

The Sulfur Cycle

Tracking sulfur through volcanic systems to the oceans and atmosphere



Sulfur is an important element that plays crucial roles in climate variability, ocean chemistry, and biological activity. It is exchanged between the atmosphere and the oceans and is removed from the oceans

into the seafloor via alteration of the oceanic crust, sedimentation and microbial processes. The sulfur stored in the crust is recycled into the mantle at subduction zones, where oceanic crust dehydrates as it descends to great depths. Sulfur and other volatiles are released from the subducting crust into the overlying mantle as the crust reaches higher temperatures and pressures. The presence of these volatiles lowers the melting temperature of the mantle and leads to volcanism, with volcanoes forming in “arcs” and with further volcanism occurring behind the arc, in what is termed a back-arc basin. These volcanoes pump large quantities of sulfur back into the atmosphere and the oceans by passive degassing (venting) or eruptive activity. Large volcanic eruptions can lead to climate change due to an increase in sulfur gases in the atmosphere.

Despite its relevance, the mechanism and extent of sulfur cycling through subduction systems remains largely elusive. Our DOEI-funded study addresses this mystery using samples from active land-based volcanoes in Costa Rica, and submarine volcanoes in the Lau back-arc basin

(SW Pacific). Our strategy is to track how sulfur moves through subduction zones by targeting processes that fractionate sulfur isotopes (separate atoms of sulfur that have different numbers of neutrons and thus different atomic mass). In Costa Rica, we collected volcanic gases by inserting a titanium tube into a degassing vent and running the gas sample through chemical filters that trap the sulfur present in the gas. We also collected erupted rocks, which contain minerals that formed in the magma chamber and that trapped some magma as a “melt inclusion.” Analyses of melt inclusions give us the sulfur isotope composition of the magma chamber. Comparing this with the isotopic composition of volcanic gases allows us to evaluate whether degassing processes change the isotopic composition of sulfur. In the Lau Basin, erupting lavas chill very quickly, forming glass. Isotope analyses of this glass (partially-degassed lava) can be compared to isotope analyses of melt inclusions (undegassed material) to estimate to what extent the process of degassing affects the sulfur isotope values as the lava rises to the seafloor. If the values are the same, then degassing has no significant effect on sulfur isotopes, and the values thus reflect the source magma.

This work on determining sulfur isotope compositions of mantle material, gas, and glass is essential for understanding how sulfur behaves in subduction zones and volcanic systems, important parts of the global sulfur cycle and Earth’s climate and biological systems.

