Fate of silicate melts at core-mantle boundary conditions

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The early vision of the mantle crystallizing from the bottom upwards towards the surface has been disputed due to computational data on melt densities supporting crystallization at an intermediate depth and an accumulation of dense melts in the deep mantle. The controversy between the two models arises because the exact nature of the partitioning of iron between solid and liquid phases in the lower mantle remains unclear. In addition, no experimental studies have measured directly the density of melts at the conditions of the deep mantle, even though it is the key parameter controlling the entrainment and/or settling of matter in the deep mantle.

Using a novel approach, we measured the density of $MgSiO_3$ amorphous glass in the small sample environment of the diamond anvil cell up to the core-mantle boundary pressure. We discovered that $MgSiO_3$ glass (300 K) and melt (4000 K) are as dense, within the uncertainties, as their crystalline $MgSiO_3$ Bridgmanite counterpart phases in the lowermost mantle. Our data on $MgSiO_3$ glass and melt provide the first experimental evidence for such high-density melts in the deep mantle.

Taking into account that iron will partition into the melt phase, we conclude that melting in the $MgSiO_3$-$FeSiO_3$ system will produce magmas that are denser than the residual solids, regardless of the exact nature of iron partitioning. This study therefore supports the theory of a deep basal magma ocean concomitant with the late accretion stage of the Earth. Such a magma ocean surrounding the core would be an ideal candidate for storing incompatible elements, thermally insulating the iron-rich core, thus delaying the crystallization time of the inner core and the onset of the geodynamo.