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Interconnected weak layers of micas in fault rocks, and implications for the mechanics of misoriented faults

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Brittle fault zones can be considered weak either in an absolute or relative sense. In the second case, weakness is detected since the fault is active under unfavourable tensional conditions, which means that it is unfavourably oriented with respect to the regional stress field. Three classes of mechanisms have been proposed to explain the “anomalous” (but not so uncommon) weakness of faults, which may be related to the presence of weak minerals, high pore fluid pressure, and stress rotation. However, no one of these mechanisms explains why some faults tend to nucleate (particularly in certain tectonic environments) with an unfavourable orientation. In this contribution we discuss how the mechanical anisotropy (or anisotropic weakness) of foliated phyllosilicate-rich rocks provides both a weakening mechanism, and a mechanism that is likely to guide the nucleation of large scale brittle faults in a misoriented attitude.

Experiments and microphysical models indicate that mechanical anisotropy exerts a substantial influence on shear failure and subsequent frictional sliding. Intermediate-grade metamorphic rocks composed of > 30% phyllosilicates show an anisotropic internal friction coefficient which varies from ca. 0.6, at high angle to foliation, to ca. 0.3 for shear initiation along an inherited foliation. This may result in the nucleation of misoriented faults/fractures (fractures or faults oriented unfavourably with respect to classic Mohr-Coulomb fracture criterion) and inhibit the development of classical “well-oriented” Andersonian conjugate sets.

To test the relevance of this mechanism at the regional scale, we have developed a Slip Tendency analysis, which has been modified to account for anisotropy in friction coefficients, thus named Anisotropic Slip Tendency analysis. The analysis has been applied to different large-scale, mature fault zones in the Alps, showing different kinematics and relationships with respect to the regional-scale stress field, but all classified as relatively weak faults, and all characterized by slip along phyllosilicate-rich mylonitic foliations. Anisotropic Slip Tendency analysis demonstrates that the activation of a mechanically weak misoriented phyllosilicate-rich foliation must be considered not only possible, but even more probable than the development of new Andersonian conjugate sets of strong faults. This quantitative modelling is confirmed by the field observation that, where faulting develops along a phyllosilicate-rich foliation, almost no classical Andersonian faults can be found.

To characterize the micro-scale deformation processes associated with this macroscopic mechanical anisotropy, we have investigated the progressive development of an interconnected network of shear cracks and micro-faults, lined by ultra-thin cataclasites seams, developed along weak phyllosilicate layers in fault rocks from gneissic mylonitic protoliths along the Simplon Fault and the Periadriatic Fault System (Central Alps). The fault rocks developed under P, T conditions where quartz and feldspars deformed in a brittle way and underwent extensive fracturing. The fractures are coated by chlorite and muscovite, and the mica-rich layers define an SCC’ fabric in the fault rock. It is proposed that frictional sliding along the interconnected layers of micas accommodated large part of the deformation. Fracturing of the stronger phases eventually resulted in a through-going weak interconnected network, capable of influencing the macroscopic properties of these rocks.