



Development of interconnected fine-grained polyphase networks during progressive exhumation of a shear zone

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Present exposure of the ductile Caledonian retrowedge in northwestern Scotland records the evolution of a shear zone that was exhuming while actively deforming, providing a natural laboratory to study strain localization in a progressively cooling system. Examination of rocks from two detailed transects across this region consistently show a transition from microstructures that are dominated by interconnected phyllosilicate networks in a quartz-rich matrix with feldspar porphyroclasts, to interconnected fine-grained regions of mixed quartz + phyllosilicate + feldspar. These polyphase regions are demonstrably weaker than surrounding quartz layers and likely deform by grain-size sensitive mechanisms including diffusion-accommodated grain boundary sliding.

Microstructures characterized by a quartz-rich matrix and interconnected phyllosilicates undergo quartz recrystallization by high temperature grain boundary migration and are dominated by prism a slip. In contrast, fine-grained polyphase microstructures record quartz recrystallization dominated by subgrain rotation and activation of rhomb a and basal a slip systems. We propose transient hardening occurs in quartz-dominated regions as quartz with a strong Y-axis maximum undergoes the switch from prism a easy slip to basal a easy slip during cooling, and thus partitions strain into interconnected phyllosilicate layers. In response, interconnected phyllosilicate layers undergo mechanical comminution, becoming increasingly mixed by grain-size sensitive creep processes to form polyphase layers as they accommodate an increased proportion of strain. This transition from quartz-rich matrix with phyllosilicate interconnected weak layers to fine-grained, polyphase weak layers could be of first-order importance in strain localization within polyphase mylonitic and ultramylonitic rocks.