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The importance of healing on the deformation of fluid-filled layered systems

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Fractures in the brittle crust form by the combination of gravity, tectonic forces and fluid pressures. Fractures heal as a result of material precipitation forming veins that can refracture due to further deformation. Understanding this cycle (fracturing-healing-refracturing) is a fundamental part of studying the deformation dynamics and the permeability evolution of rocks. In spite of this, not many previous studies have examined the influence of healing and the veins' mechanical properties on the rock deformation. To address this issue we present results from a two-dimensional coupled hydro-mechanical model within the modeling environment 'Elle'. Our simulations have large time ($\sim$ 54.8 ka years) and spatial (3 km depth) scale, and show the dynamic fracturing and healing of a porous medium under the influence of gravity, tectonic stretching and elevated fluid pressures. Mechanical properties of the matrix, the embedded layers and the new bonds can be varied in order to investigate their influence on the evolving fracture and vein patterns. Our results show that at early stages of deformation the overall porosity decreases and increases after the maximum differential stress is obtained. The system reaches a steady-state (saturation) that is characterized by minor fluctuations in stress as the strain is accommodated along pre-existing fractures. Small-scale fractures link up to propagate which then evolve to large fracture zones and faults that are responsible for draining the system. It is shown that for the general evolution of the system the veins' strength is more important than their elastic modulus. Hard veins, such as quartz or ore, make the aggregate progressively stronger which leads to overall healing of the system, limited fracturing and thus fluid flow, greater stresses and delayed saturation. Weak veins, such as calcite, make the system weaker in which refracturing of the healed bonds is the dominant process that creates more open fractures and thus increases the permeability. These results provide clues for the importance of the veins' mechanical properties and can enhance our understanding of the deformation dynamics and the permeability evolution of the rock systems.