Goldschmidt2017 Abstract

Evidence for a cool and depleted Archaean convecting mantle: Some implications

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Mantle potential temperature (T_P) and composition are crucial parameters that regulate terrestrial dynamics and geochemical cycles, ranging from controls on the peridotite solidus and consequent geochemical differentiation, to plate stiffness conducive to the operation of plate tectonics, and the recycling efficiency of volatiles in subduction zones. Earth's mantle has been cooling, but there is little agreement on the rate at which this proceeded. It is also unclear whether the Archaean ambient mantle was similar to, or more or less depleted than that giving rise to modern MORB. Since the ambient convecting mantle is most reliably sampled at spreading ridges, ancient kimberlite-borne eclogite xenoliths with low-pressure oceanic crustal protoliths, together with orogenic eclogites and (meta)basalts from allochtonous greenstone belts, may be used to constrain some characteristics of the convecting mantle sources from which their protoliths were ultimately derived.

Carefully screened eclogite suites up to 3 Ga in age have TiO_2-REE relationships consistent with fractionation of olivine±plagioclase during formation of picritic protoliths from a melt that separated from a garnet-free peridotite source, implying intersection of the solidus at ≤3.0 GPa. Low melt fractions (F<0.25), calculated from samples with the least fractionated protoliths using the batch melting equation, further argue against deep intersection of the mantle solidus. This is contingent on correctly identifying the mantle source (C_0) as depleted, which is supported by depleted initial $^{176}Hf/^{177}Hf$ in 2.9 to 2.6 Ga orogenic eclogite suites. Inversion of melt fractions for temperature suggests moderately elevated T_P of ~1420-1470° C, significantly lower than some estimates for the ambient convecting mantle at that time.

If these results are accurate, the unusual degree of melt depletion experienced by cratonic lithospheric mantle (F = 0.3-0.5) underpinning Earth's oldest continental cores requires formation at excess T_P and/or from fertile mantle which sustains longer melting columns and higher melt productivity, either during plume-ridge interactions or plume subcretion. This matches increasing evidence that ancient continental crust formed by melting at the base of oceanic plateau-like enriched oceanic crust. A moderate Mesoarchaean T_P also argues for early plate strengthening that would support plate tectonics and topography.

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Plateau-like crust:

Melting of 30-45 km thick eoarchaean oceanic crust (Hastie et al., 2016 Geology) – refer to rutile stabilisation in more differentiated oceanic plateau basalt, assume that mesozoic plateaus are analogues for eoarchaean oceanic crust

Nair and Chacko, Reimink et al. 2016 PR

Martin et al. OIB-like traces

Topography: Sr isotopes satkoski