Effect of Stress on Chemically Induced Creep and Rock Transformation: Insights from Indenter Experiments

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ABSTRACT

In the Earth's upper crust, the slow deformation of rocks, also called creep, is commonly associated with development of mineralogical layering, leading to irreversible transformations of their microstructure. Moreover, active faults in the Earth's upper crust can slide either steadily by aseismic creep or abruptly causing earthquakes. Seismic and aseismic processes are closely related: earthquakes are often followed by transient afterslip creep, and rocks are transformed due to dissolution-precipitation mechanisms. To study these processes where stress is coupled to dissolution and precipitation, indenter experiments developed in the past ten years have been developed and are reviewed in this presentation. This experimental technique is very simple: an indenter is applied onto a rock sample, with controlled stress and temperature, and in the presence of various reactive aqueous solutions. This setup represents how stress is concentrated along grain contacts of a rock, leading to local non-hydrostatic loading conditions that may drive chemical transformations. This experimental technique can be used to study:

- Pressure solution creep laws relevant at upper to middle crustal conditions;
- The interactions between fracturing and comminution processes induced by dynamic stress loading and how they drastically accelerate the displacement rates accommodated by pressure solution creep, providing a mechanism for post-seismic creep;
- The development of differentiated mineralogical layering, similar to that observed in natural deformation in fault zones and sedimentary rocks.

All these indenter experiments share common properties: simplified geometry, high resolution time-lapse measurement of deformation, long-term rheology (some experiments last up to one year), and well-controlled stress. Several samples were also imaged using high-resolution X-ray microtomography to provide additional insights on the damage and geometry. In the past ten years, they have provided unique data sets that demonstrates that the Earth's upper crust is not only brittle, but also show slow aseismic deformations that are localized in space and time.