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Fast and slow temporal evolution of the upper crust ductile rheology: the role of fluid-rock interactions

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Pressure solution creep is a major mechanism of ductile deformation of the upper crust, accommodating basin compaction, folding, shear zone development, and fault creep and interseismic healing. However, its kinetics is strongly dependent on the composition of the rocks (mainly the presence of clays and phyllosilicates minerals that activate pressure solution) and on its interaction with fracturing and healing processes (that activate and slow down pressure solution, respectively). It is shown how fluid-rock interactions control both the slow temporal evolution of rock composition and the fast episodic effect of fracturing and healing processes.
Observations of natural deformation show how the initial mixing of soluble minerals (as quartz, feldspars, calcite, serpentine) and insoluble minerals (as clay, phyllosilicates) facilitates the pressure solution process and how the progressive passive concentration of insoluble species associated with pervasive pressure solution creep processes leads to the localization of the deformation along creeping fault and shear zones.
Experiments with dynamic indenter technique show how episodic fracturing events activate pressure solution kinetics by opening paths for diffusion and precipitation and how the progressive healing of such fractures slow down the pressure solution kinetics. Displacement-rate versus time relation shows that post-fracturing displacement fit first a power law (with an exponent of about 0.4) then the same linear evolution as before fracturing and healing. Such displacement-rate versus time relation can also be found in temporal evolution of post-seismic displacement.
Consequently, in natural deformation, pressure solution is likely to be a non-steady-state creep process.
- Fracturing (weakening effect) competes with healing (strengthening effect) during earthquake cycles and the change in shear zones, and probably also in all the deformation processes that are triggered by human activity (fluid extraction or geological storage).
- Phyllosilicates content increase (weakening effect) competes with vein sealing (strengthening) at all time scales from earthquake cycles to basin compaction or mountain building leading to tectonic segregation. This complex behaviour is true for all the stress-driven mass transfer mechanisms including metamorphic reactions when they imply a thin fluid phase trapped under stress.