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Microstructures of healed granitoid Fault Gouge - a Combination of Cathodoluminescence and BSE-Contrast SEM Imaging.

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The healing processes in fault gouge are not well understood in terms of microstructural processes. It is generally assumed that a high temperature and the presence of fluids promote the healing processes. Earlier studies propose that under hydrostatic conditions healing is achieved by neck-growth (sealing of the grain to grain contacts), or by cementation (the filling of pore space by material from a super-saturated advecting fluid). Under non-hydrostatic stress healing may be driven by a pressure solution process. With our study, we hope to contribute to the further understanding of fault gouge healing, by studying experimentally and naturally deformed granitoid samples with different microscopy techniques.

Coaxial deformation and healing experiments were carried out on isotropic Verzasca gneiss using a Grigg's deformation apparatus at $300-500\,^{\circ}\mathrm{C}$, 500 MPa, strain rates of 10^{-4} to $10^{-7}s^{-1}$ and 0.2 %wt H_2O added. Samples were fractured to create fault gouge. After fracturing the samples were kept at hydrostatic or non-hydrostatic conditions for 4 hours to 14 days at 300 or $500\,^{\circ}\mathrm{C}$ (healing). Thin sections of the samples were prepared and analyzed with a light microscope (LM) connected to a cathodoluminescence camera (CL) and with a scanning electron microscope under back-scattered electron contrast (BSE). Digital images with different magnifications were used for the analysis of the grain shape, grain size, and changes in luminescence. The experimentally deformed granitoids were compared to natural fault rock samples originating from the Alps (deformation in Tertiary) and the Black Forest (Tertiary).

The evolution of fresh experimental fault gouge to healed gouge is different for hydrostatically and non-hydrostatically healed grains: after a few days small bridges connecting grains are observed in hydrostatically healed samples. In non-hydrostatically healed samples small grains coalesce into a solid healed zone. Non-hydrostatic healing is very efficient at $500\,^{\circ}\mathrm{C}$: low magnification CL reveals fault zones, where the gouge is surrounded by newly precipitated material. On the corresponding BSE micrographs the evidence for the earlier deformation is lost. A BSE micrograph of a sample healed under hydrostatic conditions at $500\,^{\circ}\mathrm{C}$ still displays individual grains.

Naturally deformed samples from the Black Forest show two different fracturing events under different temperature conditions with CL, whereas LM and BSE only showed the last event. In CL healing microstructures that were established after the first fracturing event resemble those of the hydrostatically healed samples. Healing after the last fracturing event occurred by cementation, strongly affecting the grain size and grain shape distribution of the fault gouge. Microstructural details of healing of fault gouge, obtained by CL in comparison with LM and BSE, are demonstrated.