What controls passive and active mantle upwelling beneath Mid-Ocean Ridges?

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The basic mechanisms underneath a mid-ocean ridge and the magma generation are reasonably well known: The mantle is passively pulled upwards by the plate divergence and crosses its solidus temperature at 50-100km depth. However, the details of subsequent processes (e.g. melt migration mechanisms or the reason(s?) for melt focusing)remain much less well understood.

Using a newly developed Finite Element Code we reproduce some numerical calculations done in the early Nineties by Turcotte and Phipps Morgan [1992] and conduct several new numerical model runs to explore the structure of ridge upwelling when there is a stratified mantle rheological structure beneath the axis. Calculations including a weak and buoyant asthenosphere layer show a return flow towards the ridge within the lower asthenosphere, which also affects mantle flow and melting processes at the shallow (<100km) level.

By using a modified tracer particle advection scheme, we simulate a number of different mantle components (e.g. peridotite, pyroxenite, etc), which differ in their melting behavior and chemical trace element contents. By tracking geochemical evolution during melting, we calculate synthetic melt compositions that give us additional constraints on our calculations. We also test the influence of mantle heterogeneities of different sizes to gain more insights into the upper mantle composition that melts near a ridge axis. We find that buoyancy forces like melt and Fe-depletion become important if viscosity is lowered to about 10^{18}Pas. Mantle flow then shows a transition from passive to active upwelling.

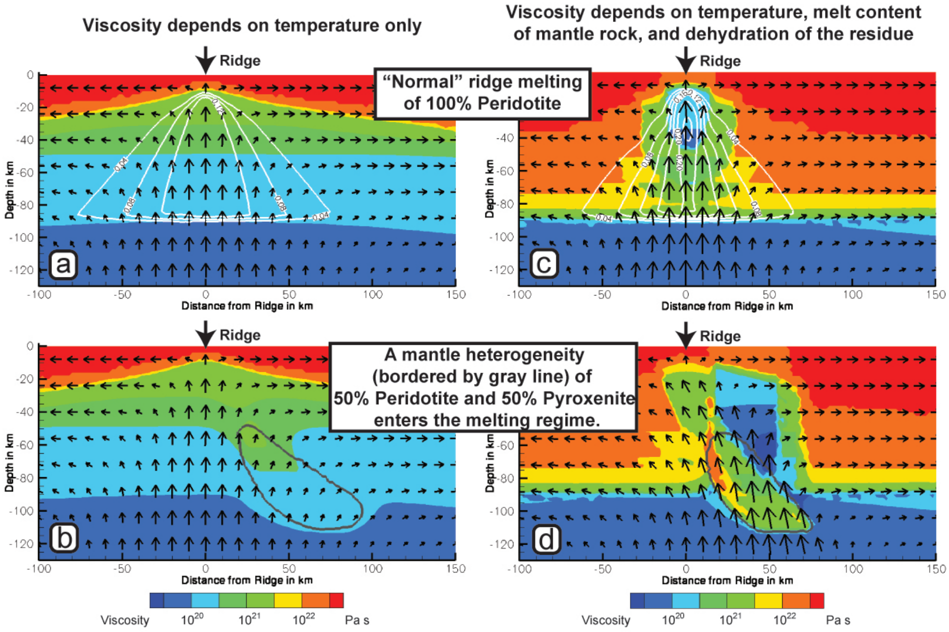

Figure 1: Flow, melting rates (white lines), and viscosity field (colors). Left pictures: Viscosity depends only on temperature. The flow field of a single-component mantle (a) is only slightly affected by the fertile mantle heterogeneity entering the melting zone (b). Right pictures: Viscosity depends also on mantle dehydration and the melt. The melting zone is narrower and bordered by highly viscous mantle (c), faster upwelling leads to higher melting rates. Enhanced off-axis melt production by a fertile mantle heterogeneity (d) weakens the mantle so that the highest upwelling rates are shifted away from the ridge. This may cause the ridge to change its morphology and/or location.