Melt segregation and textural evolution of partially molten system

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Partially molten state is one of the most typical examples which exhibit self-organized behavior in complex composite system. Tiny fluctuation in composition, temperature and stress fields leads drastic change in the internal structure, which in turn could modify composition, temperature and stress fields. The essential part of this system is fragile nature of the internal structure with respect to the external forcings. When partially molten system is considered in terms of packing state, three kinds of packing fraction of the solid phase characterize the system into 4 states; Fl, the loose packing fraction, Fc, the close packing fraction and Fp, the percolation threshold packing fraction. Below Fl solid phase looses continuous connection and only the melt phase is continuous. This state is called suspension state. The viscosity is mostly dominated by the melt phase. Between Fl and Fc both solid and liquid phases retain continuous connection and the system has low value of yield strength, which can be called as a fragile partially molten state. The rheological property of this state is complicated. It strongly depends on applied stress, strain rate, type of deformation, and even the history of deformation (memory effect). The solid skeletal frame which supports the externally applied stress can be easily deformed and broken, which results in drastic change of the internal structure. Between Fc and Fp also both phases retain continuous connection but the system has high to infinite yield strength. The solid skeletal frame is hard enough. This state can be called as a hard partially molten state. The rheological property of this state is dominated by that of solid phase modified by melt phase. Above Fp the melt phase looses connectivity. The system behaves as a solid. The most important and interesting state is the fragile partially molten state. Since this state is essentially unstable the life time is short so that temporal and spatial extent of this state should be quite limited. But through this state the system can easily switch between solid-like behavior and liquid-like behavior. The time-, and spatial scale of the formation/destruction of connectivity of solid phase critically controls evolutionary path of partially molten state as well as segregation of melt phase. As for this evolutionary path two representative cases are explained. One is the case for thermo-convective coupling. Ogawa,Yamagishi and Kurita (JGR 2003) modeled melting process of permafrost layer by intrusion of magmatic body in simulation for the water-outbursting phenomena on Mars. Progressive increase of the molten zone by conductive heating results in initiation of permeable convective motion in this zone. Strongly localized heat flux by convection enhances localized melting. This works as a positive feedback; localized convection promotes localized melting and localized melting concentrates and enhances convective flow. Because of this spatial extent of the molten zone is strongly controlled by convective fluid flow. The second example is viscous coupling. Since viscosity depends on the solid phase fraction, heterogeneity in the degree of melting causes heterogeneous distribution of viscosity and yield strength. Under stress-constrained system some parts increases degree of melting and other parts decreases it because of destruction of solid skeletal frame.