Geochemical and geomechanical influences on the permeability of wellbore cement fractures exposed to CO_2-rich brine

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The objective of this work was to quantify the relationships between chemical alteration, deformation, and permeability at the wellbore/caprock interface important to long-term geologic carbon storage through experiment and modeling. The core flood experiments span variable pCO_2, flow rate, and cement – caprock fracture apertures at 60°C and 24.8 MPa. We used x-ray computed micro tomography to spatially resolve the fracture surface and the extent of alteration, three dimensional digital image correlation to spatially resolve plastic deformation resulting from chemical alteration, and time dependent solution chemistry and pressure to track coupled evolution of chemical alteration and mechanical deformation. Coupled processes between chemical alteration and material compressibility were largely responsible for decrease in permeability despite measured porosity increase at the cement/caprock interface. CO_2-rich brines alter wellbore cement into distinct portlandite depleted, carbonate, and aluminum-bearing amorphous silicate layers and change the compressibility of cement at the wellbore/caprock interface. Dissolution of portlandite from the cement resulted in plastic deformation of the surface contacts restricting flow paths and lowering the overall permeability. Chemical alteration of the cement was controlled by ion diffusion through cement and its alteration layers, as well as calcite equilibrium at the carbonate/amorphous silicate boundary and analcime equilibrium at cement/caprock interface.

Uncertainties in global CCN and cloud drops: which aerosol processes are important?

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Aerosol-cloud interaction has remained the largest uncertainty in the radiative forcing of climate through all IPCC assessments. Despite this persistent problem, very little research has been done to tackle the problem of uncertainty reduction directly. Here, we use new uncertainty analysis techniques to identify the leading causes of uncertainty in global CCN and cloud drop number (CDN) concentrations. The primary aims are to quantify a statistically robust "error bar" for these modelled quantities, to identify which parameters contribute most to uncertainty in different locations, and to ultimately direct research efforts towards model processes that have the greatest bearing on the uncertainty. By using Bayesian emulators we can perform a Monte Carlo statistical sampling of a complex global aerosol model across the entire space of dozens of parameters simultaneously – effectively performing many thousands of simulations for the cost of a few hundred. This approach then enables the model data to be analysed using variance decomposition so that a fraction of the uncertainty can be attributed to each parameter. We rank the importance of the parameters for CCN, CDN and first indirect forcing between 1750 and 2000. From among 28 parameters, the fraction of uncertainty caused by aerosol processes is approximately equal to that caused by emissions, but with very different spatial patterns. The parameters that are important for uncertainty in CCN and CDN are very different to those that are important for forcing, which is dominated by emissions that affect CCN under pre-industrial conditions. Finally, we introduce the Global Aerosol Synthesis and Science Project (GASSP), a community effort to reduce uncertainty in global CCN using extensive *in situ* measurements and model sensitivity and uncertainty fields.

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