Melt localization and the rheology of the partially molten mantle under shear

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The emergence of patterns of melt distribution in experiments on partially molten aggregates under simple shear (8, 3) provide a rare opportunity to test magma migration theory (5, 6, 7) by directly comparing experiments and calculations. The fundamental observation is the emergence and persistence to large strains of bands of high porosity and concentrated deformation oriented at about 15-25° to the plane of shear (4). We report results from linear analysis and numerical solutions that suggest that band angle in experiments is controlled by a balance between porosity and strain rate-weakening mechanisms. Lower angles are predicted for stronger strain rate-weakening. For the specific model considered here, a power-law stress-dependent rheology, calculations with $n \approx 6$ are consistent with the observations. These results suggest that partially molten aggregates deforming under shear may have a greater sensitivity to strain rate than previously believed (1, 2).

References:

(1) G. Hirth and D.L. Kohlstedt. Experimental constraints on the dynamics of the partially molten upper mantle: 1. Deformation in the diffusion creep regime. J. Geophys. Res., 100(2):1981–2002, 1995.

(2) G. Hirth and D.L. Kohlstedt. Experimental constraints on the dynamics of the partially molten upper mantle 2. Deformation in the dislocation creep regime. J. Geophys. Res., 100(8):15441–15052, 1995.

(3) B.K. Holtzman, N.J. Groebner, M.E. Zimmerman, S.B. Ginsberg, and D.L. Kohlstedt. Stress-driven melt segregation in partially molten rocks. Geochem. Geophys. Geosyst., 4, 2003. Art. No. 8607.

(4) B.K. Holtzman, D. L. Kohlstedt, and J. Phipps Morgan. Viscous energy dissipation and strain partitioning in partially molten rocks. J. Petrol., 2005. In press.

(5) D. McKenzie. The generation and compaction of partially molten rock. J. Petrol., 25(3):713–765, 1984.

(6) M. Spiegelman. Linear analysis of melt band formation by simple shear. Geochem. Geophys. Geosys., 4(9), 2003. article 8615, doi:10.1029/2002GC000499.

(7) D.J. Stevenson. Spontaneous small-scale melt segregation in partial melts undergoing deformation. Geophys. Res. Letts., 16(9):1067–1070, 1989.

(8) M.E. Zimmerman, S.Q. Zhang, D.L. Kohlstedt, and S. Karato. Melt distribution in mantle rocks deformed in shear. Geophys. Res. Letts., 26(10):1505–1508, 1999.