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On the usefulness of sheath folds as kinematic indicators

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Sheath folds are cone-shaped structures that can be found in different rock types. They are mostly associated with shear zones. Even though they are three-dimensional structures they are most commonly recognized in nature in cross sections perpendicular to their stretching direction. These cross-sections exhibit so called eye-structures.
The geometry of sheath folds has been used to deduce kinematic information such as strain, shear sense, and bulk strain type. However, how sheath folds form and how they evolve with increasing strain is still a matter of debate.
We studied the development of sheath folds at the tip of a slip surface (weak inclusion) embedded in a layered matrix subjected to simple shear by means of analytical and experimental modeling. With this combined approach we tested the usefulness of sheath folds as indicators of strain, shear direction and bulk strain type.
The analytical model is three-dimensional and based on an adapted external Eshelby solution. The slip surface is embedded in a homogeneous matrix, which is subjected to simple shear. Layers are introduced as passive markers for the visualization. With this method we tested the influence of the initial slip surface orientation (0°, 90°, or 135° with respect to the shear direction) and the number of layers on the evolving eye-structure. To study the effect of mechanical layering (viscosity contrast, layer thickness) on the geometry of the eye-structures we designed an experimental model using silicones as rock analogues.
Although sheath folds are commonly considered as high strain markers, the analytical model shows that very little strain is needed to produce a sheath fold and the corresponding eye-pattern, and that the minimum strain is mainly dependent on the orientation of the slip surface and the number of layers.
Our analytical as well as the experimental models revealed a sheath fold at both tips of the deformed slip surface. The two sheath folds show opposing closing direction even though they formed under a constant deformation direction. The resulting sheath folds show no limb thickening, which makes them difficult to use as shear sense indicators.
Several studies on sheath folds suggest that the bulk strain type can be obtained by measuring the aspect ratio of the eye pattern. We performed the same measurements on the sheath folds simulated in our analytical and experimental models, in which the strain type was simple shear. The obtained values, however, covered the whole range characteristic for simple shear and pure shear bulk deformation. This procedure thus appears to be not very reliable. In addition, the aspect ratio of the eye-structures seems to be dependent on the layer thickness and the viscosity contrast between the layers.
We conclude that sheath folds, though beautiful structures, are very unreliable kinematic indicators and should only be used with the utmost care.