Fault damage and healing in the seismic cycle in nature and experiment

Seminario
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Abstract:

The episodic recurrence of seismic events suggests that fault zone mechanical and transport properties may vary cyclically. During the interseismic period, elevated temperatures in hydrothermal systems are known to affect the permeability of fault zones with time, and the dynamic evolution of structural permeability in the seismogenic zone may induce fault zone weakening through the generation of elevated pore pressures. Understanding how competing fracturing/sealing processes (gouge formation, hydrothermally induced healing, pressure solution) can lead to the development of overpressured patches along fault zones is critical, as they can act as nucleation sites and trigger earthquakes (e.g. Miller et al. 2004, Nur & Booker 1972, Sibson 1974). Seismogenic fault fracturing can create considerable fracture permeability in and around the rupture zone which can initiate large fluxes of fluid through a variety of processes, and can result in hydrothermal deposition of economically important minerals such as mesothermal gold-quartz deposits (Sibson et al. 1988). For example, earthquake slip transfer in dilatational jogs along strike slip fault zones creates space via extensional fracturing (Figure 1a), lowering the mean stress and pore fluid pressure within the jog leading to a suction pump effect (Figure 1b)(Sibson 1987). Large coseismic fluid fluxes have also been shown to initiated by the ?fault valving? process first suggested by Sibson (1990) (Figure 1c). Earthquake rupturing of low permeability seals can release previously trapped high-pressure fluids, that propagate through fault fracture network created by the mainshock (Miller et al. 2004) as pressure pulses that have been directly correlated to aftershock hypocentres over periods of weeks. Experimental studies of permeability variations in fresh fractures at seismogenic temperatures have shown permeability can significantly recover over similar timescales of days to weeks (Morrow et al. 2001), and microfractures on the order of hours to days (Brantley et al. 1990). However, at larger scales, a growing body of geophysical evidence exists for damage healing processes over such longer timescales in active fault zones. For example, the Landers fault zone in California was shown to exhibit an abrupt decrease in seismic velocity following the 1992 earthquake, interpreted as rupture induced fracture damage. This was followed by a time-dependent increase in seismic velocity lasting over ten years which was inferred to be fault zone healing processes (Vidale and Li, 2003). It is clear therefore that competing fracturing and sealing processes at different scales will have a significant control on fault zone fluid flow and a variety of geological processes. It is clear therefore, that a combination of field, laboratory and geophysical techniques is required to address such problems. Laboratory studies can quantify the temporal variations of permeability due to competing fracturing and hydrothermal sealing processes, and field and geophysical investigations are required to place the experimental results into a framework of constrained natural fault zone architecture. In this presentation, I will present a general background to these themes, an overview of my own

research, and summarize areas that still need to be addressed.

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