Newly-discovered abyssal peridotite mantle xenoliths constrain mid-ocean ridge melting models

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Much of our knowledge of mantle melting beneath mid-ocean ridges comes from modelling based on the composition of MORB and of variably-serpentinized abyssal peridotites tectonically exposed on the ocean floor. Here, we report a unique occurrence of fresh nodules of young, deep, sub-ridge oceanic lithosphere with the potential to test these melting models. The setting is the West Scotia Ridge spreading centre which actively spread at intermediate-slow rates for c.25Ma. Following the cessation of spreading at c.5.5Ma (Ar-Ar and magnetic anomaly dating), a final pulse of alkali basalt erupted at c.0.3Ma carrying the peridotite nodules to the sea-floor. Thermobarometry places these nodules at an original depth of c.1±0.3 GPa (Ca-in-olivine) and a temperature of c.1050°±35C (olivine-spinel and Ca-in-orthopyroxene), the latter consistent with c.6Ma of cooling of oceanic lithosphere at c.25-30km depth. Geochemical interpretation of the nodules (spinel Cr# and clinopyroxene REE) indicates that they have experienced c.12% of fractional melting, c.5% in garnet facies and c.7% in spinel facies, so supporting models for initiation of ridge melting in garnet facies and supporting some estimates for melt production rates (dF/dP). The host alkali basalt has REE concentrations and MREE-HREE gradients consistent with formation by a small degree of mainly garnet facies melting and so supports models requiring a contribution to MORB of a deep, small-volume melt with high incompatible element concentrations. The Nd isotope ratio of the alkali basalt is less than that of the MORB/nodule (0.513015 cf. 0.513095), which may result from sources of different compositions but could also be explained by fractional melting of a heterogeneous mantle. Thus the dying ridge setting provides a useful opportunity to sample the small melt fractions and deep near-ridge lithosphere normally unavailable during active spreading and facilitates the ground-truthing of ridge melting models.

Crust-mantle links in cratons

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Cratonic crust and its underlying mantle root are both bouyant survivors of the Archean tectonic regime. A central issue in constraining the formation of continents in this Eon is the genetic relationship between these two ‘stable’ units. Peridotite and eclogite xenoliths erupted by kimberlites provide vital clues that can be matched to a growing database of crustal geochemistry and geochronology. We illustrate the diverse relations between crust and mantle in three different cratons over Gyr periods.

(i) *Crust mantle coupling:-* In the North Atlantic Craton, West Greenland, newly discovered eclogite xenoliths are of similar age to the main peridotitic lithosphere. Their elemental geochemistry shows a clear genetic relationship to the TTG crust in that region [1], providing compelling support for craton root construction via tectonic stacking.

(ii) *Crust-mantle decoupling:-* Detrital Pt-alloy grains from late Archean sedimentary basins provide robust age data to compare with depletion ages from the underlying peridotitic root. These ages are generally distinct from the main craton-building events and appear to document earlier differentiation of oceanic mantle prior to craton formation.

(iii) *Major magmatic modification of lithosphere:-*

The Slave and Kaapvaal cratons both show evidence of major magmatic crustal addition and lithospheric mantle modification/growth due to the impact of some of the planet’s largest igneous events. The entire lithosphere beneath the N. Slave craton is modified by the 1.3 Ga McKenzie LIP, with significant mass addition into the deeper cratonic crust that may go undetected in zircon studies of crustal evolution.

The Kaapvaal craton has been extensively modified by the 2.0 Ga Bushveld/Malopo Farms event that left a clear compositional imprint in the Kaapvaal lithospheric mantle. In contrast, the major 1.1-1.3 Ga Namaqua-Natal crustal event left a more subtle record on the root of the central craton but more strongly affected peri-cratonic lithospheric mantle to the SW of the craton margin. In detail, multiple linked crust-mantle events are evident over the 3.5 Gyr history of this and other cratons indicating that cratonic roots are more dynamic than usually assumed.

[1] Tappe *et al*. (2011 - submitted) *Geology*.