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Development of fluid overpressures in crustal faults and implications for earthquakes mechanics

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The development and maintenance of fluid overpressures strongly influence the mechanical behavior of the crust and especially crustal fault zones. The mechanisms allowing fluid pressure build-up are still open questions, and their influence on tectonic and fault weakening processes remain unclear. The determination of the hydraulic and mechanical properties of crustal fault zone elements is a key aspect to improve our understanding of the fluid-tectonic interactions and more particularly the role of fluids in fault mechanics and earthquake triggering. Here we address this question combining geological observations, laboratory experiments and hydromechanical models of an active crustal fault-zone in the Ubaye-Argentera area (southeastern France). Previous studies showed that the fluids located in the fault zone developed overpressures between 7 and 26 MPa, that triggered intense seismic swarms (i.e. 16,000 events in 2003-2004) (Jenatton et al., 2007; Daniel et al., 2011; Leclère et al., 2012).
The fault-zone studied here is located in the Argentera external crystalline massif and is connected to regional NW-SE steeply-dipping dextral strike-slip faults with an offset of several kilometers. The fault zone cuts through migmatitic gneisses composed of quartz, K-feldspar, plagioclase, biotite and minor muscovite. It exposes several anastomosed core zones surrounded by damage zones with a pluri-decametric total width. The core zones are made up of centimetric to pluridecimetric phyllosilicate-rich gouge layers while the damage zones are composed of pluri-metric phyllonitic rock derived from mylonite.
The permeability and elastic moduli of the host rock, damage zone and fault core were measured from plugs with a diameter of 20 mm and lengths between 26 to 51 mm, using a high-pressure hydrostatic fluid-flow apparatus. Measurements were made with confining pressures ranging from 30 to 210 MPa and using argon pore fluid pressure of 20 MPa. Data show a variation of the permeability values of one order of magnitude between host rock and fault zone and a decrease of 50% of the elastic properties between host rock and core zone. The heterogeneity of properties is related to the development of different microstructures across the fault-zone during the tectonic history.
From these physical property values and the fault zone architecture, we analyze the effects of sudden mechanical loading on the development of fluid overpressures in fault-zone. To do this, we use a series of 1-D hydromechanical numerical models to show that sudden mechanical stress increase is a viable mechanism for fluid overpressuring in fault-zone with spatially-varying elastic and hydraulic properties. Based on these results, we discuss the implications for earthquake triggering.on crustal-scale faults.