Geophysical Research Abstracts
Vol. 12, EGU2010-7964, 2010
EGU General Assembly 2010

Mechanics of Reaction Driven Fracturing during Peridotite Carbonation

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Geological storage of CO2 has emerged as a promising climate change mitigation strategy. The storage mechanism with the longest CO2 in reservoir residence time is mineral trapping. Mineral trapping aims to chemically bind the CO2 in thermodynamically stable minerals. Recent studies (Matter and Kelemen, 2009) show that the naturally occurring peridotite carbonation has reaction rates high enough to make in-situ mineral trapping feasible. For in-situ mineral trapping of CO2 in a crystalline rock new reaction surfaces have to be created constantly, in order to increase the reaction rate. We investigate, to what extent reaction driven or enhanced fracturing can contribute to such a creation of new reaction surfaces. A reaction driven fracturing mechanism will maximize the fracturing in areas that still have an affinity for the reaction.

Carbonation reactions are generally volume increasing. A volume increase of the rock matrix would normally hinder the fracturing process, due to crack closure. But if we consider an intermediate dissolution reaction with a subsequent precipitation in the pore space it is possible that the reaction products (carbonates) exert an outward stress on the crack surface. This would be equivalent to the increase of pore pressure in a classical poro-mechanical fracture problem. We perform a numerical analysis of this coupled problem. Our numerical model is used to estimate the effect of rock matrix volume change and the swelling of pore filling / fluid. We also consider that the reaction will alter the mechanical properties of the solid phases. Our study shows that, depending on which process is dominant, the fracturing can be either reaction driven or reaction limited.

Reference:

J. Matter and P. Kelemen, 2009. Permanent storage of carbon dioxide in geological reservoirs by mineral carbonation. Nature Geoscience, 2, 837-841