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Aseismic creep of mafic fault rocks - an experimental study on the mechanical behaviour of deep-seated faults

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In order to gain more information about the mechanical behaviour of fault zones at deeper crustal levels, we performed experiments on gouge material with a mafic composition at different confining pressures (Pc), temperatures (T) and aseismic but ‘fast’ displacement rates. Shear-experiments are performed on a tri-axial Griggs-type deformation apparatus with solid confining medium, at Pc = 0.5 GPa and 1 GPa, T between 300˚C and 700˚C and at constant displacement rates of 10^{-8} ms^{-1} and 10^{-7} ms^{-1}. To simulate the fault gouge we use a natural diabase (composed of $\sim$ 57% Plagioclase, 41% Pyroxene, 2% accessories), crushed and sieved to a grain size of $<125\mu$m. 0.18 wt% H_2O is added.

The mechanical data show that fault rocks at depth can be strong and are able to deform at high displacement rates without abrupt failure (bulk shear strain up to $\gamma = 4$). The strength of the fault rock shows a negative T dependence and a positive P dependence. This is interpreted that both, brittle (pressure sensitive) and viscous (temperature sensitive) deformation mechanisms are acting and determine the rheology.

All samples develop a foliation due to pervasive fracturing, shearing and rotation of fragments. Foliation is either cross-cut by discrete shear fractures or deflected by slip zones (SLZs), both in synthetic shear orientation. SLZs have a thickness between 5 and 40 μm and are characterized by a strong decrease in grain size, compositional banding, flow structures and high strain accumulation. Most of the strain in the samples is accommodated by an interconnected fault system composed of SLZs and shear fractures. Due to the localization of strain in the small volume of SLZs, the strain rate within them is at least 10x higher than the bulk strain rate.

At Pc = 1 GPa, SLZs tend to become thinner and at T = 700˚C, Pc = 1 GPa, their characteristics change: SLZs become shorter, more distributed and inclined at a lower angle with respect to the shear zone boundaries.

So far no evidence of any significant contribution of crystal plastic deformation is observed. Brittle mechanisms dominate the microstructure. However, for experiments at T>500˚C, abundant pore trails and the growth of fibres indicate that solution mass transfer processes are taking place.

The deformation mechanism within the SLZs is not yet understood. Flow-structures within SLZs could indicate a viscous deformation mechanism, which would also explain the negative T dependence of the fault rock strength.