Deep intraslab earthquake rupture due to grain size assisted thermal runaway

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The rupture of the 2017 Mw 8.2 Tehuantepec earthquake has been shown to extend to temperatures above 1,000 °C. Ruptures penetrating to regions of such temperatures are highly unusal and raise the question whether the governing rupture mechanisms at these temperatures are comparable to shallow earthquakes. It has been suggested that dehydration embrittlement could result in deep intraslab earthquakes. However, dehydration embrittlement requires the presence of fluids. In the case of the Tehuantepec earthquake, this means that fluids would have to infiltrate the slab to depths that have not been observed.
An alternative mechanism that may lead to failure at these temperatures and depths is thermal runaway, in particular in conjunction with grain size reduction. Due to the conversion from mechanical work to heat during irreversible deformation, this mechanism weakens the rock. In certain conditions, it then results in zones of highly localized viscous creep along which a significant amount of displacement can be accumulated.
Here, we investigate the onset and formation of a ductile shear zone nucleating a cold temperatures and then propagating to regions of higher temperature using 2D numerical models with a nonlinear viscoelastic rheology. We show that it is indeed possible to form a ductile shear zone through the combined action of grain size reduction and shear heating and determine the parameter ranges where this feedback loop may result in ductile shear zone formation and thus also deep earthquake rupture.

Keywords: intraslab earthquakes, deep earthquakes, thermal runaway, grain size evolution

