Lab-based assessment of engineered CO_2 mineralization in mafic rock reservoirs

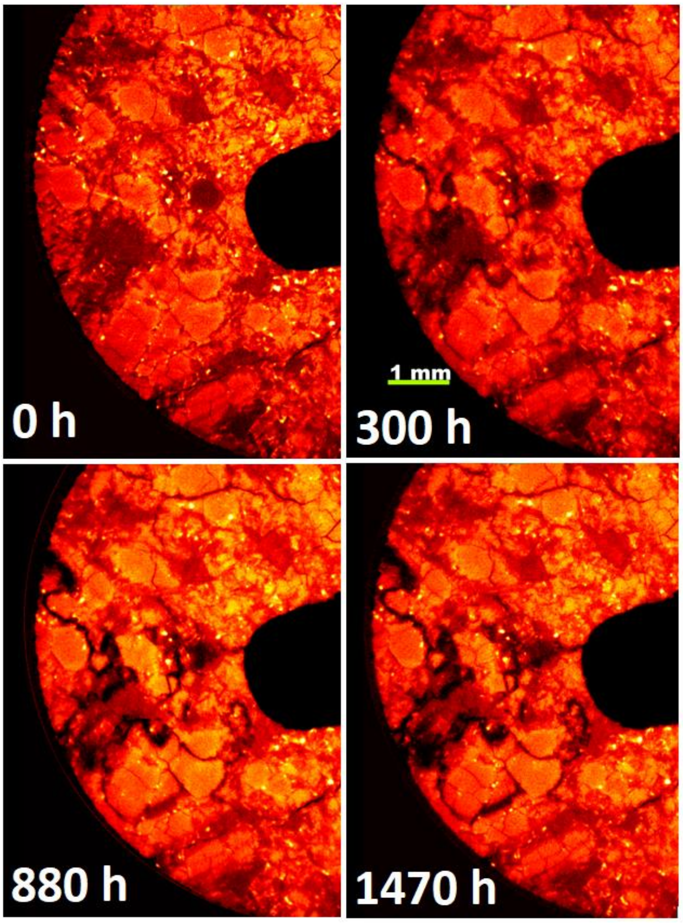
Understanding how in-situ mineralization of CO_2 affects the porosity and permeability of the host rock is critical to assessing the viability of basalt reservoirs as carbon dioxide repositories. Precipitating carbonate minerals have the potential to fill primary porespace and decrease permeability, reducing injectivity and overall reservoir capacity. Laboratory experiments that induce carbon mineralization in basalt under controlled conditions can inform how fluid transport properties evolve in geological storage reservoirs.

Here, we present time-resolved 3D datasets acquired using a novel x-ray transparent cell that allows carbon mineralization in basalt to be documented on the grain scale using x-ray microtomographic imaging (µCT). Our 4DµCT data aim to document the formation of carbonate mineral species, via ion exchange between dissolved inorganic carbon and the divalent cations of primary minerals in the basalt sample. The reaction is speculated to cause new fracture porosity by positive reactive volume changes, a hypothesis we test.

To that end, a cylindrical core of basalt with a diameter of 10 mm and a central 2 mm bore was reacted with water-dissolved CO_2 at 1.6 MPa fluid pressure, a temperature of 170°C and a flow rate of 15 µl/minute. After 900 hours the fluid composition was changed to a 0.64 mol/litre $NaHCO_3$ aqueous solution equilibrated with 1 MPa CO_2. During the ongoing experiment, the sample has been repeatedly quenched and imaged using a µCT scanner.

We use the 4DµCT dataset to track sample deformation, changes in porosity, and to model the permeability evolution on the grain scale. Our data show that new reactive surfaces can be formed under conditions favourable to carbonate mineralization (Figure, below). The basalt core will be analysed post-mortem using energy dispersive x-ray spectroscopy to investigate the chemical composition of precipitated carbonates and their paragenetic environment.

Exceptionally long operando experiments such as ours can be of particular use in assessing reservoir potential of prospective carbon mineral storage sites by recreating subsurface conditions unique to each location. The apparatus can investigate the evolution of physical rock properties over time periods relevant to field operations (months/years).



Above: Transverse view of crack propagation through time in basalt rock cylinder with a central borehole. A 0.64 mol/litre $NaHCO_3$ aqueous solution is equilibrated with 1 MPa CO_2 and flowed through the basalt core at 170^{O}C with a residence time of appoximately 3 minutes, beginning at 0 hours (top left).