

Reaction-induced changes in deformation behavior of carbonated serpentinites revealed from deformation experiments

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Earthquakes within the oceanic lithosphere are monitored at mid-ocean ridges, in deep-rooted bending faults as well as at sub-arc depth within subduction zones. Such brittle faulting at the ocean floor allows fluids to penetrate the peridotite and form serpentinites through hydration. Serpentine is a weak phase and its formation thus introduces a rheological contrast within the oceanic lithosphere that will affect the further deformation behavior upon subduction. Moreover, serpentinization along fault zones will influence intermediate-depth seismicity within subduction zones, either through reactivation of fault zones or through the release of fluids upon dehydration reactions. The rheological behavior of serpentinites is well studied from low to high pressure conditions. However, the circulation of ocean water can additionally cause carbonates to precipitate, which will ultimately affect the strength of the serpentinites.

We experimentally investigated the frictional behavior of serpentinites and carbonated serpentinites with variable carbonate content at elevated temperatures in a rotary-shear apparatus. The pure serpentine is frictionally unstable prior to its dehydration. The addition of only 5 wt. % CaCO_3 , however, causes stable sliding to occur but decreases the sliding strength. Similar results are obtained by adding 5 wt. % MgCO_3 . At temperatures of 500 °C to 550 °C the CaCO_3 reacts with serpentine to form olivine and clinopyroxene. The amount of these secondary phases produced significantly depends on the bulk carbonate content and temperature. X-ray tomography analyses reveal that 5 wt. % CaCO_3 results in the formation of isolated individual secondary grains at 550 °C, whereas 10 - 20 wt. % CaCO_3 results in the formation of a throughgoing network. The latter drastically reduces the sample strength.

Our results show that carbonated serpentinites can deform without brittle failure and suggest that strain will be localized within the carbonated parts of serpentinites. Upon increasing temperature and/or under the influence of shear heating, mineral reactions can cause the formation of a network of weak anhydrous phases. We propose that such heterogeneous rock structures will affect the rheology of the subducting slab and the location of earthquake nucleation.