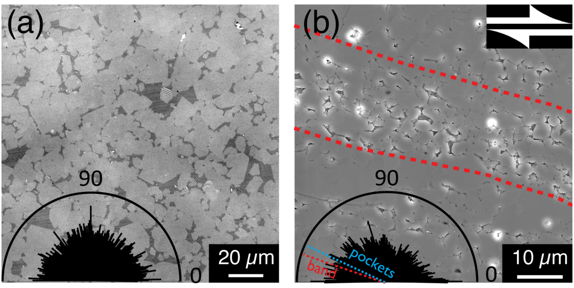
Influence of stress on melt topology in viscously deforming, partially molten rocks

D.L. KOHLSTEDT[1]*, M. PEC[1] AND B.K. HOLTZMAN[2]

[1]Earth Sciences, University of Minnesota, Minneapolis, MN 55455 (*dlkohl@umn.edu, mpec@umn.edu)

[2]Lamont-Doherty Earth Observatory, Columbia University, Palisades NY 10964 (holtzman.ben@gmail.com)

Deviatoric stress profoundly influences the distribution of melt in viscously deforming, partially molten rocks. Prior to deformation of an olivine-rich rock, basaltic melt forms an interconnected network primarily along grain edges (triple junctions), representing the equilibrium microstructure as determined by minimization of interfacial energy. In addition, melt wets a small fraction of the grain boundaries due to anisotropy in the solid-melt interfacial energy. With the application of a non-hydrostatic stress, melt quickly redistributes at the grain scale, introducing a pronounced melt preferred orientation. Melt pockets align with their long axes ~20° to the maximum principal stress in triaxial compression experiments and at ~25° to the shear plane, antithetic to the shear direction in shear experiments. This stress-induced, grain-scale alignment of melt produces an anisotropy in rock viscosity. In response, melt redistributes over distances greater than the grain scale. Two types of redistribution occur. First, in torsion experiments, a diffuse migration of melt occurs from the outer radius toward the axial center of the sample. Second, in simple shear and torsion experiments, melt spontaneously segregates into melt-enriched bands spaced at distances smaller than compaction length. In Earth's upper mantle, these bands act as high-permeability pathways for rapid melt transport and zones of weakness for localizing deformation. Once formed, melt-enriched bands thicker than ~10 m will not be destroyed by surface tension driven flow in times <150 My even if the stress state becomes hydrostatic. However, the melt pockets within the bands will quickly adjust to the equilibrium microstructure.



Melt distribution in (a) annealed and (b) sheared samples.