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Oceanic crust recycling and the formation of lower mantle heterogeneity

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The Earth's lower mantle is heterogeneous at multiple scales as demonstrated for example by the degree-2 distribution of LLSVPs seen in global tomography and widespread distribution of small scale heterogeneity as seen in seismic scattering. The origin of this heterogeneity is generally attributed to leftovers from Earth's formation, the recycling of oceanic crust, or a combination thereof.

Here we will explore the consequences of long-term oceanic crust extraction and recycling by plate tectonics. We use geodynamical models of mantle convection that simulate plates in an energetically consistent manner. The recycling of oceanic crust over the age of the Earth produces persistent lower mantle heterogeneity while the upper mantle tends to be significantly more homogeneous. We quantitatively compare the predicted heterogeneity to that of the present day Earth by tomographic filtering of the geodynamical models and comparison with S40RTS. We also predict the scattering characteristics from S-P conversions and compare these to global scattering observations.

The geophysical comparison shows that lower mantle heterogeneity is likely dominated by long-term oceanic crust recycling. The models also demonstrate reasonable agreement with the geochemically observed spread between HIMU-EM1-DMM in ocean island basalts as well as the long-term gradual depletion of the upper mantle as observed in Lu-Hf systematics.