Thermochemical structure of cratons from Rayleigh wave phase velocities

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The thermal and compositional structure of the lithospheric keels underlying the Precambrian cratonic cores of the continents may shed light on their evolution and long-term stability. A number of seismic studies have found significant 3D seismic heterogeneity in cratonic lithosphere, which is enigmatic because temperature variations in old shields are expected to be small and seismic sensitivity to major-element compositional variations is limited. Previous studies show that metasomatic alteration may lead to significant variations in shield velocities with depth. Here we perform a grid search for thermo-chemical structures including metasomatic compositions, to model Rayleigh-wave phase velocities between 20 and 160 s for the northeastern part of North America comprising the Superior craton, the largest Archean craton in the world, and surrounding Proterozoic belts. We find smooth variations in thermal structure that include variations in thermal thickness within the Superior and decreasing thickness towards the edges of the shield. Four types of distinct compositional structures are required to match the long-period phase velocities. The different types appear to correlate with: (i) the unaltered oldest cores of the Superior, (ii) Archean and Proterozoic lithosphere modified by rifting and plume activity, and two distinct types of subduction signatures: (iii) an Archean/Paleo-Proterozoic signature that includes a high-velocity eclogite layer in the mid-lithosphere and (iv) a post Paleo-Proterozoic signature characterised by strongly altered shallow mantle lithosphere. Thus, processes that have affected the formation and modification of cratonic lithosphere and were previously recognised in xenoliths appear to have also left large-scale imprints in seismic structure.