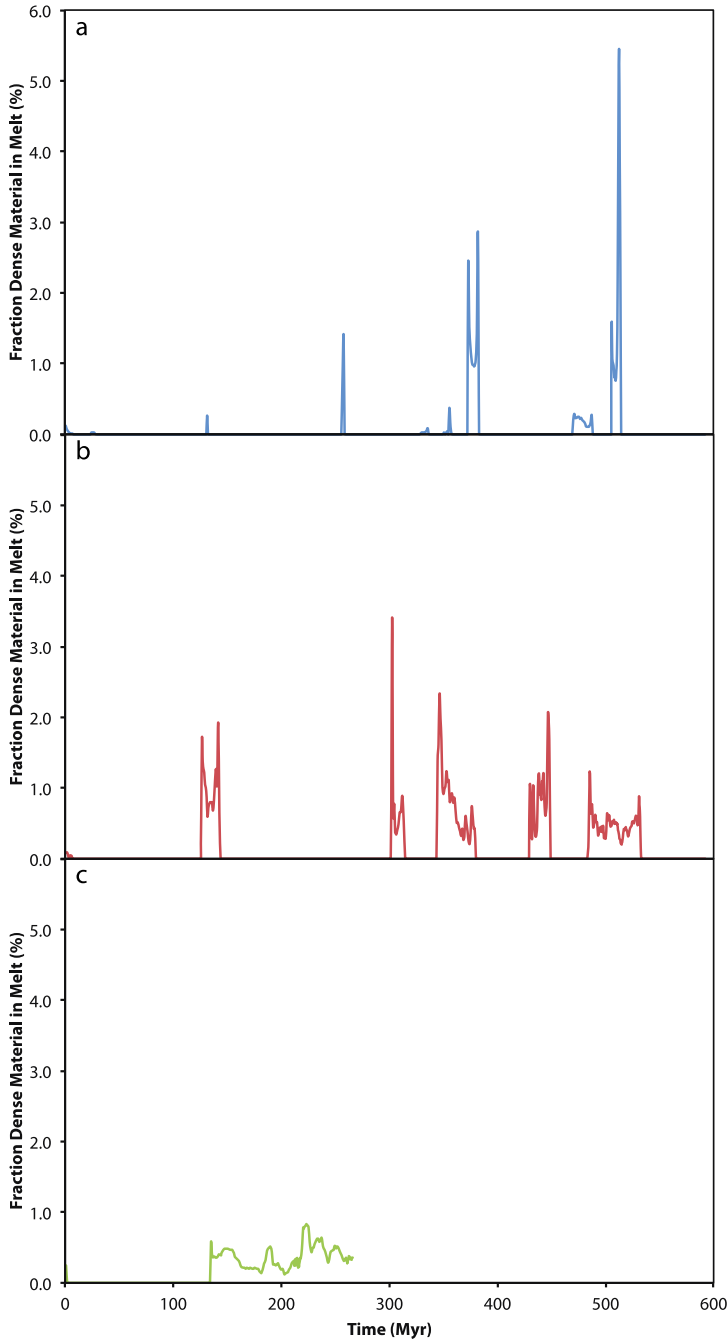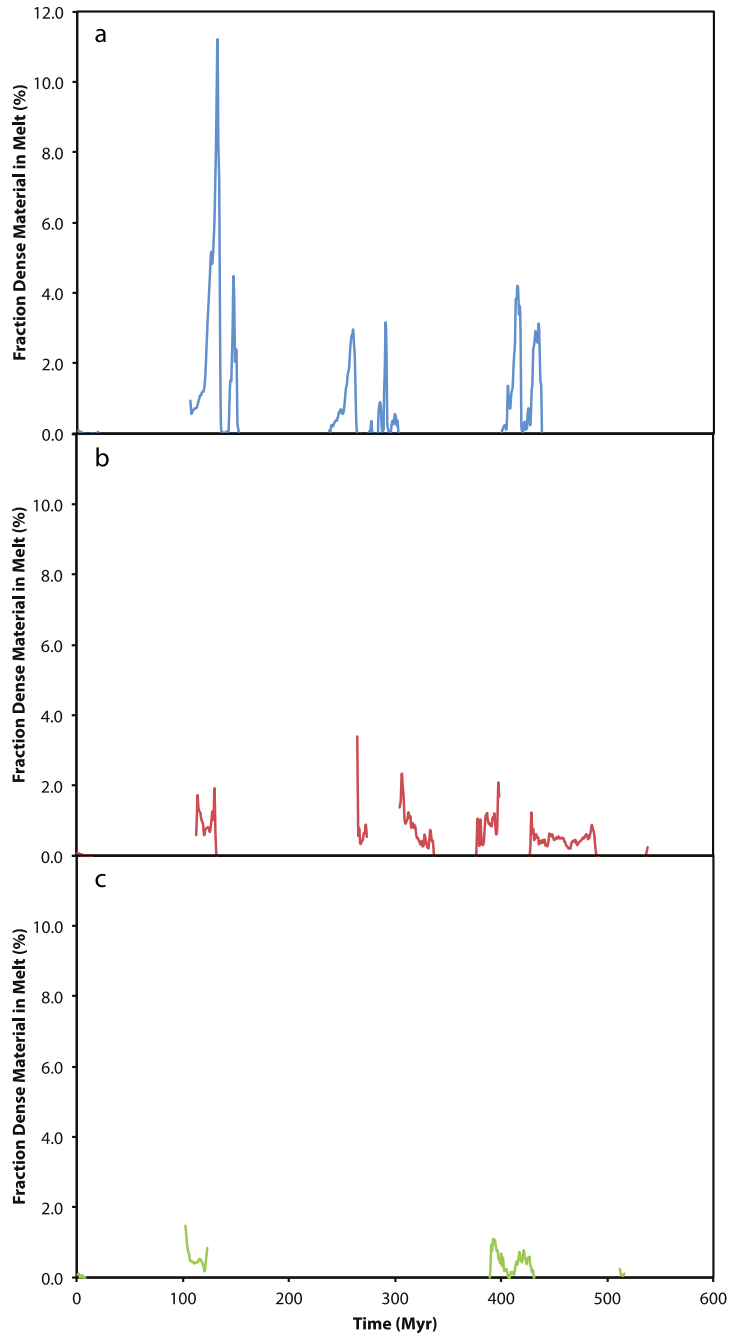**Supplementary Figure 1** Fraction of dense material in melt as a function of potential temperature across the mantle. **a** Temperature difference between hottest and coldest part of mantle is 3000. **b** Temperature difference between hottest and coldest part of mantle is 3500. **c** Temperature difference between hottest and coldest part of mantle is 4000.

Supplementary Figure 2 Fraction of dense material in melt as a function of the activation coefficients associated with the temperature-dependent viscosity across the mantle. **a** Maximum viscosity contrast equals 1,000 times due to temperature. **b** Maximum viscosity contrast equals 10,000 times due to temperature. **c** Maximum viscosity contrast equals 100,000 times due to temperature.

Supplementary Figure 3 Fraction of dense material in melt as a function of the buoyancy number (B) with a potential temperature across the mantle of 3000. **a** Non-dimensional buoyancy number equals 0.7. **b** Non-dimensional buoyancy number equals 0.8. **c** Non-dimensional buoyancy number equals 0.9.