SCEC Abstract

Rheological controls on the seismicity and fault zone structure of oceanic transform faults

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Oceanic transform faults (OTFs) play a critical role in the tectonic water cycle by enabling circulation of seawater along associated fault zone structures. Teleseismic studies of OTFs reveal seismicity or interpreted brittle deformation in peridotite below 600 °C. These observations are reinforced by laboratory studies of pure olivine powder, which show the onset of stick-slip deformation at 600 °C. However, recent studies of OTF seismicity employing ocean-bottom instruments reveal earthquakes occurring at depths corresponding to ~1000 °C in modeled thermal structure. Additionally, these deployments reveal complex rupture patterns, showing foreshock regions behaving as barriers to quasi-periodic, large events. This seismological heterogeneity is interpreted to result from along-strike variations in fault zone material properties, which allow enhanced fluid circulation to inhibit rupture in the apparent barrier zones.

To further investigate controls on OTF seismicity and fault zone structure, we conducted micromechanical, petrologic, and laboratory observations of dredge peridotite mylonite samples from the Shaka Transform Fault, Southwest Indian Ridge. Petrographic characterization reveals growth of a hydrous amphibole phase as well as planar mineral fluid inclusions. Additionally, orthopyroxene porphyroclasts show cataclastic deformation accommodated on grain-scale faults filled by recrystallized olivine. These observations, coupled with P-T constraints from the hydration reaction and modeled geotherm, suggest that brittle deformation in peridotite and hydration by seawater extends to depths corresponding to ~900 °C. Preliminary laboratory torsion tests on these samples reinforce our estimates, showing the onset of stick-slip from stable creep at 900 °C and 300 MPa. We also examined lower strain samples and find little to no preserved evidence of hydration at the brittle-ductile transition. However, in contrast to the unaltered mylonites these samples show significant fracture and growth of low temperature hydrous phases, suggesting that the feedback between hydration and strain localization represents a first order control on fracture toughness in the seismogenic zone. Consequently, we propose that hydration and rheological evolution of peridotite at the brittle-ductile transition may explain observations of OTF seismicity above 600 °C, as well as the variations in fault zone properties that control along-strike rupture dynamics.

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