Geophysical Research Abstracts
Vol. 18, EGU2016-1564, 2016
EGU General Assembly 2016

The Pulse of the Crust: Slow fracture and rapid healing during the seismic cycle (Louis Néel Medal Lecture)

Philip Meredith

Rock & Ice Physics Laboratory, Department of Earth Sciences, University College London, London WC1E 6BT, United Kingdom

Earthquake ruptures and volcanic eruptions are the most dramatic manifestations of the dynamic failure of a critically stressed crust. However, these are actually very rare events in both space and time; and most of the crust spends most of its time in a highly stressed but subcritical state.
Under upper crustal conditions most rocks accommodate applied stresses in a brittle manner through cracking, fracturing and faulting. Cracks can grow at all scales from the grain scale to the crustal scale, and under different stress regimes. Under tensile stresses, single, long cracks tend to grow at the expense of shorter ones; while under all-round compressive, multiple microcracks tend to coalesce to form macroscopic fractures or faults.
Deformation in the crust also occurs over a wide range of strain rates, from the very slow rates associated with tectonic loading up to the very fast rates occurring during earthquake rupture. It is now well-established that reactions between chemically-active pore fluids and the rock matrix can lead to time-dependent, subcritical crack propagation and failure in rocks. In turn, this can allow them to deform and fail over extended periods of time at stresses well below their short-term strength, and even at constant stress; a process known as brittle creep.
Such cracking at constant stress eventually leads to accelerated deformation and critical, dynamic failure. However, in the period between sequential dynamic failure events, fractures can become subject to chemically-enhanced time-dependent strength recovery processes such as healing or the growth of mineral veins. We show that such strengthening can be much faster than previously suggested and can occur over geologically very short time-spans. These observations of ultra-slow cracking and ultra-fast healing have profound implications for the evolution and dynamics of the Earth's crust. To obtain a complete understanding of crustal dynamics we require a detailed knowledge of all these time-dependent mechanisms. Such knowledge should be based on micromechanics, but also provide an adequate description at the macroscopic or crustal scale. One way of moving towards this is to establish a relationship between the internal, microstructural state of the rock and the macroscopically observable external quantities.
Here, we present a number of examples of attempts to reconcile these ideas through external measurements of stress and strain evolution during deformation with simultaneous measurements of the evolution of key internal variables such as elastic wave speeds, acoustic emission output, porosity and permeability. Overall, the combined data are able to explain both the complexity of stress-strain relations during constant strain rate loading and the shape of creep curves during constant stress loading, thus providing a unifying framework to describe the time-dependent mechanical behaviour of crustal rocks.