Compositional heterogeneity in the mantle through time

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Shedding of heat from the Earth's interior is manifest as convection, resulting in adiabatic decompression that causes upper mantle rocks to cross their solidus. This partial melting of Earth's upper mantle, subsequent crust stabilisation and its eventual return into the mantle engenders compositional heterogeneity. Evidence of these processes are captured by their preservation in direct samples from the mantle, and put into a spatial context in peridotite massifs. Partial melting products of these ultramafic lithologies are erupted as basaltic rocks, and, earlier in Earth's history, komatiites.

Secular cooling of the Earth's mantle is documented by a systematic decrease in the MgO contents (a proxy for eruption temperature) of primary magmatic liquids over time. However, this first-order constraint hinges upon the assumption of a constant mantle source composition. Rather, Archean komatiitic magmas exhibit a shift in their La/Sm ratios and stable isotopic proxies from near primitive mantle at 3.5 Ga, to values typical of contemporary depleted mantle at 2.7 Ga. This chemical transition attests to a mantle record of the formation and isolation of continental crust over this time interval. In so doing, it contravenes the implicit constancy of mantle composition from the Archean to the present-day. As such, the decline in mantle temperatures may be overestimated due to the greater difficulty in producing melts from refractory mantle.

Indeed, mantle rocks exhumed in peridotite massifs are typically more clinopyroxene-poor (i.e., devoid of fusible components) than for a hypothetical primitive mantle. However, they are riddled with pyroxenite bands that account for 5-10% of the exposure. Contrary to the expectation that they are sourced from recycled oceanic crust, many of these pyroxenites have chemical and isotopic signatures that suggest local derivation. Furthermore, field evidence points not solely to their formation by partial melting, but also to pressure-solution and re-distribution of clinopyroxene. Chemical trends in global peridotite compilations suggest that this should be a ubiquitous process in the upper mantle. Bimodal pyroxenite bands, at temperatures near the peridotite solidus, reach a consolute point at which only clinopyroxene is stable. This results in solidi that are similar to, or higher than, ambient peridotite. As such, pyroxenites, in many cases, are the most refractory component in the upper mantle, and are not necessarily major contributors to partial melting.