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Determining the mechanical strength of CO_2-induced reaction zones in wellbore cement: is it worth it?

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CO_2 injection, either for long-term CO_2 storage (CCS) or Enhanced Oil Recovery (EOR), strongly hinges on maintaining storage integrity. Injection and legacy wells penetrating the caprock pose one of the most likely points of leakage. In order to be able to predict the long-term integrity of such wellbores, it's important to understand their chemical, hydrological and mechanical behaviour, and how it may change due to CO_2 exposure. Generally, in response to CO_2/brine/cement interactions, a number of different reaction zones are observed, each with their own chemical, and hence mechanical, signature. To aid mechanical modelling efforts, assessing the risk of cement failure caused by stress and temperature changes, knowledge is required of the strength of each of these zones.

We performed experiments on Class G Portland cement to investigate the chemical-mechanical coupling due to CO_2-exposure. Batch reaction experiments, in the presence of CO_2-rich brine, were performed under typical storage conditions (T = 65°C, PCO_2 = 8 MPa) for various periods of time (1, 2, 3, 4, 5 and 6 months). After exposure, mechanical tests were performed on the observed reaction zones, using the so-called core scratching technique, to evaluate the unconfined compressive strength (UCS) as a function of exposure time. Chemical analyses (CT-imaging, SEM microscopy, EDX chemical analysis) showed the formation of three reaction zones, similarly to what has been observed in other studies. Measurements of the mechanical strength of these different zones showed highly variable results. Such variations have also been observed in other studies, using different measurement techniques. The large variability in strength measurements is most likely an inherent result of the heterogenic nature of cement, which affects the extent and location of reaction throughout the sample. This begs the question: is it worth studying the mechanical strength of reaction-induced zones in cement? Or will it suffice to take into account large uncertainties when modelling the mechanical behaviour of cement?