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Numerical modelling of melt segregation during partial melting beneath an oceanic spreading centre: Novel prediction of magmatic cycles.

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The physical processes capable of concentrating melt within the lower part of the partially molten mantle horizon beneath an oceanic spreading centre have been considered using one-dimensional numerical models which take into account the effects of shear segregation during ductile deformation, compaction and liquid-solid surface tension. These models show that when the viscosity of the solid fraction of the mantle is constant, shear segregation is too slow to be a geologically relevant process. However, if, as suggested experimentally, the ductility of the solid fraction of the mantle increases in the presence of interstitial melt, shear segregation is found to develop on time-scales compatible with mantle upwelling. The critical melt fraction at which shear segregation occurs is predicted to be positively correlated with the melt-free viscosity of the mantle, a value of ~5% being typical for simulations run with a melt-free viscosity of 10^18 Pa.s. No characteristic length-scale is found for this segregation, suggesting that melt will tend to concentrate at the length scale at which it is produced (i.e. that of mantle olivine grains). At face value this would imply that shear is not an efficient mechanism to concentrate liquid. However, segregation will occur parallel to the direction of compression, such that towards the bottom of the zone of partial melting beneath an oceanic spreading centre, horizontal veins are expected. Because of the local extraction of the interstitial melt, these horizontal veins will drastically reduce vertical permeability, a fact that will trigger compaction in that direction. In this case, rapid formation of melt-rich horizons approximately one compaction length in height is predicted. High permeability and high melt-free viscosity both act to efficiently drain liquid from throughout the lower region of the melting column leading to the formation of thick widely spaced compaction waves. On the other hand low values of these parameters lead to formation of thin closely spaced horizons derived from locally produced liquids. Liquid contained in these melt-rich horizons will be transported through the uppermost mantle, either in horizontal structures if the viscosity of the mantle is high (>10^19 Pa.s), or rapidly drained towards the surface if the direction of compression rotates vertically, a situation expected if the viscosity of the melt-free mantle is ~10^18 Pa.s. This complex interplay of shear segregation, compaction and regional stress fields may potentially help to explain certain geochemical and petrological features of rocks from mid-ocean ridges and ophiolite complexes, such as the apparent lack of interaction of MORB-like liquids with the uppermost mantle and the planar geometry of dissolution channels observed in ophiolite complexes.