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Cycles of fluid involved cataclasis and ductile flow at mid-crustal level during Alpine deformation in the Aar massif (Central Alps, Switzerland)

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Today's seismic activity through the Swiss Alps is ranging from the surface to about 25 km depth. At around 12-15 km depth a change from a purely brittle domain into a ductile deformation regime is suggested. The basement rocks of the Aar massif in the central Swiss Alps can be viewed as an analogue from the past for today's mid-crustal deformation. We aim to provide insights into the processes and mechanisms occurring at the transition between brittle and ductile regimes.

Shear zone initiation and evolution is studied at a variety of scales along shear zones located in the southern Aar massif (from Rätrichsbodensee to Grimselpasshöhe). Detailed field mapping combined with microscopic analysis along strain gradients has been carried out. During the Alpine orogeny, strain localized and re-activated along the following pre-existing mechanical anisotropies: i) Lithological variations between Post-Variscan intrusives and Pre-Variscan basement; ii) between primary magmatic features (i.e. varying mica content in the Post-Variscan intrusive), iii) pre-existing brittle and ductile faults.

During the Alpine orogeny alternations of ductile and brittle deformation occur. Ductile deformation is characterized by dynamically recrystallized quartz (i.e. subgrain rotation) frequently together with newly crystalized biotite. Despite occurrence of a ductile background strain, several microstructures indicate simultaneous activity of hydro-fracturing and cataclasis at similar P-T conditions: (i) Overprinting of the ductile structures, by fractures filled with precipitated biotite and epidote and (ii) ultracataclasites overgrown by biotite probhyroblasts. The fact that both, fracture infill and mineral overgrowths, contain biotite suggest formation temperatures above $\sim$400°C, i.e. metamorphic conditions under which quartz is generally interpreted to deform in a ductile manner.

Chlorite overgrowth of biotite in the previously described ductile shear zones indicates continuous shearing during cooling. Moreover, the retrograde decomposition of feldspars into fine-grained reaction products combined with a decrease in crystal plastic deformation of quartz, forced deformation to localize in these ultrafine-grained high strain zones. Here viscous granular flow, again accompanied by instantaneous brittle events, represents the dominant ductile deformation mechanism. With ongoing uplift and exhumation these late ductile shear zones are overprinted by cataclasites (frictional granular flow), which cut and/or reactivate the aforementioned precursor structures.

Altogether, this sequence shows alternating brittle and ductile processes under the presence of fluids at elevated temperatures (>400°C). These cyclic processes are most likely responsible for the seismic activity found nowadays at depths of about 12-15 km in the Swiss Alps.