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Partial melting in pelitic rock under shear deformation

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We describe the mechanism of strain localization, coupled with the process of melt segregation in partially molten metapelitic rocks. Torsion experiments were performed on very fine grained aggregates of muscovite and quartz (respectively 0.3 and 0.7 by volume) at T = 750° C, P = 300 MPa, and a constant shear strain rate of 3x10-4 s-1 for finite shear strains ranging from 0.5 to 5.0. We also ran static experiments on the same materials under the same P and T conditions with durations as in the dynamic experiments (1, 2 and 5 hours). The starting material was developed by first uni-axial pressing of the powder material at 200 MPa at room temperature and then by hot isostatic pressing at P = 160 MPa and T = 580° C for 6 hours. The samples had a porosity of about 17-20% and a strong foliation defined by muscovite shape orientation. In the torsion experiments, cylindrical samples (10mm diameter) were used with the foliation parallel to the cylinder axis. The stress vs. strain relation of the deformed material showed initially a steep hardening stage (peak stress 120 MPa) after the yield (70 MPa). The deformation then follows a sharp linear strain weakening, and steady state flow at significantly low shear stress (15 MPa). In the samples with foliation parallel to the cylinder axis, at low shear (shear strain = 0.5 - 1.0) the foliations rotated about 25° towards the direction of shear and long muscovite grains were boudinaged across the extension direction. At shear strain = 1.5, the shear localization was first observed in brittle-ductile mode at very low angles (20-22°) to the bulk shear plane. With progressive shearing, the fractures dilated across their width and developed a discreet damage zone. Melting of quartz and muscovite appeared only after shear strain = 2, where melts began to be accumulated in the dilated damage zones. Comparison between the static and dynamic experiments suggests that melting is greatly enhanced by the dynamic condition. When extrapolated to nature, the deformation-enhanced melting noticed in our experiments might explain rapid segregation of melts, forming large S-type plutons, as observed in many tectonic belts, e.g. the Himalaya.