# Influence of initial preferred orientations on strain localisation in non-linear viscous anisotropic materials

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## 1. Motivation

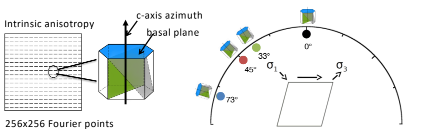
Deformation localisation can lead to a variety of structures, such as shear zones and shear bands (from grain to crustal scale), from isolated zones to anastomosing networks. The heterogeneous strain field can furthermore result in a wide range of highly diverse fold geometries.

In anisotropic materials the deformation behaviour is controlled by the viscoplastic anisotropy of the material and their ability to form a crystallographic preferred orientation (CPO).

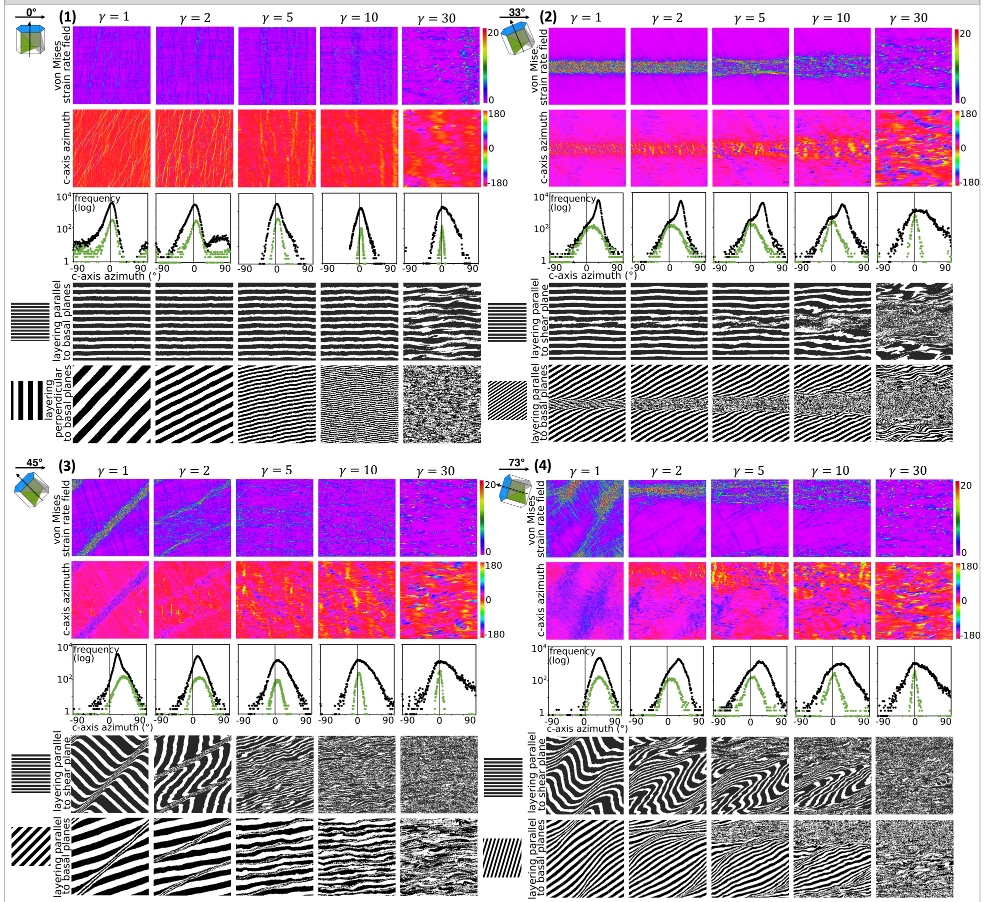
Here we present a selection of a series of numerical simulations which aim to investigate (1) the influence of an initial CPO in an anisotropic material on localization behaviour and (2) the role of layering/passive markers on the development of deformation structures.

## 2. Methods

We present a series of numerical simulations of the deformation of an intrinsically anisotropic non-linear viscous material with a single maximum crystal preferred orientation (CPO) in dextral simple shear. We use the Viscoplastic Full-Field Transform (VPFFT) crystal plasticity code (e.g. Lebensohn & Rollett, 2020) coupled with the modelling platform ELLE (http://elle.ws) to achieve very high strains. The VPFFT-approach simulates viscoplastic deformation by dislocation glide, taking into account the different available slip systems and their critical resolved shear stresses. The approach is well suited for strongly non-linear anisotropic materials (de Riese et al., 2019). Here we use a material with a high anisotropy (according to the relative critical resolved shear stress required to activate the different slip systems: $A = \frac{\tau_{(non-basal)}}{\tau_{(basal)}} = 64$) and an initial single maximum orientation for which we vary the orientation from -90° to 90°, with a noise of +-5°. Here we show four examples which are representative for the different groups of behaviour. To visualise deformation structures, we use passive markers on top of our model, for which we also vary the initial orientation.




## 3. Modelling results




Depending on the initial CPO, four groups can be distinguished:

(1) Distributed localisation, with the development of conjugate high strain rate zones.

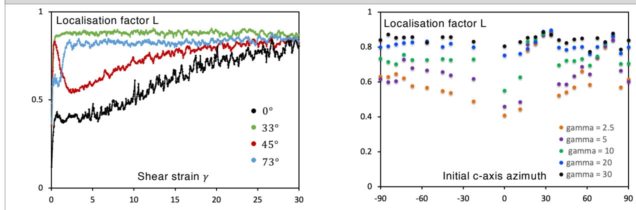
(2) Development of a synthetic shear zone. With ongoing deformation the zone widens, until it collapses. With an initial passive layering parallel to the (initial) basal plane orientations the zone becomes apparent after a few steps. With a layering parallel to the shear plane a huge amount of strain is needed until the shear zone can be seen.

(3) Development of a rotating antithetic high strain rate zone, which dissolves after $\gamma = 2$. With passive layers parallel to the initial orientation of basal planes, the rotating shear bands are observable longer in comparison with layers parallel to the shear plane. Folds develop in between the shear bands when layers are parallel to the shear plane.

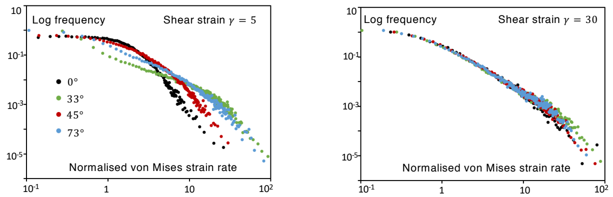
(4) A combination of (2) and (3). During the first steps a rotating shear band develops, afterwards a synthetic shear zone, with lozenges in that part of the model which is not heavily deformed. With layers parallel to the shear plane folds develop. At very high strains the shear zone becomes wider until it collapses.

After a shear strain of $\gamma = 30$ all models reach a similar state, with patches of high von Mises strain rates and basal planes oriented parallel to the shear plane. Shear bands/zones are mostly no longer visible.

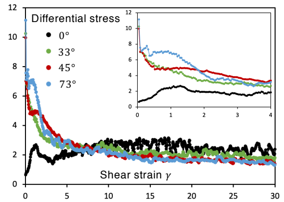
## 4. Data / Statistics




For low strains the localisation behaviour depends on the initial CPO in the material ($L$=0 denotes homogeneous localisation, $L$=1 denotes maximum localisation). After a shear strain of $\gamma = 30$ all simulations reach a consistent state with strong strain rate localisation.




Frequency distributions of normalised von Mises strain rates show variations for low strains. After a shear strain of $\gamma = 30$ all simulations show the same power-law distribution. High von Mises strain rate values become overrepresented, the major part of the material deforms at a lower rate than the mean strain rate.




Depending on the initial c-axis azimuth orientation the stress shows either softening or hardening for low strains. A steady-state situation is reached after a shear strain of $\gamma = 10$.

## 5. Conclusions

At relatively low strains the amount of strain rate localisation and resulting deformation structures depend on the initial single maximum orientation in the anisotropic material. Three regimes can be recognised: distributed shear localisation, synthetic shear bands and antithetic shear bands. However, at very high strains localisation behaviour always tends to converge to a similar state, independent of the initial orientation of the anisotropy.

In rocks, shear localisation is often detected by the deflection and/or folding of layers, which may be parallel to the anisotropy (e.g. cleavage formed by aligned mica), or by deflection/deformation of passive layering, such as original sedimentary layers. The resulting fold patterns vary strongly, depending on the original orientation of the layering relative to the deformation field. This can result in misleading structures that seem to indicate the opposite sense of shear

References:

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