The Earthquake-fluid Dynamical System

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One of the most dramatic changes in properties of the solid earth is the hydraulic changes associated with the formation of a fracture. A sudden change in hydraulic properties, up to eight orders of magnitude, creates new pathways for fluid flow and their concomitant effects on the mechanical, thermal and thermodynamic behavior of the system. This flow trigger also provides a binary switch that makes complexity a natural consequence. That is, for the most part fluid is either not moving much, or moving extremely rapidly over relatively short timescales. Earthquakes are new fractures at all scales, resulting in a very complex flow system that includes important feedbacks between earthquake, aftershocks, and earth degassing. In tectonic systems where a source of fluid is present, such as CO_2, the post-seismic movement of this high pressure fluid can trigger earthquakes and aftershocks along the flow path by reducing the effective normal stress. The role of CO_2 in generating earthquakes and aftershocks has been documented in the 1997 Colfiorito earthquake sequence in Italy, and the recent L'aquila sequence in 2009 add further evidence for this important coupling. In this talk, I explore the hypothesis that many extended aftershock sequences are driven by the post-seismic release of trapped high pressure fluids (CO_2 and H_2O) at depth through a study of aftershock sequences and patterns for a range of tectonic environments. Observations are compared with non-linear diffusion models, and show that the general aftershock patterns are consistent with a post-seismic degassing model. In addition, the rate of aftershock decay (Omori Law) is shown to be controlled by the ability of fluids to escape. Fast decay rates occur where the main-shock rupture plane is not optimally oriented for fluid flow relative to the prevailing regional stress field, and slower decay rates where the main-shock rupture plane is well-oriented for fluid flow.