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Imaging the continental lithosphere: Perspectives from global and regional anisotropic seismic tomography

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Azimuthal seismic anisotropy, the dependence of seismic wave speeds on propagation azimuth, is largely due to fabrics within the Earth's crust and mantle, produced by deformation. It thus provides constraints on the distribution and evolution of deformation within the upper mantle. Lateral variations in isotropic-average seismic velocities reflect variations in the temperature of the rocks at depth. Seismic tomography thus also provides a proxy for lateral changes in the temperature and thickness of the lithosphere. It can map the deep boundaries between tectonic blocks with different properties and age of the lithosphere.

Our new global, anisotropic, 3D tomographic models of the upper mantle and the crust are constrained by an unprecedentedly large global dataset of broadband waveform fits (over one million seismograms) and provide improved resolution of the lithosphere at the global scale, compared to other available models. The most prominent high-velocity anomalies, seen down to around 200 km depths, indicate the cold, thick, stable mantle lithosphere beneath Precambrian cratons. The tomography resolves the deep boundaries of the cratons even where they are not exposed and difficult to map at the surface. Our large waveform dataset, with complementary large global networks and high-density regional array data, also produces improved resolution of azimuthal anisotropy patterns, so that regional-scale variations related to lithospheric deformation and mantle flow can be resolved, in particular in densely sampled regions.

The depth of the boundary between the cold, rigid lithosphere (preserving ancient, frozen anisotropic fabric) and the rheologically weak asthenosphere (characterized by fabric developed recently) can be inferred from the depth layering of seismic anisotropy and its comparison to the past and present plate motions. Beneath oceans, the lithosphere-asthenosphere boundary (LAB) is defined clearly by the layering of anisotropy, with a dependence on the lithospheric age consistent with the half-space cooling model. Beneath continents, azimuthal anisotropy is characterized by smaller-scale 3D variations. Although not all of them can be mapped at the wavelengths of global anisotropy tomography, significant patterns emerge from the analysis of global lithospheric anisotropy beneath continents.