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Revealing core-mantle boundary temperature and corresponding lower mantle heterogeneities by numerical simulations

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Lower Mantle heterogeneities and Core-Mantle boundary temperature are important issues of modern Deep Earth science. Most of seismic studies show presence of heterogeneous material (LLSVP, ULVZ) at CMB and above it. Temperature is also a problematic question, estimates vary from 4500±500K [Knittle, Jeanlouz, 1989] to 3570±200K [Nomura et al., 2014] with moderate values around 4200±200K [Buffett, 2012].

We use long-term (hundreds of Ma) numerical simulations to find a stationery state (thermal profile and amount of melt) of the pyrolitic mantle at arbitrary CMB temperatures. The most important constraints are solid state of the mantle above (that limits upper boundary) and molten outer core (lower limit), and possibility of presence of partially molten mantle piles to explain presence of Ultra-Low Velocity Zones ([Garnero et al., 1998], 5 to 30% of melt).

StagYY code (e.g. [Tackley, 2008]) calculates mantle convection, including behavior of melts. Melting model uses four components (SiO_2, MgO, FeO and XO) to calculate melting temperatures and physical properties. Solid phases' properties are calculated with [Stixrude, Lithgow-Bertelloni, 2011] database and liquids are parametrized using EoS constants from [de Koker et al., 2013] with corrections for iron-bearing systems fitting [Thomas et al., 2012] and referenced therein data. KD values for iron are estimated according to database of [Tateno et al., 2014]. Phase diagram from [de Koker et al., 2013] is shifted for specific chemical composition and arbitrary pressure to agree experimental data on complex systems ([Andrault et al., 2011], [Andrault et al., 2014], [Fiquet et al., 2010], [Hirose et al., 1999], [Mosenfelder et al., 2007], [Nomura et al., 2014], [Zerr et al., 1998]).

Density difference between coexisting solid and liquid results in melt segregation and migration. Our calculations satisfy hypothesis, that melts at core-mantle boundary might be denser than solid counterpart (e.g. [Labrosse, 2007], [de Koker et al., 2013], [Beuchert & Schmeling, 2013]). Melt migration downwards causes iron and other components extraction and accumulation around CMB. This process can produce layer of refractory material above partialy molten rocks at CMB.

Our calculations show, that at 3900K mantle is totally solid. If we do not take into account melt segregation processes, molten layer will exceed 60 km already at 4100K. Darcy filtration causes drastical thinning of this layer, so it does not exceed 40 km even at 4500K. In that case a layer of iron depleted solid material forms above core-mantle boundary. This seems to be a natural way of mantle heterogeneity production.

We conclude, that revealing of the Lower Mantle structure is a complex question, which cannot be solved by static models; chemical differentiation and melt buoyancy require long-term dynamic simulation. Partial melting may produce chemically heterogeneous mantle consisting depleted and fertilized counterparts. Our preliminary results agree with moderate estimates of CMB temperature [Buffett, 2012].