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Coseismic fluid pressure drop and postseismic recharge: Direct laboratory evidence and implications for earthquakes

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Dilatancy during rock failure has been widely documented experimentally, and has been recognised as a key process promoting fluid flow in the crust. Since rock failure leads to strong spatio-temporal localisation of deformation, dilatancy is expected to be strongly localised around the fault plane, and to lead to dramatic, but very local, reductions in fluid pressure during rupture, with important implications for dynamic weakening processes such as thermal pressurisation. In order to measure local fluid pressure variations in situ during rock failure, a new type of miniature pore pressure transducer has been designed and built, and equipped on a granite sample tested under trixial stress conditions. The sample was deformed at a confining pressure of 70 MPa and an initial pore pressure of 30 MPa. The sample was macroscopically drained, i.e. the pore pressure kept constant at the both ends. During failure, the pore pressure measured on the fault dropped quickly to zero, indicating fluid vaporisation. After rupture, a slow recharge was observed, quantitatively consistent with the hydraulic properties of the intact off-fault material. Further sliding on the newly formed fault produced stick-slip events, all associated with near-instantaneous reductions in on-fault pore pressure, followed by slow recharge. The pressure drop, net pore volume change and slip data are combined to produce predictions of the fluid pressure changes induced by dynamic slip events at a range of depth in the upper crust, and indicate that fluid vaporisation may be a widespread phenomenon for small earthquakes in fresh rocks in the top 5 km of the crust. As a consequence, dilatancy is shown to severely impact the possibility of dynamic weakening by thermal pressurisation, at least on newly formed faults.