Harvard University, Solid Earth Physics Seminar
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Faculty Lounge, 4th Floor, Hoffman Lab, 20 Oxford Street

The Role of Fluids on the Brittle-Ductile Transition in the Crust

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To characterize earthquake rupture, degree of localization, and stress at the base of the seismogenic zone we need to understand the mechanical role of pore fluids and how the mechanical properties of fluid-rock systems respond to variations in temperature and strain rate. The role of fluids on the processes responsible for the brittle-plastic transition in quartz-rich rocks has not been explored at experimental conditions where the kinetic competition between microcracking and viscous flow is similar to that expected in the Earth. Our initial analysis of this competition between these brittle and ductile processes suggests that the effective pressure law for fracture and sliding friction should not work as efficiently near the brittle-plastic transition (BPT) as it does at shallow conditions.

Our motivation comes from two observations. First, extrapolation of viscous creep laws for quartzite indicates the brittle-plastic transition (BPT) occurs at a temperature of ~300°C at geologic strain rates for conditions where fault strength is controlled by a coefficient of friction of 0.6 with a hydrostatic pore-fluid pressure gradient. Second, by considering the influence of pore-fluids on brittle deformation, we suggest that the preservation of relatively high stress viscous microstructures indicates that the effective pressure law must sometimes evolve rapidly near the BPT - for example - from highly efficient to zero efficiency with increasing depth. To illustrate this point, first consider the abundant evidence for the presence of fluids during viscous deformation of mylonites (e.g., recrystallization and redistribution of micas, dissolution and reprecipitation of quartz). Furthermore, analyses of fluid inclusions preserved in mylonitic rocks indicate near lithostatic pore fluid pressures. Based on the simple interpretation of the strength-depth diagrams, maintenance of high pore fluid pressure is incompatible with viscous creep stresses in the range of 100-200 MPa. A similar “paradox” is evident at experimental conditions where we study viscous creep in the laboratory. In this case, the presence of fluid (which should produce low effective stress) does not promote localized brittle failure, even though these experiments are conducted under undrained conditions. Indeed, the introduction of fluids is actually *required* to inhibit brittle processes at experimental strain rates, through the effects of hydrolytic weakening.

Experiments involving dehydration of hydrous minerals provide further insight into these problems. Our work on serpentinite (*Chernak and Hirth*, 2011; *Proctor and Hirth*, in prep) demonstrates dramatic weakening under undrained conditions – but little weakening under drained conditions - during the initiation of serpentine dehydration. Weakening is promoted with very small (<1%) reaction progress and the strength drop occurs due to decrease in effective pressure. The dramatic weakening observed in these tests (as well as modest strain rate dependence and evidence for microcracking observed at temperatures just below dehydration temperature) are indicative of semi-brittle deformation – which is why the effective pressure law is apparently so effective, in contrast to our discussion of quartzite above.