Review on Symmetric Structures in Ductile Shear Zones

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Ductile shear zones may consist of symmetric augen, lenticular mineral fish, clasts with or without mantles/wings/tails, lozenges, boudins, veins and folds in a wide range of rock types. Symmetric augen, clasts, lozenges and boudinaged clasts can have a number of shapes such as lenticular, sub-circular, euhedral, rectangular, rhombic, squarish etc. Augen can have syntectonic or postectonic growth, can act as a porphyroblast or even a porphyroclast, may have magmatic origin, and might be defined by more competent minerals. More competent minerals such as hornblende over feldspar develop naked clasts more feasibly. Separate analogue- and numerical modeling and microstructural observations indicate that the degree of symmetry and geometry of clast and mantle depends on *(i)* the flow pattern developed within the matrix; *(ii)* matrix rheology: whether Newtonian or non-Newtonian; *(iii)* rheological contrast between the clasts and the matrix; *(iv)* degree of slip of clasts within the matrix; *(v)* variation of rate of shear across shear zone; (vi) deformation temperature; and *(vii)* shear intensity. For example, winged clasts form when the mantle and the matrix are of nearly the same competency. Coiled mantles develop in more viscous media. However, how all the seven constraints can govern the shape asymmetry of clasts simultaneously is not known. Additionally, the mantle/wing geometry is primarily controlled by *(i)* the initial aspect ratio of the clast; *(ii)* rate of fall of clast size; *(iii)* ratio of simple- to pure shear; and *(iv)* relative rates of crystallization and strain. Recrystallization of clasts can supply materials for mantle and help transform a delta structure into a phi structure, and then into a sigma structure. A slow recrystallization rate, on the other hand, can produce a theta structure. Pure shear can produce symmetric pressure shadows, -fringes and augen. Lower curvature of tails can indicate a pure shear. Symmetric lozenges form for certain angular relation between shear zone and planes of anisotropy in rocks, and that between cross-cutting shear zones. Ductile shear sense might still be deduced from symmetric clasts by noting either any quarter fold of matrix foliation formed around clasts, or sigmoidal nature of the inclusion pattern (S-internal) inside them. Extension of a non-Newtonian matrix with Non-Newtonian clasts embedded develops symmetric necking around clasts. Asymmetry develops upon intense extension. Near symmetric bone-shaped boudins might be produced by rotation of veins. Pure shear can produce highly convex bulging symmetric boudins. False/pseudo boudins may be symmetric and lenticular. Orthorhombic symmetric boudins produce by no slip of inter-boudin surfaces. Unlike clasts, matrix rheology may not decide geometry of all kinds of (foliation) boudins. Extensional stress parallel to foliation planes can develop symmetric pinch and swell structures, and compressional stress symmetric folds. Parasitic folds of a lower order fold not affected by ductile shear are symmetric Newtonian viscous layer under pure shear within a non-Newtonian matrix may form symmetric folds. Post-tectonic veins cutting across main foliations (primary shear C-planes) and do not give shear sense. Natural examples of symmetric objects from Himalayan ductile shear zones show internal foliations inside augen concordant with the matrix foliation. Symmetric lenticular objects with high aspect ratios might indicate pronounced ductile shear and might have a previous asymmetric shape. Tails of centrally pinched augen indicate a pure shear component, whihc has been deduced from Greater Himalayan Crystallines by previous workers.