Understanding CO_2-brine-wellbore cement-rock interactions for CO_2 storage integrity

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Well leakage may be caused by poorly cemented casing/hole annulus, casing failure, and abandonment failure[1]. Several studies on the integrity of well cements in contact with CO_2 and CO_2-brine (saturated formation water) have been reported[2-4]. These studies have indicated that cement degradation in the well adjacent to the caprock can be important with respect to well integrity[3]. Therefore, the aim of this research is to improve our understanding of well integrity by conducting investigations into the flow, geomechanical and geochemical properties of cement and reservoir rocks under conditions representative of the subsurface temperatures and pressures at the wellbore, thus the CO_2-brine-wellbore cement-rock interactions.

A large number of composite cement-rock core samples were prepared and the samples went through baseline flow, mechanical and elastic properties measurements to determine porosity, permeability and strength/ elastic properties at Imperial College. Samples which have gone through non-destructive testing only were then allocated for hydrothermal experiments at Heriot-Watt University. Prior to hydrothermal experiments, the reservoir rock/cement and caprock/cement composite samples were imaged by a micro-CT scanner. The results have shown that the cement has micro-cracks, but not in the region next to the rock, which means that the core samples prepared are suitable for the following hydrothermal experiments.

Following baseline geochemical characterisation, the intact composite core samples were aged using a set of high-pressure and high-temperature hydrothermal vessels to mimic downhole environments (25 MPa and 90°C) for periods of time varying between 3 to 9 months. These hydrothermal vessels have been designed to study CO_2-brine-rock interactions[5]. The composite cement-rock core samples were placed in the vessels and covered with synthetic brines that mimic the corresponding formation water. An average brine composition of a typical oil field in North Sea was selected as the target concentration. Due to the complex composition of natural brines, only major ions were considered to prepare the synthetic brines, including Na^+, K^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} and Cl^-. CO_2 was injected to saturate the brine and curing conditions (temperature and pressure) were adjusted and maintained during the hydrothermal studies. ICP-AES analysis of the brined solutions after 3 months hydrothermal experiments show a decrease in Ca^{2+} and Ba^{2+} as well as increase in K^+, indicating the possible formation of carbonates and dissolution of the cement-rock samples.

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Upon completion of the hydrothermal experiments, the aged samples are once again taken through geochemical characterisation, micro-CT scanning, flow and mechanical/elastic properties characterisation in order to establish the effects of hydrothermal treatment on the cement and cement-rock interface. This paper will present the pre- and post-treatment XRD, SEM/EDX, micro-CT, flow and strength properties characterisation studies of all the series and the interpretation of the results with respect to CO_2-brine-wellbore cement-rock interactions at injection wells. The experimental findings are utilised as input for numerical modelling in investigating wellbore integrity and leakage assessment in another study.

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