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Phase mixing and the spatial distribution of material heterogeneities in a crustal fault zone: Insights from New Zealand's Alpine Fault

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Large-scale continental faults represent zones of inherent weakness and focused deformation in the crust. Heterogeneities in fault zone rocks, such as grain-boundary pores, fine-grained secondary phases, and fluid inclusions can provide nucleation points for deformation instabilities, which are required for strain localisation. However, these heterogeneities are not uniformly distributed at any scale within fault zones. Therefore, a systematic characterisation of the nature and distribution of fault rock heterogeneities will improve our understanding of the mechanisms of strain localisation and fault zone dynamics.

The Alpine Fault is the main Pacific-Australian plate-boundary structure on the South Island of New Zealand, with rapidly exhumed hangingwall mylonite and cataclasite sequences that are equivalent to the fault rocks currently deforming at depth. We have sampled across the ductile strain gradient of the Alpine Fault zone to examine how microstructures and material heterogeneities evolve with increasing strain. Synchrotron micro-computed x-ray tomography (Sμ-CT), electron microprobe analyses (EPMA), and scanning electron microscopy (SEM) imaging reveal that at lower strains, pure quartz domains are common and grain-boundary pores are concentrated on monophase quartz boundaries, while with increasing strain phase mixing is more prominent and pores are progressively found on boundaries between different phases. Electron backscatter diffraction (EBSD) is used to evaluate the evolution of fabric anisotropy, such as crystallographic preferred orientations (CPO) across the strain gradient. Using both the J-index and M-index to quantify quartz CPO strength, we find a decrease in the CPO intensity with increasing strain in polyphase rocks. We infer this is due to a switch in the dominant deformation mechanism associated with increased phase mixing. Here we explore the relationship between phase mixing, microstructural evolution, and the spatial distribution of material heterogeneities with increasing strain, and the overall affect this has on strain localisation in the Alpine Fault.