Sulfur isotopic compositions of deep arc cumulates: implications for redox conditions and metal mobility in subduction zones

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Subduction zone volcanoes outgas excess quantities of oxidized S, but because most of the mantle contains reduced S in the form of sulfide, this excess S is thought to come from sulfate in seawater-altered oceanic crust and sediments subducted into the mantle. To test this hypothesis, we examined the S isotopic composition of deep arc cumulates from 45-90 km beneath the Sierra Nevada batholith in California, a Cretaceous continental arc. These cumulates represent the crystal line of descent from magmatic differentiation of a hydrous basalt, providing a window to the S isotopic composition of primitive, deep-seated arc magmas before degassing and eruption. Earliest differentiates are low in Fe and have high Mg/(Mg+Fe), whereas more evolved differentiates are high in Fe and have low Mg/(Mg+Fe). Bulk rock δ34S correlates with Fe and negatively with Mg/(Mg+Fe). The most primitive cumulates are isotopically identical to the Earth's mantle whereas the more evolved cumulates are heavier by 5 ‰ in the direction of seawater sulfate. These observations suggest that Sierran arc magmas derived most of their seawater sulfate signature from the upper plate via magma-wallrock interaction with pre-batholithic crust, dominated by marine metasediments and metabasalts associated with accreted island arc terranes. Such rocks likely have seawater-like S isotopic compositions as we show that even young submarine lavas and glasses already have their S signatures modified by seawater. Our results suggest that much of the sulfate in subducting oceanic lithosphere and sediments is released before the slab reaches the active magmatic front, that is, beneath the forearc. Such a scenario would leave residual sulfide in the slab to survive to depths of magma generation and beyond. Alternatively, if sulfate is retained in the slab long enough to be released beneath the arc front, significant isotopic re-equilibration with sulfur in the mantle wedge must have occurred. In either scenario, intrusion and subsequent interaction of arc magmas with the upper plate oxidized and imposed a seawater S isotopic signature on the magmas with profound implications for the transport of metals.