Sound velocities of mantle and slab materials and the fate of stagnant slab

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The composition of the mantle transition region, characterized by anomalous seismic-wave velocity and density changes at depths of ˜400 to 700 km, has remained controversial. Some have proposed that the mantle transition region has an olivine-rich 'pyrolite' composition whereas others have inferred that it is characterized by pyroxene- and garnet-rich compositions ('piclogite'), because the sound velocities in pyrolite estimated from laboratory data are substantially higher than those seismologically observed. Although the velocities of the olivine polymorphs at these pressures (wadsleyite and ringwoodite) have been well documented, those of majorite (another significant high-pressure phase in the mantle transition region) with realistic mantle compositions have never been measured. Here we use combined in situ X-ray and ultrasonic measurements under the pressure and temperature conditions of the mantle transition region to show that majorite in a pyrolite composition has sound velocities substantially lower than those of earlier estimates, owing to strong nonlinear decreases at high temperature, particularly for shear-wave velocity. We found that pyrolite yields seismic velocities more consistent with typical seismological models than those of piclogite in the upper to middle parts of the region, except for the potentially larger velocity jumps in pyrolite relative to those observed at a depth of 410 km. In contrast, both of these compositions lead to significantly low shear-wave velocities in the lower part of the region, suggesting possible subadiabatic temperatures or the existence of a layer of harzburgite-rich material supplied by the subducted slabs stagnant at these depths.