論文の内容の要旨

論文題目：Estimate of seismic anisotropy around subduction zone based on numerical simulations of mantle convection

(マントル対流の数値計算に基づく沈み込み帯付近の地震波速度異方性の推定)

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The observations of seismic anisotropy are considered to be useful to constrain the mantle flow and they suggest the existence of complex 3D mantle flow around subduction zones. In this thesis, I aim to understand the type of the mantle flow around the subduction zones by comparing the seismic anisotropy estimated from the numerical simulation of mantle convection and that from observations.

First, as a useful tool to compare the results of numerical simulation with the observations of specific subduction zones, I improved the previous numerical model of subduction zone so that cylindrical and spherical geometries are taken into account. Using this improved model, I found that the effects of Earth's curvature on the mantle flow in the upper mantle is not so large, at least for the assumed parameters.

Second, as a case study to constrain the mantle flow around subduction zones by using seismic anisotropy, I estimated P-wave anisotropy in the mantle wedge below Tohoku region, Japan, in the presence of small-scale convection and compared these results with observations. I modified the

numerical model of subduction zone so that the deformation due to the dislocation creep (i.e., non-linear rheology) is taken into account. The estimated fast direction of P-wave propagation projected on horizontal cross-sections is almost the same as the direction of plate motion, which implies that the effects of large-scale mantle flow associated with subducting slab is still dominant even when small-scale convection occurs. On the other hand, in vertical cross-sections, the projected fast direction of P-wave propagation tends to tilt vertically in the presence of small-scale convection, particularly near its downwellings. However, the present studies of P-wave anisotropy determine the fast direction of P-wave propagation only in the horizontal cross-sections. Therefore, the seismological technique to determine the fast direction of P-wave propagation including vertical direction (or in 3D) gives us the essential information to know whether the small-scale convection occurs in the mantle wedge or not. I further showed the possibility that we can resolve seismically the upwelling and downwelling associated with the small-scale convection with the spatial resolution of $\sim$10 km, if it exists. These findings provide us with new perspectives in interpreting the observation of seismic anisotropy in the mantle wedge.

Finally, I estimated P-wave anisotropy in the subduction zone from Tohoku to southwestern Kurile region, Japan. I found that the geometry of subducting slab obtained in the numerical simulation qualitatively agrees with that from the seismic observations, that is, (1) the angle of subduction is smallest at the plate junction, and (2) the angle of subduction is larger in the place where oblique subduction occurs than in the place with non-oblique subduction. These characteristic features may be explained by the torque balance acting on subducting slab for the case with oblique subduction and the following bending at the plate junction. The fast direction of P-wave propagation in the mantle wedge is trench-normal at all the depths considered. Assuming that this direction is almost the same as the fast polarization direction of S-wave splitting, the obtained result is consistent with the observation. It suggests that the 3D mantle flow similar to that obtained in the numerical simulation exists in the mantle wedge in this region. The shape of the trench is an important factor that controls both the mantle flow and the deformation of subducting slab.