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Architecture and hydraulic properties of a brittle fault core zone - example from the Semmering area (Austria)

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Permeability structures of fault zones exhibit different zonation configurations and thus fault zones may represent hydraulic barriers or conduits, or a combination of both, depending on their tectonic evolution, petrophysical properties of the protolith and the existing stress regime (Caine et al., 1996). The investigated fault zone, which is part of the Talhof fault system in the Eastern Alps, is characterized by a polyphase tectonic evolution with all three domains (protolith, damage zone and core zone) well exposed at the contact between metamorphic carbonates, quartzites and quartz phyllites at the location "Stiegerinhütte". The units are characterized by contrasting deformational behavior from distinct fractures (damage zone) over different types of cataclasites to fault gouge (core zone). The fault core of approximately 10 m thickness is built up by cataclasites and fault gouges with a planar fabric parallel to the fault zone boundary. The architecture and the hydraulic properties of the core zone were investigated along two scan-lines. More than 50 steel pipe samples were taken in three orientations referring to a kinematic coordinate system. The samples were analyzed with respect to grain size distribution, mineralogical composition and hydraulic conductivity. The hydraulic conductivity was determined by triaxial penetration cell tests using varying confining and penetration pressure (increasing pressure from 0.24 bar, 0.36 bar, 0.46 bar, 0.65 bar, 1.2 bar to 2.4 bar).

The fault core cataclasites are dominated by grain sizes between 0,02 and 2 mm, by the minerals quartz and muscovite and the clay minerals muscovite and smectite. The hydraulic conductivities range from 1.0E-06 m/s to 4.5E-11 m/s showing a hydraulic anisotropy corresponding to the fault orientation. Hydraulic conductivities parallel to the fault zone boundary are found to be two orders of magnitude higher than those perpendicular to the fault zone boundary. The architecture of the core zone is characterized by two distinct subdomains: Zone 1 is next to the zone of main displacement represented by a slickenside at the contact to the damage zone. Zone 2 is attached to zone 1. The two zones are distinguished by their grain size distribution and their hydraulic properties. The hydraulic conductivity as well as the grain size increase with distance to the zone of main displacement. The hydraulic conductivity of the samples parallel to the fault zone boundary decreases with increasing pressure, whereas perpendicular to the fault zone boundary the hydraulic conductivity seems to be independent of pressure. A strong dependence of hydraulic conductivity on pressure is also confirmed by experiments in a high pressure cell (ENS Paris) with up to 50 bar, indicating a significant reduction with increasing pressure. This indicates a decrease of porosity with increasing pressure corresponding to observed changes in the geometry of the sample (compaction). Accompanying petrophysical measurements confirm a decrease of the porosity corresponding to the decrease of the hydraulic conductivity.

Caine, S. J., Evans, J.P., Forster, C. B: Fault zone architecture and permeability structure; Geology, v.24, no.11, p. 1025-1028 (1996).