Fault gouge evolution in highly overconsolidated mudrocks - a field study

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Faults in brittle lithologies can form highly conductive fluid pathways at small displacements. At increasing displacement the transport properties of the fault zone are more complex. In sandstones and carbonates cataclastic gouges are formed which remain rather permeable but may be re-cemented by diagenetic fluids. In mudrocks the evolution is very different: here the progressive mechanical reworking produces a clay gouge which is initially mineralogically similar to the country rock. This gouge can restore the low permeability of the gouge much more rapidly because diagenetic processes are not required, although the mechanical softening of the fault remains due to the loss of cohesion.

We studied this process of reworking in outcrops exposing late normal faults in the Variscan slate belts of the Ardennes and Eifel. The slates which were initially buried to depths over 6 km, developed a cleavage and a high degree of illite crystallinity during the Variscan orogeny. The normal faults studied are related to upper crustal extensional faulting of this exhumed package in Tertiary times. We present results of detailed field mapping of the fault gouges, combined with XRD, SEM and Hg-porosimetry of carefully preserved samples. Starting with intact wall rock, the fault gouge initially consists of wall rock fragments, forming a microbreccia with a low Mercury displacement pressure. With progressive deformation this gouge is reworked into a fine clay gouge which has a high porosity corresponding to the shallow level of faulting but a high Mercury displacement pressure. Once this reworking is completed the fault gouge regains its sealing capacity and remains in critical state during further deformation. At this stage, along-fault fluid flow will be focussed in the damage zone outside the clay gouge and around fault tips.