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Understanding deformation behavior of lower crustal rocks from experimentally deformed metapelitic aggregate: an EBSD-based approach

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Partial melting of metapelites at high-P and high-T conditions typical of lower crustal levels is a well-known phenomenon. Its role in strain localization – both at micro- and regional scale – and subsequent rheological weakening of rocks have been widely investigated. Previous researchers have also explored the influence of such melt networks on the variation of the dominant phases' active deformation processes – especially quartz – over the entire range of tectono-thermal evolution of the rock. However, mechanisms driving the deformation of the phases crystallized in-situ from the melt has so far been largely overlooked.

In this work, we focus on the deformation behavior of the in-situ crystallized phases with increasing shear strain. In that pursuit, we took a quartz-muscovite mixture (dry) that was initially cold pressed at 200 MPa, followed by hot pressing at 160 MPa and 580 °C to obtain an analogue of pelite. The cylindrical sample was then experimentally deformed in a Patterson-type apparatus under a finite shear strain (γ) of 15.0 at 750 °C, a confining pressure of 300 MPa, and constant shear strain rate ($3 \times 10^{-4} s^{-1}$). Subsequently, a longitudinal axial section was cut and was examined using electron backscattered diffraction (EBSD).

The initial minerals, quartz (Qtz) and muscovite (Ms), underwent deformation and reacted to produce K-Feldspar (Kfs), Mullite (Mul), Cordierite (Crd), Ilmenite (Ilm), and Biotite (Bt). The Qtz grains show limited evidence of dynamic recrystallization. Ms, on the other hand, exhibit strong crystal preferred orientations (CPO). The J-Indices of both Qtz and Ms increase with shear strain (from the center to the edge of the cylinder). Among the reaction products, Kfs (maximum in volume) show weak CPO throughout, similar to Qtz. The maxima of [001] plot near parallel to the shear direction in the pole figures for all values of γ. The rest of the phases show strong CPOs. The J-Index of Crd and Mul increase with shear strain, whereas that of Ms and Kfs increase till γ = 7 and fall at higher strains. Neighbor-pair misorientation axes for Crd, Ilm, and Kfs, corresponding to the high-angle boundaries (HAGBs), are randomly oriented, implying 'rigid grain rotation,' which could also be responsible for the lower [001] pole figure intensities. Overall, with increasing shear strain, the number of HAGBs decreases. The corresponding misorientation axes exhibit stronger preferred alignment, probably signifying restricted rotation with progressive melt crystallization.

Although the area-equivalent diameters for all the melt-crystallized phases are nearly close (RMS: 1.5 – 2 μm), the Kfs CPOs are considerably weaker than the rest. This possibly affirms the dominance of fluid/melt in triggering diffusion creep and grain boundary sliding over grain size.