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Experimental determination of the rate of fluid flow through mantle rocks

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The nature of the fluid flow mechanisms that allow fluid transport from a subducting slab to the mantle wedge are poorly understood. These processes have implications for the geochemistry of the fluids, as channelized flow will leach elements from much smaller volumes of the slab compared to pervasive flow. It is also important to understand the factors that control the timescale of fluid transport because if it is too slow, fluids will tend to be subducted with the slab rather than being released into the overlying mantle.

We have designed a type of high-pressure experiment to explore fluid migration time scales. A sintered polycrystalline core of olivine or orthopyroxene is produced with a particular average grain size. The core is then sandwiched between a fluid source, either serpentine or aluminium hydroxide $Al(OH)_3$ and a fluid sink of MgO. At the experimental conditions, the source dehydrates, inducing an overpressure and resulting in a fluid flow through the dense sintered core. The fluid can then be captured in the MgO fluid sink on the other side of the core through the formation of brucite ($Mg(OH)_2$). This method allows the rate of water transport through the bulk sample to be determined and does not require e.g. spectroscopic methods to determine the amount of water transport.

The results show that while it is possible for water to pass through a mineral core of orthopyroxene on a reasonable experimental time scale when using $Al(OH)_3$ as the water source, this is not possible on similar timescales when serpentine is used as the source. This implies that the fluid overpressure, which is much higher in the case of $Al(OH)_3$, is playing a role in the rate of water transport. The results also show that at conditions of serpentinite dehydration, water diffusivities are relatively low and similar to those expected for grain boundary diffusion. When these diffusivities are extrapolated to grain sizes of the upper mantle, they appear to be too slow to allow transport of water into the overlying mantle wedge.