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Simulations of oceanic lithosphere serpentinization

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Seawater circulation through oceanic lithosphere and the associated hydration reactions play a key role in many geological processes and settings. At mid-ocean ridges, hydrothermalism mines heat from the young ocean floor, causes hydration of mafic and ultramafic rocks, and is associated with the formation of ore deposits. At active margins, bending and faulting at the trench outer rise may again trigger deep seawater circulation and hydration. One key hydration reaction is the serpentinization of mantle rocks. The transformation of a dry peridotite to a wet serpentinite results in an uptake of ∼13wt.% of water, a volume increase and density decrease of ∼40%, and a strong decrease in mechanical strength. These drastic changes in rock properties illustrate the importance of quantifying the degree of serpentinization caused by deep seawater circulation. For this purpose, we have developed a new hydrothermal convection model that also accounts for serpentinization. The key feedbacks of the reaction on fluid flow, i.e. variations in permeability due to volume changes and reaction induced fluid consumption, are all accounted for. We have applied this model to two test cases: hydrothermal convection at mid-ocean ridges and bend-faulting related hydration of subducting plates.

For the mid-ocean ridge test case, we have coupled a kinematic thermal ridge model to the hydrothermal convection model. The coupled model allows us to study the feedbacks between serpentinization and hydrothermal flow. We find that, on the one hand, hydrothermal convection is not confined to the crust but may extend well below the Moho. On the other hand, pervasive serpentinization has the ability to close pore space and reduce permeability thereby hindering flow. Similar processes occur at subduction zones. Bend-faulting of subducting lithosphere, may provide the pathways for seawater to reach and react with the cold lithospheric mantle to make serpentine. To test this hypothesis, we explore under which conditions seawater may reach the mantle and what the likely hydration pattern around fault zones are.