Effect of the hot plume on the bending of the Philippine Sea slab beneath Kyushu

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1. Introduction

The Philippine Sea (PHS) plate is subducting beneath Kyushu, which turns sharply to a higher dip angle at a depth of about 70 km (e.g., Wang and Zhao, 2006). It has been suggested that the hot plume, which is considered to have existed beneath northwestern Kyushu, flowed horizontally in the southeast direction, causing bent of the PHS slab (Shinjo et al., 2000). However, none of the studies has yet been demonstrated the cause of the sharp bending of the subducting PHS plate quantitatively. In this study, we attempted to evaluate the effect of the upwelling hot plume on the sharp bending of the subducting PHS plate, by using numerical simulations.

2. Method

In this study, we constructed a two-dimensional box-type thermal convection model, by using the method proposed by Torii and Yoshioka (2007). In this model, the hot plume upwelling from deeper portion beneath northwestern Kyushu and the subducting PHS plate from off southeastern Kyushu were simulated numerically. The model domain was set to 1000 km in the horizontal direction and 700 km in the depth direction, with grid intervals of 20 km for the flow field and 5 km for the temperature field. As for the hot plume, a heat source with a fixed temperature of about 1900˚C at its center and 1700˚C around it was set at a depth of 200 km and at a horizontal length of 450 km away from the trench. The size of the heat source was 100 km in the horizontal direction and 150 km in the depth direction. As for the PHS slab, the plate cooling model (McKenzie et al., 1969) was used to provide temperature at the right boundary of the model domain, and the slab was set to sink along a prescribed guide with a convergence rate of 5.8 cm/yr, mimicking subduction of the PHS plate. The viscosity equation was followed by Burkett and Billen (2010), and the slab thickness was given as a function of the plate age (Yoshii, 1975). Slab thickness and upper limits for viscosity were assumed as free parameters in the numerical simulations.

Through these calculations, we investigated how the PHS slab behaves when it collides with the hot plume flowing horizontally from the northwest direction in the southeastern part of Kyushu.

3. Results and discussion

As a result of numerical simulations, we found that the behavior of the slab when it collides with the hot plume can be classified into four categories: (1) the slab bends at a higher angle and sinks, (2) the slab bends at a higher angle and tears, (3) the slab bends little and sinks, and (4) the slab bends little and tears. The most preferable model (1) was realized when the slab thickness is thin and the upper limit of the viscosity is low. In other words, the preferable conditions are that the slab thickness is 24-34 km and the upper limit of the viscosity is ranging from 5×10^{22} Pas to 2.5×10^{25} Pas.

The numerical simulations show that the slab can be bent by a horizontally flowing hot plume. Therefore, we concluded that the hot plume may be responsible for the sharp bending of the PHS slab at a depth of about 70 km beneath southeastern Kyushu.

Keywords: Philippine Sea slab, hot plume, Kyushu, numerical simulation

