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What can asymmetry tell us? Investigation of asymmetric versus symmetric pinch and swell structures in nature and simulation

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Pinch and swell structures occur from microscopic to landscape scales where a more competent layer in a weaker matrix is deformed by pure shear, often in rifting environments. The Anita Shear Zone (ASZ) in Fiordland, New Zealand has an example of landscape scale (1 km width) asymmetric pinch and swell structures developed in ultramafic rocks. Field work suggests that the asymmetry is a result of variations in the surrounding 'matrix' flow properties as the ultramafic band is surrounded to the east by an orthogneiss (Milford Orthogneiss) and to the west by a paragneiss (Thurso Paragneiss). In addition, there is a narrow and a much wider shear zone between the ultramafics and the orthogneiss and paragneiss, respectively. Detailed EBSD analysis of samples from a traverse across the pinch and swell structure indicate the ultramafics in the shear zone on the orthogneiss side have larger grain size than the ultramafics in the shear zone on the paragneiss side. Ultramafic samples from the highly strained paragneiss and orthogneiss shear zones show dislocation creep behaviour, and, on the paragneiss side, also significant deformation by grain boundary sliding.

To test if asymmetry of pinch and swell structures can be used to derive the rheological properties of not only the pinch and swell lithologies, but also of the matrix, numerical simulations were performed. Numerical modelling of pure shear (extension) was undertaken with (I) initially three layers and then (II) five layers by adding soft high strain zones on both sides of the rheological hard layer. The matrix was given first symmetric, then asymmetric viscosity. Matrix viscosity was found to impact the formation of pinch and swell structures with the weaker layer causing increased tortuosity of the competent layer edge due to increased local differential stress. Results highlight that local, rheologically soft layers and the relative viscosity of matrix both impact significantly the shape and symmetry of developing pinch and swell structures.