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Numerical modeling of shear zones patterns

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Areas with shear zones usually show one of two different patterns: a network of anastomosing shear zones like at Cap de Creus (Spain) or the Alpine external Oisan Massif (France); relatively straight shear zones, like the Porcupine-Destor Shear Zone and the Cadillac-larder Lake Shear Zone (both in the Canadian Abitibi Subprovince).

The question arises which parameters control the lengths, shapes and patterns of a shear zones? Clearly, the rheology of the deforming rocks is an important controlling factor. One the small scale, the rheology is controlled by parameters such as grain size, temperature, mineralogy, strain rate etc.. However, it still is difficult to determine which of these parameters is dominant in controlling the evolution of large-scale (≥m) shear zones and what the effects are of interaction and coupling of some or all these parameters.

At a scale much larger than the grain scale (i.e. ≥m-scale), the two most important factors controlling shear zone patterns are probably strain softening and hardening of the rock. Shear heating may be another factor. We used idealised softening and hardening laws in numerical simulations up to high strain. Softening tends to localise strain into shear zones, while hardening counteracts this effect. We made the softening a function a function of stress. Hardening was made a function of time, simulating the recovery of the rock (by dynamical recrystallisation, grain growth, etc.).

Using the numerical modelling platform Elle and Basil, we show how different shear zone patterns develop as a function of the relative rates or dominance of softening versus hardening (recovery). Relatively weak recovery and strong softening leads to strong and permanent shear localisation. Relatively strong recovery, on the other hand, means that the rock has a "poor memory" for its previous deformation history. The sites of localisation vary over time, leading to multiple, cross-cutting shear zones.