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Modelling komatiitic melt accumulation and segregation in the transition zone

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Komatiites are assumed to be the products of very hot mantle upwellings in the Archean, At such conditions melting of a chondritic mantle will take place deeply within the upper mantle or even within or below the mantle transition zone. Due to its compressibility at such pressures melt might have a higher density than olivine, but remains buoyant with respect to a pyrolitic mantle both above and below the olivine – wadsleyite phase boundary because of the presence of garnet. We study the physics of melting and melt segregation within a hot upwelling mantle flow region passing through the transition zone with particular emphasis on the effect of depth dependent density contrasts between melt and the ambient mantle. Assuming a 1D plume we solve the two-phase flow equations of the melt – matrix system accounting for matrix compaction and porosity dependent shear and bulk viscosity. We assume a constant rising velocity leading to a constant rate of melt generation. In a first model series the level of neutral buoyancy z_neutral is assumed to lie above the depth of onset of melting, i.e. there exists a region where highly dense melt may sink with respect to the rising mantle. Depending on two non-dimensional numbers (accumulation number Ac, retention number Rt) we find four regimes: 1) time-dependent melt accumulation in standing porosity waves which scale with the compaction length, 2) steady state weak melt accumulation near z_neutral , 3) no melt accumulation due to small density contrast, 4) no melt accumulation due to high matrix viscosity. In regime 4 the high mantle viscosity prohibits melt pore space opening and accumulation. In a second series the rising mantle crosses the olivine – wadsleyite phase boundary, which imposes a jump in density contrast between melt and ambient mantle, but melt is always assumed to be buoyant. In this case, a sharp melt fraction contrast forms with high melt fraction immediately above the phase boundary. In a third set of models, a hot 1D plume head is assumed to move through the transition zone. The top of the plume head is assumed to be below the solidus temperature and the melt density is always below the ambient mantle density. In this case melt percolates upwards and accumulates near the top of the plume head into a very thin layer, reaching up to 100% melt fraction. The olivine – wadsleyite boundary has only a very mild effect, and changes the slope of the melt fraction – depth curves only weakly. In conclusion, these models show 1) that not only melt density, but also porosity dependent matrix viscosity controls the melt ascent or accumulation, 2) that there are parameter ranges and physical conditions which may lead to very large melt fractions (> degree of melting), 3) that in spite of melt being denser than olivine at some depth in general these melts escape these regions and continue to percolate upward faster than the rising mantle.