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Upper mantle anisotropy beneath the Superior and Grenville Provinces, Ontario, Canada: insights from tomographic inversion of Rayleigh wave phase velocities.

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The Superior Province of the Canadian Shield, the world's largest Archean craton, has been shaped by a variety of accretionary and orogenic events, periods of rifting and the influence of a number of mantle hotspots over its ˜3 Ga history. Local-scale geophysical studies carried out in the Superior Province and the neighbouring Grenville Province to its southeast suggested complex heterogeneity and anisotropy in the crust and upper mantle, thought to be related both to lithospheric processes and lithosphere-asthenosphere interaction.

With the deployment of the POLARIS/FedNor broadband seismograph network across northern and eastern Ontario from 2002, it has been possible to study the properties of the Superior and western Grenville Provinces on a regional scale. Rayleigh wave phase velocity analysis was applied to 150 2-station paths across the region, providing dispersion measurements in the ˜25-180 second period range. Path-averaged 1D shear velocity models were calculated for selected stable paths. The models show a velocity profile typical of continental cratons worldwide, with a 'lid' of high velocities in the upper mantle, interpreted as the seismological lithosphere. The nature and depth extent of the lithosphere varies significantly across the region, with thicknesses ranging from $<$150 km to ˜240 km and velocity anomalies ranging from 2-6% above global reference models. Moreover, variations in phase velocity with inter-station azimuth indicate significant upper mantle anisotropy, particularly in the western Superior.

We combine the data from the 2-station dispersion measurements in a tomographic inversion that solves simultaneously for isotropic phase velocity heterogeneity and azimuthal anisotropy as a function of period to present a series of anisotropic phase velocity maps for the period range 40-160 seconds. This method allows us to investigate azimuthal anisotropy as a function of depth in the upper mantle, and provides insight into the layering of anisotropy within the lithosphere and asthenosphere. The results are compared to inferences from shear-wave splitting measurements and receiver function analysis. Phase velocities are generally higher in the western Superior than the east. In the western Superior, strong ENE-WSW trending anisotropy is detected in the lower lithosphere. Fast propagation directions inferred from shear-wave splitting analysis in this region coincide with the directions we observe in this depth range, indicating that most of the splitting signal is due to ‘frozen’ fabric within the lower lithosphere. An area of low phase velocities beneath the Lake Superior region coincides with the northernmost extent of the Mid-continent Rift. We examine the variations in anisotropic structure across the region in the context of the tectonic history of the province and the likely mantle dynamic processes occurring beneath this region of North America.