An investigation into CO₂-brine-cement-caprock interactions for wellbore integrity in CO₂ geological storage

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Abstract

Wellbore integrity is one of the most important technical risks for CO₂ geological storage [1]. It has been recognised that poorly cemented casing/borehole annulus, casing failure, and abandonment failure are more prominent reasons for wellbore leakage [2, 3]. Cement-caprock, cement-reservoir (host) rock and cement-casing interfaces are potential pathways for CO₂ leakage [4]. The CO₂-rich formation water may react with minerals in the reservoir rock, caprock and borehole cement and may cause either mineral dissolution or mineral precipitation [5]. Therefore, cement degradation adjacent to the caprock and reservoir rock is of great concern with respect to well integrity. Previous work published by the authors has focused on understanding cement-reservoir (host) rock behaviour using a number of cement-sandstone composite core samples under simulated deep wellbore environments [6]. Solution profiles for a number of composites were determined for Na, K, Ca, Ba, Mg, Sr, Fe and S. Moreover, the variation of ions concentration in brine at two different time-scales of 3 and 11 months was studied. We observed that Na, Ca and Sr were consumed in the early stages (within 3 months) however, they re-dissolved in the solution later (up to 11 months). Solution profiles showed decreasing Mg and Ba concentrations with time, whilst K increased initially (within 3 months) but decreased over time. High concentration of Fe and S was detected after 11 months, which can be due to the carbonation reaction of the cement-reservoir rock samples [6]. Following on from these previous studies, the objective of the work presented in this paper was to establish an understanding of the interactions between CO₂-brine-cement-cap rock composite samples to help assess well integrity.

In this research, a series of 38 mm diameter core samples, including caprock only, cement only and cement-caprock composites were prepared and investigated. A typical salinity of 10,285 ppm was selected to prepare a synthetic brine, including Na⁺, K⁺, Mg²⁺, Ca²⁺, Sr²⁺ and Ba²⁺. The core samples were aged in CO₂-rich brine for periods of 3, 6 or 9 months using hydrothermal vessels to mimic downhole environments (250 bars at 90°C). After completing the hydrothermal experiments, the chemical composition of the brine was analysed using inductive coupled plasma mass spectroscopy (ICP-MS).

Figure 1 shows the changes in ions concentration over time for the composite cement-caprock cores. Ca, Sr and Ba were consumed in the early stages (within 3 months), but they re-dissolved in the solution later, whilst concentration of Mg decreased with time. There was no Fe, S and Si present in the initial brine, but their concentrations increased in the solution with time. Concentrations of Fe and S increased over six months and decreased later, but concentration
of Si increased further up to 9 months, similar to that observed in the earlier experiments with the cement-host rock composite samples.

![Figure 1: Ions concentration change over time for three composite cement-caprock core samples](image)

This paper will present a comprehensive characterisation of the core samples, including porosity, permeability and mechanical properties measured before and after the experiments. Some of the composite core samples were further analysed by XRD, SEM and micro CT. Comparison between the composite cement-reservoir rock and cement-caprock samples will also be conducted.

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References

