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The role of pressure solution in aseismic creep and the dynamic equilibrium between fracturing and sealing processes in active faults

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Active faults in the upper crust can either slide steadily by aseismic creep or abruptly during earthquakes with post-seismic creep and sealing processes. Creep relaxes the stress and prevents large earthquakes to occur. Sealing controls post-seismic strength and permeability recovery timing. Identifying these mechanisms and their evolutions with time and depth represents a major challenge for prediction of the long-term evolution of active faults. Microstructural studies of rock samples collected from the San Andreas Fault Observatory at Depth (SAFOD) indicate that a pervasive and widespread deformation mechanism, pressure solution creep, can account for both creep and sealing processes in active fault. Experimental data on minerals such as quartz and calcite are used to demonstrate that pressure solution creep can accommodate the present 20 mm/yr aseismic displacement rate of the SAF creeping zone and is compatible with its microseismicity and low strength deduced from heat measurements.

Pressure solution creep strain rate is inversely proportional to the cube of the distance of mass transfer (d), which is either fracture spacing or grain size. Consequently, (d) is a key parameter of the creep process. If (d) is small enough (10 – 100 micrometers) steady state aseismic pressure solution creep can accommodate the displacement rate along the active creeping zone of the SAF. Alternatively, if it is larger (>100 micrometers), pressure solution creep occurs but cannot accommodate the displacement rate and cannot relax the stress, consequently small earthquakes occur that in turn activate the creep process since fracturing opens new paths for solute transport along fluid-filled fractures, which decrease the distance of transfer. However, this effect slowly disappears if fractures are sealed. So pressure solution creep results from a dynamic equilibrium between activating (fracturing) and slowing down (sealing) processes.

Another specificity of pressure solution creep is that it is associated with foliation development as insoluble species are passively concentrated in solution cleavage. This could favor low friction sliding on weak phyllosilicates. However, such sliding that occurs on discrete curved surfaces always needs associated internal deformation by pressure solution.

A final question is why, at a given time, pressure solution creep is localized along some segments of the fault. The answer could be that pressure solution creep needs specific conditions to develop at a significant rate. Soluble minerals such as feldspar, calcite, quartz and serpentine must be involved and mixed with phyllosilicates that activate mass transfer. The distance of mass transfer must be as small as possible requiring either intense seismic fracturing or fine-grained material and reactive fluids. Under these conditions, the process is self-organized through positive feedback process, which allows pressure solution creep process localization and migration with time within the fault zone.

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