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Cockade-bearing breccias, cataclasites and gouges in a single fault zone: Microstructures and geochemisty

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The seismic-interseismic cycle strongly relates to the interplay between dilation owing to fracturing and frictional granular flow on one hand side and hydrothermal cementation processes on the other side. This study investigates different fault rocks of a crustal-scale fault zone in the Central Alps (Switzerland). We combine microstructural with geochemical approaches to decipher the interaction of grain size reduction via frictional processes with precipitation and resulting particle size increases. The three major fault rocks, i.e. (1) cockade-bearing breccias, (2) cataclasites, and (3) fault gouges, differ in their microstructure. The chemical data clearly demonstrate a decreasing gain of volume along this group of tectonites. Their different precipitation volumes most likely relate to dynamic changed of the local permeability of these rocks. The fluid pathways control the precipitation at different localities and times, which affect the healing of these fault rocks inducing a gain in rock strength. During the next deformation event, the extent of healing therefore directly controls the mechanical behavior of the rock. The estimated volume gain (~+110%) in cockade-bearing breccias is consistent with the seismic dilatant behavior of these frictional rocks as already proposed from other arguments (Berger and Herwegh 2019). This is in contrast to the fault-gouges with only minor gains in volume and mass resulting in a predominantly non-cohesive deformation style. This example indicates that permeability evolution (and related hydrothermal processes) strongly influences the mechanical behavior of such faults. This shows the highly dynamic behavior with time in long-lived fault systems. These dynamic changes in precipitation and resulting different strengths occur at different timescales from minutes (seismic events) to thousands of years.

Ref.: Berger, A., Herwegh, M., 2019. Cockade structures as a paleo-earthquake proxy in upper crustal hydrothermal systems. Nature Scientific Reports, 9, 9209.