High body wave attenuation in the upper mantle and the role of melt

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Seismic attenuation offers a powerful constraint on the physical state of the Earth’ s interior. Anelastic processes can generate strong variation in amplitudes and wave speeds of P and S waves, seen in both regional and teleseismic observations. The effect of temperature on attenuation in mantle rocks is reasonably well calibrated in the laboratory. However, these laboratory predictions deviate systematically from seismic observations. We demonstrate this with analysis of a new ocean-bottom seismometer dataset spanning the Juan de Fuca plate and ridge system, measuring seismic attenuation and velocity across an entire oceanic plate. Spectral ratios of teleseismic P and S waves show the highest attenuation anomalies and largest delays at in a narrow zone <50 km from the Juan de Fuca and Gorda ridge axes, with implied seismic quality factor for shear waves (Qs) 25 (extrapolated to 1 Hz) over the upper 150 km of the mantle beneath the ridge, among the lowest observed worldwide. We compare these results with measurements of Qs in subduction zones, observed from regional intraslab earthquakes. In those data, attenuation is strongest (Qs ~ 20-70) for paths traversing the mantle beneath arcs and backarcs. Although these two sets of observations (teleseismic Qs beneath a ridge and regional Qs beneath arcs) are made at different frequencies, when corrected for laboratory-calibrated frequency dependence they show comparable values. However, these Qs values are 2-5 times lower than predicted for any reasonable extrapolation of laboratory measurements in dry rocks. We infer a large effect of melt on Qs both beneath ridges and beneath arcs, with forward calculations suggesting up to 2% in situ melt.

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