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Sulfur cycling in oceanic lithosphere: from mid-ocean ridges to subduction zones

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Earth's surficial and internal sulfur cycles are interconnected through the subduction of sediments and the variably altered oceanic lithosphere at convergent plate margins. Notably, significant amounts of sulfur are incorporated during hydrothermal alteration processes within the altered oceanic crust and upper mantle. Sulfur uptake is driven by both abiogenic processes—such as high-temperature thermochemical sulfate reduction and seawater-sulfate uptake—and biogenic processes like microbial sulfate reduction. These processes can substantially modify the budget of oxidized and reduced sulfur, as well as the bulk sulfur isotopic composition of the rocks. As the altered oceanic lithosphere is subducted, sulfur is transported into Earth's interior, where part of it is released by metamorphic dehydration reactions and eventually transported into the overlying mantle wedge contributing to ore forming and magmatic processes.

Using bulk rock and in situ sulfur isotope analyses from ocean floor drill cores and ophiolite sequences, we can resolve the sulfur cycling processes occurring within the altered oceanic lithosphere. This allows to identify the main drivers of sulfur uptake and loss during seafloor fluid-rock interactions. In addition, in situ sulfur isotope analyses of exhumed oceanic slab fragments retain signatures from the ocean floor while providing detailed insights into the stages of sulfur release from the slab, as well as the mechanisms involved in sulfur mobilization and transport within the subducting slab. Recent studies have shown that combining in situ $\delta^{34}S$ values, distinct metal (e.g., Co, Ni) zonations, and silicate mineral inclusions in sulfide minerals allows for the resolution of distinct phases of sulfur mobilization within the slab.

Understanding the factors that control sulfur speciation and budgets in the oceanic lithosphere, along with the processes occurring in the dehydrating oceanic slab, is crucial for comprehending porphyry ore deposit formation and magmatic processes in volcanic arcs, and the redox and sulfur isotopic evolution of Earth's interior.