Hydrodynamic controls on dynamic fault strength during rapid slip

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Fluid pressure evolution during rapid slip has been shown theoretically to dictate strength changes and overall stress release during earthquakes. In particular, frictional heating of pore fluid can cause a rapid fluid pressure increase, resulting in a large drop in effective stress and therefore strength of the deforming zone. This process of thermal pressurization involves firstly the relationship between frictional strength and heat production, and secondly the relationship between heat production and the fluid pressure response. Applications of such theoretical models are hindered by the lack of data on the appropriate physical properties of the slip zone and surrounding material which control these relationships. Highlighted by previous theoretical works is the uncertainty in appropriate permeability values which will seriously affect the fluid behaviour during slip.

This presentation firstly reports data on permeability and poroelastic properties of fault gouge samples from a currently inactive portion of the Median Tectonic Line. The sampling site in western Mie Prefecture is an excellent exposure of the fault zone, displaying a central 10 cm wide slip zone interpreted to be the zone of last rapid slip event(s). The laboratory data were obtained from gas rig experiments using a nitrogen pore fluid. The experiments determined both bulk compressibility during confining pressure increase steps, and pore compressibility from storage capacity measurements using the sinusoidal pore pressure oscillation technique also used to measure permeability. The data are used to estimate hydraulic diffusivity in the case of water as a pore fluid. It is found that compressibility is not constant, but varies with effective pressure in a log-normal manner. Furthermore, it is affected by previous peak effective pressure, and only after this initial compaction does it behave elastically.

Previous models of thermal pressurization and other responses to rapid slip are assessed using the data. It is shown that gouge from the central slip zone at the Median Tectonic Line contact has hydraulic diffusivities lower than estimated thermal diffusivity, provided that the gouge has been subjected to a peak effective pressure of at least 80 MPa. Hence pressurized fluid is unlikely to escape at a faster rate than the frictional temperature pulse, suggesting that thermal presurization is likely to occur if the rupture plane is confined to the previous low permeability central slip zone.