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Making and stabilising the deep roots of continents (Robert Wilhelm Bunsen Medal Lecture)

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Despite the undisputed life-preserving role played by deep cratonic keels in the survival of Earth's oldest continental crust, considerable debate revolves around the origin and age of these deep, rheologically stiff mantle roots. Increasing sharpness in the view afforded by geophysics and geochemistry has revealed the complexity of cratonic roots, which in turn requires a diversity of origins. This contribution examines the setting and timing of initial melt depletion in cratonic peridotites and the possible role played by lateral collision and shortening in craton formation.

Bulk rock compositional relations in cratonic peridotites are blurred by a variety of metasomatic processes. Examination of the most depleted, least re-enriched samples using Ca-Al and Cr-Al relations indicates the action of relatively shallow (∼5 GPa and less) melt depletion, a result consistent with mildly incompatible trace elements. These compositions are most like peridotites produced in modern-day subduction settings. Other peridotite xenoliths show variations in compatible and mildly incompatible trace elements far outside the spectrum that is possible to produce by melt depletion alone. These compositions are likely produced by cumulate-processes in the hot Archean crust. Other compositions may represent the residues of much higher pressures of melting. Hence it is likely that cratonic keels are an amalgamation of peridotites produced in different ways, at different times, making it easier to reconcile their complex age and compositional spectra.

How are such roots thickened and consolidated? Geodynamical modeling of viscous refractory peridotites illustrate the possibility of creating deep highly depleted mantle keels with optimal stability at circa 200 to 250 km thickness – the typical thickness of cratonic mantle lithosphere observed for the past billion years – by compressional thickening. This scenario is also a mechanism for i) incorporating highly refractory ultramafic rocks that may have been produced as shallow-level cumulates in the Eoarchean into the mantle root and ii) generating the often extensive thick ultra-depleted zones in cratonic keels, with the more fertile, less strong section removed by thermomechanical erosion.

Such a model produces cratonic keels comprising peridotites of multiple origins, of various ages, widely varying in composition, juxtaposed in potentially complex ways – all features observed in cratonic mantle roots.