

Rheological transition during large strain deformation of melting and crystallizing metapelites

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Torsion experiments (strain-rate = $3 \times 10^{-4} \text{s}^{-1}$) were performed to investigate the large strain (γ 15) rheology on quartz-muscovite aggregate as analogue to pelitic rocks undergoing melting and crystallization during deformation at 300 MPa confining pressure and 750 °C temperature. Microstructures reveal four distinct but gradational stages of crystal-melt interactions during deformation ; (a) solid state deformation, (b) initiation and domination of partial melting, (c) simultaneous partial melting and crystallization, and (d) domination of crystallization. The microstructural stages are linked to the rheology of the deforming samples. Partial melting starts at relatively low finite shear strains ($\gamma=1$ to 3) showing approximately 60% strain softening. At $\gamma=4$ to 10 the partially molten bulk material shows a steady state flow at low stress. Further crystallization of new crystals at the expense of melt between $\gamma = 10$ and 15 causes weak strain hardening until the material fails by developing brittle fractures. The stress exponent (n), calculated at $\gamma = 1, 5,$ and 10, increases from ~ 3 to ~ 43 , indicating a transition from power to power law breakdown or exponential flow of the bulk system. Hydrostatic experiments for equivalent times and conditions of the torsion experiments were also conducted to evaluate the reaction kinetics and microstructures under static conditions. The new experimental data establish that partially molten rock does not flow according to a constant strain rate-dependent power law (steady state) rheology. The rheological transition from strain rate sensitive to strain rate insensitive flow is interpreted as a function of melt-crystal ratio, their mutual interactions, and the evolution of microstructures in the partially molten rock. EBSD measurements reveal weak crystal preferred orientations, which are different for each mineral.

Keywords: Rheology, Deformation, Melting, Crystallization, Crystal preferred orientation, Localization