Pore-scale mineral dissolution rates measured in reactive microfluidics at variable pH and fluid velocity

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Water-rock interactions occur at the boundary between fluids and minerals in subsurface systems. Quantifiation and simulation of reaction rates at this scale, coined the pore scale, is important for elucidating scaling behavior of reaction rates to larger scales of interest in field systems. In this study we present mineral dissolution rates measured at the pore scale using microfluidic approaches. We have developed methods to engineer microfluidic chips using reactive mineral substrates (see image) where pore network channels (total size 57x21 mm) are ablated into a polished mineral wafer (e.g. anorthite, fig. 1) with a Yb femtosecond fiber laser with a chirped pulse amplifier (185 fs pulse, 1035 nm wavelength and ~5 nm bandwidth). The chip is sealed by plasma-bonding a polydimethylsiloxane (PDMS) cap across the device and holes are punched to insert capillary tubing into reservoirs at ends of the device to and fluid is pumped through the device with a syringe pump.

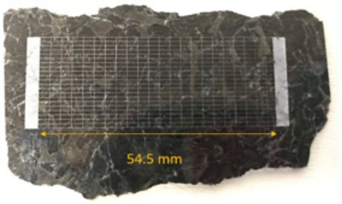

Figure 1. Rectangular pore network ablated into polished anorthite wafer.

Mineral dissolution rates are calculated from Ca^{2+} concentrations in the effluent at variable velocity and pH. At pH ~3 and fast rates of average fluid velocity (~ 1 mm sec^{-1}) anorthite dissolution rates are fast compared to those previously measured in batch experiments (~ 8e-10 mol cm^{-2} sec^{-1}). These fluid velocities are faster than expected in pore scale flow by at least several ordes of magnitude. Experiments with variable pH, fluid velocity, and pore architecture will map anorthite dissolution rates as a function of Peclet and DamKöhler conditions at the pore-scale to elucidate the effects of pore-scale heterogeneity on reaction rates.