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Water-serpentine interactions and deformation in subduction zones

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The circulation of substantial amounts of fluids in subduction zones results in volcanism, tremors, brine springs and electrically conductive zones, in particular above the subducting slab and in the mantle wedge. The mantle wedge is serpentinized by fluids coming from the dehydration of the slab at pressure and temperature conditions that favor the formation the antigorite species of serpentine. The evolution of the mantle wedge is linked to the interactions between the aqueous fluids and antigorite. In order to investigate these interactions in detail, we reacted antigorite powder with liquid D_2O at high pressure and high temperature in a Belt apparatus in the range 1.5 to 3.0 GPa and from 315˚C to 540˚C, corresponding to the conditions of the mantle wedge. Antigorite samples were then analyzed by Raman micro-spectrometry, from which D/(D+H) maps were calculated, in order to quantify the exchanges between hydrogen (H) from the hydroxyl (OH) groups of antigorite and deuterium (D) from the liquid water (D_2O). Solid state diffusion was previously characterized on single-crystals, and we obtained a solid-state diffusion law for D/H inter-diffusion in antigorite. At the aggregate scale, we observe zones where the exchange between antigorite and water is much more important than expected for solid-state diffusion. These zones correspond to highly micro-cleaved antigorites, with up to tens of open fractures per micrometer. The high amount of cleavages raises the reactional surface between water and antigorite and allows fluids to interact much more with micro-fractured grains than with non-fractured grains. The highly fractured zones displaying high D/H exchanges correspond to shear zones that form in response to the non-hydrostatic conditions in the belt apparatus. Deformation creates fractures sub-parallel to the cleavage of antigorite, and to the foliation of the serpentinite. Our observations indicate that sheared antigorite serpentinites are highly permeable and reactive with aqueous fluids.

The serpentinized subduction interface is a zone of intense deformation just above the slab, and deformation with veins is observed in natural samples from the micrometer to the outcrop scale. We discuss applications of our experimental observations to subduction zones and in particular to high deformed serpentinite layers above the slab.