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Grain Boundary Structure Control on Fluid Transport, Deformation Mechanisms and Fabrics in Calcite Deformed at Low Temperature

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Limestones from the Tuscan Nappe sequence, northern Apennines, Italy, have been deformed during crustal thickening at temperatures less than 250°C. As part of this deformation, bedding-parallel shear zones have formed within two distinct protoliths: (1) very fine-grained (< 5μm) micritic calcite (with some veins) that comprises the host material and (2) initially coarse-grained vein calcite. Evolution of the shear zones produced extreme grain size reduction in the vein calcite such that at high strains, the grain size distribution and microstructure of host micrite and deformed vein calcite is essentially the same. Although vein calcite in the micrite experiences similar microstructural changes to that of the vein hosted shear zone, indicative of similar deformation conditions, the grain size of the deformed micrite is comparable or slightly larger than the starting material. In terms of the mechanical and microstructural changes, the variation in initial grain size would, at first blush, be the dominating factor. Although, in the end-state, the two initially distinct calcites are microstructurally similar, they none the less exhibit contrasting crystallographic fabrics and chemical signatures. The micrite shear zone, despite a well-developed SPO, exhibits no CPO, while the vein-hosted shear zone has an intense CPO irrespective of SPO development. Likewise, micrite shear zones exhibit extreme Sr depletion relative to adjacent undeformed layers.

Throughout the evolution of the shear zones, grain boundaries in each calcite type exhibit, and maintain, contrasting structures. Micrite grain boundaries are heavily decorated with voids and tubules indicative of fluid transport and interaction; this can explain the selective chemical depletion in these shear zones, and inferred activity of grain-size-sensitive flow processes. In contradistinction to the micrite, recrystallized vein calcite has ‘tight’, clean grain boundaries effectively bereft of inclusions. The latter is consistent with a more quasi-uniform deformation in which macroscopic and grain-scale dislocation-mediated dominates. Examination of these two calcite types demonstrates that microstructural similitude at high strain may not be sufficient to infer comparable rheological response; instead, differences in initial defect substructure, in this case grain boundary structure, constrain the micromechanical behaviour as deformation accumulates.