Velocity and density characteristics of subducted oceanic crust and the origin of seismic heterogeneity in the lower mantle

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Seismological studies[1,2] have found numerous seismic heterogeneities with different length scales in the lower mantle, which directly involve the thermochemical evolution and geodynamics of our planet. The subducted oceanic crust that has a distinctive chemical composition from the pyrolitic lower mantle[3] was proposed as the main chemical origin for these heterogeneities[2]. However, the velocity and density characteristics of subducted oceanic crust at lower-mantle pressures and temperatures still remain unknown. Here we performed first-principles calculations to obtain the elastic properties of calcium ferrite□type (CF-type) phases with substitutional solutes, and determined the velocity and density of oceanic crust along different mantle geotherms, combining our results and previous studies[4-7]. We found that the subducted oceanic crust shows a large negative shear velocity anomaly around the phase boundary between stishovite and $CaCl_2$-type silica, highly consistent with the features of detected mid mantle seismic scatterers. After the phase transition of silica, the oceanic crust has relatively higher wave velocities than those of the ambient mantle even when its temperature profile is +1000 K hotter than that of the ambient mantle and rules out the possibility that the LLSVPs mainly originates from subducted oceanic crust. The accumulation of subducted oceanic crust can cause extremely high velocity heterogeneities (~2 %) in the lower mantle imaged by seismic tomography. Our findings strongly support the presence of subducted oceanic crust in the lower mantle. The current scenario of subducted oceanic crust has important implications for our interpretation of the interaction between the subducted slab and the lower mantle, the strength of mantle convection, deep cycles from the mantle to the crust, and geochemical signatures from deep mantle.

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