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Alteration of porosity and permeability within a shale matrix during hydraulic fracturing

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Unconventional hydraulic fracturing of shale has transformed U.S. gas and oil production, and is being pursued internationally as a route to replace coal with cleaner-burning natural gas. It has been hypothesized that the acidic fluid injected during hydraulic fracture can alter the shale matrix permeability and damage the formation. Our previous work has shown that acidic fluid interacts with fracture surfaces and causes porosity and permeability alteration due to a series of geochemical reactions. Pyrite and carbonate in the shale matrix dissolve, which generates secondary porosity. The resulting ferric iron precipitates as Fe(III)-(oxyhydr)oxides in the shale matrix, as a function of pH neutralization by carbonate dissolution. Because of the low permeability of shale matrices, until recently these reactions were only characterized on the fracture surface. Here, using multi-component reactive transport modeling and experimental characterization, we show that acid can penetrate into the shale matrix for several centimeters within months, and that the distance over which the matrix mineralogy is altered is in millimeter range. Reactive transport modeling results show that reaction front thickness is dependent on fracture width, dissolved oxygen concentration, and matrix porosity, but it is not significantly dependent on pressure gradients due to low matrix permeability. In carbonate-poor zones, secondary porosity is generated in a 700 μm zone, whereas in carbonate-rich zones, secondary porosity is more distinct and confined to the fracture-matrix interface. These findings motivate continued study of matrix permeability alteration by chemical reactions. Ultimately, a more systematic understanding of shale matrix alteration as well as the mineralogy, pore network, and fluid chemistry of the reservoir can improve our ability to predict and enhance gas/oil production.