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Focused fluid release and percolation mechanisms in subduction zones revealed by experimental dehydration of brucite veins in serpentinite

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Serpentinites are among the most important H_2O carriers in subduction zones. The aqueous fluids they release during prograde subduction metamorphism fundamentally influence the rheology of the subducting rocks, mantle metasomatism and island arc volcanism. The mechanisms that control the fluid release and transport at depth are, however, not fully understood, partly because recognizing and interpreting the rock record of these processes is challenging.

Here we experimentally address the role of pre-existing structural and mineralogical heterogeneities of serpentinites on dehydration and fluid migration at forearc conditions. We performed a piston-cylinder experiment at 1.5 GPa on a low-grade metamorphic serpentinite containing a brucite vein formed by the lizardite–antigorite transition. The geometry of the assembly ensured a temperature gradient of 480 – 520 °C across the sample, allowing us to constrain the prograde release of fluids from the heterogeneous natural sample. Combining X-ray micro-computer tomography analyses before and after the experiment with electron microscopy methods and thermodynamic calculations, we could relate dehydration reactions to mineralogical and structural heterogeneities in 3D. Based on this, we calculated the permeability of the partially dehydrated sample using advanced statistical methods.

The experimental results reveal fluid release by two olivine-forming reactions: Mg-rich olivine produced by the antigorite+brucite reaction, and Fe-rich olivine from reaction of antigorite+magnetite with infiltrated H_2. Mg-rich olivine forms monomineralic aggregates with high porosity (up to 32%) and permeability (10^{-13} – 10^{-14} m²), tracing the pre-existing brucite vein. These observations indicate that transient, highly permeable fluid channels may evolve from pre-existing structural heterogeneities, allowing fluid drainage and enhancing open-system exchange with neighbouring lithologies. The infiltration of reduced external fluids (e.g. CH_4 from graphite-bearing metasediments) along these fluid channels triggers redox dehydration, which renews porosity and propagates focused fluid flow. The distribution of brucite and magnetite therefore has a first-order control on how deep fluid flow paths develop during subduction metamorphism of serpentinites.

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