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Physico-chemical constraints on cratonic lithosphere discontinuities

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The origins of the mid-lithospheric discontinuity (MLD) and lithosphere-asthenosphere boundary (LAB) have received much attention over the recent years. Peculiarities of cratonic lithosphere construction - compositional and rheological stratification due to thickening in collisional settings or by plume subcretion, multiple metasomatic overprints due to longevity - offer a variety of possibilities for the generation of discontinuities.

Interconnected small degrees of conductive partial melt (carbonate-rich melts, such as carbonatites and kimberlites, or highly alkaline melts) at the cratonic LAB, which produce seismic discontinuities, may be generated in the presence of volatiles. These depress the peridotite solidus sufficiently to intersect the mantle adiabat at depths near the cratonic LAB at ∼160-220 km, i.e. above the depth of metal saturation where carbonatite becomes unstable. The absence of agreement between the different seismic and magnetotelluric estimates for the depth of the LAB beneath Kaapvaal may be due to impingement of a plume, leading to a pervasively, but heterogeneously metasomatised ("asthenospherised") hot and deep root. Such a root and hot sublithosphere may yield conflicting seismic-thermal-geochemical depths for the LAB. The question arises whether the chemical boundary layer should be defined as above or below the asthenospherised part of the SCLM, which has preserved isotopic, compositional (non-primitive olivine forsterite content) and physical evidence (e.g. from teleseismic tomography and receiver functions) for a cratonic heritage and which therefore is still distinguishable from the asthenospheric mantle. If cratonic lithosphere overlies anomalously hot mantle for extended periods of time, the LAB may be significantly thinned, aided by penetration of relatively high-degree Fe-rich partial melts, as has occurred beneath the Tanzanian craton. Xenoliths from the deep Slave craton show little evidence for "asthenospherisation". Its root was penetrated by cooler carbo-silicate melts (kimberlites) between ∼60 and 350 Ma ago, which are expected in the absence of excess T_P, and this may produce discontinuities rather than gradual changes in physical properties near the LAB.

MLDs have been detected in continental lithosphere globally at depths from ∼60 to 150 km. This may relate to melt infiltration fronts beneath Tanzania and Kaapvaal. However, the global presence of melts or fluids at MLDs is unlikely, and the spinel-garnet transition in typically Cr-rich cratonic lithosphere occurs over too large a pressure interval. This discontinuity is therefore suggested to represent "proto-LABs" that relate to craton construction. Dipping discontinuities are frequently explained with craton thickening during subduction-accretion, but can likewise reflect thinning and erosion of cratonic lithosphere at its edges prior to root thickening by plume subcretion. Anisotropy can then result from deformation in upwelling mantle that flows laterally after impinging upon a lithospheric lid. The greater strength of the MLD signature compared to the LAB may relate to the sharpness of the discontinuity rather than the size of the seismic velocity anomaly. Thinned edges may be preferred pathways of kimberlites and their mapping may aid in the discovery of potentially diamondiferous kimberlites, provided the "diamond window" was not consumed by erosion.