Seismic attenuation of body waves measured across an entire oceanic plate

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Measurements of seismic wave speeds and attenuation provide complementary constraints on the thermal and compositional state of the Earth's interior. We have used teleseismic $P$- and $S$-waves to measure differential attenuation ($\Delta t^*$) on the Cascadia Initiative’s Amphibious Array, providing the first maps of attenuation across an entire oceanic plate from ridge to trench. Our data elucidate the thermal control on seismic dissipation by comparison with well-understood plate cooling solutions. For $>$2 Ma oceanic crust, differential attenuation follows a shallow trend, consistent with plate cooling predictions based on extrapolations from laboratory conditions. However, close to the ridge axis there is a sharp departure from this trend to markedly higher values of attenuation. Ocean bottom seismometers close to both Juan de Fuca and Gorda ridges record $\Delta t^*$ values up to 2.0 s, implying values of $Q_S < 30$ in the upper mantle. Such low values have only been previously observed in back-arc settings. Differential travel times also imply slow velocities proximate to the ridge axis. This strong, localized attenuation cannot result from a purely thermal control: we propose that focused melt and/or volatiles play a role. This work provides a comparison to previous studies using surface waves and contributes to our developing understanding of anelastic controls on seismic parameters by probing the Earth in a different frequency range.

Station-averaged $\Delta t^*$ of teleseismic $S$-waves recorded on OBS stations on the Juan de Fuca (red) and Gorda (blue) plates, as a function of plate age. Symbol size scaled by number of measurements. Predicted values for a plate cooling model using the anelastic scaling relationship of Jackson and Faul, 2010 are shown, for three different grainsizes. High apparent values of $\Delta t^*$ recorded at shelf stations (age $> 7$ Ma) are affected by sediments.