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Water-Alternating-Gas (WAG) injection as a plausible scheme to optimize carbon dioxide mineralization in the basaltic oceanic crust

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Carbon storage in basaltic aquifers has demonstrated enormous potential for securely and permanently storing atmospheric carbon dioxide through mineralization. Recent experimental and field-scale studies have investigated CO_2 injection as either a supercritical or dissolved phase and discovered that dissolved phase injection results in faster mineralization than the supercritical phase scenario because it bypasses the rate-limiting CO_2 dissolution step. However, to meet the magnitude of the current climate crisis, dissolved CO_2 injection schemes will likely need considerable improvements in efficiency to be implemented at gigaton-per-year levels. Here, we consider a scheme that alternates CO_2 and water injection (i.e., water-alternating-gas (WAG) injection), which has long been used in the hydrocarbon industry to enhance extraction efficiencies. In principle, WAG for CO_2 mineralization can maximize injection volumes and reduce energy requirements, while promoting CO_2 dissolution and increasing mineralization efficiency. We performed a series of reactive transport simulations of WAG injection into an oceanic basalt at the Cascadian basin, an area under active investigation for basalt carbonation demonstration, and present evidence to support the hypothesis that higher carbonation efficiency can be achieved by optimizing WAG ratio and cycle. The findings indicate that implementing WAG and optimizing the injection parameters improves mineralization by increasing the quantity of CO_2 in the dissolved phase. This, in turn, allows for greater extents of reaction between dissolved CO_2 and the basalt. Our results indicate that, in lieu of implementing fully dissolved CO_2 injection at the field scale, implementing, and optimizing WAG schemes for CO_2 mineralization in the basaltic oceanic crust can offer significant advantages over supercritical CO_2 injection. Thus, WAG injection schemes should be strongly considered when developing a site-specific injection strategy capable of achieving large scale carbon mineralization in basaltic aquifers.