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Numerical simulations on fall of stagnant slabs into the lower mantle

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Global seismic tomography has recently revealed horizontally lying slabs near the upper and lower mantle boundary beneath the Northwestern Pacific region. Although physical mechanisms that could produce such slab stagnation have been proposed based on numerical simulations, there has been little research into what occurs after slab stagnation. We proposed trench advance and trench jumps as effective mechanisms related to the fall of stagnant slabs into the lower mantle, and our numerical simulations of temperature and fluid flow associated with slab subduction in a 2-D box model confirmed these mechanisms. Our results indicate that a supply of slab material associated with further slab subduction after slab stagnation plays an important role in differentiating further slab stagnation from the falling of slabs into the lower mantle. A shortage of material supply would produce extended slab stagnation near the 660-km boundary for ringwoodite to perovskite + magnesiowüstite phase transformation, whereas downward force due to further slab subduction on a stagnant slab would enhance its fall into the lower mantle. The behaviors of falling stagnant slabs were not affected by Clapeyron slope values associated with phase equilibrium transformation within the range from -3.0 to 0.0 MPa/K. Compared with models of normal mantle viscosity, a high-viscosity lower mantle played a role in hindering the fall of slabs into the lower mantle, resulting in complicated shapes and slow falling velocities. Lower mantle viscosity structure also affected slab behavior. Slabs tended to stagnate when a low-viscosity zone (LVZ) existed just below a depth of 660km because friction between the slab and the LVZ was weak there. Slab stagnation around a depth of 660km also occurred when a high-viscosity zone existed below a depth of 1200km and acted as a resistive force against a slab, even if the slab existed in the lower part of the upper mantle.