沈み込むスラブの構造と運動学的観測から見た滞留スラブの形成と進化

Stagnant slab formation and evolution inferred from kinematic and geometrical observations of the subduction zone

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Seismic tomography revealed variable slab structure in the mantle transition zone (e.g., Fukao et al., 2009). Numerical modeling that incorporates phase transition at the 660 km depth and trench migration succeeded to simulate formation and avalanche of the stagnant slab (Christensen, 1996; Torii and Yoshioka, 2007; Nakakuki et al., 2010). Mechanisms to control structure of the transition zone slab are still controversial (e.g., Karato et al., 2001; King et al., 2015), since we have not sufficiently understood relationship of the slab dynamics with tectonic features in the actual subduction zone (cf. Billen, 2010). In this study, subduction zone geometric and kinematic observations are analyzed aiming to construct a scenario for the stagnant slab formation and evolution. The data, which are compiled by Lallemand et al. (2005) and (2008), include absolute motions of the subducting plate, the overriding plate and the trench based on a global plate motion model (SB04) constructed by Steinburger et al. (2004), slab depths, and slab dip angles.

Important observations connected to the stagnant slab dynamics are summarized as follows. (1) Most of upper mantle slabs are retreating with the velocity larger than 1 [cm/yr]. (2) In the subduction zone with the slab penetrating at the depth between 660 to 1200 km, trench motion is advance (e.g., Mariana, Java) or retreat with the slower velocity (< 1 [cm/yr], e.g., north Kuril) than that in the subduction zone with the upper slab. (3) Back-arc extension often occurs in the subduction zone in which the maximum slab depth is 660 km (e.g., Tonga). (4) Dip angles of the upper and lower mantle slabs become steeper with the age. (5) Stagnant slabs are classified into 2 types. (i) The first type has young age (< 60 [Ma]), slow subducting plate motion (the slab descending motion occur as if the plate peeled and fell off from the surface (e.g., New Hebrides). (ii) The second type has old age (> 100 [Ma]) and dip angles obviously shallower (< ~50 [deg], e.g., south Kuril, Japan) than those of the slab penetrating into the lower mantle.

These results indicate important relationship of the slab dip angle and trench migration to the slab structure varying with the sinking depth. The following scenario emerges as a possible explanation for the stagnant slab mechanics. (1) A relatively young slab with shallow dip angle and trench retreat collides to the 660 km phase transition. (2) The slab start stagnates at 660 km, and the slab rollback is further enhanced. (3) When the dip angle of the stagnating slab is shallow, the slab retains the stagnation at the 660 km after the trench retreat is declined. (4) When the dip angle is steepened and/or the trench advance is generated owing to increase of subducting plate age or collision of the continent, the slab penetrates into the lower mantle.

キーワード：滞留スラブ、マントル遷移層、プレート運動、沈み込み帯
Keywords: stagnant slab, mantle transition zone, plate kinematics, subduction zone