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Cyclic micromechanical controls of transient crustal deformation

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Episodic brittle-ductile behaviour reflects the complex interplay of micromechanical hardening and softening, often with some type of fluid pressure associated with introduction of new material that acts as the switch from coseismic to interseismic response. Brittle features observed in nature can in general be characterized as discrete surfaces or narrow zones across which fast particle displacements have occurred, with or without dilatant behaviour; this descriptively meets the criteria for generation of earthquakes. Likewise, non-brittle flow is a priori associated with slower particle velocities. This reduces the problem to one of how and why rocks cycle between slow and fast displacements. Particle displacement in the solid-state is limited to three processes: individual atoms, glide of packets of atoms and frictional displacement across an essentially free surface. Each of these processes, however large the feature being studied or rapid the displacements, necessitates the sequential overcoming of extant atomic bonding energies. Within the rock record, evidence of seismic events are embedded as new or reconstituted material introduced to the deforming host as a consequence of brittle deformation; for example, veins and pseudotachylyte. This new material acts as an important sink for strain energy whereby brittle responses are suppressed until such time as a new critical state is reached. In turn, the strain rate softening abetted by the new material provides a ductile overprint of their syn-fracture origin. Consequently, rheological transitions within Earth's crust are spatially and temporally transient, evidence for which may be routinely lost. As part of this cyclic behaviour, localization of deformation can be viewed as the default state, with macroscopic deformation a result of organization into required dissipative structures.