Geophysical Research Abstracts
Vol. 19, EGU2017-8049, 2017
EGU General Assembly 2017

Rock species formation due to deep-mantle melting

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Melting and melting migration are processes leading to chemically distinct rock species from a homogeneous substrate in the Earth mantle. Iron-rich melts and corresponding rock species are proposed to result from magma ocean progressive crystallization [Labrosse et al., 2007], and modern geophysical models of ULVZ (e.g. [Beuchert & Schmeling, 2013]) discuss their presence at around the CMB today. We perform long-term (tens of millions of years) numerical simulations of the Earth's mantle for a plausible range of CMB temperatures to understands the possibility of melting and it's consequences.

Our model of melting is based on experimental data and ab initio simulations. Physical properties (liquid-solid density differences) are adjusted with data of [de Koker et al., 2013; Mosenfelder et al., 2007; Stixrude & Lithgow-Bertelloni, 2011; Thomas & Asimow, 2013]. This model is included in StagYY numerical code (e.g. [Tackley, 2008]) to simulate mass and thermal fluxes within the Earth mantle.

Melt segregation (rocks' permeability and velocities) is considered using equations listed in [Abe, 1995; Solomatov, Stevenson, 1993; Martin & Nokes, 1989]. Thermal effects (adiabatic heating and viscous dissipation) are considered. Viscous dissipation term includes Darcy flux term, but omits highly non-linear Brinkman contribution [Nield, 2007].

Modeling predicts formation of melt if temperature at CMB exceeds 4000-4050K. It's segregation and reequilibration results in sufficient volumes of slightly iron-enriched melt lighter than solid counterpart and moving upward. However, it's propagation is strongly controlled by temperature. Partial melting atop the molten layer results in formation of refractory iron-poor restite which delaminates and sink down, so that a layer of iron-depleted material forms underneath the molten layer.

Our model applied to homogeneous pyrolitic mantle results in formation of layers of iron-depleted material with average FeO around 4.6 mol.% and iron-enriched material with average FeO up to 9.5 mol.%. Thickness of those layers might be up to several tens to hundreds of kilometers and is controlled by initial T(CMB) and heat production (since gravitational differentiation is a favored process). Other compositions (like MORB) will be tested soon.