I212-009 **Room: 201A** **Time: May 27 16:00-16:15**

Numerical simulations of the behavior of the oceanic crust and the slab in the mantle transition zone

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Irifune and Ringwood (1993) and Hirose et al. (1999) showed that the density crossover took place between a subducted oceanic crust and the peridotitic mantle in the uppermost part of the lower mantle (660km to 720km in depth) by high P-T experiments. They suggested that the possibility of the separation of the oceanic crust from the slab there. In this study we investigated the behavior of the oceanic crust and the slab in the mantle transition zone, focusing on the possibility of the separation quantitatively through numerical simulations. For this purpose, we developed a 2-D box-type mantle convection model of Tagawa et al. (2007), in which the lithosphere subduction dynamically occurs without an imposed plate velocity. We incorporate a layered lithospheric structure consisting the oceanic crust and the peridotic mantle layers into the density and rheology models.To solve a transport equation of mass for such thin oceanic crust, the high-resolution mesh of 250m was set in the area of horizontal distance of 4000km and depth of 1000km where around the subduction zone. We assume that the mantle lithospheric layer is composed of two rheological layers:a less viscous layer simulating a hydrated harzburgite with the 34km thickness right beneath the oceanic crust and a high viscosity layer due to the low temperature simulating a normal (pyrolite) mantle lithoshpere under the harzburgite layer.Different depth profiles of density and viscosity and the values of the Clapeyron slope associated with the phase transitions were assumed between the crust and mantle layers of the slab. For the mantle layer, the phase transitions of olivine at depths of 410km and 660km were taken into account, and the phase transitions of garnet at depths of 40km, 400km and 700km were considered for the oceanic crust.Dynamic behaviors of the three layers were able to trace, by solving the transport equation using the CIP method. The model area is 8000km in the horizontal distance, and 2000km in depth. The mechanical boundary condition was assumed to be free slip at all the boundaries. The thermal boundary condition of was assumed to be constant at the upper boundary and adiabatic at the rest of the three boundaries. As the initial condition, there was no flow, and the temperature distribution of the mantle was assumed to be stratified horizontally except the lithosphere layers. The oceanic plate was set at the left uppermost in the model, and the continental plate was set at the right uppermost. The yield stress at the plate boundary was reduced to the small value to simulate weak fractured rocks once it reached the yield stress of strong fresh rocks. This results in subduction of the oceanic plate dynamically. We tested several numerical models, changing some parameters such as velocity of trench retreat, the amount of viscosity jump at a depth of 660km, viscosity of harzburgite layer, and the Clapeyron slope associated with the phase transitions of the oceanic crust. Separation of the oceanic crust from the slab did not take place due to the density difference alone when the realistic depth distributions of density were given to the three layers and the surrounding mantle, and other parameters were fixed. We also tested some models that the viscosity of harzburgite was dropped by 1 to 4 orders. But, the separation did not occur. This is not consistent with the results of previous numerical simulation and theoretical consideration (van Keken et al., 1996; Karato, 1997). The cause of the difference between them may be due to the difference in model setting: Boundary condition may affect the behavior of the oceanic crust and the slab in the model of van Keken et al. (1996), and Karato (1997) assumed steady state condition. On the other hand, our model is set to have wider convection layer and solves the slab behaviors dynamically, which is more realistic.