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Seismic Tomography of the Arctic Lithosphere and Asthenosphere

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Lateral variations in seismic velocities in the upper mantle, mapped by seismic tomography, primarily reflect variations in the temperature of the rocks at depth. Seismic tomography thus provides a proxy for lateral changes in the temperature and thickness of the lithosphere, in addition to delineating the deep boundaries between tectonic blocks with different properties and age of the lithosphere.

Our new, 3D tomographic model of the upper mantle and the crust of the Arctic region is constrained by an unprecedentedly large global dataset of broadband waveform fits (over one million seismograms) and provides improved resolution of the lithosphere, compared to other available models. The most prominent high-velocity anomalies, seen down to 150-200 km depths, indicate the cold, thick, stable mantle lithosphere beneath Precambrian cratons. The northern boundaries of the Canadian Shield's and Greenland's cratonic lithosphere closely follow the coastlines, with the Greenland and North American cratons clearly separated from each other. Sharp velocity gradients in western Canada indicate that the craton boundary at depth closely follows the Rocky Mountain Front. High velocities between the Great Bear Arc and Beaufort Sea provide convincing evidence for the recently proposed 'MacKenzie Craton', unexposed at the surface. In Eurasia, cratonic continental lithosphere extends northwards beneath the Barents and eastern Kara Seas. The boundaries of the Archean cratons and intervening Proterozoic belts mapped by tomography indicate the likely offshore extensions of major Phanerozoic sutures and deformation fronts.

The old oceanic lithosphere of the Canada Basin is much colder and thicker than the younger lithosphere beneath the adjacent Amundsen Basin, north of the Gakkel Ridge. Beneath the slow-spreading Gakkel Ridge, we detect the expected low-velocity anomaly associated with partial melting in the uppermost mantle; the anomaly is weaker, however, than beneath faster-spreading ridges globally. South of the ridge, the Nansen Basin shows higher seismic velocities in the upper mantle beneath it, compared to the Amundsen Basin. At 150-250 km depth, the oceanic central Arctic region is underlain by a moderate low-velocity anomaly characteristic of a warm asthenosphere, similar to that beneath northern Pacific but much cooler than that beneath Iceland and northern Atlantic.