‰ to +4.4‰. The combination of high S content and positive $\delta^{34}S$ at arcs indicates that excess S with positive $\delta^{34}S$ is transferred from the subducting slab into the mantle wedge. Isotopically heavy slab fluids/melts are expected to be oxidised, whether they form directly from a sulfate-rich source or due to fluid-slab interaction that enriches percolating fluids in sulfate. Slab-derived sulfur may influence the oxidation state of arc magmas. Assuming a DM mantle wedge composition and using Ti to estimate mantle melting degree, we find that melting degrees across the studied locations vary from 7% to 40%, with the highest melt fractions found at Tonga. Under Tonga the mantle wedge may contain ~1000 ppm S, while at other arcs this value is mostly between 200 and 500 ppm. However, these calculations highly depend on the trace element and S content of the pre-subduction mantle source. The proportion of slab-derived S in the mantle wedge is highly variable on a global scale, varying between 40% and 80%. Therefore, material passing through subduction zones may be expected to have variable sulfur content, depending on the efficiency of S removal during subduction, driving deep mantle sulfur heterogeneity.