The interaction of subducted oceanic crust with long-lived compositional reservoirs in the deep mantle

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Seismic tomography reveals the presence of two large, low shear velocity provinces (LLSVPs) in the lowermost mantle beneath Africa and the Pacific. Additional seismic studies provide evidence that these regions are compositionally-distinct from the surrounding, background mantle. The LLSVPs are hypothesized to be caused by ancient, more-primitive reservoirs that formed early in Earth's history. If so, it is important to discover how these long-lived reservoirs interact with subducted oceanic crust throughout geologic time because this process has fundamental implications for our understanding of geochemical evolution, mantle plume chemistry, and small-scale mantle structure. We have performed geodynamical calculations that include reservoirs of more-primitive material and subducted oceanic crust. We find that subducted oceanic crust takes multiple pathways in the mantle. It is either (a) viscously stirred into the background mantle (forming a marble-cake texture), (b) advected directly into mantle plumes, or (c) flushed into long-lived compositional reservoirs along their tops. Within the compositional reservoirs, oceanic crust is stretched and stirred to produce considerable spatial heterogeneity, possibly explaining the seismic heterogeneity observed within LLSVP regions. Furthermore, some of this older oceanic crust is entrained back out of the reservoirs into mantle plumes. These experiments predict that mantle plumes should, at a minimum, contain the following: (a) background mantle (MORB source), (b) relatively young oceanic crust, (c) more-primitive material, and (d) much older, more-evolved oceanic crust. Finally, we investigate how compositional reservoir material is entrained into mantle plumes, producing a temporal and spatial variability of more-primitive material that is expected to melt at hotspots to produce ocean island basalts (OIBs).