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Majorite-ringwoodite strength contrast: Implication for the separation of crustal material from slab near 660 km depth

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Many seismic observations have shown that some of subducting lithospheres penetrates into deeper mantle across 660 km discontinuity. Former oceanic crust, which forms uppermost layer of the slab, consists mainly of majorite-rich garnet (hereafter majorite) near 660 km depth. Majorite is denser than surrounding mantle at shallower depth than 660 km where the ambient mantle consists mostly of ringwoodite, but is less dense at deeper part of the mantle where the Mg-perovskite is the dominant phase. Thus the crustal component may separate from the slab near 660 km depth. Karato (1997) discussed that the separation of crustal component can occur when the crustal component is significantly stronger than surrounding mantle based on dynamic calculation. However, it is unclear whether the separation of the crustal material occurs because plastic strength of related materials at the deep mantle conditions has not been known. In this study, we conducted deformation experiments at pressure and temperature conditions corresponding to the Earth's deep mantle in order to determine strength contrast between majorite and ringwoodite.

Deformation experiments at pressure of ~15 GPa and temperature of 1473-1673 K were carried out using SPEED-MkII-D installed at BL04B1, SPring-8, Japan. Majorite (Mj) synthesized from a gel with chemistry of the majoritic garnet in oceanic crust and $(Mg_{0.6}Fe_{0.4})_2SiO_4$ ringwoodite synthesized from olivine were placed vertically and deformed uniaxially under same temperature, pressure and stress conditions. Strain measurements were done during deformation based on X-ray radiography using synchrotron radiation. Strain rates were 0.7-2.4 x 10^{-5} s^{-1} for Mj and 1.2-14.5 x 10^{-5} s^{-1} for Rw. Relative strain rate of Rw and Mj (strain rate for Rw divided by that of Mj at same condition) determined at 6 different deformation conditions were 1.3-2.5 (Mj was always stronger in the present experimental conditions). However, an extrapolation of present results to realistic strain rate in the mantle suggests that strength of Mj is similar to that of Rw or lower. Assuming that the dominant deformation mechanism in the Earth's mantle is same as that in present experiments (most probably power-law dislocation creep), the separation of the oceanic crust component may not occur at near the 660 km discontinuity.