Geophysical Research Abstracts
Vol. 20, EGU2018-10536, 2018
EGU General Assembly 2018

Scaling lab data to investigate conditions for dehydration-induced earthquakes

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Over the last decade, a wealth of new lab data have been acquired to investigate the processes responsible for intermediate-depth earthquakes. In our lab, we have employed the technique of combining temperature ramps during high-pressure deformation to constrain the competing mechanical effects of dehydration reaction rate and strain rate. Several observations appear robust. (a) Comparison of drained and undrained tests indicates that the frictional behavior of dehydrating antigorite is strongly dependent on temperature and pore-fluid pressure. (b) The tendency towards frictional instability – rather than stable, or slow, slip – correlates well with the rate-dependence of the frictional properties of the dehydrating phase. (c) The weakening rate scales with the ratio of the temperature ramp rate over the strain rate. We interpret that under laboratory conditions this observation reflects the influence of overstepping on the reaction rate. For comparison, in the earth it would be more appropriate to think of the rate of advection of material across the thermal stability limit, as the reaction kinetics probably allow dehydration to occur at the phase boundary. (d) The observation of AE also appears to correlate with the frictional properties, with rate-weakening material (i.e. lawsonite) showing more AE's than rate-strengthening material (i.e. antigorite) at the onset of the dehydration reaction. Indeed, at room temperature (where signal to noise is maximized) we cannot resolve any AE during brittle/semi-brittle deformation of antigorite. One of the more intriguing observations is that we have not been able to produce unstable slip of antigorite at the onset of the dehydration reaction – leading us to speculate that this behavior is inhibited by the velocity strengthening behavior of this material. It is appropriate here to acknowledge Harry Green. Harry pushed the envelope to make many novel experimental advancements. In our case, we are investigating processes that are leading us to push our apparatus (the Griggs apparatus) to resolve signals that it was not necessarily designed for (similar problems led Harry to actually redesign the same apparatus). In this case, we modified the Griggs apparatus to allow variation of the rig compliance by up to an order of magnitude, to investigate conditions that lead to frictional instability. The initial experiments on antigorite conducted with the more compliant system still illustrate stable weakening at the onset of dehydration. However, the maximum slip rate increases with increasing compliance. In addition, we see some AE later in the deformation history (perhaps consistent with observations of Ferrand et al., 2017) after more reaction has occurred. Quantifying these effects of reaction rate and compliance provides a way to scale results to natural conditions (e.g., Okazaki and Hirth, 2016) and constrain the conditions where slow slip or stick slip occur during dehydration reactions.