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Exploring new frontiers in fluids processes in subduction zones

Novel isotope tracers of slab-derived fluids

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Subduction zones are the main site of volatile element transfer between the downgoing plate, the overriding mantle wedge and the Earth's deep interior. The breakdown of serpentine minerals within the downgoing slab and the fluids released play a fundamental role in volatile cycling as well as the redox evolution of the sub-arc mantle. Constraining subduction-related serpentinite devolatilisation is essential in order to better understand of the nature and composition of slab-derived fluids and fluid/rock interactions.

Iron and Zn stable isotopes are recently-established geochemical tracers can trace fluid composition and speciation as isotope partitioning is driven by changes in oxidation state, coordination, and bonding environment. In the case of serpentinite devolatilisation, Fe isotope fractionation should reflect changes in Fe redox state and the formation of chloride and sulfide complexes; Zn isotope fractionation should be sensitive to complexation with carbonate, sulfide and sulfate anions.

This study involved targeting samples from Western Alps ophiolite complexes, interpreted as remnants of serpentinized oceanic lithosphere metamorphosed and devolatilized during subduction. A striking negative correlation is present between bulk serpentinite Fe isotope composition and proportion of ferric iron, with the highest grade samples displaying the heaviest Fe isotope compositions and proportion of oxidised iron. The same samples also display a corresponding variation in Zn isotopes, with the highest grade samples displaying isotopically light compositions. The negative correlation between Fe and Zn isotopes and decrease in ferric iron content can explained by serpentinite sulfide breakdown and the release of fluids enriched in isotopically light Fe and heavy Zn sulfate complexes. The migration of these highly oxidizing sulfate-bearing fluids from the slab to the slab-mantle interface or mantle wedge has important implications for the redox evolution of the sub-arc mantle and the transport of metals from the subducting slab. Our results also demonstrate that novel stable isotopes can be used as probes to study the nature of slab fluids and to trace volatile transfer, with potential future applications for both sulfur and carbon subduction cycles.