Capturing and storing CO$_2$ in globally widespread basalt formations is a potential solution for reducing atmospheric greenhouse gas concentrations. Injecting to depths greater than 800 m, these CO$_2$ and CO$_2$-SO$_2$ gas mixtures will reside as water-wet supercritical fluids in contact with the basalt reservoir rocks. Here we examine reaction products resulting from exposing Hawaiian picrite basalts to water equilibrated with scCO$_2$, water bearing scCO$_2$, and mixtures containing gaseous sulfur compounds.

Hawaiian basalts in this study were fresh, vesicular, and olivine-rich (≥20 vol%). Basalts, crushed or in large pieces, were exposed to wet supercritical fluid and aqueous dissolved gases for 80 to 550 days at 100 bar and 50°-100°C. Basalt in the pure scCO$_2$ system showed the least amount of reactivity. Carbonate precipitates formed discrete circular coatings on the olivine grain surfaces after 550 days of exposure to the aqueous dissolved CO$_2$. However, the olivine surface was significantly altered in just 80 days after exposure to wet scCO$_2$ containing 1% SO$_2$. The most reactive basalt components were olivine grains, with surfaces dominated by cracks and precipitates of Mg-S compounds; the cracked surface was depleted in Mg and rich in Si. Minor amounts of sulfur were detected in this leached layer as well. Olivine interiors retained the original olivine chemistry. Surface precipitates on olivine crystals include hexahydrite (MgSO$_4$•6H$_2$O), magnesium thiosulfate hydrate (MgS$_2$O$_3$•6H$_2$O), and three different hydrated sulfite phases. These results illustrate the potential that basalt formations hold for long term storage of CO$_2$. 