Sheath folds as late stage flanking structures: analytical models and field observations

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Sheath folds can be described as highly non-cylindrical folds or as cone shaped with a rounded apex. A cross section of a sheath fold perpendicular to its elongation direction shows usually an elliptical shape. Sheath folds can be observed in nature within a wide range of materials and across many orders of size magnitude.
Different initial conditions such as rigid objects and precursor folds formed through buckling were suggested as a trigger for the development of sheath folds. However, in nature sheath folds can also be observed where no rigid objects or precursor folds can be seen. In such cases we propose weak objects or zones (slip surfaces) as possible activators. According to this approach sheath folds represent a late stage of flanking structures. To simulate the weak zone we use an infinitely weak elliptical inclusion embedded in a homogeneous matrix. Planar markers such as bedding or foliation make the sheath geometry visible.
To test the impact of the initial shape of the weak zone on the formation of the sheath folds the aspect ratio of the slip ellipse is changed systematically. The ellipse shows an initial orientation with respect to the simple shear direction of either 45 degrees or 135 degrees. As the geometry of sheath folds is truly three dimensional we use a 3D analytical model to investigate their formation. The model is based on an adapted internal and external Eshelby solution (Eshelby, Proceedings of the Royal Society of London series A-Mathematical and Physical Sciences, 1957 and 1959) for viscous rheologies and elliptical inclusions described in Exner and Dabrowski (Journal of Structural Geology, 2010 (submitted)). The ellipse as well as the matrix has linear viscous, isotropic, incompressible material properties. To analyze the cross-section the calculated folds are cut perpendicular to the simple shear stretching direction while the base and the nose of the fold are avoided. We cut the folds systematically in different places and classify them based on the Alsop and Holdsworth scheme (Journal of Structural Geology, 2006).
The modeled results are then compared to field observations of sheath folds in the large scale shear zone of the Nordfjord-Sogn Detachment, western Norway, where the relation of the sheath folds and slip surfaces can be observed.