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Volatile-consuming reactions fracture rocks and self-accelerate fluid flow in the lithosphere: Experimental insights from MgO–H_2O system

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Hydration and carbonation reactions within the Earth cause an increase in solid volume by up to several tens of vol%, which can induce stress and rock fracture [e.g., 1]. Observations of naturally hydrated and carbonated peridotite and troctolite suggest that permeability and fluid flow are enhanced by reaction-induced fracturing [e.g., 2, 3]. However, permeability enhancement during solid-volume-increasing reactions has not been achieved in the laboratory, and the mechanisms of reaction-accelerated fluid flow remain largely unknown. Here, we present the first report of significant permeability enhancement by volume-increasing reactions under confining pressure [4]. The hydromechanical behaviour of hydration of sintered periclase [MgO + H_2O â†' $Mg(OH)_2$] depends mainly on the initial pore-fluid connectivity (Fig. 1). Permeability increased by three orders of magnitude for low-connectivity samples, whereas it decreased by two orders of magnitude for high-connectivity samples. Permeability enhancement was caused by hierarchical fracturing of the reacting materials, whereas decrease was associated with homogeneous pore-clogging by the reaction products. These behaviors suggest the fluid flow rate, relative to reaction rate, is the main control on hydromechanical evolution during volume-increasing reactions. We suggest that an extremely high reaction rate and low pore-fluid connectivity lead to local stress perturbations, and are essential for reaction-induced fracturing and accelerated fluid flow during hydration/carbonation.

[References]

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