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Deep ultra-hot melting in cratonic mantle roots

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The persistence of Archaean cratons for >2.5Ga was aided by thick, mechanically strong, and cool lithospheric mantle keels up to 250km deep. It is widely accepted that the cratonic mantle, dominated by depleted harzburgite, lherzolite and dunite, was formed by extensive melt extraction from originally fertile mantle peridotite. Models seeking to explain the formation of deep cratonic mantle in the garnet and diamond stability fields, initially sought to answer how such rocks could form in-situ at high temperatures and pressures and envisaged large-scale thermochemical plume upwellings. More recently, mineralogical and geochemical observations, namely the high Cr content of garnet and low whole rock HREE concentrations in cratonic harzburgites, have led to the conclusion that the deep cratonic mantle couldn't have originally melted in the garnet stability field. Mechanical stacking of shallowly depleted oceanic lithosphere was therefore proposed to have thickened the depleted lithosphere cratonic roots. In this process, the spinel facies minerals are envisaged to transform into the garnet stability field.

Here we present the first results of combined thermodynamic and geochemical modelling at temperatures high enough to reconcile the very refractory residues. We found that the requirement for initially shallow melting is no longer supported. Deep (150-250km), ultra-hot (>1800°C), incremental melting can produce the mineralogical and geochemical signatures of depleted cratonic harzburgites. The modelling also implies a link between areas of extreme depletion in the deep lithospheric mantle and the genesis of Earth's hottest lavas (Al-enriched komatiite) by re-melting depleted harzburgite. Diamond inclusion minerals have a well-documented skew to the most refractory compositions found in cratonic peridotite. We propose that these ultra-depleted, highly reducing regions of the lithospheric root possess the highest diamond formation and preservation potential.