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Seismic structure and dynamics of cratons: Stability and modification, continental collision and subduction

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The Archean crust of stable cratons within today's continents is typically underlain by cold, thick mantle lithosphere. These mechanically strong, compositionally buoyant mantle roots (overall, roughly neutrally buoyant due to the density increase caused by low temperatures) have ensured the survival of cratons since their formation. Global and regional seismic tomography detects cratons readily by the anomalously high seismic velocities within their mantle lithosphere. The increasing resolution of seismic imaging now enables detailed mapping of the locations, boundaries and properties of cratons and offers new insight into their dynamics and evolution. Here, we summarise inferences on cratonic structure and dynamics based on recent multimode-waveform tomography on the global and continental (Europe, N America) scales and from regional, surface-wave array imaging.

Where crustal cratonic boundaries can be mapped at the surface, they are, normally, closely matched by the boundaries of the high-velocity (thick and cold) mantle lithosphere beneath. Where the ancient crust is covered by sediments, with crustal block boundaries thus unclear, cratons can be mapped accurately by the seismic imaging of their high-velocity lithosphere. (Important exceptions include cratons that lost their ancient mantle roots in the Phanerozoic, e.g., eastern Sino-Korean Craton). On average, the upper mantle beneath cratons shows shear-wave speeds higher than elsewhere down to depths smaller than 300 km; large shear-speed anomalies are seen down to around 200 km depth only. Layered azimuthal anisotropy within cratonic lithosphere indicates frozen fabric that is probably a record of complex, vertically stratified deformation during the formation and stabilisation of cratons. Lateral variations in seismic velocities within cratonic roots present evidence for their modification and evolution after their formation. Beneath cratons in northern Europe, the locations of kimberlites coincide with relatively low shear-wave speeds in the mantle lithosphere. This anomaly is present in regions of both Proterozoic and Archean crust, which suggests an alteration of the mantle lithosphere after the formation of the cratons.

In orogenies, cratons generally resist deformation and subduction. Collisions of cratonic blocks, such as seen presently in the western part of the India-Asia convergence zone, can change the character of the orogeny, as well as the motions of the entire tectonic plates that are converging. Beneath western Tibet, cratonic Indian lithosphere has been stripped of its upper crust, pushed down underneath the thick Tibetan crust, and is now colliding with the Tarim Craton to the north. This recent deepening of the cold Indian lithosphere explains the exceptionally high shear speeds (up to 5.0 km/s) within it, higher than beneath any stable cratons with steady-state geotherms. High-velocity anomalies beneath central and eastern Tibet require negative thermal anomalies of hundreds of degrees at depths below 120-150 km, indicating, most likely, subducted Indian lithosphere. The active India-Asia convergence zone thus demonstrates different mechanisms of continental convergence, from craton-craton collision to underthrusting of a craton beneath thick orogenic crust and to shallow-angle subduction of cratonic lithosphere.

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