Melting and compaction in deformable two-phase media

Ondřej Šrámek[1], **Yanick Ricard**[2] **and David Bercovici**[1]

[1] *Department of Geology and Geophysics, Yale University, USA*
[2] *Laboratoire de Sciences de la Terre, CNRS UMR 5570, Lyon, France*

Melt generation and extraction are often modeled using the two-phase equations developed by McKenzie (1984) or Scott & Stevenson (1984). Usually various approximations are made to simplify the problem which may lead to some unphysical results. We present a generalized version of the set of equations introduced by Bercovici *et al.* (2001) that allows for mass transfer between the two phases and consider a self-consistent set of equations. In our description the two phases are submitted to different pressure fields whose difference is related to the surface tension at the interfaces, to the changes in porosity and to the melting rate. A kinetic relation for the melting rate arises from the second law of thermodynamics. The condition of chemical equilibrium corresponds to the usual univariant equality of the chemical potentials of each phase when the matrix and melt are motionless. In the most general form, the Gibbs-Thomson effect comes out naturally from thermodynamic equilibrium considerations. We apply these new equations to a steady state problem of pressure release of a univariant system. We treat melting and compaction simultaneously and we observe several new effects and several possible boundary layers near the onset of melting. A consequence of matrix compaction (dilation) is a pressure difference between melt and solid which favors (inhibits) melting. Melting is favored when the extraction of melt from the matrix is efficient, *i.e.* when the Darcy velocity is larger then the initial upwelling velocity of the solid matrix. For parameters corresponding to pressure release melting under mid ocean ridges melting is favored and could start at most $\sim 2\,\mathrm{km}$ below the standard solidus. Numerical results suggest that the movement of melt and matrix should be close to the Darcy equilibrium where the buoyancy of melt is equilibrated by the mechanical interaction between the phases. The Darcy equilibrium follows an initial stage where the matrix viscous stresses balance the Darcy friction. In all situations the steady state porosity profile remains a monotonous function of depth. The existence of a compaction layer following a melting zone where the porosity is maximum as described in various earlier publications has never been found.

References:

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