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The nature of cratonic lithosphere: Combining constraints from seismology, mineral physics, and petrology

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In recent years, the prevailing notion of Precambrian continental lithosphere as a thick boundary layer (∼200-300 km) with a very depleted composition and temperature structure controlled by steady-state conductive cooling has been challenged by several lines of seismological evidence. One, profiles of shear velocity with depth beneath cratons exhibit lower wave speed at shallow depths and higher wave speed at greater depths than can be explained by temperature alone. These profiles are also characterized by positive or flat velocity gradients with depth in the uppermost mantle and anomalously high attenuation, both of which are difficult to reconcile with the low temperatures and large thermal gradient expected in the thermal boundary layer. Two, body-wave receiver-function studies have detected a mid-lithospheric discontinuity that requires a large and abrupt velocity decrease with depth in cratonic regions that cannot be achieved by thermal gradients alone. We have used a forward-modeling approach to identify the suite of shear-velocity profiles that are consistent with phase-velocity observations made for Rayleigh waves traversing cratons in North America, Africa, and Australia. We have also calculated the range of lithospheric temperatures and compositions that are consistent with the elastic and anelastic seismological models, using laboratory measurements on the sensitivity of velocity and attenuation to temperature, major-element composition, and mineralogy. Finally, we consider the implications of the models for the long-term stability of cratons.