Experimental characterization of the chemical reactivity of wet $scCO_2$ in reservoir and caprocks under elevated pressure and temperature conditions

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Abstract. CO_2-Plume Geothermal (CPG) systems have been proposed as an affordable and scalable strategy to deploy Capture, Utilization, and Storage (CCUS) globally. These systems utilize CO_2 to extract geothermal energy from the subsurface while ensuring its permanent sequestration in geologic formations. Unlike conventional hydrothermal systems that use water or brine, CPG utilizes pure supercritical CO_2 ($scCO_2$) or water-bearing $scCO_2$ as the subsurface working fluid. While the thermal-hydraulic performance of CPG systems has been extensively studied, their chemical behavior remains largely unexplored due to a lack of field and experimental observations. In this study, we address this knowledge gap by investigating the chemical performance of CPG systems through core-scale laboratory experiments. We conducted batch reactions on rock specimens from the Muschelkalk and Gipskeuper formations in Switzerland, subjecting them to interactions with wet $scCO_2$ under reservoir conditions (~35 MPa, 150 °C) for approximately 500 hours. High-resolution techniques, including scanning electron microscopy (SEM), X-ray diffraction (XRD), X-ray computed tomography (XRCT), and stable isotope analysis, were employed to characterize the evolution of petrophysical properties, morphology, and mineralogical composition. Furthermore, we analyzed fluid effluents using inductively coupled plasma optical emission spectroscopy (ICP-OES) to gain insights into ion transport processes associated with dissolution reactions. Our experimental investigation provides critical insights into fluid-mineral interactions involving CO_2-rich fluids and represents a crucial step in ensuring the long-term security and technical feasibility of deploying global CCS and CO_2-based geothermal energy systems.