I021-016 Room: International Conference Room Time: May 29 9:45-10:00

The effect of temperature dependency of Clapeyron slope at a depth of 660km on mantle convection

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1. Introduction

It is well known that Clapeyron slope (dP/dT) for the phase transformation from ringwoodite to Pv + Mw at the upper and lower mantle boundary is negative(e.g., Ito and Takahashi, 1989). However, recent results of high P-T experiments show a possibility that Clapeyron slope for the phase transformation from garnet to Mg-perovskite, which corresponds to the 660km seismic discontinuity, becomes positive above 1800 degrees C.(Hirose, 2002). These indicate that the 660km phase boundary plays an important role to suppress whole mantle convection for cold plumes, but to promote it for high-temperature hot plumes. In this study, we investigated such temperature dependency of Clapeyron slope at the 660km phase boundary on mantle convection, taking the phase transformation from olivine to wadsleyite at a depth of 410km, temperature and depth dependency of viscosity, adiabatic compression, internal heat generation and viscous heating into account.

2. Model

Here we constructed a 2-D boxed model whose thickness is 2000km with its aspect ratio 1:2. The cases in which temperature differences between the top and bottom boundaries are 2000, 2500 and 3000 degrees C. were considered. As boundary conditions, free slip and fixed temperature conditions were assigned to the top and bottom boundaries, and reflective boundary conditions were given for the left and right boundaries. Using the extended Boussinesq approximation, the 410km phase boundary, temperature and depth dependency of viscosity, and the adiabatic compression were incorporated for all the models. The value of dP/dT at the 410km phase boundary adopted here is +2.28MPa/K. As for the dP/dT at the 660km phase boundary, when the temperature dependency is not considered, the value of -2.8MPa/K is given, whereas when the temperature dependency is considered, the value of +1.3MPa/K is given above 1800 degrees C.

3. Results

As a result of the numerical simulation, when there are no temperature dependency of dP/dT at a depth of 660km, and internal heat generation and viscous heating, temperature in the upper mantle becomes low, and that in the lower mantle becomes high, resulting in two layered convection. In this case, viscosity of the upper mantle is about 10 times as large as that of the lower mantle. When the temperature dependency of dP/dT is considered, two layered convection changes into whole mantle convection. The frequency increases with increasing the temperature difference between the top and bottom model boundaries. Viscosity of the lower mantle just after the whole mantle convection occurred increases a dozen of times as large as that of the upper mantle. The result is consistent with the results obtained from geoid and post-glacial rebound studies, and present situation of the mantle might be in such a time stage. The similar effect is obtained when internal heat generation and viscous heating are incorporated into the model. When both effects are considered, the whole mantle convection occurs more frequently. It becomes dominant when the temperature difference between the top and bottom boundaries is 3000 degrees C.