Influence of MORB bulk composition on 3-D spherical models of thermo-chemical mantle convection with self-consistently calculated mineral physics

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The density profile of MORB has a critical effect on mantle dynamics, determining whether compositional layering occurs around 660 km [1] and above the CMB, where piles of dense material are thought to exist. We have implemented a self-consistent mineralogical treatment based on free energy minimization, with ratios of 5 oxides representing compositions of harzburgite and MORB, into 3-D spherical models of thermo-chemical mantle convection [1]. Uncertainties exist, however, because a 6th oxide (Na_2O) and variations in the alumina content of MORB affect MORB density profiles [2] and hence the dynamics.

Here we test the sensitivity of dynamical models to the presence of Na_2O and increased MORB alumina content compared to [2]. The numerical code STAGYY for thermo-chemical mantle convection in 3-D spherical geometry is combined with a database on mineral phase assemblages and resulting physical properties calculated by Perple_X [3]. A mechanical mixture of (depleted) harzburgite and MORB is assumed, with the bulk composition of harzburgite approximated as 5 oxides (CFMAS) and the bulk composition of MORB as either 6 oxides (NCFMAS, i.e., including Na_2O) or 5 oxides, with an alumina content increased to 16-18%. These changes increase the MORB density inversion below 660 km hence dynamical layering there, as well as strongly influencing the density of MORB in the deep mantle. In all cases, long-wavelength convection, similar to Earth, is found.

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Possible role of carbon and hydrogen in the Earth's core

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Carbon and hydrogen are possible candidates of the light elements in the Earth's core. In order to study the possible role of carbon and hydrogen in the Earth's core, we carried out a series of experiments to study high-pressure phase relations, thermoelastic properties and melting curves for FeH_x, Fe_3C and Fe_7C_3.

Pressure-Volume-Temperature (PVT) measurements of γ-FeHx were performed using a multi-anvil apparatus (MA) at 11-25 and 873-1573 K at SPring-8 synchrotron facility. We also collected PVT data of carbides using MA and a laser-heated diamond-anvil cell (LHDAC) at 0–69 GPa and 300–1073 K for Fe_3C and 0–72 GPa and 300–1973 K for Fe_7C_3, respectively. Using obtained data set, Mie-Grüneisen-Debye (MGD) equations of state (EOS) for FeH_x, Fe_3C and Fe_7C_3 were constructed.

Melting relations of FeH_x and Fe_3C were determined up to 20 GPa and 29 GPa, respectively, using a multi-anvil apparatus (MA) and synchrotron radiation at SPring-8 facility in Japan. The melting temperatures of FeH_x (found to be nearly stoichiometric) are 700 K lower than that of pure-Fe under corresponding pressure [1]. It was observed that Fe_3C melts incongruently to Fe_7C_3 and melt up to at least 29 GPa [2]. The solidus temperature at 29GPa is 1950 K, which is 600 K lower than pure-Fe.

Using experimental data obtained in the present study, the melting temperatures of FeH and Fe_3C were calculated to be more than 1000 K lower than pure Fe under core pressures. If carbon and hydrogen are the dominannt light elements in the Earth's core, the temperature of the core is significantly lower than previous estimates based on the melting temperatures in the Fe-S-O system [3]. We also propose that the stable carbide phase in the Fe-C system would be Fe_7C_3 rather than Fe_3C under core pressures. Calculated density of Fe_7C_3 gives a good explanation for density of the inner core obtained from seismological observations.

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