Numerical modelling of shear localisation in anisotropic materials

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Localisation of ductile deformation in rocks is commonly found at all scales from crustal shear zones down to grain scale shear bands. Of the various mechanisms for localisation, mechanical anisotropy has received relatively little attention, especially in numerical modelling. Mechanical anisotropy can emerge due to dislocation slip-system activity of minerals (e.g. ice or mica) and/or layering in rocks (e.g. bedding, cleavage). Here we present a series of numerical simulations, which aim to quantify the amount of strain (rate) localisation as a function of anisotropy. We use a Viscoplastic Full-Field Transform (VPFFT) crystal plasticity code (Lebensohn, 2001) coupled with the multipurpose modelling platform ELLE (Griera et al., 2013; Llorens et al., 2016; http://elle.ws) to simulate simple shear deformation of a monophasic, intrinsically anisotropic material that has power-law rheology. The VPFFT-approach simulates viscoplastic deformation by dislocation glide, taking into account the different available slip systems and their critical resolved shear stresses (τ). We varied the intensity of anisotropy, which is defined as A = τ(non-basal)/τ(basal), and is set to 1 (effectively isotropic), 4, 16 and 64 (highly anisotropic). Localisation of strain rate in narrow shear bands occurs, depending on the magnitude of anisotropy (A). At high anisotropy values, strain-rate frequency distributions become approximately log-normal with heavy, exponential tails. Heavy-tailed frequency distributions emphasize the continuous character of strain rates. Although strain-rate and finite strain distribution suggests the presence of distinct shear bands, the results indicate there is actually no sharp distinction between low and high-strain rates, but instead a continuum. When plotting stresses against strain rates (for each point on the model grid) these plot as cloud, which spreads with increasing A. Both stresses and strain rates become increasingly variable. Although the published range of strain localisation mechanisms can all operate in rocks, we show that anisotropy is an effective additional mechanism. Localisation due to anisotropy is scale-independent and thus provides a single mechanism for a self-organized hierarchy of shear bands and zones from the mm- to km-scale.

References

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